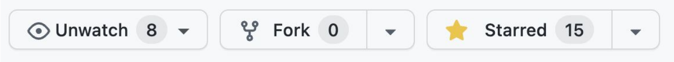
Class Announcement

- Make sure your info are complete in [UMD DATA605 - Class Project Teams - Spring 2023]
  - Need GitHub handle
  - Need Telegram handle
- **Make sure you have a team for the class project**
  - **No team -> no grade**
- Install Docker on your computer
  - If you have problems installing it on your laptop, use one computer from UMD or your friends
- Sorrentum
  - Accept invitation to collaborate here
  - Watch, star, and fork the repo
- Contact your team members
  - E.g., on Telegram group
- Check your GitHub issue based on your team
  - https://github.com/sorrentum/sorrentum/issues
  - Make sure you are assigned to it
- Assignments
  - Run Git / GitHub tutorial from https://github.com/gpsaggese/umd_data605/tree/main/tutorials
  - Run Docker tutorial



UMD DATA605 - Big Data Systems

Relational DBs

SQL Intro

SQL tutorial

Relational DB internals

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with thanks to Prof.

Alan Sussman

Amol Deshpande

UMD DATA605 - Big Data Systems

Relational DBs

SQL Intro

SQL tutorial

Relational DB internals

Silbershatz: Chap 2

Relational Model: Overview

- Introduced by [Ted Codd] (late 60's, early 70's)
- **First prototypes**
  - Ingres Project at Berkeley (1970-1985)
    - Ingres (INteractive Graphics REtrieval System) → PostgreSQL (=Post Ingres)
  - IBM System R (1970) → Oracle, IBM DB2
- **Contributions from relational data model**
  - Formal semantics for data operations
  - Data independence: separation of logical and physical data models
  - Declarative query languages (e.g., SQL)
  - Query optimization
- **Key to commercial success**

Relational Model: Key Definitions

- A relational DB consists of a collection of **tables / relations**
  - Each table has a unique name and a schema
- Each **row / tuple / record** in a table represents a relationship among a set of values
- Each **element** of a row corresponds to a **column / field / attribute**
  - Each element in a column is atomic (e.g., a phone number is a single object and not a sequence of numbers)
  - `NULL` represents a value that is unknown or doesn't exist (e.g., someone not having a phone number)
- E.g., *`instructor`* and *`course`* relations
- **Schema of a relation**
  - A list of attributes and their domains
  - It's like type definition in programming languages
  - E.g., the domain of `salary` is integers >= 0
- **Instance of relation**
  - A particular instantiation of a relation with actual values
  - Will change over time

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

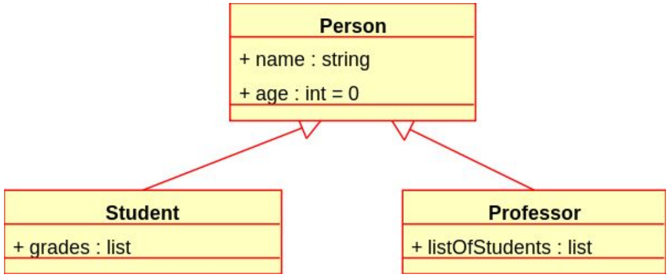
`instructor` relation

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

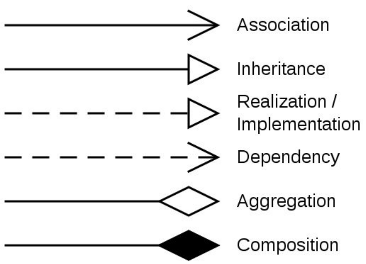
`course` relation

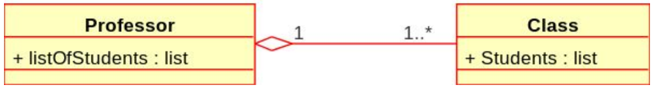
UML Class Diagram

- [UML class diagram](#)
  - UML = Unified Modeling Language
  - Used in OOP and DB design

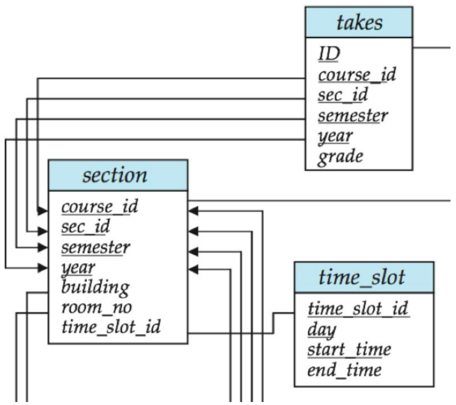


- **In OOP design**
  - Diagram showing classes, attributes, methods, and relationships





