

# Relational Algebra

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# Relational Algebra

- Simplest query: **relation name**

*instructor*

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

(a) The *instructor* table

- Use **operators** to filter, slice, combine

# Select operator: pick certain rows

- Select *instructors* where the instructor is in the “Physics” department.

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

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
33456	Gold	Physics	87000

- Select instructors in Physics depart  
with salary > 90000.

$$\sigma_{dept\_name = \text{“Physics”} \wedge salary > 90000}(instructor)$$

- $\sigma_{cond} Rel$
- Comparisons: =, ≠, >, ≥, <, ≤
- Logic connectives:  
 $\wedge$  (and),  $\vee$  (or),  $\neg$  (not)

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
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15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

(a) The *instructor* table

# Project operator: pick certain columns

- Pick ID, name and salary of *instructor*

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

- Result:

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

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

$$\Pi_{A_1, A_2, A_3 \dots A_k} (r)$$

# Compose operator: pick both rows and columns

- Find the names of all instructors in the Physics department.

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

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

- $\Pi_{A1, A2} Expr$
- $\sigma_{cond} Expr$

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

(a) The *instructor* table

# Cross-product: combines two relations (a.k.a Cartesian-product)

*instructor* X *teaches*

*instructor.ID*

<i>instructor</i>
<u><i>ID</i></u>
<i>name</i>
<i>dept_name</i>
<i>salary</i>

<i>teaches</i>
<u><i>ID</i></u>
<u><i>course_id</i></u>
<u><i>sec_id</i></u>
<u><i>semester</i></u>
<u><i>year</i></u>

*teaches.id*

<i>instructor.ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>	<i>teaches.ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>
10101	Srinivasan	Comp. Sci.	65000	10101	CS-101	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	10101	CS-315	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	10101	CS-347	1	Fall	2017
10101	Srinivasan	Comp. Sci.	65000	12121	FIN-201	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	15151	MU-199	1	Spring	2018
10101	Srinivasan	Comp. Sci.	65000	22222	PHY-101	1	Fall	2017
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...
12121	Wu	Finance	90000	10101	CS-101	1	Fall	2017
12121	Wu	Finance	90000	10101	CS-315	1	Spring	2018
12121	Wu	Finance	90000	10101	CS-347	1	Fall	2017
12121	Wu	Finance	90000	12121	FIN-201	1	Spring	2018

# Cross-product: combine two relations (a.k.a Cartesian-product)

*instructor* X *teaches*

- Find the instructors and the courses that they taught

<i>instructor</i>	<i>teaches</i>
<u>ID</u>	<u>ID</u>
name	<u>course_id</u>
dept_name	<u>sec_id</u>
salary	<u>semester</u>
	<u>year</u>

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



# Natural join

- Combine two relations, enforce equality on all attributes with same name
- Eliminate the copy of duplicated attributes

<i>instructor</i>
<u>ID</u>
name
dept_name
salary

*instructor* ⋈ *teaches*

<i>teaches</i>
<u>ID</u>
<u>course_id</u>
<u>sec_id</u>
<u>semester</u>
<u>year</u>

- Find all the names of instructors whose department building is 303 and who have taught a course in 2024.

<i>department</i>
<u>dept_name</u>
building
budget

$\Pi_{name} (\sigma_{building = '303' \wedge year = 2024} instructor \bowtie teaches \bowtie department)$

# Theta join

- $\text{Exp}_1 \bowtie_{\theta} \text{Exp}_2$ 
  - $\theta$  denotes the selection condition
  - Equivalent to  $\sigma_{\theta}(\text{Exp}_1 \bowtie \text{Exp}_2)$
- Basic operation implemented in DBMS

# Wrap up

- Data definition language
- Basic steps in creating and using relational DB
- Data manipulation language
- Relational algebra
  - Simplest query: relation name
  - Use operators to filter, slice, combine
  - Operators so far: select, project, cross-product, natural join, theta join

# Query Quest

*employee (person name, street, city)*

*works (person name, company name, salary)*

*company (company name, city)*

- Find the Query
  - a. Find the ID and name of each employee who works for “BigBank”.
  - b. Find the ID, name, and city of residence of each employee who works for “BigBank”.
  - c. Find the ID, name, street address, and city of residence of each employee who works for “BigBank” and earns more than \$10000.

