



Databases

Relational Model & SQL

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2021/2022, Lesson #2 - T

From Previous Less(ons)...

- Databases, DBMS and applications
- Models: relational model
- Design: conceptual model (ER) *vs* physical model (tables)
- Languages: SQL
- Engine: PostgreSQL, Oracle, Microsoft SQL Server
- System Architecture: storage manager, query processor, transaction manager
- Application Architecture: two-tier, three-tier, n-tier
- Users and administrators
- SQL basics



Outline

- Relational Model
 - Relational Databases
 - Relation and Database Schema
 - Keys (Primary and Foreign)
 - Schema Diagrams
 - Relational Query Languages
- Introduction to SQL
 - Overview of the SQL Query Language
 - SQL Data Definition Language (DDL)
 - Structure of SQL Queries (select)
 - Modifying the Data (insert, update, delete)

*These slides use the following book as reference:
Abraham Silberschatz, Henry F. Korth and S. Sudarshan,
"Database System Concepts", McGraw-Hill Education,
Seventh Edition, 2019.*

Databases

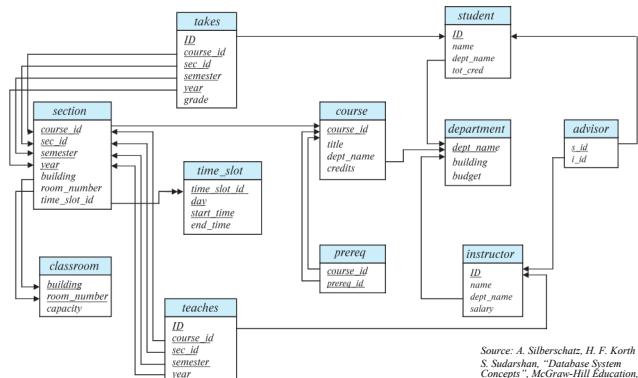
*Relational Databases
Relation and Database Schema
Keys (Primary and Foreign)
Schema Diagrams
Relational Query Languages*

RELATIONAL MODEL



Relational Model

- Primary model for data processing, proposed by Edgar F. Codd, 1970
- Simple, independent from any low-level data structures
- Incorporated new features and capabilities over time



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What is a Relation (aka Table)?

Relation of instructors
in a university

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
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
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76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

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Relational Databases

- A **relational database** is a collection of **relations** (tables)
 - Each table has an unique name and is a collection of related data
- A **tuple** (row) in a **relation** (table) represents a relationships among a set of values, each one representing an **attribute** (column)
- A **relation instance** refers to a specific instance of a relation, containing a sepcific set of rows

attributes
(or columns)

Order of attributes
and tuples is irrelevant!

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45565	Katz	Comp. Sci.	75000
50505	Califiori	History	62000

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Some more Relations...

university database

course			
course_id	title	dept_name	credits
BIO-101	Intro. to Biology	Biology	4
BIO-301	Genetics	Biology	4
BIO-399	Computational Biology	Biology	3
CS-101	Intro. to Computer Science	Comp. Sci.	4
CS-190	Game Design	Comp. Sci.	4
CS-315	Robotics	Comp. Sci.	3
CS-319	Image Processing	Comp. Sci.	3
CS-347	Database System Concepts	Comp. Sci.	3
EE-181	Intro. to Digital Systems	Elec. Eng.	3
FIN-201	Investment Banking	Finance	3
HIS-351	World History	History	3
MU-199	Music Video Production	Music	3
PHY-101	Physical Principles	Physics	4

department		
dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

prereq	
course_id	prereq_id
BIO-301	BIO-101
BIO-399	BIO-101
CS-190	CS-101
CS-315	CS-101
CS-319	CS-101
CS-347	CS-101
EE-181	PHY-101

what is the meaning
of the prereq relation?

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Domain of the Attributes

- The **domain** is the set of permitted values for the attribute
 - e.g. the domain of the *salary* attribute of the *instructor* relation is the set of all possible salary values
 - What is the domain of the attribute *name* of the *instructor* relation?
- The domain of each attribute must be **atomic**, i.e. cannot be divided
 - e.g. the *salary* attribute of the *instructor* relation can store a single salary value
 - Is the *dept_name* attribute atomic?
 - Imagine that an attribute *phone_number* is added to the *instructor* relation, to represent the (several) phone numbers of each instructor. Is this atomic?
 - What if that attribute is used to store a single phone number?