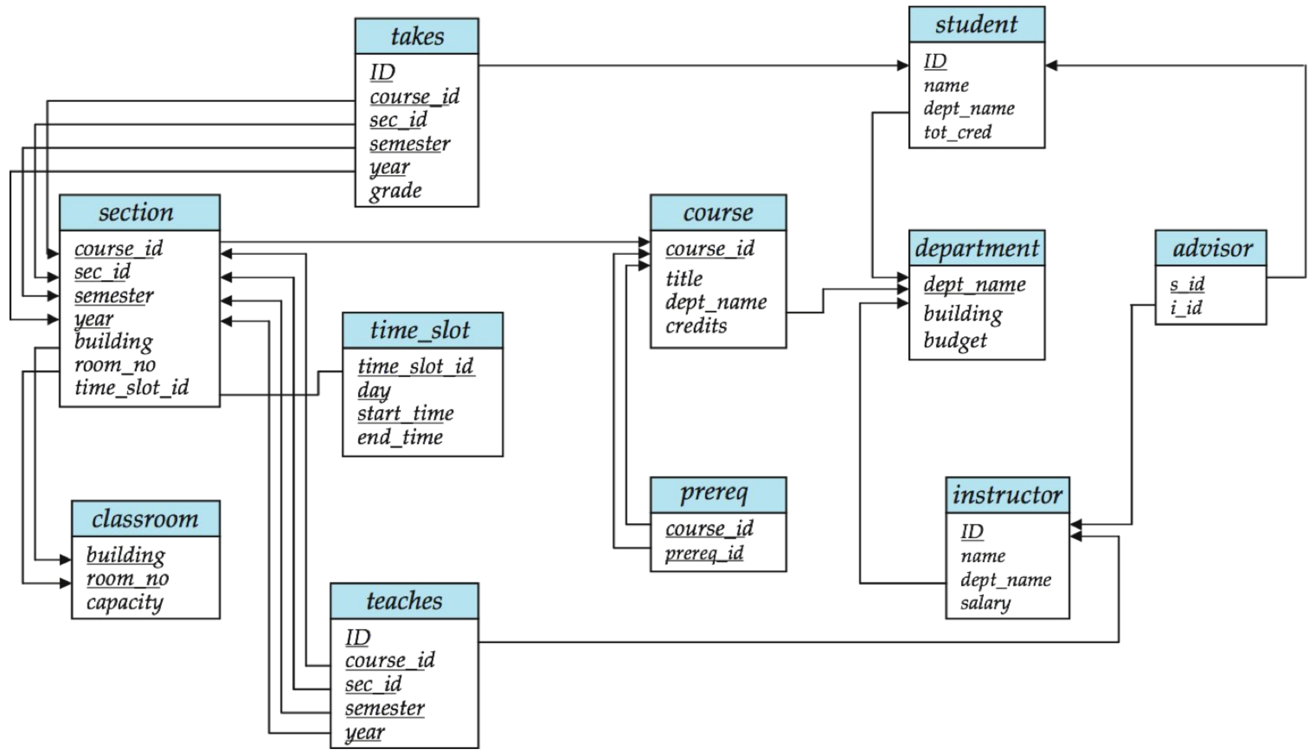
- **In DB design**
  - Each box is a table / relation
  - Columns / fields / attributes are listed inside the box
  - Primary keys are underlined
  - Foreign key constraints are arrows



Example: University DB

- **UML diagram of a DB and schemas representing a University**
- Each box is a table / relation
- Column / fields / attributes are listed inside the box
- Primary keys are underlined fields
- Foreign key constraints are arrows between boxes

- **Analysis of the diagram**
- ER model
- Entities
  - student
  - department
  - ...
- Relationships
  - takes
  - teaches
  - ...

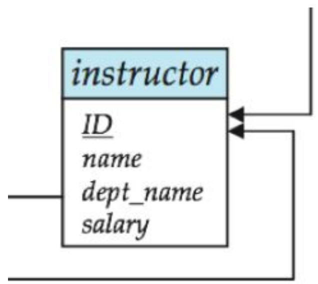


Primary Key

- *R* is the set of attributes of a relation *r*
  - E.g., `ID, name, dept_name, salary` are attributes of relation ***instructor***
- **K is a superkey of R** if values for *K* are sufficient to identify a unique tuple of each possible relation *r(R)*
  - E.g., `(ID)` and `(ID, name)` are both superkeys of ***instructor***
  - `(name)` is not a superkey of ***instructor***
- **Superkey K is a candidate key** if *K* is minimal
  - E.g., `(ID)` is a candidate key for ***instructor***
- One of the candidate keys is selected to be the **primary key**
  - Typically one that is small and immutable (or at least it doesn't change often)
  - Would **SSN** be a primary key? Yes and no
- A primary key is a minimal set of attributes that identify *uniquely* each possible row
- **Primary key constraint**: rows in the relation can't have the same primary key

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

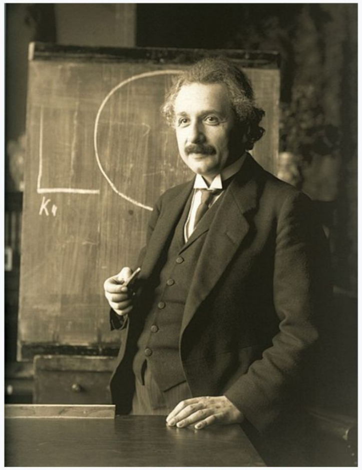
instructor relation



Question: What are Primary Keys?

