

*W4111 – Introduction to Databases
Section 002, Fall 2023*

Lecture 5: ER, Relational, SQL (IV)



Contents

Contents

- Some more relational algebra.
- Some complex examples pulling together concepts.
- Integrity constraints, part 2:
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- Indexes: Concepts and examples.
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- Views
- Codd's Rules
- ER design patterns and advanced concepts.
- Applications: REST and web applications.

More Relational Algebra

What are all those other Symbols?

- τ order by
- γ group by
- \neg negation
- \div set division
- \bowtie natural join, theta-join
- \bowtie_l left outer join
- \bowtie_r right outer join
- \bowtie_f full outer join
- \bowtie_s left semi join
- \bowtie_r right semi join
- \triangleright anti-join

- Some of the operators are useful and “common,” but not always considered part of the core algebra.
- Some of these are pretty obscure
 - Division
 - Anti-Join
 - Left semi-join
 - Right semi-join
- Most SQL engines do not support them.
 - You can implement them using combinations of JOIN, SELECT, WHERE,
 - But, I cannot every remember using them in applications I have developed.
- Outer JOIN is very useful, but less common. We will cover.
- There are also some “patterns” or “terms”
 - Equijoin
 - Non-equi join
 - Natural join
 - Theta join
 -
- I may ask you to define these terms on some exams or the obscure operators because they may be common internships/job interview questions.

Anti – Join

- “An anti-join is when you would like to keep all of the records in the original table except those records that match the other table.”

instructor \triangleright ID=i_id advisor

instructor.ID	instructor.name	instructor.dept_name	instructor.salary
12121	'Wu'	'Finance'	90000
15151	'Mozart'	'Music'	40000
32343	'El Said'	'History'	60000
33456	'Gold'	'Physics'	87000
58583	'Califieri'	'History'	62000
83821	'Brandt'	'Comp. Sci.'	92000

$\sigma_{i_id=null} (\text{instructor} \bowtie \text{ID}=i_id \text{ advisor})$

instructor.ID	instructor.name	instructor.dept_name	instructor.salary	advisor.s_id	advisor.i_id
12121	'Wu'	'Finance'	90000	null	null
15151	'Mozart'	'Music'	40000	null	null
32343	'El Said'	'History'	60000	null	null
33456	'Gold'	'Physics'	87000	null	null
58583	'Califieri'	'History'	62000	null	null
83821	'Brandt'	'Comp. Sci.'	92000	null	null

Group By, Order By

classroom

classroom.building	classroom.room_number	classroom.capacity
'Packard'	101	500
'Painter'	514	10
'Taylor'	3128	70
'Watson'	100	30
'Watson'	120	50

- These are very simple examples.
- We can apply them to relations created by operations on other tables.

$\tau \text{total_seats } (\gamma \text{ building; sum(capacity)} \rightarrow \text{total_seats} \text{ (classroom)})$

classroom.building	total_seats
'Painter'	10
'Taylor'	70
'Watson'	80
'Packard'	500

Complex Examples

(Classic Models, DataGrip)

Integrity Constraints, Part 2

Simple Example

- Consider a simple example of an entity class *major*:
 - *major(id, name, track)*
 - “id” is a uniquely generated ID
 - “name” is the major name, e.g. “Computer Science,” “Economics,”
 - “track” is a sub-track/specialty within the major, e.g. “Applications,” “AI/ML,” ...
 - “track” is optional
 - The combination of *(name, track)* is *unique*.
- **Note:** In many DBMS, this automatically creates indices for keys/constraints.
- Switch to Notebook.

```
create table if not exists majors
(
    id          int auto_increment
    primary key,
    major_name  varchar(64) not null,
    major_track varchar(64) null,
    constraint table_name_pk
        unique (major_name, major_track)
);
```



The check clause

- The **check** (P) clause specifies a predicate P that must be satisfied by every tuple in a relation.
- Example: ensure that semester is one of fall, winter, spring or summer

```
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', 'Winter', 'Spring', 'Summer')))
```

DFF:

- We could handle the *semester check* with an *enum*.
- Switch to notebook for a slightly different example.



Referential Integrity

- Ensures that a value that appears in one relation for a given set of attributes also appears for a certain set of attributes in another relation.
 - Example: If “Biology” is a department name appearing in one of the tuples in the *instructor* relation, then there exists a tuple in the *department* relation for “Biology”.
- 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.

Examples

- Do a couple of examples.

Indexes

Concepts and Examples



Index Creation

- Many queries reference only a small proportion of the records in a table.
- It is inefficient for the system to read every record to find a record with particular value
- An **index** on an attribute of a relation is a data structure that allows the database system to find those tuples in the relation that have a specified value for that attribute efficiently, without scanning through all the tuples of the relation.
- We create an index with the **create index** command

```
create index <name> on <relation-name> (attribute);
```



Index Creation Example

- **create table student**
*(ID varchar (5),
name varchar (20) not null,
dept_name varchar (20),
tot_cred numeric (3,0) default 0,
primary key (ID))*
- **create index studentID_index on student(ID)**
- The query:

```
select *  
from student  
where ID = '12345'
```

can be executed by using the index to find the required record, without looking at all records of *student*

DFF:

- An index on (column1, column2, column3)
- Is also an index on (column1) and (column1, column2)
- But not (column2), (column3), (column2, column3).
- We will see “why” later in the semester.

Subqueries

Concepts and Examples

(Including Set Membership)

Concepts Reminder



Nested Subqueries

- SQL provides a mechanism for the nesting of subqueries. A **subquery** is a **select-from-where** expression that is nested within another query.
- The nesting can be done in the following SQL query

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

as follows:

- **From clause:** r_i can be replaced by any valid subquery
- **Where clause:** P can be replaced with an expression of the form:

$B <\text{operation}> (\text{subquery})$

B is an attribute and $<\text{operation}>$ to be defined later.

- **Select clause:**

A_i can be replaced by a subquery that generates a single value.

Note:

- This is a little cryptic.
- I think I know what they mean.
- There are some operations we will see later in the material, e.g IN, EXISTS,



Consider a Subquery Tables

```
select *, (select name from student where student.id=takes.id) as name from takes;
```

Takes

ID	course_id	sec_id	semester	year	grade
00128	CS-101	1	Fall	2017	A
00128	CS-347	1	Fall	2017	A-
12345	CS-101	1	Fall	2017	C
12345	CS-190	2	Spring	2017	A
12345	CS-315	1	Spring	2018	A
12345	CS-347	1	Fall	2017	A
19991	HIS-351	1	Spring	2018	B
23121	FIN-201	1	Spring	2018	C+
44553	PHY-101	1	Fall	2017	B-
45678	CS-101	1	Fall	2017	F
45678	CS-101	1	Spring	2018	B+
45678	CS-319	1	Spring	2018	B
54321	CS-101	1	Fall	2017	A-
54321	CS-190	2	Spring	2017	B+
55739	MU-199	1	Spring	2018	A-
76543	CS-101	1	Fall	2017	A
76543	CS-319	2	Spring	2018	A
76653	EE-181	1	Spring	2017	C
98765	CS-101	1	Fall	2017	C-
98765	CS-315	1	Spring	2018	B
98988	BIO-101	1	Summer	2017	A
98988	BIO-301	1	Summer	2018	None

- Assume I wrote a function
`find_student_name(x)`

- Input is an x
- Loops through all students and returns students with `student.ID = x`.

- The query with a subquery above is like:

`result = []`

For t in takes:

```
new_r = t + find_student_name(t.id)  
result.append(new_r)
```

Student

ID	name	dept_name	tot_cred
00128	Zhang	Comp. Sci.	102
12345	Shankar	Comp. Sci.	32
19991	Brandt	History	80
23121	Chavez	Finance	110
44553	Peltier	Physics	56
45678	Levy	Physics	46
54321	Williams	Comp. Sci.	54
55739	Sanchez	Music	38
70557	Snow	Physics	0
76543	Brown	Comp. Sci.	58
76653	Aoi	Elec. Eng.	60
98765	Bourikas	Elec. Eng.	98
98988	Tanaka	Biology	120

Examples

Views



Views

- In some cases, it is not desirable for all users to see the entire logical model (that is, all the actual relations stored in the database.)
- Consider a person who needs to know an instructors name and department, but not the salary. This person should see a relation described, in SQL, by

```
select ID, name, dept_name  
from instructor
```

- A **view** provides a mechanism to hide certain data from the view of certain users.
- Any relation that is not of the conceptual model but is made visible to a user as a “virtual relation” is called a **view**.



View Definition

- A view is defined using the **create view** statement which has the form

create view *v* as <query expression>

where <query expression> is any legal SQL expression. The view name is represented by *v*.

- Once a view is defined, the view name can be used to refer to the virtual relation that the view generates.
- View definition is not the same as creating a new relation by evaluating the query expression
 - Rather, a view definition causes the saving of an expression; the expression is substituted into queries using the view.



View Definition and Use

- A view of instructors without their salary

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

- 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;
```



Views Defined Using Other Views

- One view may be used in the expression defining another view
- A view relation v_1 is said to **depend directly** on a view relation v_2 if v_2 is used in the expression defining v_1
- A view relation v_1 is said to **depend on** view relation v_2 if either v_1 depends directly to v_2 or there is a path of dependencies from v_1 to v_2
- A view relation v is said to be **recursive** if it depends on itself.



Views Defined Using Other Views

- **create view *physics_fall_2017* as**
select course.course_id, sec_id, building, room_number
from course, section
where course.course_id = section.course_id
and course.dept_name = 'Physics'
and section.semester = 'Fall'
and section.year = '2017';
- **create view *physics_fall_2017_watson* as**
select course_id, room_number
from *physics_fall_2017*
where building= 'Watson';



View Expansion

- Expand the view :

```
create view physics_fall_2017_watson as
    select course_id, room_number
        from physics_fall_2017
    where building= 'Watson'
```

- To:

```
create view physics_fall_2017_watson as
    select course_id, room_number
        from (select course.course_id, building, room_number
              from course, section
             where course.course_id = section.course_id
               and course.dept_name = 'Physics'
               and section.semester = 'Fall'
               and section.year = '2017')
    where building= 'Watson';
```



View Expansion (Cont.)

- A way to define the meaning of views defined in terms of other views.
- Let view v_1 be defined by an expression e_1 that may itself contain uses of view relations.
- View expansion of an expression repeats the following replacement step:

repeat
 Find any view relation v_i in e_1
 Replace the view relation v_i by the expression defining v_i
until no more view relations are present in e_1
- As long as the view definitions are not recursive, this loop will terminate



Materialized Views

- Certain database systems allow view relations to be physically stored.
 - Physical copy created when the view is defined.
 - Such views are called **Materialized 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.



Update of a View

- 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 into the *instructor* relation

- Must have a value for salary.

- Two approaches

- Reject the insert
 - Insert the tuple