Domain of the Attributes

- The **null value** is a special case representing that the value is unknown or does not exist
 - e.g. if an instructor does not have a phone number, we would use a null value
 - Null values create a great deal of problems and should be avoided, if possible
- Let's be more specific...
 - What defines a domain? Data type? Can the domain of an attribute depend on the value of another attribute? ...

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

What is the domain of the attributes in this relation?



Relation Schema and Instance

- Attributes: A_1, A_2, \dots, A_n
- Relation schema is the logical structure of the relation:
 - $R = (A_1, A_2, \dots, A_n)$
- Relation instance is a snapshot of the data in the table at a given instant in time
- Schema of the relation *instructor*:
 - $\text{instructor} = (\text{ID}, \text{name}, \text{dept_name}, \text{salary})$
- An instance r defined over schema R is denoted by $r(R)$:

ID	name	dept_name	salary
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Database Schema

- Database schema is the logical structure of the database
- Database instance is a snapshot of the data in the database at a given instant in time
- Schema of the relations in the *university* database:
 - $\text{classroom}(\text{building}, \text{room_number}, \text{capacity})$
 - $\text{department}(\text{dept_name}, \text{building}, \text{budget})$
 - $\text{course}(\text{course_id}, \text{title}, \text{dept_name}, \text{credits})$
 - $\text{instructor}(\text{ID}, \text{name}, \text{dept_name}, \text{salary})$
 - $\text{section}(\text{course_id}, \text{sec_id}, \text{semester}, \text{year}, \text{building}, \text{room_number}, \text{time_slot_id})$
 - $\text{teaches}(\text{ID}, \text{course_id}, \text{sec_id}, \text{semester}, \text{year})$
 - $\text{student}(\text{ID}, \text{name}, \text{dept_name}, \text{tot_cred})$
 - $\text{takes}(\text{ID}, \text{course_id}, \text{sec_id}, \text{semester}, \text{year}, \text{grade})$
 - $\text{advisor}(\text{s_ID}, \text{i_ID})$
 - $\text{time_slot}(\text{time_slot_id}, \text{day}, \text{start_time}, \text{end_time})$
 - $\text{prereq}(\text{course_id}, \text{prereq_id})$

what's missing?

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Keys

- How do we identify (univocally) a specific row in a table?
- How do we establish a relation between a row in one table and a row in another table?
- Keys!
 - e.g. how can we univocally identify a Portuguese person?
- **Superkey** is a set of one or more attributes that can be used to identify univocally a tuple in a relation
 - Let $K \subseteq R$, K is a superkey of R if values for K are sufficient to identify a unique tuple of each possible instance of R , i.e. $r(R)$
 - Example: $\{ID\}$ and $\{ID, name\}$ are both superkeys of *instructor*
 - Superkeys may contain extraneous attributes, so if K is a superkey, then so is any superset of K



Candidate Keys

- A **candidate key** is a minimal superkey, i.e. a superkey for which no proper subset is a superkey
 - No two tuples in a relation can have the same value for a candidate key
 - Is $\{ID, name\}$ a candidate key for *instructor*?
 - What about $\{ID\}$?
- It is possible to have several candidate keys for a single relation
 - Suppose that no two courses can have the same name in the same department, what are the candidate keys of *course*(*course_id*, *title*, *dept_name*, *credits*)?



Primary Key

- The **primary key** is one of the candidate keys
 - How to select the primary key?
 - For the course relation, should we use $\{course_id\}$ or $\{title, dept_name\}$?
 - Can the attribute *name* be a primary key of *instructor*?
 - Primary keys are sometimes referred as **primary key constraints**
- Primary key attributes are customarily listed first and underlined:
 - *department(dept_name, building, budget)*
 - *course(course_id, title, dept_name, credits)*
- In case the primary key includes several attributes:
 - *classroom(building, room_number, capacity)*
 - *prereq(course_id, prereq_id)*