- Marital status
  - `Married(person1_ssn, person2_ssn, date_married, date_divorced)`
- Bank account
  - `Account(cust_ssn, account_number, cust_name, balance, cust_address)`
- Research assistantship at UMD
  - `RA(student_id, project_id, supervisor_id, appt_time, appt_start_date, appt_end_date)`
- Information typically found on Wikipedia
  - `Person(Name, Born, Died, Citizenship, Education, ...)`
- Info about US President on Wikipedia
  - `President(name, start_date, end_date, vice_president, preceded_by, succeeded_by)`
- Tour de France: historical rider participation information
  - `Rider(Name, Born, Team-name, Coach, Sponsor, Year)`

Albert Einstein



Einstein in 1921, by Ferdinand Schmutzer

Born	14 March 1879 Ulm, Germany
Died	18 April 1955 (aged 76) Princeton, New Jersey, U.S.
Citizenship	Full list [show]
Education	Federal polytechnic school in Zurich (Federal teaching diploma, 1900) University of Zurich (PhD, 1905)
Known for	General relativity Special relativity Photoelectric effect *E=mc*^{2} (Mass–energy equivalence) *E=hf* (Planck–Einstein relation) Theory of Brownian motion

Answer: What are Primary Keys?

- Marital status
  - Married(**person1_ssn, person2_ssn, date_married,** date_divorced)
- Bank account
  - Account(cust_ssn, **account_number**, cust_name, balance, cust_address)
- Research assistantship at UMD
  - RA(**student_id, project_id**, supervisor_id, appt_time, **appt_start_date**, appt_end_date)
- Information typically found on Wikipedia
  - Person(**Name, Born, Died, Citizenship, Education, ...**)
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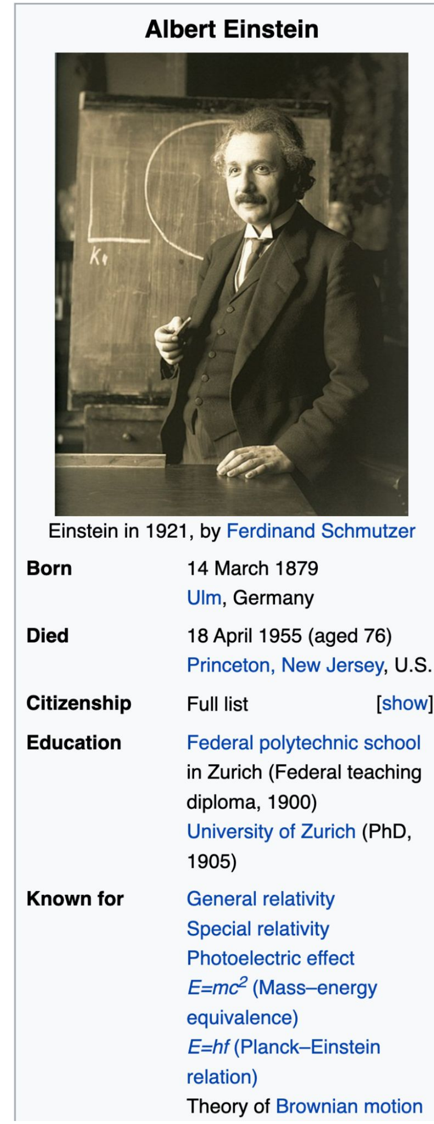
- Tour de France: historical rider participation information
  - Rider(**Name, Born, Team-name,** Coach, Sponsor, **Year**)



Foreign Key

- **Foreign key** = primary key of a relation that appears in another relation
  - E.g., `(ID)` from *`student`* appears in the relations *`takes`*, *`advisor`*
  - *`takes`* is the "referencing relation", has the foreign key
  - *`student`* is the "referenced relation", has the primary key
  - Typically shown by an arrow from referencing → referenced
- **Foreign key constraint**: for each row, the tuple corresponding to a primary key must exist
  - Aka referential integrity constraint
  - If there is a `(student101, DATA605)` in *`takes`*, there must be a tuple with `student101` in *`student`*
- In words, the key referenced as foreign key needs to exist as primary key

Relational Algebra: 1/4

- **Relation**: set of tuples (without replication)
- **Relational algebra**: operations that take one or more relations as input and produce a new relation, e.g.,
  - Unary relation: selection, projection, rename
  - Binary relation: union, set difference, intersection, Cartesian product, join
- **Selection (σ)**: select tuples that satisfy a given predicate
  - E.g., select tuples of `instructor` where **`dept_name = "Physics"`**
- **Projection (π)**: return tuples with a subset of attributes
  - E.g., project tuples of `instructor` with only **`(name, salary)`**
- **Set operations**: union, intersection, set_difference of relations
  - Need to be compatible (i.e., have the same attributes)