```
('30765', 'Green', 'Music', null)
```

into the *instructor* relation



Some Updates Cannot be Translated Uniquely

- **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');
- Issues
 - Which department, if multiple departments in Taylor?
 - What if no department is in Taylor?



And Some Not at All

- ```
create view history_instructors as
 select *
 from instructor
 where dept_name= 'History';
```
- What happens if we insert  
('25566', 'Brown', 'Biology', 100000)  
into *history\_instructors*?



# View Updates in SQL

- Most SQL implementations allow updates only on simple views
  - 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.

# *Codd's Rules*

# Codd's 12 Rules

## Rule 1: Information Rule

The data stored in a database, may it be user data or metadata, must be a value of some table cell. Everything in a database must be stored in a table format.

## Rule 2: Guaranteed Access Rule

Every single data element (value) is guaranteed to be accessible logically with a combination of table-name, primary-key (row value), and attribute-name (column value). No other means, such as pointers, can be used to access data.

## Rule 3: Systematic Treatment of NULL Values

**The NULL values in a database must be given a systematic and uniform treatment. This is a very important rule because a NULL can be interpreted as one the following – data is missing, data is not known, or data is not applicable.**

## Rule 4: Active Online Catalog

**The structure description of the entire database must be stored in an online catalog, known as data dictionary, which can be accessed by authorized users. Users can use the same query language to access the catalog which they use to access the database itself.**

## Rule 5: Comprehensive Data Sub-Language Rule

A database can only be accessed using a language having linear syntax that supports data definition, data manipulation, and transaction management operations. This language can be used directly or by means of some application. If the database allows access to data without any help of this language, then it is considered as a violation.

## Rule 6: View Updating Rule

All the views of a database, which can theoretically be updated, must also be updatable by the system.

# Codd's 12 Rules

## Rule 7: High-Level Insert, Update, and Delete Rule

A database must support high-level insertion, updation, and deletion. This must not be limited to a single row, that is, it must also support union, intersection and minus operations to yield sets of data records.

## Rule 8: Physical Data Independence

The data stored in a database must be independent of the applications that access the database. Any change in the physical structure of a database must not have any impact on how the data is being accessed by external applications.

## Rule 9: Logical Data Independence

The logical data in a database must be independent of its user's view (application). Any change in logical data must not affect the applications using it. For example, if two tables are merged or one is split into two different tables, there should be no impact or change on the user application. This is one of the most difficult rules to apply.

## Rule 10: Integrity Independence

A database must be independent of the application that uses it. All its integrity constraints can be independently modified without the need of any change in the application. This rule makes a database independent of the front-end application and its interface.

## Rule 11: Distribution Independence

The end-user must not be able to see that the data is distributed over various locations. Users should always get the impression that the data is located at one site only. This rule has been regarded as the foundation of distributed database systems.

## Rule 12: Non-Subversion Rule

If a system has an interface that provides access to low-level records, then the interface must not be able to subvert the system and bypass security and integrity constraints.

# Codd's 12 Rules

## Rule 3: Systematic treatment of null values:

- “Null values (distinct from the empty character string or a string of blank characters and distinct from zero or any other number) are supported in fully relational DBMS for representing **missing information** and **inapplicable** information in a systematic way, independent of data type.”
- Sometimes programmers and database designers are tempted to use “special values” to indicate unknown, missing or inapplicable values.
  - String: “”, “NA”, “UNKNOWN”, ...
  - Numbers: -1, 0, -9999
- Indicators can cause confusion because you have to carefully code some SQL statements to the specific, varying choices programmers made.

# NULL and Correct Answers

```
In [4]: 1 %%sql describe aaaaS21Examples.null_examples;
* mysql+pymysql://dbuser:***@localhost
3 rows affected.
```

```
Out[4]:
Field Type Null Key Default Extra
name varchar(32) NO PRI None
weight int YES None
net_worth int YES None
```

```
In [5]: 1 %%sql select * from aaaaS21Examples.null_examples;
* mysql+pymysql://dbuser:***@localhost
4 rows affected.
```

```
Out[5]:
name weight net_worth
Joe 100 100
Larry 0 0
Pete None None
Tim 200 200
```

Without NULL, to get a correct answer:

- I must understand the domain to determine “unknown” values or know what choice a developer made.
- Explicitly include “where weight != 0” in all statements.
- And this varies from column to column, table to table, schema to schema, etc.

```
In [7]: 1 %%sql select avg(weight) as avg_weight, avg(net_worth) as avg_net_worth
 from aaaaS21Examples.null_examples where name in ('Joe', 'Larry', 'Tim')
* mysql+pymysql://dbuser:***@localhost
1 rows affected.
```

```
Out[7]: avg_weight avg_net_worth
100.0000 100.0000
```

```
In [9]: 1 %%sql select avg(weight) as avg_weight, avg(net_worth) as avg_net_worth
 from aaaaS21Examples.null_examples where name in ('Joe', 'Pete', 'Tim')
* mysql+pymysql://dbuser:***@localhost
1 rows affected.
```