Foreign Keys

- A **foreign-key constraint** from attribute(s) *A* (**foreign key**) in r_1 to the primary key *B* of r_2 states that the values of *A* for each tuple in r_1 must be the value of *B* for some tuple in r_2
 - i.e., the value in one relation must appear in the other, e.g., the value of *dept_name* in *instructor* must exist in *department*
- The **referencing relation** is the one where the foreign key exists (r_1)
- The **referenced relation** is then one referenced by the foreign key (r_2)
 - Referenced attributes must be the primary key of the referenced relation
 - In **referential integrity constraints** the referenced attributes must be a candidate key (the requirement above is relaxed)
- *dept_name* in *instructor* is a foreign key from *instructor* (referencing relation) to *department* (referenced relation)

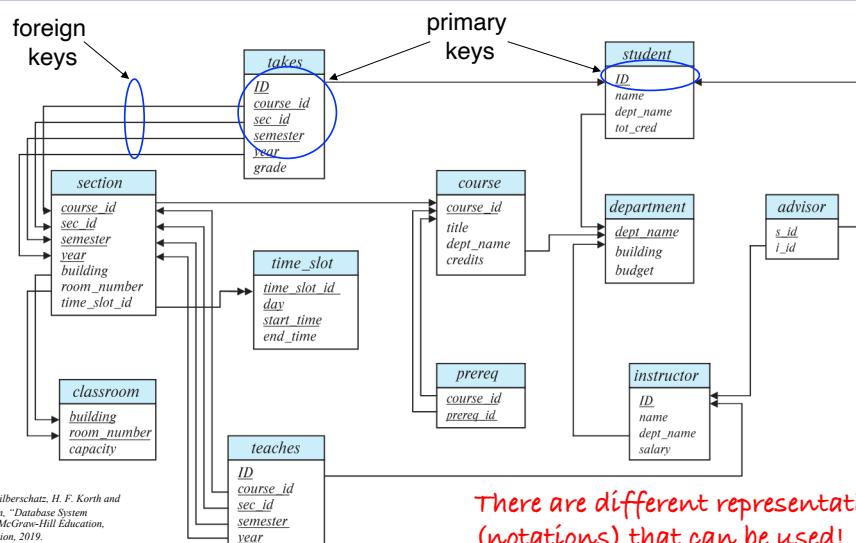


Schema of the University Database

- *classroom(building, room_number, capacity)*
- *department(dept_name, building, budget)*
- *course(course_id, title, dept_name, credits)*
- *instructor(ID, name, dept_name, salary)*
- *section(course_id, sec_id, semester, year, building, room_number, time_slot_id)*
- *teaches(ID, course_id, sec_id, semester, year)*
- *student(ID, name, dept_name, tot_cred)*
- *takes(ID, course_id, sec_id, semester, year, grade)*
- *advisor(s_ID, i_ID)*
- *time_slot(time_slot_id, day, start_time, end_time)*
- *prereq(course_id, prereq_id)*

What's missing?

Schema Diagrams





Relational Query Languages

- A **query language** is used to request information from the database
 - Languages normally in a higher level than other programming languages
- **Imperative query language:** the programmer instructs the system to perform a sequence of operations to compute the result
- **Functional query languages:** computation expressed as the evaluation of functions that operate on data or on the results of other functions
 - e.g., relational algebra, which forms the base of SQL
- **Declarative query languages:** the programmer describes the desired information to be obtained and not the steps for obtaining it
 - e.g., tuple relational calculus and domain relational calculus
- SQL includes elements of imperative, functional and declarative

Databases

*Overview of the SQL Query Language
SQL Data Definition Language (DDL)
Basic Structure of SQL Queries (select)
Modifying the Data (insert, update, delete)*

INTRODUCTION TO SQL



Structured Query Language (SQL)

- SQL was initially developed at IBM by Donald D. Chamberlin and Raymond F. Boyce after learning about the relational model, 1970's
 - Several ANSI and ISO standards over the years: 1986, 1989, 1992, 1999, 2003, 2006, 2008, 2011 and 2016
- Although called a query language, it can be used to do more than just query a database
 - Define the structure of the database
 - Modify data
 - Specify security constraints
 - ...