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

ID	*name*	*dept_name*	*salary*
22222	Einstein	Physics	95000
33456	Gold	Physics	87000

$\sigma_{dept\_name = \text{"Physics"}}(instructor)$

ID	*name*	*salary*
10101	Srinivasan	65000
12121	Wu	90000
15151	Mozart	40000
22222	Einstein	95000
32343	El Said	60000
33456	Gold	87000
45565	Katz	75000
58583	Califieri	62000
76543	Singh	80000
76766	Crick	72000
83821	Brandt	92000
98345	Kim	80000

$\Pi_{ID,\ name,\ salary}(instructor)$

Relational Algebra: 2/4

- **Cartesian product**: combine information from two relations into a new one
  - *instructor* = **(ID, name, dept_name, salary)**
  - *teaches* = **(ID, course_id, sec_id, semester, year)**
- E.g., *instructor* x *teaches* gives **(instructor.ID, instructor.name, instructor.dept_name, teaches.ID, ...)**

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

instructor relation

ID	*course_id*	*sec_id*	*semester*	*year*
10101	CS-101	1	Fall	2017
10101	CS-315	1	Spring	2018
10101	CS-347	1	Fall	2017
12121	FIN-201	1	Spring	2018
15151	MU-199	1	Spring	2018
22222	PHY-101	1	Fall	2017
32343	HIS-351	1	Spring	2018
45565	CS-101	1	Spring	2018
45565	CS-319	1	Spring	2018
76766	BIO-101	1	Summer	2017
76766	BIO-301	1	Summer	2018
83821	CS-190	1	Spring	2017
83821	CS-190	2	Spring	2017
83821	CS-319	2	Spring	2018
98345	EE-181	1	Spring	2017

teaches relation

instructor.ID	*name*	*dept_name*	*salary*	*teaches.ID*	*course_id*	*sec_id*	*semester*	*year*
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2017
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2017
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2018
12121	Wu	Finance	90000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018
12121	Wu	Finance	90000	15151	MU-199	1	Spring	2018
12121	Wu	Finance	90000	22222	PHY-101	1	Fall	2017
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
15151	Mozart	Music	40000	10101	CS-101	1	Fall	2017
15151	Mozart	Music	40000	10101	CS-315	1	Spring	2018
15151	Mozart	Music	40000	10101	CS-347	1	Fall	2017
15151	Mozart	Music	40000	12121	FIN-201	1	Spring	2018
15151	Mozart	Music	40000	15151	MU-199	1	Spring	2018
15151	Mozart	Music	40000	22222	PHY-101	1	Fall	2017
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
22222	Einstein	Physics	95000	10101	CS-101	1	Fall	2017
22222	Einstein	Physics	95000	10101	CS-315	1	Spring	2018
22222	Einstein	Physics	95000	10101	CS-347	1	Fall	2017
22222	Einstein	Physics	95000	12121	FIN-201	1	Spring	2018
22222	Einstein	Physics	95000	15151	MU-199	1	Spring	2018
22222	Einstein	Physics	95000	22222	PHY-101	1	Fall	2017
...	...	...	...	...	...	...	...	...

instructor x teaches

Relational Algebra: 3/4

- **Join**: composition of two operations
  - Cartesian-product and then
  - a selection based on equality between two fields
- E.g., `instructor x teaches` when **`instructor.ID = teaches.ID`**

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

`instructor` relation

ID	course_id	sec_id	semester	year
10101	CS-101	1	Fall	2017
10101	CS-315	1	Spring	2018
10101	CS-347	1	Fall	2017
12121	FIN-201	1	Spring	2018
15151	MU-199	1	Spring	2018
22222	PHY-101	1	Fall	2017
32343	HIS-351	1	Spring	2018
45565	CS-101	1	Spring	2018
45565	CS-319	1	Spring	2018
76766	BIO-101	1	Summer	2017
76766	BIO-301	1	Summer	2018
83821	CS-190	1	Spring	2017
83821	CS-190	2	Spring	2017
83821	CS-319	2	Spring	2018
98345	EE-181	1	Spring	2017

`teaches` relation

instructor.ID	name	dept_name	salary	teaches.ID	course_id	sec_id	semester	year
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018
15151	Mozart	Music	40000	15151	MU-199	1	Spring	2018
22222	Einstein	Physics	95000	22222	PHY-101	1	Fall	2017
32343	El Said	History	60000	32343	HIS-351	1	Spring	2018
45565	Katz	Comp. Sci.	75000	45565	CS-101	1	Spring	2018
45565	Katz	Comp. Sci.	75000	45565	CS-319	1	Spring	2018
76766	Crick	Biology	72000	76766	BIO-101	1	Summer	2017
76766	Crick	Biology	72000	76766	BIO-301	1	Summer	2018
83821	Brandt	Comp. Sci.	92000	83821	CS-190	1	Spring	2017
83821	Brandt	Comp. Sci.	92000	83821	CS-190	2	Spring	2017
83821	Brandt	Comp. Sci.	92000	83821	CS-319	2	Spring	2018
98345	Kim	Elec. Eng.	80000	98345	EE-181	1	Spring	2017