```
Out[9]: avg_weight avg_net_worth
150.0000 150.0000
```

# Metadata and Catalog

- ‘Metadata is "data that provides information about other data". In other words, it is "data about data". Many distinct types of metadata exist, including descriptive metadata, structural metadata, administrative metadata, reference metadata and statistical metadata.’  
(<https://en.wikipedia.org/wiki/Metadata>)
- “The database catalog of a database instance consists of metadata in which definitions of database objects such as base tables, views (virtual tables), synonyms, value ranges, indexes, users, and user groups are stored. ....”

The SQL standard specifies a uniform means to access the catalog, called the INFORMATION\_SCHEMA, but not all databases follow this ...”

([https://en.wikipedia.org/wiki/Database\\_catalog](https://en.wikipedia.org/wiki/Database_catalog))

- Codd’s Rule 4: Dynamic online catalog based on the relational model:
  - The data base description is represented at the logical level in the same way as ordinary data, so that authorized users can apply the same relational language to its interrogation as they apply to the regular data.

# Data Definition Language (DDL)

- Specification notation for defining the database schema

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

- DDL compiler generates a set of table templates stored in a ***data dictionary***
- Data dictionary contains metadata (i.e., data about data)
  - Database schema
  - Integrity constraints
    - Primary key (ID uniquely identifies instructors)
  - Authorization
    - Who can access what

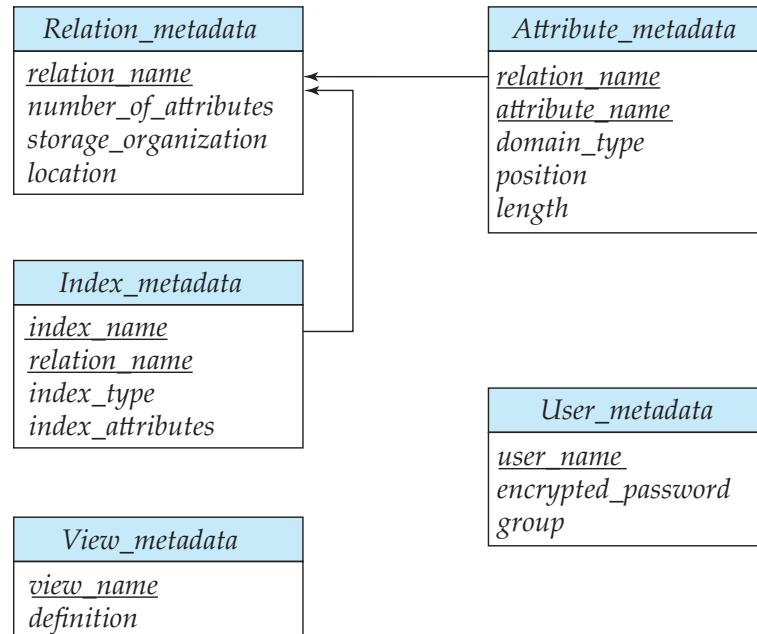
# Data Dictionary Storage

The **Data dictionary** (also called **system catalog**) stores **metadata**; that is, data about data, such as

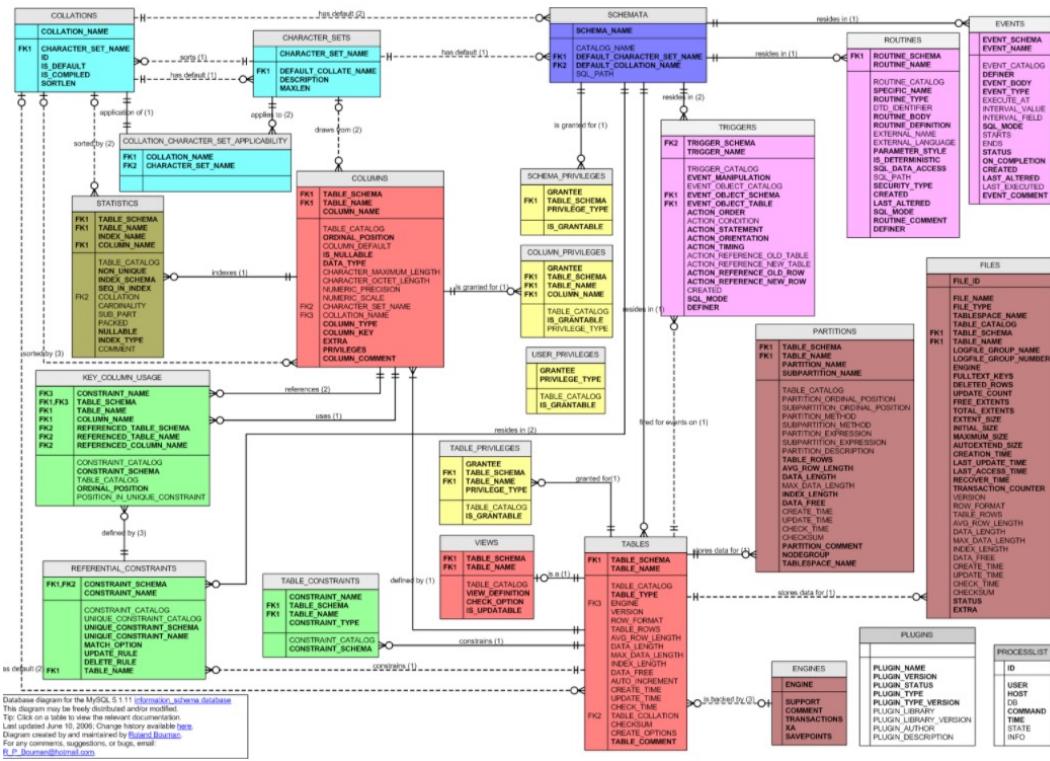
- Information about relations
  - names of relations
  - names, types and lengths of attributes of each relation
  - names and definitions of views
  - integrity constraints
- User and accounting information, including passwords
- Statistical and descriptive data
  - number of tuples in each relation
- Physical file organization information
  - How relation is stored (sequential/hash/...)
  - Physical location of relation
- Information about indices (Chapter 14)

# Relational Representation of System Metadata

- Relational representation on disk
- Specialized data structures designed for efficient access, in memory



# MySQL Catalog (Information\_Schema)



## **Some** of the MySQL Information Schema Tables:

- 'ADMINISTRABLE\_ROLE\_AUTHORIZATIONS'
  - 'APPLICABLE\_ROLES'
  - 'CHARACTER\_SETS'
  - 'CHECK\_CONSTRAINTS'
  - 'COLUMN\_PRIVILEGES'
  - 'COLUMN\_STATISTICS'
  - 'COLUMNS'
  - 'ENABLED\_ROLES'
  - 'ENGINES'
  - 'EVENTS'
  - 'FILES'
  - 'KEY\_COLUMN\_USAGE'
  - 'PARAMETERS'
  - 'REFERENTIAL\_CONSTRAINTS'
  - 'RESOURCE\_GROUPS'
  - 'ROLE\_COLUMN\_GRANTS'
  - 'ROLE\_ROUTINE\_GRANTS'
  - 'ROLE\_TABLE\_GRANTS'
  - 'ROUTINES'
  - 'SCHEMA\_PRIVILEGES'
  - 'STATISTICS'
  - 'TABLE\_CONSTRAINTS'
  - 'TABLE\_PRIVILEGES'
  - 'TABLES'
  - 'TABLESPACES'
  - 'TRIGGERS'
  - 'USER\_PRIVILEGES'
  - 'VIEW\_ROUTINE\_USAGE'
  - 'VIEW\_TABLE\_USAGE'
  - 'VIEWS'
  - CREATE and ALTER statements modify the data.
  - DBMS reads information:
    - Parsing
    - Optimizer
    - etc.

# *ER Modeling*

## *Design Patterns and Advanced Concepts*

# *Some Advanced ER Modeling*



## Weak Entity Sets

- Consider a *section* entity, which is uniquely identified by a *course\_id*, *semester*, *year*, and *sec\_id*.
- Clearly, section entities are related to course entities. Suppose we create a relationship set *sec\_course* between entity sets *section* and *course*.
- Note that the information in *sec\_course* is redundant, since *section* already has an attribute *course\_id*, which identifies the course with which the section is related.
- One option to deal with this redundancy is to get rid of the relationship *sec\_course*; however, by doing so the relationship between *section* and *course* becomes implicit in an attribute, which is not desirable.



## Weak Entity Sets (Cont.)

- An alternative way to deal with this redundancy is to not store the attribute *course\_id* in the *section* entity and to only store the remaining attributes *section\_id*, *year*, and *semester*.
  - However, the entity set *section* then does not have enough attributes to identify a particular *section* entity uniquely
- To deal with this problem, we treat the relationship *sec\_course* as a special relationship that provides extra information, in this case, the *course\_id*, required to identify *section* entities uniquely.
- A **weak entity set** is one whose existence is dependent on another entity, called its **identifying entity**
- Instead of associating a primary key with a weak entity, we use the identifying entity, along with extra attributes called **discriminator** to uniquely identify a weak entity.



## Weak Entity Sets (Cont.)

- An entity set that is not a weak entity set is termed a **strong entity set**.
- Every weak entity must be associated with an identifying entity; that is, the weak entity set is said to be **existence dependent** on the identifying entity set.
- The identifying entity set is said to **own** the weak entity set that it identifies.
- The relationship associating the weak entity set with the identifying entity set is called the **identifying relationship**.
- Note that the relational schema we eventually create from the entity set *section* does have the attribute *course\_id*, for reasons that will become clear later, even though we have dropped the attribute *course\_id* from the entity set *section*.