Parts of the SQL Language

- **Data Definition Language (DDL):** defining relations, deleting relations, and modifying relations
- **Data Manipulation Language (DML):** query information from the database and insert, delete and modify tuples
- Integrity: DDL commands for specifying integrity constraints
- View definition: DDL commands for defining views
- Transaction control: specifying the beginning and end of transactions
- Authorization: specifying access rights to relations and views
- Embedded SQL and dynamic SQL: specifies how SQL can be embedded in general-purpose programming languages



SQL Data Definition Language (DDL)

- Use to specify not only a set of relations, but also information about each relation:
 - Schema for each relation
 - Data types of the values associated with each attribute
 - Integrity constraints
 - Set of indices to be maintained for each relation
 - Security and authorization information for each relation
 - Physical storage structure of each relation on disk



Basic Data Types

- char(n)
- varchar
- int
- smallint
- numeric(p, d)
- real, double precision
- float(n)

create table...

- SQL DDL command used to define a relation:

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

```
create table department
  (dept_name varchar(20),
   building varchar(15),
   budget numeric(12,2),
   primary key (dept_name));
```

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

Integrity Constraints

- **primary key ($A_{j_1}, A_{j_2}, \dots, A_{j_n}$)**: specifies the set of attributes that act as primary key, which are required to be *nonnull* and *unique*
- **foreign key ($A_{k_1}, A_{k_2}, \dots, A_{k_n}$) references s**: defines a set of attributes that are a foreign key, where the attributes in s must be a primary key

```
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),
   foreign key (course_id) references course);
```



Integrity Constraints

- **not null**: specifies the attributes for which a value must exist
- **unique ($A_{j_1}, A_{j_2}, \dots, A_{j_n}$)**: defines a set of attributes that form a superkey
- **check(P)**: specifies a condition that must be satisfied for every tuple in the relation
- SQL prevents any update that violates an integrity constraint

```
create table instructor
    (ID varchar(5),
     name varchar(20) not null,
     dept_name varchar(20),
     salary numeric(8,2),
     primary key (ID),
     foreign key (dept_name) references department,
     check (salary>0));
```

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alter table...

- SQL DDL command used to alter a relation:

```
alter table instructor
    alter column name type varchar(50),
    alter column name set not null,
    alter column dept_name type varchar(20),
    alter column dept_name set not null;
```

- Fails if the new constraints cannot be satisfied by the existing data
 - e.g., if there are tuples in *instructor* where *dept_name* is null

ID	name	dept_name	salary
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Physics	40000
22222	Einstein	Physics	95000

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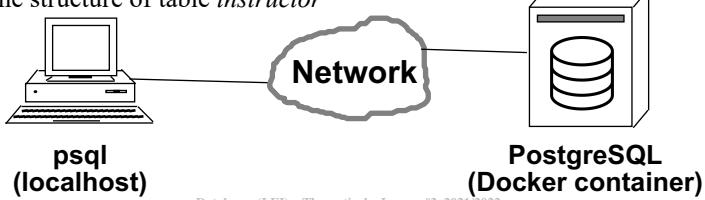
drop table...

- SQL DDL command used to remove a relation:

```
drop table course;
```
- Fails if the table is referenced by any other table with a foreign key
 - e.g., if table *section* has a foreign key to the table *course* (which is being dropped)
- Note that **drop table** is different from **delete**
 - *delete* is used to delete data from a table, but the table is not removed
 - *drop* is used to remove the table (data is obviously lost)

DEMO #1

- **Server:** PostgreSQL server – Docker container
- **Client:** *psql*
- **TODO:**
 - Explore the DDL commands needed to create the University database tables
 - Connect to database *dbcourse*, username *dblesson1*, password *dblesson1*
 - Execute the script to create the tables (*create_unidb.sql*)
 - Get the list of tables created
 - Get the structure of table *instructor*





Basic Structure of SQL Queries (select)

- SQL DML command used to get data from the database:

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

- A₁, A₂, ..., A_n are the attributes to be obtained from the relations r₁, r₂, ..., r_m
- P is a predicate to be evaluated to decide which data to consider
 - If the where clause is omitted, then P is true

```
select name
from instructor;
```

name
Srinivasan
Wu
Mozart
Einstein
El Said
Gold
Katz
Galfiori



Selecting from Multiple Relations

- Consider this form of a select:

```
select A1, A2, ..., An
from r1, r2, ..., rm;
```

- It is executed this way:

```
for each tuple t1 in relation r1
    for each tuple t2 in relation r2
        ...
        for each tuple tm in relation rm
            Concatenate t1, t2, ..., tm into a single tuple t
            Add t into the result relation
```

- What is the result? How does it work?