$\sigma_{instructor.ID = teaches.ID}(instructor \times teaches)$

Relational Algebra: 4/4

- **Query**: combination of relational algebra operations
  - E.g., "find the `course_id` from the rows of the table section for the fall semester of 2017"

$$\Pi_{course\_id} (\sigma_{semester = \text{"Fall"} \wedge year=2017} (section))$$

- **Assignment**: assign parts of relational algebra to temporary relation variables
  - A query can be written as a sequential program
  - E.g., "find the `course_id` for the classes that are run in both fall 2017 and spring 2018"

$$courses\_fall\_2017 \leftarrow \Pi_{course\_id}(\sigma_{semester = \text{"Fall"} \wedge year=2017} (section))$$
$$courses\_spring\_2018 \leftarrow \Pi_{course\_id}(\sigma_{semester = \text{"Spring"} \wedge year=2018} (section))$$
$$courses\_fall\_2017 \cap courses\_spring\_2018$$

- **Equivalent queries**: two queries that give the same result on any DB instance
  - Some formulation can be more efficient than others

SQL Overview

- **Relational algebra**: mathematical description of a language to manipulate *relations*
- **SQL**: programming language to describe and transform data in a relational DB
  - Originally called Sequel
  - Name was changed to Structured Query Language
- **SQL statements can be grouped based on their goal**
  - Data definition language (DDL)
    - Define schema of the data (e.g., tables, attributes, indices)
    - Specify integrity constraints (e.g., primary key, foreign key, not null)
  - Data modification language (DML)
    - Modify the data in tables
    - Insert
    - Update
    - Delete
  - Control transactions
    - E.g., specify beginning and end, control isolation level
  - Query data
  - Define views
  - Authorization
    - Specify access and security constraints

SQL Overview

- Data description language (DDL)

```
CREATE TABLE <name> (<field> <domain>, ... )
```

- Data modification language (DML)

```
INSERT INTO <name> (<field names>) VALUES (<field values>)

DELETE FROM <name> WHERE <condition>

UPDATE <name> SET <field name> = <value> WHERE <condition>
```

- Query language

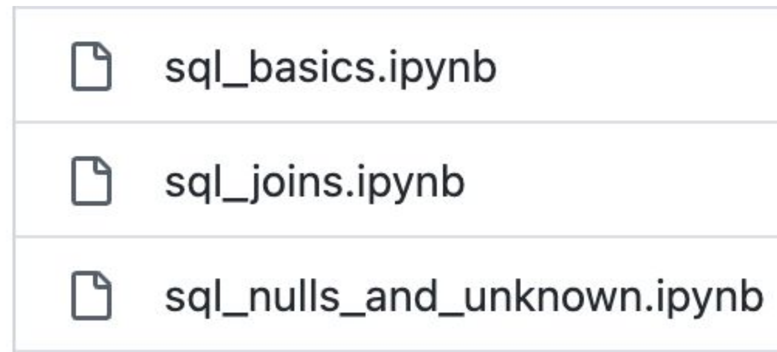
```
SELECT <fields> FROM <name> WHERE <condition>
```

Jupyter Tutorial

- Let's start with a tutorial of Jupyter notebooks
- Jupyter tutorial dir
- Readme
  - Explains how to run the tutorial
- Notebook to execute / study

SQL Tutorial

- [SQL tutorial dir]
- [Readme]
  - Explains how to run the tutorial
- Three notebooks in tutorial_university



- **How to learn from a tutorial**
  - Reset the notebook
  - Execute each cell one at the time
  - Ideally create a new file and retype (!) everything
  - Understand what each cell does
  - Look at the output
  - Change the code
  - Play with it
  - Build your mental model

Create Table

```
CREATE TABLE r
   (A_1 D_1,
   A_2 D_2,
   ...
   A_n D_n,
   IntegrityConstraint_1,
   IntegrityConstraint_n);
```

where:

- r is name of *table* (aka *relation)*
- A_i name of *attribute* (aka *field*, *column*)
- D_i domain of attribute A_i

- **Constraints**
  - SQL will prevent changes to the DB that violate any integrity constraint
  - Primary key
    - Need to be all non-null and unique
    - `PRIMARY KEY (A_j1, A_j2, ..., A_jn)`
  - Foreign key
    - Values of attributes for any tuple in current relation must correspond to values of the primary key attributes of some tuple in relation s
    - `FOREIGN KEY (A_k1, A_k2, ..., A_kn) REFERENCES s`
  - Not null
    - Specify that null value is not allowed for that attribute
    - `A_i D_i NOT NULL`

Select

```
SELECT A_1, A_2, ..., A_n
    FROM r_1, r_2, ..., r_m
    WHERE P;
```

- `SELECT`: select the attributes to list (i.e., projection)
- `FROM`: list of tables to be accessed
  - Define a Cartesian product of the tables
  - The query is going to be optimized to avoid to enumerate tuples that will be eliminated
- `WHERE`: predicate involving attributes of the relations in the FROM clause (i.e., selection)