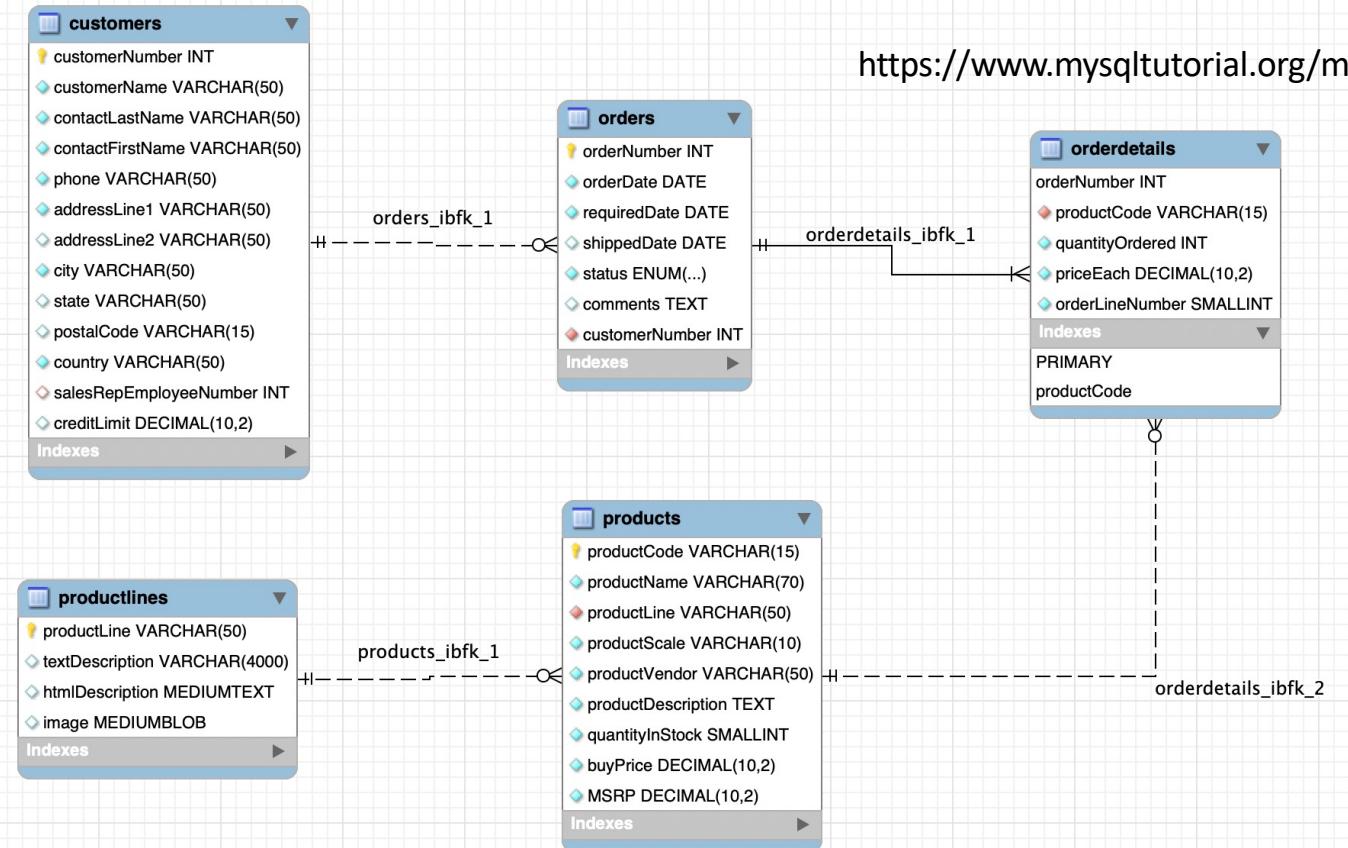


# Expressing Weak Entity Sets

- In E-R diagrams, a weak entity set is depicted via a double rectangle.
- We underline the discriminator of a weak entity set with a dashed line.
- The relationship set connecting the weak entity set to the identifying strong entity set is depicted by a double diamond.
- Primary key for *section* – (*course\_id*, *sec\_id*, *semester*, *year*)



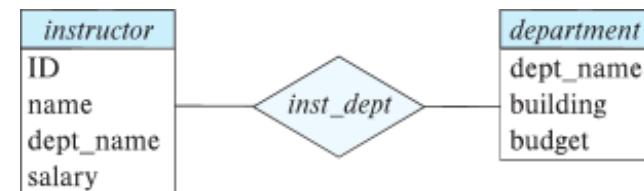
# An Example – Classic Models



<https://www.mysqltutorial.org/mysql-sample-database.aspx/>

# Redundant Attributes

- Suppose we have entity sets:
  - *instructor*, with attributes: *ID, name, dept\_name, salary*
  - *department*, with attributes: *dept\_name, building, budget*
- We model the fact that each instructor has an associated department using a relationship set *inst\_dept*
- The attribute *dept\_name* in *instructor* replicates information present in the relationship and is therefore redundant
  - and needs to be removed.
- BUT: when converting back to tables, in some cases the attribute gets reintroduced, as we will see later.





# Design Alternatives

- In designing a database schema, we must ensure that we avoid two major pitfalls:
  - Redundancy: a bad design may result in repeat information.
    - **Redundant representation of information may lead to data inconsistency among the various copies of information**
  - Incompleteness: a bad design may make certain aspects of the enterprise difficult or impossible to model.
- Avoiding bad designs is not enough. There may be a large number of good designs from which we must choose.

**Emphasis  
Added**



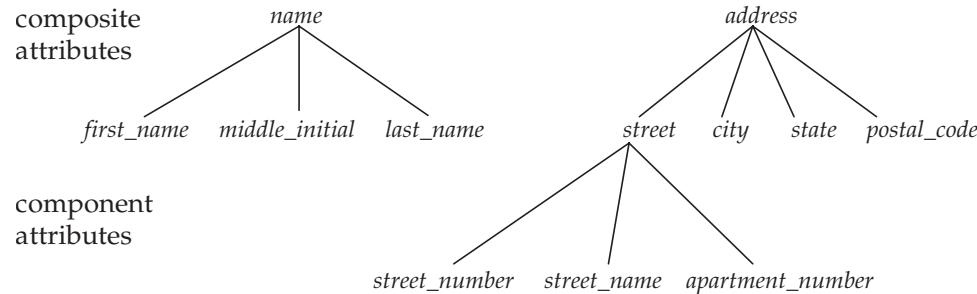
# Complex Attributes

- Attribute types:
  - **Simple** and **composite** attributes.
  - **Single-valued** and **multivalued** attributes
    - Example: multivalued attribute: *phone\_numbers*
  - **Derived** attributes
    - Can be computed from other attributes
    - Example: age, given date\_of\_birth
- **Domain** – the set of permitted values for each attribute



# Composite Attributes

- Composite attributes allow us to divide attributes into subparts (other attributes).



# Example from IMDB

- Consider name\_basics

|    | nconst    | primaryName     | birthYear | deathYear | primaryProfession                   | knownForTitles                          |
|----|-----------|-----------------|-----------|-----------|-------------------------------------|-----------------------------------------|
| 1  | nm0000001 | Fred Astaire    | 1899      | 1987      | soundtrack,actor,miscellaneous      | tt0050419,tt0031983,tt0072308,tt0053137 |
| 2  | nm0000002 | Lauren Bacall   | 1924      | 2014      | actress,soundtrack                  | tt0071877,tt0117057,tt0037382,tt0038355 |
| 3  | nm0000003 | Brigitte Bardot | 1934      | <null>    | actress,soundtrack,music_department | tt0049189,tt0056404,tt0057345,tt0054452 |
| 4  | nm0000004 | John Belushi    | 1949      | 1982      | actor,soundtrack,writer             | tt0077975,tt0072562,tt0080455,tt0078723 |
| 5  | nm0000005 | Ingmar Bergman  | 1918      | 2007      | writer,director,actor               | tt0050986,tt0060827,tt0069467,tt0050976 |
| 6  | nm0000006 | Ingrid Bergman  | 1915      | 1982      | actress,soundtrack,producer         | tt0077711,tt0038109,tt0034583,tt0036855 |
| 7  | nm0000007 | Humphrey Bogart | 1899      | 1957      | actor,soundtrack,producer           | tt0043265,tt0034583,tt0042593,tt0037382 |
| 8  | nm0000008 | Marlon Brando   | 1924      | 2004      | actor,soundtrack,director           | tt0078788,tt0068646,tt0070849,tt0047296 |
| 9  | nm0000009 | Richard Burton  | 1925      | 1984      | actor,soundtrack,producer           | tt0061184,tt0087803,tt0057877,tt0059749 |
| 10 | nm0000010 | James Cagney    | 1899      | 1986      | actor,soundtrack,director           | tt0029870,tt0035575,tt0042041,tt0055256 |

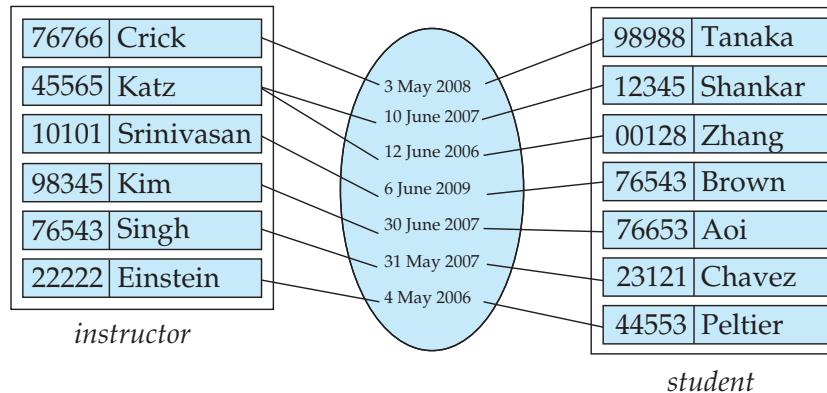
- There
  - Is one composite attribute, primaryName.
  - Are two multivalued attributes: primaryProfession, knownForTitles
  - knownForTitles is also tricky, which we will see.
  - Names are also a little tricky

Switch to notebook



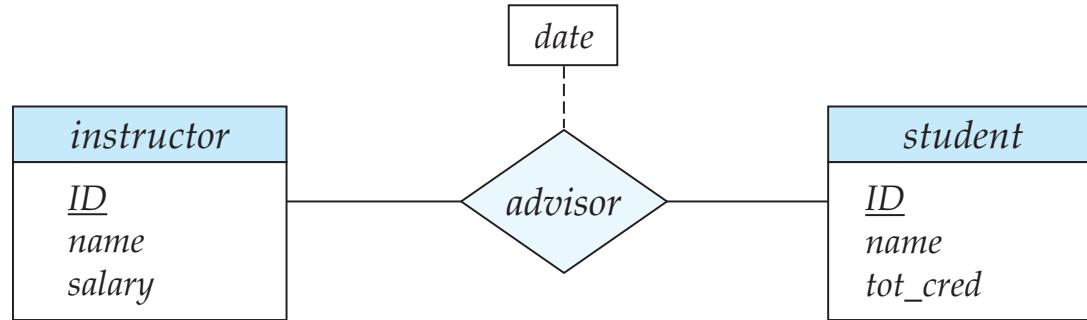
## Relationship Sets (Cont.)

- An attribute can also be associated with a relationship set.
- For instance, the *advisor* relationship set between entity sets *instructor* and *student* may have the attribute *date* which tracks when the student started being associated with the advisor





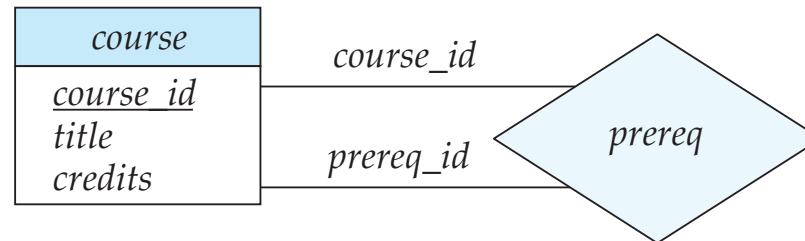
# Relationship Sets with Attributes





# Roles

- Entity sets of a relationship need not be distinct
  - Each occurrence of an entity set plays a “role” in the relationship
- The labels “*course\_id*” and “*prereq\_id*” are called **roles**.





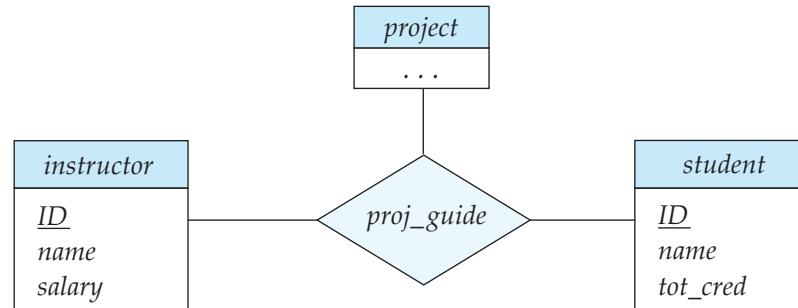
# Degree of a Relationship Set

- Binary relationship
  - involve two entity sets (or degree two).
  - most relationship sets in a database system are binary.
- Relationships between more than two entity sets are rare. Most relationships are binary. (More on this later.)
  - Example: *students* work on research *projects* under the guidance of an *instructor*.
  - relationship *proj\_guide* is a ternary relationship between *instructor*, *student*, and *project*



# Non-binary Relationship Sets

- Most relationship sets are binary
- There are occasions when it is more convenient to represent relationships as non-binary.
- E-R Diagram with a Ternary Relationship