# Set operation

## ■ Union Operation

- Find the names of instructors and the names of the depart

$$\Pi_{name} instructor \cup \Pi_{dept\_name} instructor$$

## ■ Intersection operation

- Find names that are both an instructor name and a department name

$$\Pi_{name} instructor \cap \Pi_{dept\_name} department$$

<i>department</i>
<u><i>dept_name</i></u>
<i>building</i>
<i>budget</i>

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>salary</i>
22222	Einstein	Physics	95000
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32343	El Said	History	60000
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## ■ Set difference operation

- Find the names of the departments  
who has no instructors

$$\Pi_{dept\_name} department - \Pi_{dept\_name} instructor$$

# The Rename Operation

- Rename operator,  $\rho$ , name and format the results of an expression
- $\rho_{x(A1,A2, \dots An)}(E)$  general form
  - $\rho_x(E)$
  - $\rho_{A1,A2, \dots An}(E)$
- Functions:
  - To unify schemas for set operations
    - Find names that are both an instructor name and a department name

$$\Pi_{name} \text{instructor} \cap \Pi_{dept\_name} \text{instructor}$$

$$\rho_{x(A)}(\Pi_{name} \text{instructor}) \cap \rho_{x(A)}(\Pi_{dept\_name} \text{instructor})$$

# The Rename Operation

- Rename operator,  $\rho$ , name and format the results of an expression

- General form  $\rho_{x(A1,A2, \dots An)}(E)$

- $\rho_x(E)$
- $\rho_{A1,A2, \dots An}(E)$

- Functions:

- Unify schemas for set operations
- For disambiguation in “self-joins”
  - Find pairs of instructors in the same dept
    - Instructor x instructor ?

ID	name	dept_name	salary
22222	Einstein	Physics	95000
12121	Wu	Finance	90000
32343	El Said	History	60000
45565	Katz	Comp. Sci.	75000
98345	Kim	Elec. Eng.	80000
76766	Crick	Biology	72000
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76543	Singh	Finance	80000

(a) The *instructor* table

- $\rho_{r1(a1,b1,c1,d1)} \text{ Instructor } \bowtie \rho_{r2(a2,b2,c2,d2)} \text{ Instructor}$
- $\sigma_{r1.c1 = r2.c2}$
- $\rho_{r1(a1,b1,c,d1)} \text{ Instructor } \bowtie \rho_{r2(a2,b2,c,d2)} \text{ Instructor}$

# Assignment Operation

- Break down relational algebra expressions to their parts
- Find all instructor in the “Physics” and Music department.