- In SELECT or WHERE clauses, might need to use the table names as prefix to qualify the attribute name
  - E.g., instructor.ID vs teaches.ID

- A SELECT statement can be expressed in terms of relational algebra
  - Cartesian product → selection → projection
  - Difference: SQL allows duplicated values, relational algebra works with mathematical sets

Null values

- An arithmetic operation with NULL yields NULL
- Comparison with NULL
  - 1 < NULL?
  - What about NOT(1 < NULL)?
  - SQL yields UNKNOWN when comparing with NULL value
  - There are 3 logical values: True, False, Unknown
- Boolean operators
  - Can be extended according to common sense, e.g.,
  - True AND Unknown = Unknown
  - False AND Unknown = False
- In a WHERE clause, if the result is Unknown it's not included

Group by Query

- The attributes in GROUP BY are used to form groups
  - Tuples with the same value on all attributes are placed in one group
- Any attribute that is not in the GROUP BY can appear in the SELECT clause only as argument of aggregate function

```
SELECT dept_name, AVG(salary)
    FROM instructor
    GROUP BY dept_name;

-- Error.
SELECT dept_name, salary
    FROM instructor
    GROUP BY dept_name;
```

- salary is not in GROUP BY so it must be in an aggregate function

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

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

Having

- State a condition that applies to groups instead of tuples (like WHERE)
- Any attribute in the HAVING clause must appear in the GROUP BY clause
- E.g., find departments with avg salary of instructors > $42k

```
SELECT dept_name, AVG(salary) AS avg_salary
    FROM instructor
    GROUP BY dept_name
    HAVING AVG(salary) > 42000;
```

- How does it work
  - FROM is evaluated to create a relation
  - (optional) WHERE is used to filter
  - GROUP BY collects tuples into groups
  - (optional) HAVING is applied to each group and groups are filtered
  - SELECT generates tuples of the results, applying aggregate functions to get a single result for each group

Nested subqueries

- SQL allows to use the result of a query in another query
  - E.g., one can use a subquery returning only one attribute (aka scalar subquery) in any place a value is used
  - E.g., use the result of a query for set membership in the WHERE clause
  - E.g., use the result of a query in a FROM clause

```
SELECT tmp.dept_name, tmp.avg_salary
   FROM (SELECT dept_name, AVG(salary) AS
avg_salary
      FROM instructor
      GROUP BY dept_name) AS tmp
WHERE avg_salary > 42000
```

dept_name	avg_salary
Finance	85000.00000000000
History	61000.000000000000
Physics	91000.000000000000
Comp. Sci.	77333.333333333333
Biology	72000.000000000000
Elec. Eng.	80000.000000000000

With

- WITH clause allows to define a temporary relation containing the results of a subquery
- It can be equivalent to a nested subqueries, but clearer
- Find department with the maximum budget.

```
WITH max_budget(value) as (
    SELECT MAX(budget) FROM department)
    SELECT department.dept_name, budget
        FROM department, max_budget
        WHERE department.budget = max_budget.value
```

dept_name	budget
Finance	120000.00

Delete

- One can delete tuples using a query returning entire rows of a table

```
DELETE FROM r WHERE p
```

  where:

  - r is a relation
  - P is a predicate

- Remove all tuples (but not the table)

```
DELETE FROM instructor
```

Insert

To insert data into a relation we can specify tuples to insert

- Tuples

```
INSERT INTO course VALUES (‘DATA-605’, ‘Big data systems’, ‘Comp. Sci.’, 4)
INSERT INTO course(course_id, title, dept_name, credits) VALUES (‘DATA-605’,
‘Big data systems’, ‘Comp. Sci.’, 4)
```

- Query whose results is a set of tuples

```
INSERT INTO instructor (
    SELECT ID, name, dept_name, 18000
    FROM student
    WHERE dept_name = ‘Music’ AND tot_cred > 144)
```

- Nested queries are evaluated and then inserted so this doesn’t create infinite workload

```
INSERT INTO student (SELECT * FROM student)
```

- Many DB have bulk loader utilities to insert a large set of tuples into a relation, reading from formatted text files
    - This is much faster than INSERT statements

Update

- SQL can change a value in a tuple without changing all the other values
- E.g., increase salary of all instructors by 5%

```
UPDATE instructor
   SET salary = salary * 1.05
```

- E.g., conditionally

```
UPDATE instructor
   SET salary = salary * 1.05
   WHERE salary < 70000
```

- Nesting is allowed

```
UPDATE instructor
   SET salary = salary * 1.05
   WHERE salary < (SELECT AVG(salary) FROM instructor)
```

UMD DATA605 - Big Data Systems
Movie Database Example (Optional)

