

# RDBMS and SQL

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# Relational algebra — select and project

- List instructors from Physics department with salary above 90,000

$\sigma$  dept\_name = Physics (*Instructor*)  
     $\wedge$  — and  
    salary > 90000

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



# Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List names of instructors

$\pi_{\text{name}}(\text{Instructor})$

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

# Relational algebra — select and project

- List instructors from Physics department with salary above 90,000
- List names of instructors
- List names of instructors from Physics department with salary above 90,000

$\pi_{\text{name}}(\sigma_{\text{dept\_name} = \text{Physics}} (\text{Instructor}))$   
 $\wedge$   
 $\text{salary} > 90000$

$\sigma_{\text{salary} > 90000}$

$\sigma_{\text{dept} = \text{Physics}} (\text{Instr})$

name  
Einstein

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

# Relational algebra — join

- List details of courses offered by instructors

for each

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

Instructor

Nested loop

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

Teaches

# Relational algebra — join

- List details of courses offered by instructors

"Simulate" nested loop

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

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

# Relational algebra — join

## ■ Instructor × Teaches

| <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        |
| 12121                | Wu          | Finance          | 90000         | 15151             | MU-199           | 1             | Spring          | 2018        |
| 12121                | Wu          | Finance          | 90000         | 22222             | PHY-101          | 1             | Fall            | 2017        |
| ...                  | ...         | ...              | ...           | ...               | ...              | ...           | ...             | ...         |
| ...                  | ...         | ...              | ...           | ...               | ...              | ...           | ...             | ...         |

# Relational algebra — join

- $\sigma_{\text{Instructor.ID} = \text{teaches.ID}}(\text{Instructor} \times \text{Teaches})$

| <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        |
| 12121                | Wu          | Finance          | 90000         | 12121             | FIN-201          | 1             | Spring          | 2018        |
| 15151                | Mozart      | Music            | 40000         | 15151             | MU-199           | 1             | Spring          | 2018        |
| 22222                | Einstein    | Physics          | 95000         | 22222             | PHY-101          | 1             | Fall            | 2017        |
| 32343                | El Said     | History          | 60000         | 32343             | HIS-351          | 1             | Spring          | 2018        |
| 45565                | Katz        | Comp. Sci.       | 75000         | 45565             | CS-101           | 1             | Spring          | 2018        |
| 45565                | Katz        | Comp. Sci.       | 75000         | 45565             | CS-319           | 1             | Spring          | 2018        |
| 76766                | Crick       | Biology          | 72000         | 76766             | BIO-101          | 1             | Summer          | 2017        |
| 76766                | Crick       | Biology          | 72000         | 76766             | BIO-301          | 1             | Summer          | 2018        |
| 83821                | Brandt      | Comp. Sci.       | 92000         | 83821             | CS-190           | 1             | Spring          | 2017        |
| 83821                | Brandt      | Comp. Sci.       | 92000         | 83821             | CS-190           | 2             | Spring          | 2017        |
| 83821                | Brandt      | Comp. Sci.       | 92000         | 83821             | CS-319           | 2             | Spring          | 2018        |
| 98345                | Kim         | Elec. Eng.       | 80000         | 98345             | EE-181           | 1             | Spring          | 2017        |



Income tax assesses from Chennai with income > 5cr

| Voter |      | IT |      |
|-------|------|----|------|
| Name  | Dist | N. | Inc. |

$\sigma_{\text{Voter.Name} = \text{IT.Name}} (\text{Voters} \times \text{IT})$

$\wedge$   
 $\sigma_{\text{Voter.District} = \text{Chenna}}$

$\wedge$   
 $\sigma_{\text{IT.Salary} > 5cr}$

↳ Ideally

$\sigma_{\text{District} = \text{Chenna}} (\text{Voter}) \times \sigma_{\text{Salary} > 5cr} (\text{IT})$

# Relational algebra — join

- Instructor  $\bowtie$  Instructor.ID = teaches.ID Teaches — cartesian project with select  
"bowtie"

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

$R_1 \bowtie R_2$   
 $\Downarrow$   
 $\sigma_{\theta} (R_1 \times R_2)$

Very often

Join condition is equality on  
same attribute name

Instructor  $\bowtie$  Teacher  
Instructor.ID  
= Teacher.ID

Omit  $\theta$

Instructor  $\bowtie$  Teacher

$R_1 \bowtie_{\theta} R_2$



Join Condition

"Natural  
join"