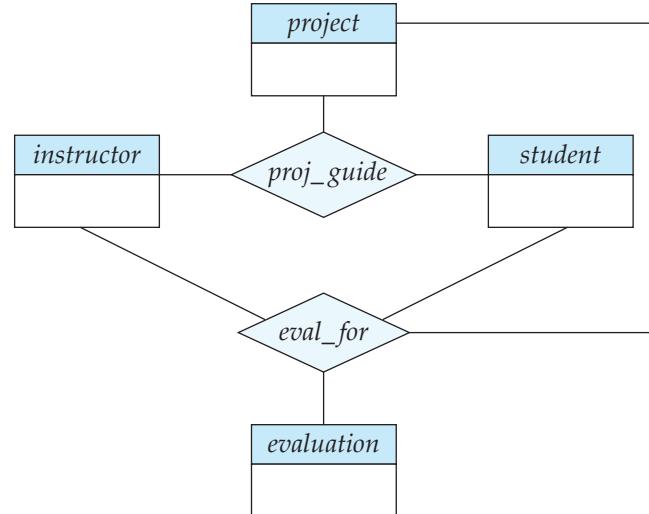
# Mapping Cardinality Constraints

- Express the number of entities to which another entity can be associated via a relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship set the mapping cardinality must be one of the following types:
  - One to one
  - One to many
  - Many to one
  - Many to many



# Aggregation

- Consider the ternary relationship *proj\_guide*, which we saw earlier
- Suppose we want to record evaluations of a student by a guide on a project





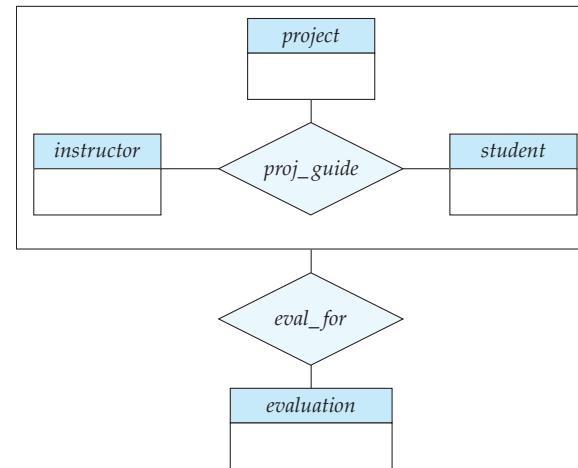
# Aggregation (Cont.)

- Relationship sets *eval\_for* and *proj\_guide* represent overlapping information
  - Every *eval\_for* relationship corresponds to a *proj\_guide* relationship
  - However, some *proj\_guide* relationships may not correspond to any *eval\_for* relationships
    - So we can't discard the *proj\_guide* relationship
- Eliminate this redundancy via *aggregation*
  - Treat relationship as an abstract entity
  - Allows relationships between relationships
  - Abstraction of relationship into new entity



# Aggregation (Cont.)

- Eliminate this redundancy via *aggregation* without introducing redundancy, the following diagram represents:
  - A student is guided by a particular instructor on a particular project
  - A student, instructor, project combination may have an associated evaluation





# Reduction to Relational Schemas

- To represent aggregation, create a schema containing
  - Primary key of the aggregated relationship,
  - The primary key of the associated entity set
  - Any descriptive attributes
- In our example:
  - The schema *eval\_for* is:  
$$\text{eval\_for} (s\_ID, project\_id, i\_ID, evaluation\_id)$$
  - The schema *proj\_guide* is redundant.



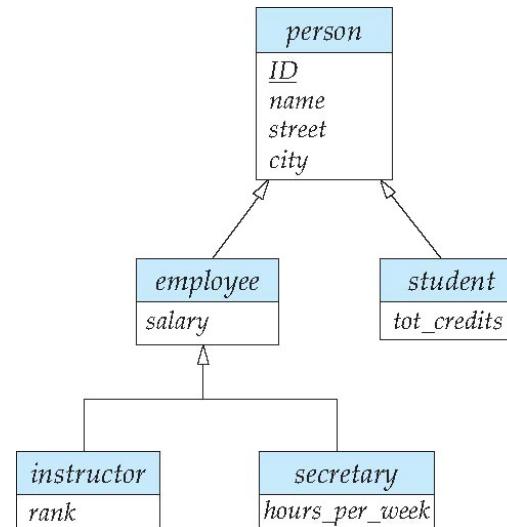
# Specialization

- Top-down design process; we designate sub-groupings within an entity set that are distinctive from other entities in the set.
- These sub-groupings become lower-level entity sets that have attributes or participate in relationships that do not apply to the higher-level entity set.
- Depicted by a *triangle* component labeled ISA (e.g., *instructor* “is a” *person*).
- **Attribute inheritance** – a lower-level entity set inherits all the attributes and relationship participation of the higher-level entity set to which it is linked.



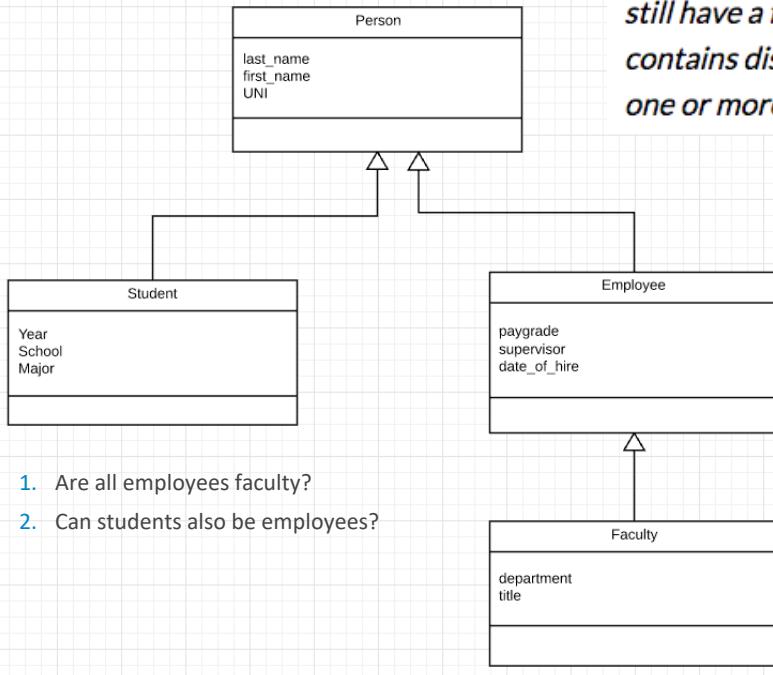
# Specialization Example

- **Overlapping** – *employee* and *student*
- **Disjoint** – *instructor* and *secretary*
- Total and partial



# Inheritance/Specialization

*In the process of designing our entity relationship diagram for a database, we may find that attributes of two or more entities overlap, meaning that these entities seem very similar but still have a few differences. In this case, we may create a subtype of the parent entity that contains distinct attributes. A parent entity becomes a supertype that has a relationship with one or more subtypes.*



1. Are all employees faculty?
2. Can students also be employees?

The subclass association line is labeled with specialization constraints. Constraints are described along two dimensions:

## 1 incomplete/complete

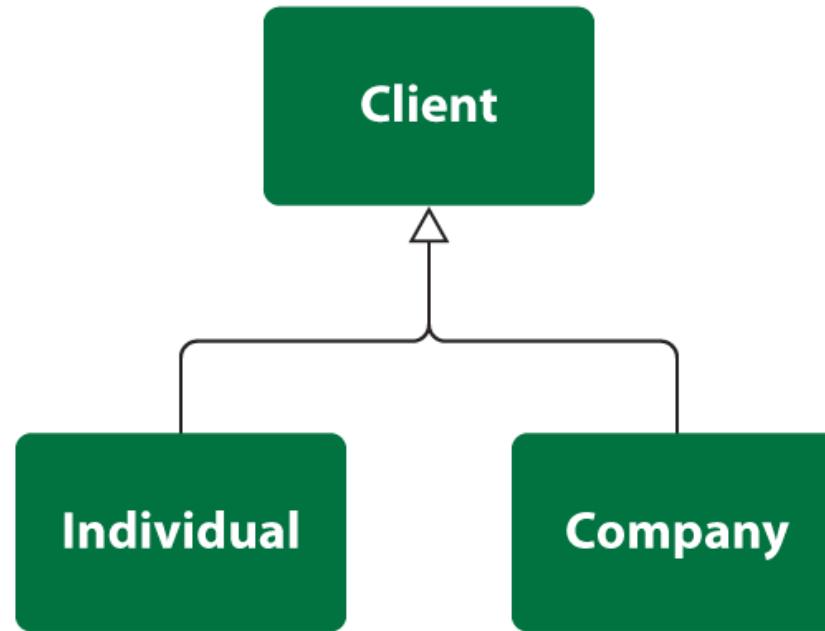
- In an **incomplete** specialization only some instances of the parent class are specialized (have unique attributes). Other instances of the parent class have only the common attributes.
- In a **complete** specialization, every instance of the parent class has one or more unique attributes that are not common to the parent class.

## 2 disjoint/overlapping

- In a **disjoint** specialization, an object could be a member of only one specialized subclass.
- In an **overlapping** specialization, an object could be a member of more than one specialized subclass.

# Specialization

In class Client we distinguish two subtypes: Individual and Company. This specialization is disjoint (client can be an individual or a company) and complete (these are all possible subtypes for supertype).

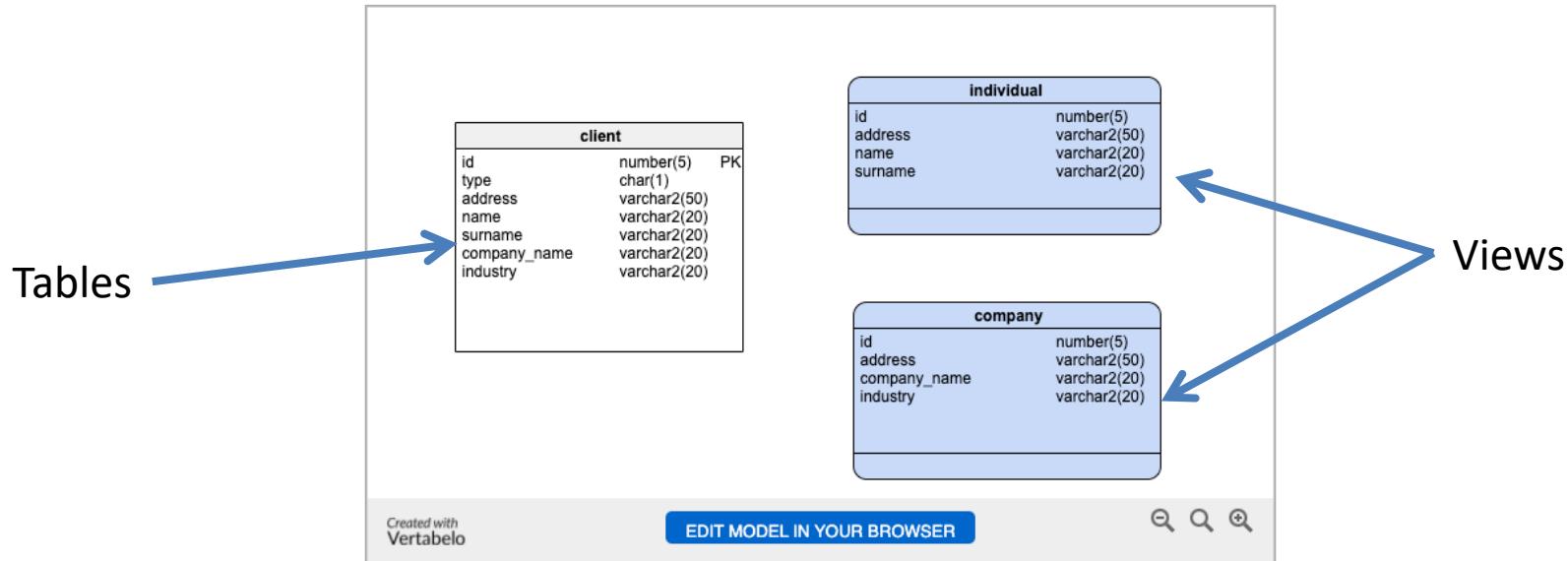


# One Table

## One table implementation

In a one table implementation, table `client` has attributes of both types.

The diagram below shows the table `client` and two views: `individual` and `company`:

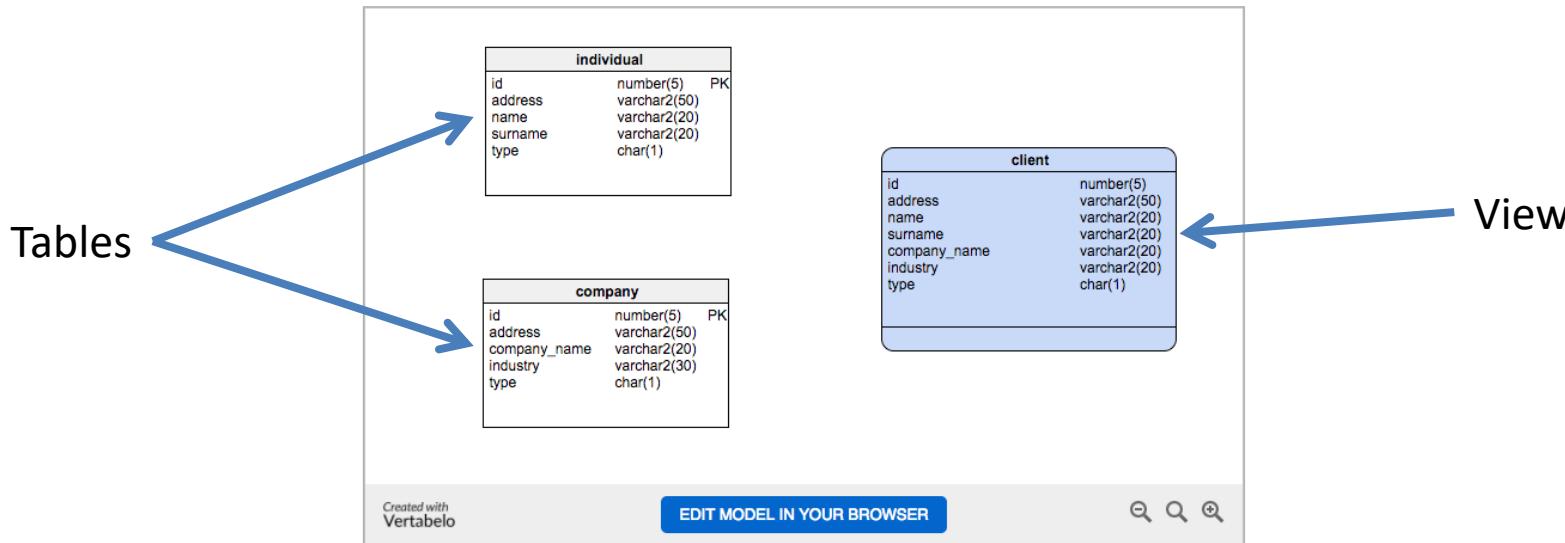


# Two Table

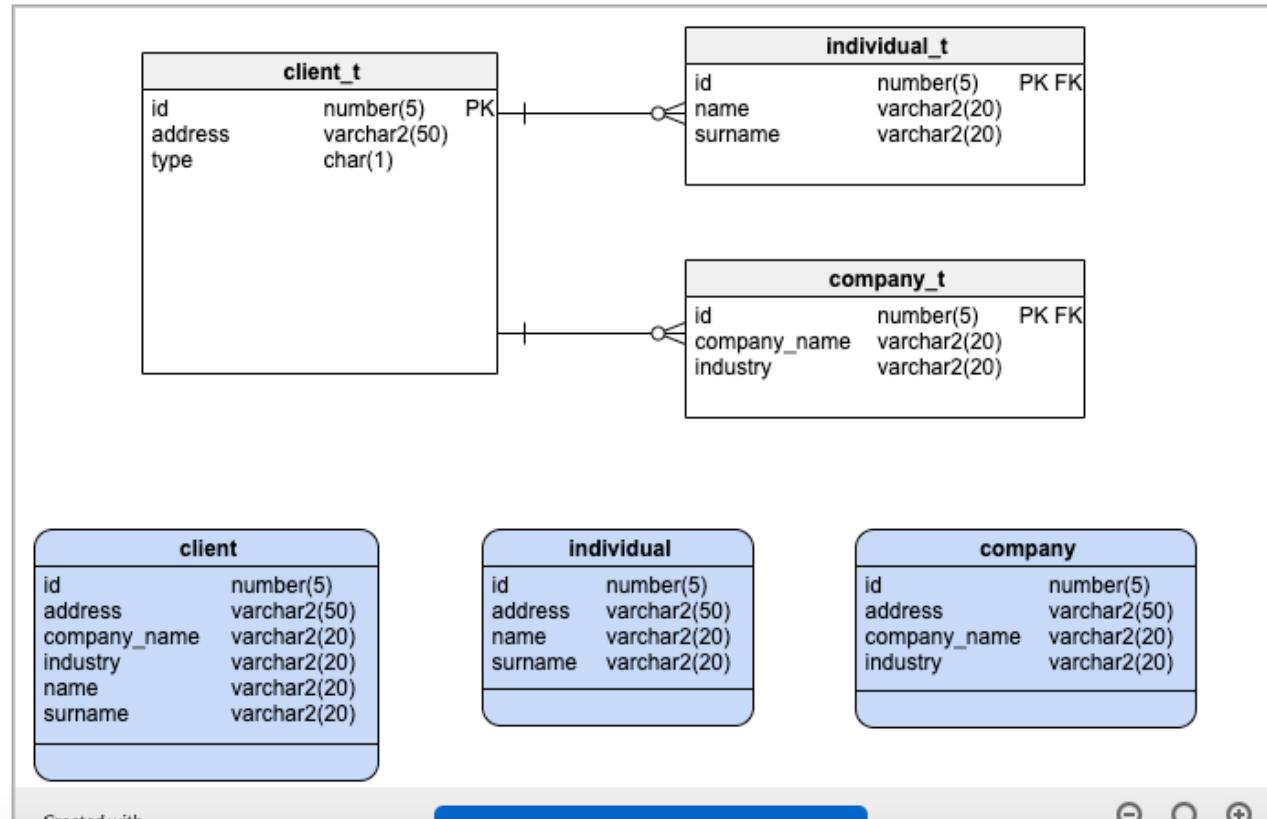
## Two-table implementation

In a two-table implementation, we create a table for each of the subtypes. Each table gets a column for all attributes of the supertype and also a column for each attribute belonging to the subtype. Access to information in this situation is limited, that's why it is important to create a view that is the union of the tables. We can add an additional attribute called 'type' that describes the subtype.

The diagram below presents two tables, `individual` and `company`, and a view (the blue one) called `client`.

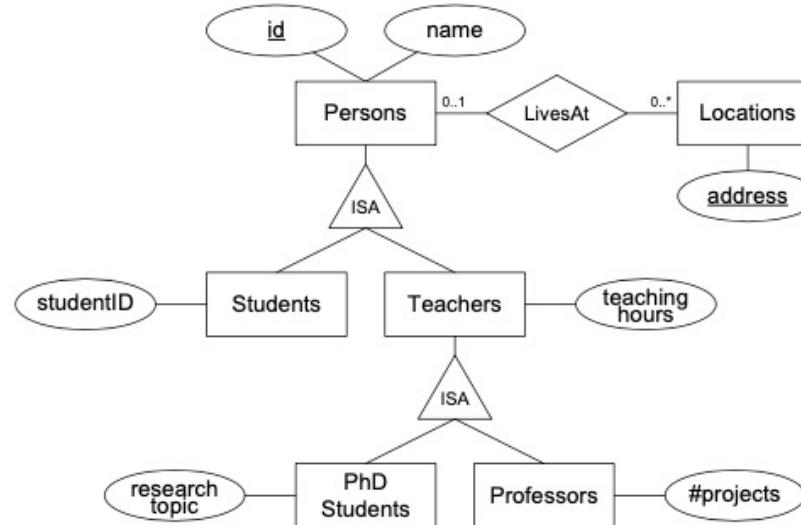


# Three Table





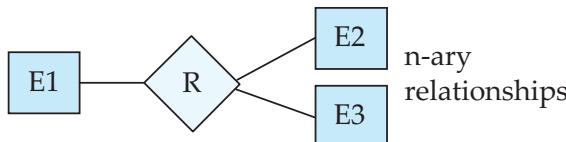
# ISA Relationship





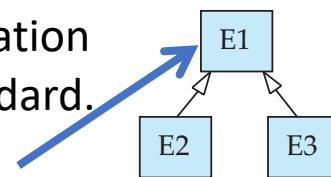
# ER vs. UML Class Diagrams

## ER Diagram Notation

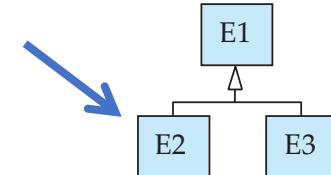


n-ary  
relationships

I use this approach  
in Crow's Foot Notation  
but that is not standard.

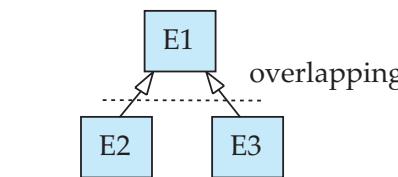
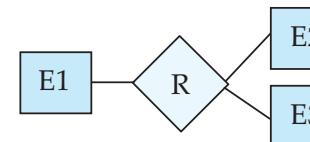


overlapping  
generalization

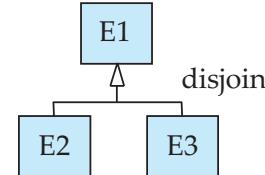


disjoint  
generalization

## Equivalent in UML



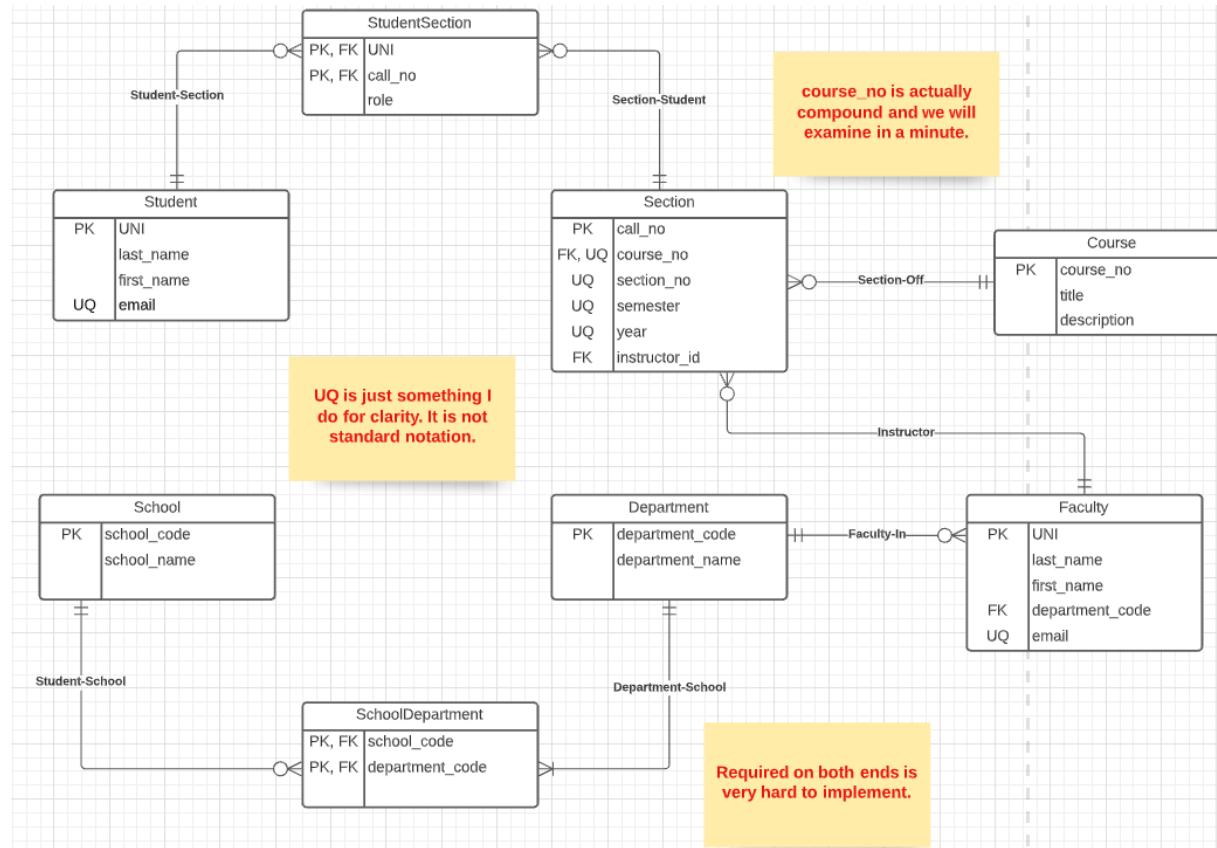
overlapping



disjoint