Example Schema for SQL Queries

```
Movie(title, year, length, inColor, studioName, producerC#)
StarsIn(movieTitle, movieYear, starName)
MovieStar(name, address, gender, birthdate)
MovieExec(name, address, cert#, netWorth)
Studio(name, address, presC#)
```

title	year	length	inColor	studioName	producerC#
Plane Crazy	1927	6	no	Disney	WD100
Casablanca	1942	102	no	Warner Bros.	HW101
Star Wars	1977	121	yes	LucasFilm	GL102
Star Wars: ESB	1980	120	yes	LucasFilm	GL102
Star Wars: TPM	1999	133	yes	LucasFilm	GL102
Raiders of the Lost Ark	1981	115	yes	Paramount	FM103

Movies

name	address	gender	birthdate
H. Ford	...	M	7/13/1942
M. Hamill	...	M	9/25/1951
C. Fisher	...	F	10/21/1956

MovieStar

movieTitle	movieYear	starName
Star Wars	1977	H. Ford
Star Wars	1977	M. Hamill
Star Wars	1977	C. Fisher
Star Wars: ESB	1980	H. Ford
Star Wars: ESB	1980	M. Hamill
Star Wars: ESB	1980	C. Fisher
Raiders of the Lost Ark	1981	H. Ford

StarsIn

name	address	cert#	netWorth
Walt Disney	...	WD100	...
Hal B. Wallis	...	HW101	...
George Lucas	...	GL102	zillions
Frank Marshall	...	FM103	...
Robert Iger	...	RI104	...

MovieExec

name	address	presC#
LucasFilm	...	GL101
Disney	...	RI103
Warner Bros.	...	...

Studio

SQL: Data Definition

- CREATE TABLE

```
CREATE TABLE movieExec (
          name char(30),
          address char(100),
          cert# integer primary key,
          networth integer);
CREATE TABLE movie (
          title char(100),
          year integer,
          length integer,
          inColor smallint,
          studioName char(20),
          producerC# integer references
             movieExec(cert#) );
```

- Must define movieExec before movie. Why?

SQL: Data Manipulation

- INSERT

```
INSERT INTO StarsIn values('King Kong', 2005, 'Naomi Watts');
INSERT INTO StarsIn(starName, movieTitle, movieYear)
        values('Naomi Watts', 'King Kong', 2005);
```

- DELETE

```
DELETE FROM movies WHERE movieYear < 1980;
```

  – Syntax is fine, but this command will be rejected. Why?

```
DELETE FROM movies WHERE length < (
     SELECT avg(length) FROM movies);
```

  – Problem: as we delete tuples, the average length changes
  – Solution:
    - First, compute avg length and find all tuples to delete
    - Next, delete all tuples found above (without recomputing avg or retesting the tuples)

SQL: Data Manipulation

- UPDATE
  - Increase all movieExec netWorth's over $100,000 by 6%, all other accounts receive 5%
  - Write two update statements:

```
UPDATE movieExec SET netWorth = netWorth * 1.06 WHERE netWorth > 100000;
UPDATE movieExec SET netWorth = netWorth * 1.05 WHERE netWorth <= 100000;
```

  - The order is important
  - Can be done better using the case statement

```
UPDATE movieExec
SET netWorth =
 CASE
     WHEN netWorth > 100000
             THEN netWorth * 1.06
     WHEN netWorth <= 100000
             THEN netWorth * 1.05
 END;
```

SQL Single Table Queries

- Movies produced by Disney in 1990: note the *rename*

```
SELECT m.title, m.year
FROM movie m
WHERE m.studioname = 'disney' AND m.year = 1990;
```

  – The **SELECT** clause can contain expressions

```
SELECT title || ' (' || to_char(year) || ')' AS titleyear
SELECT 2014 - year
```

  - The **WHERE** clause support a large number of different predicates and combinations thereof

```
year BETWEEN 1990 and 1995
title LIKE 'star wars%'
title LIKE 'star wars _'
```

Single Table Queries

- Find distinct movies sorted by title

```
SELECT DISTINCT title
FROM movie
WHERE studioname = 'disney' AND year = 1990
ORDER by title;
```

- Average length of a movie

```
SELECT year, avg(length)
FROM movie
GROUP BY year;
```

- **GROUP BY:** is a very important concept that shows up in many data processing platforms
  - What it does:
    - Partition the tuples by the group attributes (*year* in this case)
    - Do something (*compute avg* in this case) for each group
    - Number of resulting tuples == number of groups

Single Table Queries

- Find movie with the maximum length

```
SELECT title, year
FROM movie
where movie.length = (select max(length) from movie);
```

  - The smaller "subquery" is called a "nested subquery”

- Find movies with at most 5 stars: an example of a correlated subquery

```
SELECT *
FROM movies m
WHERE 5 >= (SELECT count(*)
            FROM starsIn si
            WHERE si.title = m.title AND
                  si.year = m.year);
```

  - The "inner" subquery counts the number of actors for that movie.