$Physics \leftarrow \sigma_{dept\_name=“Physics”}(instructor)$

$Music \leftarrow \sigma_{dept\_name=“Music”}(instructor)$

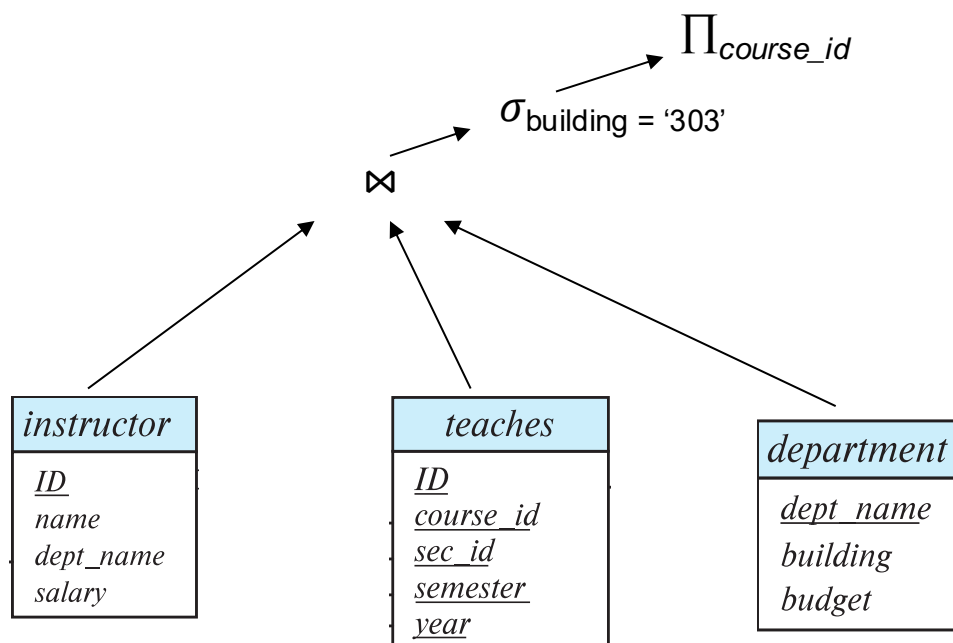
$Physics \cup Music$

- The assignment operation is denoted by  $\leftarrow$  and works like assignment in a programming language.



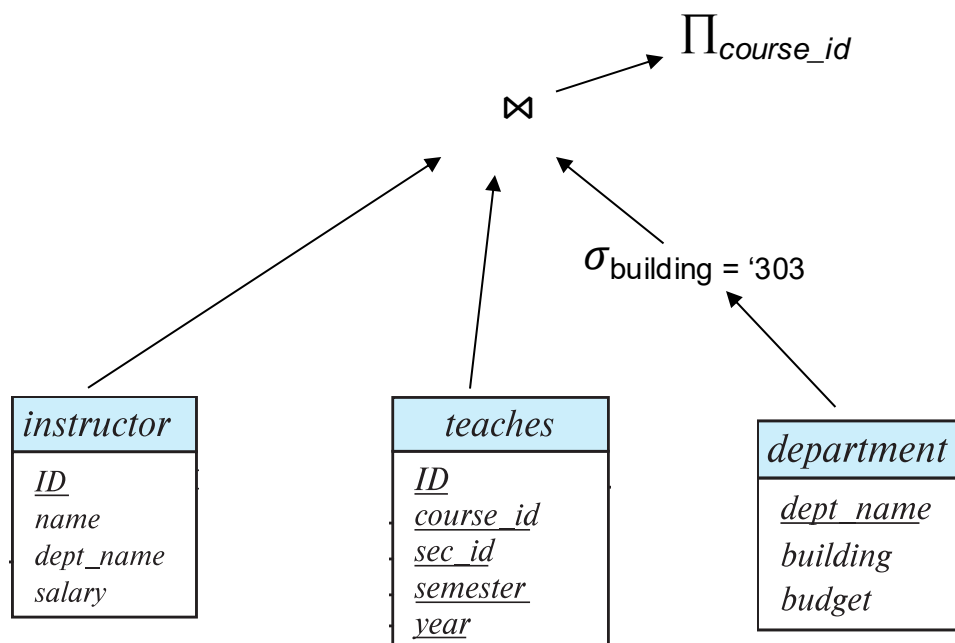
# Expression tree

- Find the course IDs whose instructors are in building 303



# Expression tree

- Find the course IDs whose instructors are in building 303



- The two queries are not identical; they are, however, equivalent -- they give the same result on any database.

# Relational Algebra

- A query language of a set of operations that take one or two relations as input and produce a new relation as their result.
- Operators
  - select:  $\sigma$
  - project:  $\Pi$
  - union:  $\cup$
  - set difference:  $-$
  - Cartesian product:  $\times$ 
    - Natural Join  $\bowtie$
    - Theta join  $\bowtie_{\theta}$
  - rename:  $\rho$
  - assignment :  $\leftarrow$
- Expression tree

# Wrap up

- Relational algebra
  - Simplest query: relation name
  - Use operators to filter, slice, combine
  - Operators: select, project, cross-product, natural join, theta join
    - Set operation, assignment, rename
  - Expression tree

# Query Quest

*employee (person name, street, city)*

*works (person name, company name, salary)*

*company (company name, city)*

- Find the Query
  - Find the ID and name of each employee in this database who lives in the same city as the company for which she or he works.

FIN

Any questions?