How does it work?

- Consider the form of a typical *select*:

`select *
from department, instructor;`

Note that there is no where clause!

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
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83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

dept_name	building	budget	id	name	dept_name	salary
Biology	Watson	90000.00	10101	Srinivasan	Comp. Sci.	65000.00
Biology	Watson	90000.00	12121	Wu	Finance	90000.00
Biology	Watson	90000.00	15151	Mozart	Music	40000.00
...
...
Comp. Sci.	Taylor	100000.00	10101	Srinivasan	Comp. Sci.	65000.00
Comp. Sci.	Taylor	100000.00	12121	Wu	Finance	90000.00

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Biology	Watson	90000.00	15151	Mozart	Music	40000.00
...
...
Comp. Sci.	Taylor	100000.00	10101	Srinivasan	Comp. Sci.	65000.00
Comp. Sci.	Taylor	100000.00	12121	Wu	Finance	90000.00
Comp. Sci.	Taylor	100000.00	15151	Mozart	Music	40000.00
...
...
Elec. Eng.	Taylor	85000.00	10101	Srinivasan	Comp. Sci.	65000.00
Elec. Eng.	Taylor	85000.00	12121	Wu	Finance	90000.00
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...
...
Finance	Painter	120000.00	10101	Srinivasan	Comp. Sci.	65000.00
Finance	Painter	120000.00	12121	Wu	Finance	90000.00
Finance	Painter	120000.00	15151	Mozart	Music	40000.00

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Joining Related Tables

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```

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
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

name	dept_name	building
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

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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```

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
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

name	dept_name	building
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

*instructor.dept_name
=
department.dept_name*

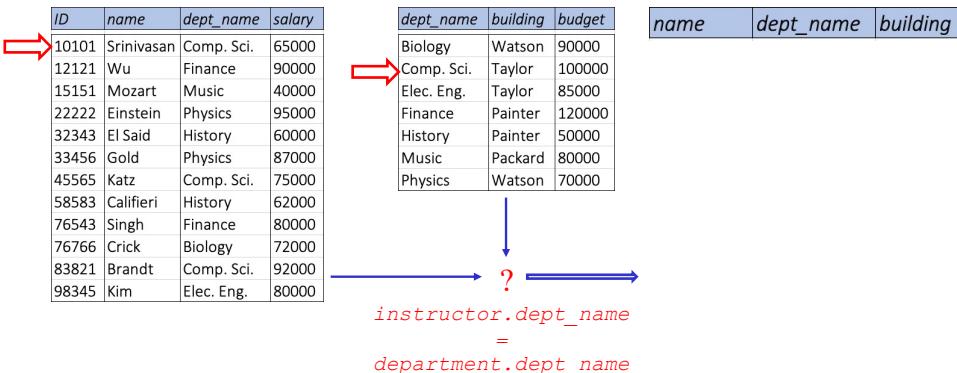
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



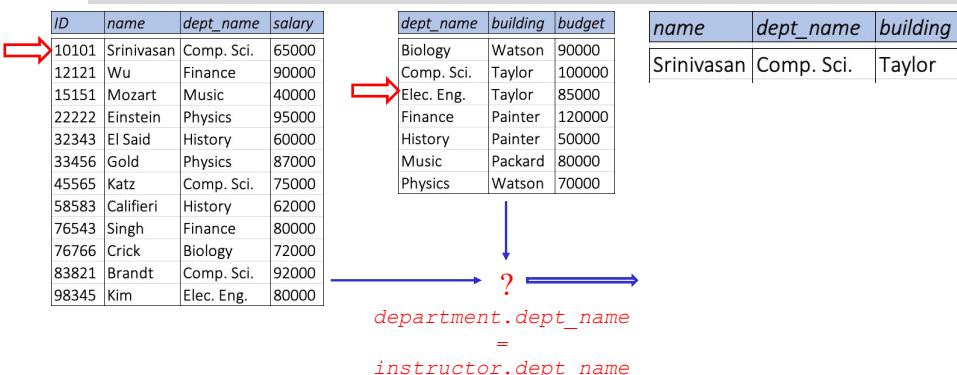
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