Single Table Queries

- Rank movies by their length

```
SELECT title, year,
     (SELECT count(*)
      FROM movies m2
      WHERE m1.length <= m2.length) AS rank
     FROM movies m1;
```

  - Key insight: A movie is ranked 5th if there are exactly 4 movies with longer length.
  - Most database systems support some sort of a *rank* keyword for doing this
  - The above query doesn't work in presence of ties, etc.
- Set operations

```
SELECT name
FROM movieExec
union/intersect/minus
     SELECT name FROM
     movieStar
```

Single Table Queries

- Set Comparisons

```
SELECT *
    FROM movies
    WHERE year IN [1990, 1995, 2000];

SELECT *
    FROM movies
    WHERE year NOT IN (
        SELECT EXTRACT(year from birthdate)
        FROM MovieStar
    );
```

Multi-table Queries

- Key:
  - Do a join to get an appropriate table
  - Use the constructs for single-table queries
  - You will get used to doing all at once
- Examples:

```
SELECT title, year, me.name AS producerName
FROM movies m, movieexec me
WHERE m.producerC# = me.cert#;
```

Multi-table Queries

- Consider the query:

```
SELECT title, year, producerC#, count(starName)
     FROM movies, starsIn
     WHERE title = starsIn.movieTitle AND
           year = starsIn.movieYear
     GROUP BY title, year, producerC#
```

  - What about movies with no stars?
  - Need to use **outer joins**

```
SELECT title, year, producerC#, count(starName)
     FROM movies LEFT OUTER JOIN starsIn
     ON title = starsIn.movieTitle AND year = starsIn.movieYear
     GROUP BY title, year, producerC#
```

  - All tuples from 'movies' that have no matches in starsIn are included with NULLs
  - So if a tuple (m1, 1990) has no match in starsIn, we get (m1, 1990, NULL) in the result
  - The count(starName) works correctly then
  - Note: count(*) would not work correctly (NULLs can have unintuitive behavior)

Other SQL Constructs

- Views

```
CREATE VIEW DisneyMovies
   SELECT *
      FROM movie m
      WHERE m.studioname = 'disney';
```

  - Can use it in any place where a table name is used
  - Views are used quite extensively to: (1) simplify queries, (2) hide data (by giving users access only to specific views)
  - Views may be *materialized* or not

Other SQL Constructs

- NULLs
  - Value of any attribute can be NULL
    - Because: value is unknown, or it is not applicable, or hidden, etc.
  - Can lead to counterintuitive behavior
  - For example, the following query does not return movies where length = NULL

```
SELECT * FROM movies
WHERE length >= 120 OR length <= 120
```

  - Aggregate operations can be especially tricky
- Transactions
  - A transaction is a sequence of queries and update statements executed as a single unit
  - For example, transferring money from one account to another
    - Both the *deduction* from one account and *credit* to the other account should happen, or neither should
- Triggers
  - A trigger is a statement that is executed automatically by the system as a side effect of a modification to the database

Other SQL Constructs

- Integrity Constraints
  - Predicates on the database that must always hold
  - Key Constraints: Specifying something is a primary key or unique

```
CREATE TABLE customer (
    ssn CHAR(9) PRIMARY KEY,
    cname CHAR(15), address CHAR(30), city CHAR(10),
UNIQUE (cname, address, city));
```

  - Attribute constraints: Constraints on the values of attributes

```
bname char(15) not null
balance int not null, check (balance>= 0)
```

Integrity Constraints

- Referential integrity: prevent dangling tuples

```
CREATE TABLE branch(
bname CHAR(15) PRIMARY KEY,
...);
CREATE TABLE loan(...,
FOREIGN KEY bname REFERENCES branch);
```

- Can tell the system what to do if a referenced tuple is being deleted

Integrity Constraints

- Global Constraints
  - Single-table

```
CREATE TABLE branch (...,
bcity CHAR(15),
assets INT,
CHECK (NOT(bcity = ‘Bkln’) OR assets>5M))
```

  - Multi-table

```
CREATE ASSERTION loan-constraint
CHECK (NOT EXISTS (
    SELECT*
    FROM loan AS L
    WHERE NOT EXISTS(
        SELECT*
        FROM borrower B, depositor D, account A
        WHERE B.cname = D.cname AND
            D.acct_no = A.acct_no AND
            L.lno= B.lno)))
```

Additional SQL Constructs

- **Select** subquery factoring
  - To allow assigning a name to a subquery, then use its result by referencing that name

```
WITH temp AS (
   SELECT title, avg(length)
   FROM movies
   GROUP BY year)
SELECT COUNT(*) FROM temp;
```

  - Can have multiple subqueries (multiple with clauses)
  - Real advantage is when subquery needs to be referenced multiple times in main select
  - Helps with complex queries, both for readability and maybe performance (can cache subquery results)

Another SQL Construct

- `SELECT HAVING` clause
  - Used in combination with `GROUP BY` to restrict the groups of returned rows to only those where condition evaluates to true

```
SELECT year, count(*)
   FROM movies WHERE year > 1980
   GROUP BY year
   HAVING COUNT(*) > 10;
```

  - Difference from `WHERE` clause is that it applies to summarized group records, and where applies to individual records