- \* Generalization can use merged or separate arrows independent of disjoint/overlapping

# Approximate Model



# Course Number

## Key to Columbia Course Listings

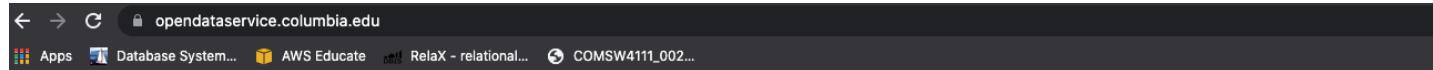
<https://www.cc-seas.columbia.edu/sites/dsa/files/handbooks/Columbia%20Key%20to%20Course%20Listing.pdf>

(Example: ECON W1105 001 Principles of Economics, 4 pts)

|       |                                           |
|-------|-------------------------------------------|
| A     | Architecture, Planning, and Preservation* |
| B     | Business*                                 |
| BC    | Barnard College                           |
| C     | Columbia College                          |
| D     | Dentistry**                               |
| E     | Engineering and Applied Science           |
| F     | General Studies                           |
| G     | Graduate School of Arts and Sciences      |
| H     | Reid Hall, Paris**                        |
| I     | Berlin Consortium Program**               |
| J     | Journalism*                               |
| K     | Continuing Education**                    |
| L     | Law**                                     |
| M     | Medicine**                                |
| N     | Nursing**                                 |
| O     | Union Theological**                       |
| P     | School of Public Health*                  |
| R     | School of the Arts*                       |
| S     | Summer Session                            |
| T     | Social Work*                              |
| TA-TZ | Teachers College*                         |
| U     | International and Public Affairs*         |
| V     | Interschool course with Barnard           |
| W     | Interfaculty course                       |
| X     | Barnard College                           |
| Z     | American Language Program(no credit)**    |

|                                                              | Example                                                  | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
|--------------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|-----------------|---|------------------|---|---------------------------------|---|-----------------|---|--------------------------------------|---|---------------------------------|---|---------------------|---|-----------------|---|--------------------------------------------------|---|------------------------------------|---|------------------------------------|---|--------------------------------|---|----------------------------------------------------------|---|-----------------|---|---------------------------|---|-------------------------------------|
| Call #<br>(5 digit number)                                   | <b>16238</b>                                             | This 5 digit code is assigned to individual courses and is specific to each semester.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| Department Code<br>(4 letter code)                           | <b>ECON</b>                                              | This 4 letter code represents the Academic Department that manages the course.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| Course Number<br>(1 capital letter followed by 4 digit code) | <b>W</b><br><br><b>1105</b>                              | The <i>capital letters</i> indicate the instructor teaching the course and their affiliation with a <b>division, school or affiliate</b> of the University.<br><br>Unless otherwise noted, courses numbers beginning with the following letters are generally open to CC/SEAS undergraduate students:<br><br><table border="1"> <tbody> <tr><td>BC</td><td>Barnard College</td></tr> <tr><td>C</td><td>Columbia College</td></tr> <tr><td>E</td><td>Engineering and Applied Science</td></tr> <tr><td>F</td><td>General Studies</td></tr> <tr><td>G</td><td>Graduate School of Arts and Sciences</td></tr> <tr><td>V</td><td>Interschool course with Barnard</td></tr> <tr><td>W</td><td>Interfaculty course</td></tr> <tr><td>X</td><td>Barnard College</td></tr> </tbody> </table><br>The first <i>digit</i> indicates the <b>level of the course</b> . Generally, levels are indicated as:<br><br><table border="1"> <tbody> <tr><td>0</td><td>Course that cannot be credited toward any degree</td></tr> <tr><td>1</td><td>Undergraduate course, introductory</td></tr> <tr><td>2</td><td>Undergraduate course, intermediate</td></tr> <tr><td>3</td><td>Undergraduate course, advanced</td></tr> <tr><td>4</td><td>Graduate course that is open to qualified undergraduates</td></tr> <tr><td>6</td><td>Graduate course</td></tr> <tr><td>8</td><td>Graduate course, advanced</td></tr> <tr><td>9</td><td>Graduate research course or seminar</td></tr> </tbody> </table> | BC | Barnard College | C | Columbia College | E | Engineering and Applied Science | F | General Studies | G | Graduate School of Arts and Sciences | V | Interschool course with Barnard | W | Interfaculty course | X | Barnard College | 0 | Course that cannot be credited toward any degree | 1 | Undergraduate course, introductory | 2 | Undergraduate course, intermediate | 3 | Undergraduate course, advanced | 4 | Graduate course that is open to qualified undergraduates | 6 | Graduate course | 8 | Graduate course, advanced | 9 | Graduate research course or seminar |