# Relational algebra — set operations

$\sigma, \pi, \times \rightsquigarrow \sigma, \pi, \bowtie$

Courses taught in 2017

$\left( \pi_{\text{course\_id}} \left( \sigma_{\text{year}=2017} (\text{Teaches}) \right) \right)$

Courses in 2018

$\cap \left( \pi_{\text{course\_id}} \left( \sigma_{\text{year}=2018} (\text{Teaches}) \right) \right)$

Either 2017 or 2018  $\Rightarrow$  Union

Both 2017 and 2018  $\Rightarrow$  Intersect

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

Union, intersection  $\Rightarrow$  same schema

Projection may change schema

- Subset of columns

- Order of columns

T<sub>1</sub> Name, ID, salary, dept-name (Instructor)

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

# Relational algebra — set operations

$\cup, \cap$  "complement"

not (—)

square  $\subseteq \mathbb{Z} \times \mathbb{Z} = \{(m, n) \mid n = m^2\}$

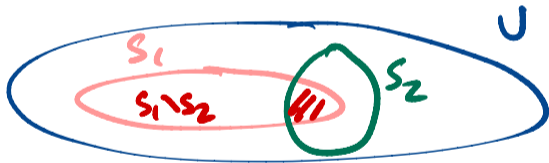
not(square) =  $\{(m, n) \mid m \in \mathbb{Z}, n \in \mathbb{Z}, n \neq m^2\}$

Complement is "relative" to universe

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

## Set difference

$$S_1 - S_2 = \{x \in S_1 \mid x \notin S_2\}$$



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

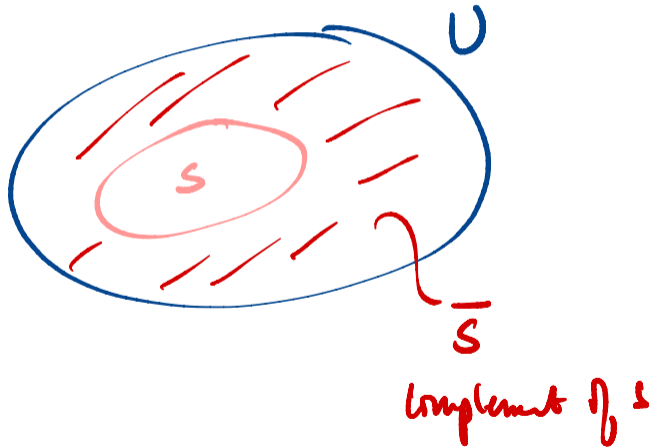
Courses in 2017 not taught  
in 2018

$(2017 \text{ query}) \setminus (2018 \text{ query})$

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



# Relational algebra — set operations



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

# Relational algebra — assignment, renaming

$\Gamma_{2017} \leftarrow \Pi_{\text{course\_id}} \left( \sigma_{\text{year}=2017} (\text{Teaches}) \right)$

$\Gamma_{2018} \leftarrow \text{---}$

$\Gamma_{2017} \cup \Gamma_{2018}$

$\Gamma_{2017} \setminus \Gamma_{2018}$

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

# Relational algebra — assignment, renaming

Renaming

$\rho$

$\rho$  MyTeaches (Teaches)

$\rho$  MyTeaches (MyID, --, My year) (Teaches)

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

"Self join"

IDs of instructors who teach more than one course

Teaches  $\bowtie$  Teaches

left ID  
= right ID

^

left course-id  
≠ right course-id

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

# Relational algebra — assignment, renaming

$\rho_{T_1}(\text{Teaches})$      $\rho_{T_2}(\text{Teaches})$

↓  
 $T_1.ID = T_2.ID$   
^  
 $T_1.course\_id \neq T_2.course\_id$

Alternatively

$T_1 \leftarrow \text{Teaches}$   
 $T_2 \leftarrow \text{Teaches}$

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

# Sets – ordering

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

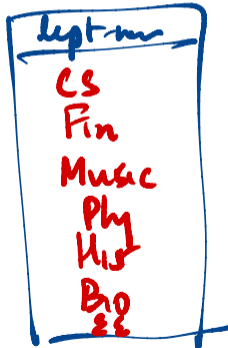
Instructor

| <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         |

Instructor, unsorted

# Sets – duplicates

$\Pi$  dept\_name (Instructor)



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

Instructor, unsorted

Relational algebra specifies what we want "Declarative"  
vs how to get the answer "Imperative"