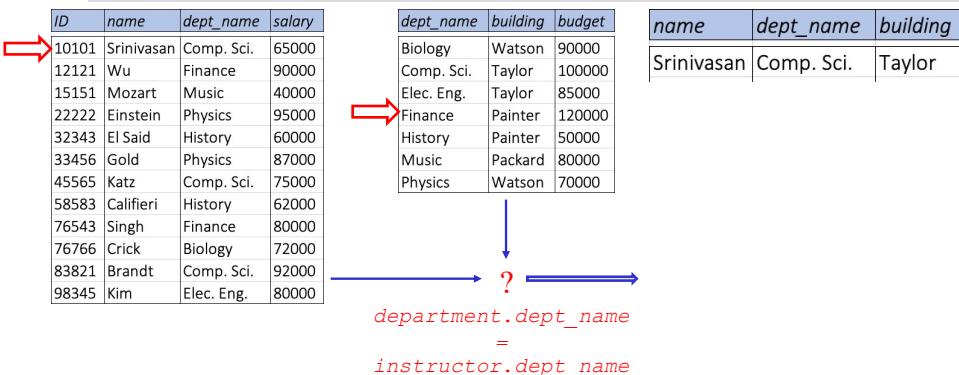
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



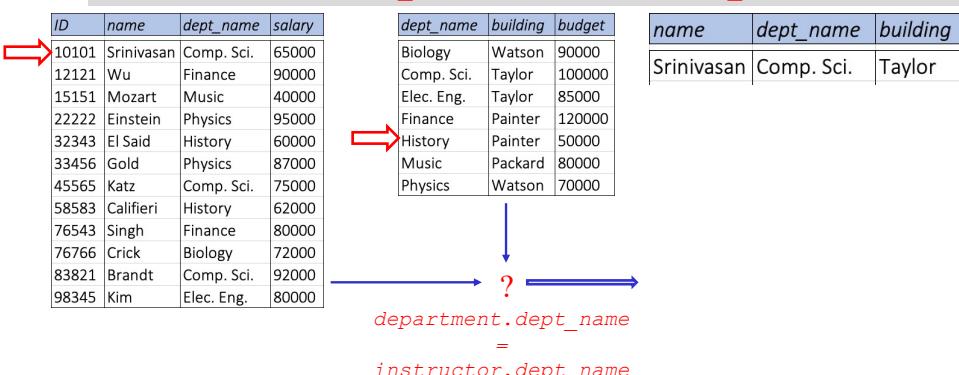
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



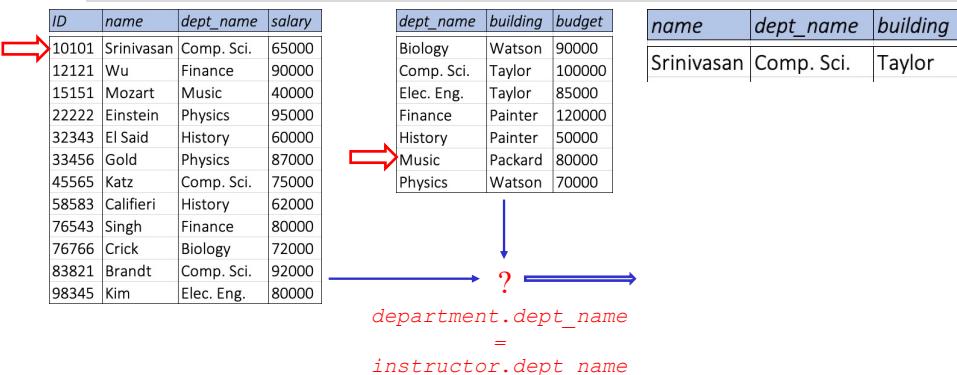
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



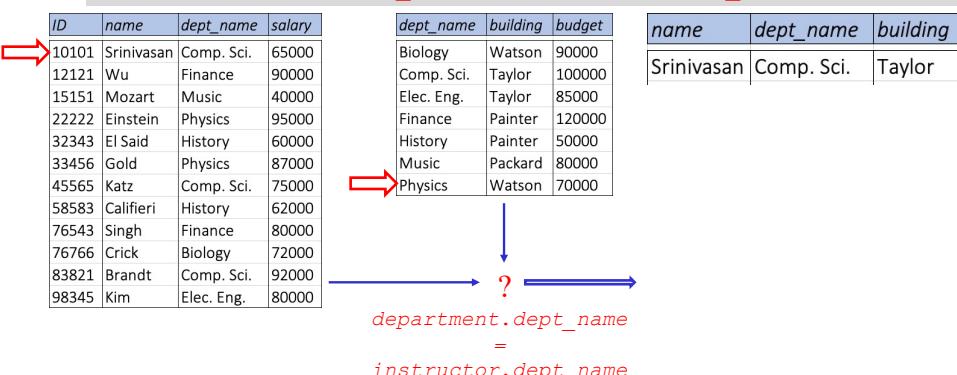
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```