| BC                                                           | Barnard College                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| C                                                            | Columbia College                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| E                                                            | Engineering and Applied Science                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| F                                                            | General Studies                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| G                                                            | Graduate School of Arts and Sciences                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| V                                                            | Interschool course with Barnard                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| W                                                            | Interfaculty course                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| X                                                            | Barnard College                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 0                                                            | Course that cannot be credited toward any degree         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 1                                                            | Undergraduate course, introductory                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 2                                                            | Undergraduate course, intermediate                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 3                                                            | Undergraduate course, advanced                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 4                                                            | Graduate course that is open to qualified undergraduates |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 6                                                            | Graduate course                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 8                                                            | Graduate course, advanced                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| 9                                                            | Graduate research course or seminar                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| Course Section                                               | <b>001</b>                                               | Based on course demand, some academic departments offer the same course during 2 or more different time slots. Each time slot is assigned a different section number.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |
| Points/Credits                                               | <b>4</b>                                                 | The term "points" and "credits" are often used interchangeably and is generally related to the number of classroom contact hours.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |    |                 |   |                  |   |                                 |   |                 |   |                                      |   |                                 |   |                     |   |                 |   |                                                  |   |                                    |   |                                    |   |                                |   |                                                          |   |                 |   |                           |   |                                     |

# Columbia Open Data Service



COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK

## OPEN DATA SERVICE

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### Data Feed Service

Columbia University offers data feeds in programming-friendly formats for research and academic purposes. The Open Data Feed Service currently offers the following data feeds:

- [Course Information](#)
- [Athletic Schedule](#)
- [Academic Commons](#)
- [CLIO - Library Catalog Data](#)
- [Textbooks Feed](#)

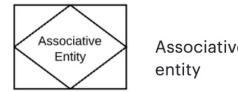
Data feed information includes the feed's refresh schedule, data diagrams, table and data element documentation, data training, and data security. More details on each feed is available on each feed's page.



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# Associative Entity

- The ER model represents “associations/relationships” as
  - First class “things”
  - That are different from “entities.”
- The SQL model does not have “relationships” or associations as first class types. You have
  - Tables
  - Columns
  - Keys
  - Constraints
  - ... ...
- You can implement some “relationships” using foreign keys. Others require something more complex – an *associative entity*.

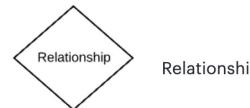


Associative entities relate the instances of several entity types. They also contain attributes specific to the relationship between those entity instances.

## ERD relationship symbols

Within entity-relationship diagrams, relationships are used to document the interaction between two entities. Relationships are usually verbs such as assign, associate, or track and provide useful information that could not be discerned with just the entity types.

| Relationship Symbol | Name | Description |
|---------------------|------|-------------|
|---------------------|------|-------------|



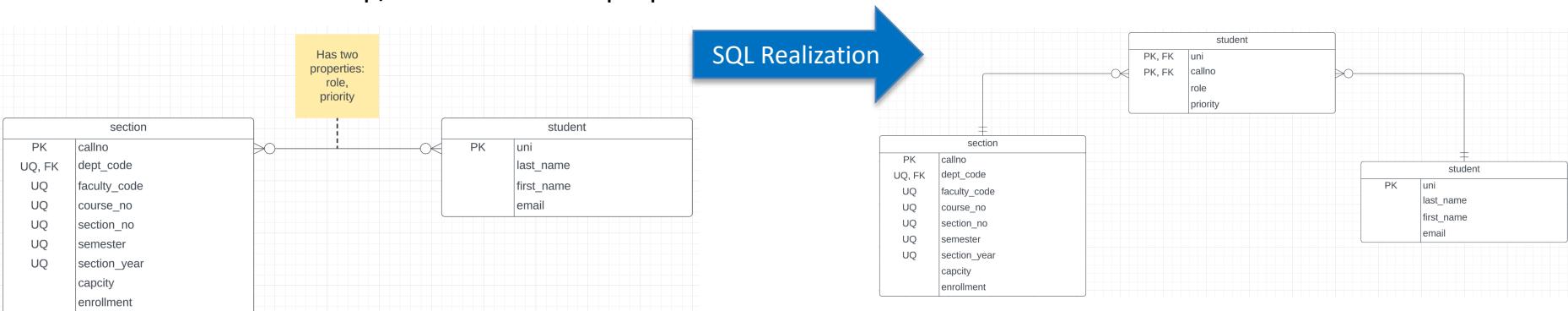
Relationships are associations between or among entities.



Weak Relationships are connections between a weak entity and its owner.

# Associative Entity

- “An associative entity is a term used in relational and entity–relationship theory. A relational database requires the implementation of a base relation (or base table) to resolve many-to-many relationships. A base relation representing this kind of entity is called, informally, an associative table.” ([https://en.wikipedia.org/wiki/Associative\\_entity](https://en.wikipedia.org/wiki/Associative_entity))
- Consider *Students – Sections*:
  - This is many-to-many. There is not way to implement in SQL. You see this in the *Advise*s table in the sample database.
  - The “relationship/association” has properties that are not attributes of the connected entities.



Switch to notebook diagram.

# *REST*

# Data Modeling Concepts and REST

Almost any data model has the same core concepts:

- Types and instances:
  - Entity Type: A definition of a type of thing with properties and relationships.
  - Entity Instance: A specific instantiation of the Entity Type
  - Entity Set Instance: An Entity Type that:
    - Has properties and relationships like any entity, but ...
    - Has at least one *special relationship* – ***contains***.
- Operations, minimally CRUD, that manipulate entity types and instances:
  - Create
  - Retrieve
  - Update
  - Delete
  - Reference/Identify/... ...

## What is REST architecture?

REST stands for REpresentational State Transfer. REST is web standards based architecture and uses HTTP Protocol. It revolves around resource where every component is a resource and a resource is accessed by a common interface using HTTP standard methods. REST was first introduced by Roy Fielding in 2000.

In REST architecture, a REST Server simply provides access to resources and REST client accesses and modifies the resources. Here each resource is identified by URIs/ global IDs. REST uses various representation to represent a resource like text, JSON, XML. JSON is the most popular one.

## HTTP methods

Following four HTTP methods are commonly used in REST based architecture.

- **GET** – Provides a read only access to a resource.
- **POST** – Used to create a new resource.
- **DELETE** – Used to remove a resource.
- **PUT** – Used to update a existing resource or create a new resource.

## Introduction to RESTful web services

A web service is a collection of open protocols and standards used for exchanging data between applications or systems. Software applications written in various programming languages and running on various platforms can use web services to exchange data over computer networks like the Internet in a manner similar to inter-process communication on a single computer. This interoperability (e.g., between Java and Python, or Windows and Linux applications) is due to the use of open standards.

Web services based on REST Architecture are known as RESTful web services. These webservices uses HTTP methods to implement the concept of REST architecture. A RESTful web service usually defines a URI, Uniform Resource Identifier a service, provides resource representation such as JSON and set of HTTP Methods.

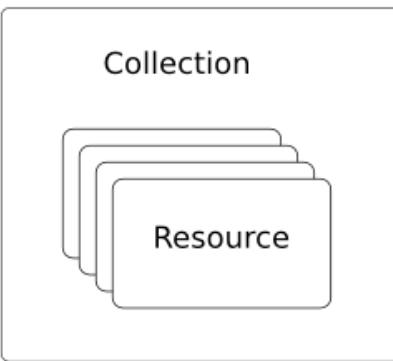
## Creating RESTful Webservice

In next chapters, we'll create a webservice say user management with following functionalities –

| Sr.No. | URI                     | HTTP Method | POST body   | Result                      |
|--------|-------------------------|-------------|-------------|-----------------------------|
| 1      | /UserService/users      | GET         | empty       | Show list of all the users. |
| 2      | /UserService/addUser    | POST        | JSON String | Add details of new user.    |
| 3      | /UserService/getUser/id | GET         | empty       | Show details of a user.     |

# REST and Resources

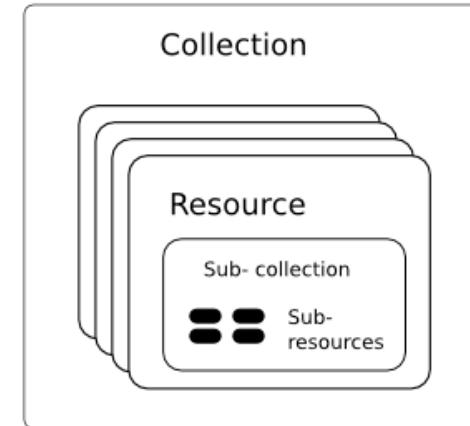
## Resource Model



A Collection with  
Resources

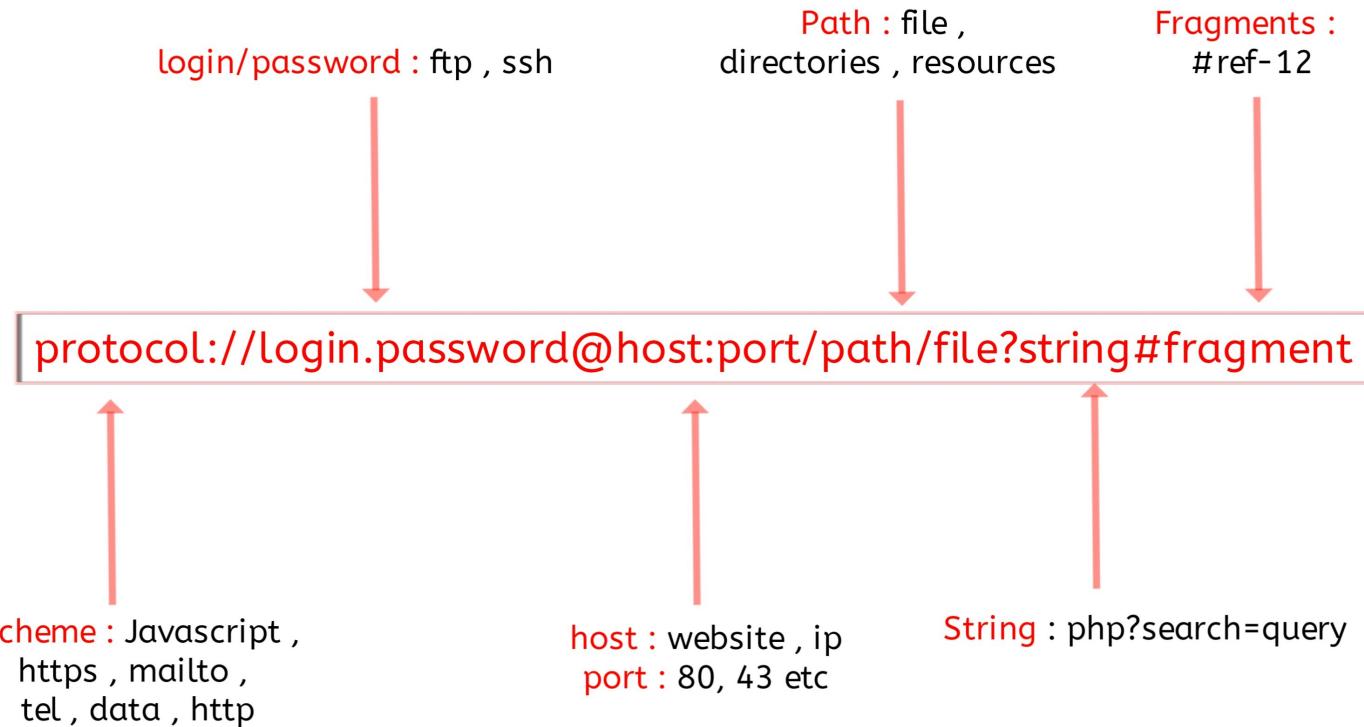


A Singleton  
Resource



Sub-collections and  
Sub-resources

# URLs



`jdbc:mysql://columbia-examples.ckkqqktwkcji.us-east-1.rds.amazonaws.com:3306`

# Simplistic, Conceptual Mapping (Examples)

| REST Method | Resource Path             | Relational Operation                                                                                             | DB Resource                |
|-------------|---------------------------|------------------------------------------------------------------------------------------------------------------|----------------------------|
| DELETE      | /people                   | DROP TABLE                                                                                                       | people table               |
| POST        | /people                   | INSERT INTO PEOPLE (...) VALUES(...)                                                                             | people table<br>people row |
| GET         | /people/21                | SHOW KEYS FROM people ...;<br><br>SELECT * FROM people WHERE<br>playerID= 21                                     | people row                 |
| GET         | /people/21/batting        | SELECT batting.* FROM<br>people JOIN batting USING(playerID)<br>WHERE playerID=21                                |                            |
| GET         | /people/21/batting/2004_1 | SELECT batting.* FROM<br>people JOIN batting USING(playerID)<br>WHERE playerID=21<br>AND yearID=2004 AND stint=1 |                            |

# Application Architecture

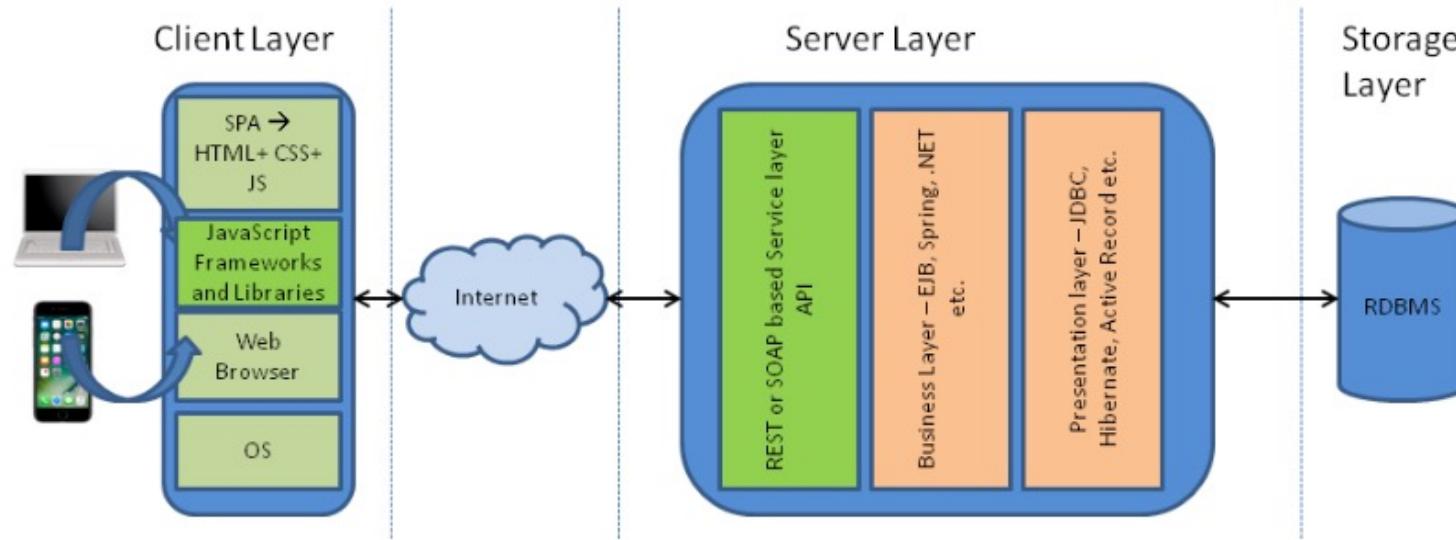


Diagram 2: The moving of the Web Layer from the Server to the Client

# Walkthrough

- Simple web application template.
- Calling some cloud APIs.

# *Data and Visualization*

## *(Walk through the data sets and visualizations)*