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
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

name	dept_name	building
Srinivasan	Comp. Sci.	Taylor

department.dept_name
=?
instructor.dept_name

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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```

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
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
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dept_name	building	budget
Biology	Watson	90000
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Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

name	dept_name	building
Srinivasan	Comp. Sci.	Taylor

department.dept_name
=?
instructor.dept_name

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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```

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
33456	Gold	Physics	87000
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58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

name	dept_name	building
Srinivasan	Comp. Sci.	Taylor

department.dept_name
=?
instructor.dept_name

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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```

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
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
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dept_name	building	budget
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

name	dept_name	building
Srinivasan	Comp. Sci.	Taylor

department.dept_name
=?
instructor.dept_name

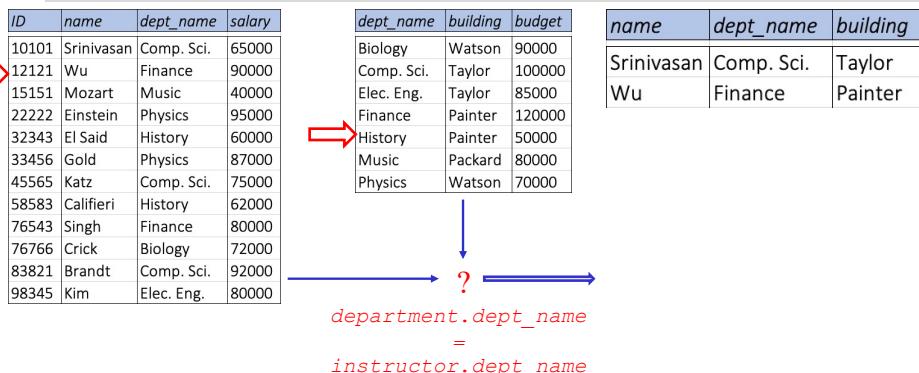
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



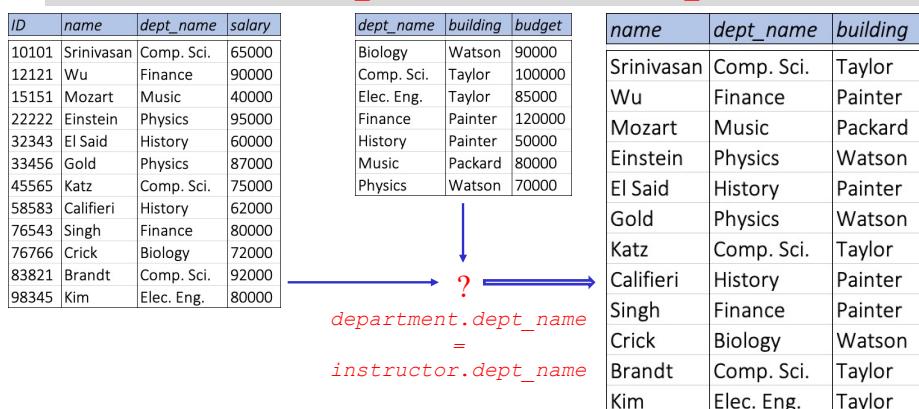
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How does it work?

- Consider the following example:

```
select name, instructor.dept_name, building
from instructor, department
where instructor.dept_name = department.dept_name;
```



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Data from Different Tables and Conditions

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

select name, course_id
from instructor, teaches
where instructor.ID = teaches.ID
and instructor.dept_name = 'Comp. Sci.';
```

name	course_id
Srinivasan	CS-101
Srinivasan	CS-315
Srinivasan	CS-347
Katz	CS-101
Mozart	MU-199
Einstein	PHY-101
El Said	HIS-351
Crick	BIO-101
Brandt	CS-190
Brandt	CS-190
Brandt	CS-319
Kim	EE-181

name	course_id
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

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Rename Tables

```
select T.name, S.course_id
from instructor as T, teaches as S
where T.ID = S.ID;

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

name
Einstein
Katz
Singh
Kim
Brandt
Wu
Gold

What?!

What happened here?

name	course_id
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

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Aggregate Functions

- **Aggregate functions** take a collection of values and return a single value, by performing some aggregation operation:
 - Average: `avg`
 - Minimum: `min`
 - Maximum: `max`
 - Total: `sum`
 - Count: `count`

```
select avg(salary)
from instructor
where dept_name = 'Comp. Sci.';
```

<code>avg</code>
77333.33333333333

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Counting Rows

```
select count(ID)
from teaches
where semester = 'Spring'
and year = 2018;
```

<code>count</code>
7

Why?

```
select count(distinct ID)
from teaches
where semester = 'Spring'
and year = 2018;
```

<code>count</code>
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```
select count (*)
from course;
```

<code>count</code>
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insert... (One Row)

- SQL DML command used to insert one row in a relation:

```
insert into r(A1, A2, ..., An)
values (v1, v2, ..., vn);
```
- A₁, A₂, ..., A_n are the attributes to be filled and v₁, v₂, ..., v_n are the values for those attributes

```
insert into course
values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

insert into course (course_id, title, dept_name, credits)
values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);

insert into course (title, course_id, credits, dept_name)
values ('Database Systems', 'CS-437', 4, 'Comp. Sci.');
```

The three commands to the same!
- The command may fail for several reasons, including **data type mismatch** and foreign **key constraint violation**



insert... (Several Rows)

- SQL DML command used to insert several rows in a relation:

```
insert into r
select ...
```
- The output of the *select* is inserted into table *r*

```
insert into instructor
select ID, name, dept_name, 18000
from student
where dept_name = 'Music' and tot_cred > 144;
```



delete...

- SQL DML command used to delete data from a relation:

```
delete from r  
where P;
```

- P is a predicate to be evaluated to decide which data to delete

- If the *where* clause is omitted, all data is deleted

```
delete from instructor;
```

```
delete from instructor  
where dept_name = 'Finance';
```

```
delete from instructor  
where salary between 13000 and 15000;
```

- The command may fail if rows in other tables reference the rows being deleted

- Unless “*on delete cascade*” was specified when creating the referencing table



update

- SQL DML command used to update data in a relation:

```
update r  
set A1 = v1, A2 = v2, ..., An = vn  
where P;
```

- P is a predicate to be evaluated to decide which data to update

- If the *where* clause is omitted, all rows are updated

```
update instructor  
set salary = salary * 1.05;
```

```
update instructor  
set salary = salary * 1.05, name = upper(name)  
where salary < 70000;
```

```
update instructor  
set salary = salary * 1.05  
where salary < (select avg(salary) from instructor);
```

DEMO #2



- **Server:** PostgreSQL server – Docker container
- **Client:** `psql`
- **TODO:**
 - Explore the DML commands needed to fill the University database tables
 - Connect to database `dbcourse`, username `dblesson1`, password `dblesson1`
 - Execute the script to insert data into the tables (`insert_unidb.sql`)
 - Find the IDs of all students who were advised by an instructor named *Einstein*
 - Find the highest salary of any instructor
 - Create a new course `CS-001`, titled *Weekly Seminar*, with 3 credits
 - Update the department of the `CS-001` to *Comp. Sci.*
 - Delete the course `CS-001`

Take-Away(s)

- Relational Model
 - Relational databases
 - Relation or table, tuple or row, attribute or column
 - Superkeys, candidate keys, primary key and foreign key
 - Integrity restrictions: primary key (entity), foreign key (referential), domain, ...
- SQL
 - `create table`, `alter table`, and `drop table`
 - Query the database: `select...`
 - Cartesian product and joining tables
 - Aggregation functions
 - Modifying the data (`insert`, `update`, `delete`)



Next Lesson(s)

- Database Design Using Entity-Relationship Model
- Database Design Process
- Entities and Relationships
- Relationship Cardinalities and Participation
- Alternative Notations for E-R Diagrams
- From E-R Diagrams to Relational Schemas

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Q&A



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Databases

Relational Model & SQL

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