RDBMS and SQL

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Lecture 3, 2 Sep 2026

Relational algebra — select and project

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

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

σ = select

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

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

π = project

$\pi_{\text{name, salary}}$ (T)

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000
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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

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

σ, π Tables → Tables

Name
Einstein

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
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76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Relational algebra — join

- List details of courses offered by instructors

Who offer courses

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

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

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

Relational algebra — join

- Instructor $\bowtie_{\text{Instructor.ID} = \text{teaches.ID}}$ Teaches — cartesian project with select

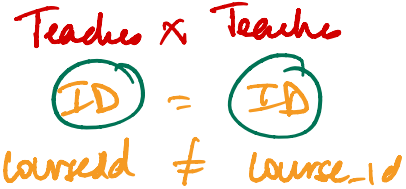
$\sigma_\theta(T_1 \times T_2)$

$T_1 \bowtie_\theta T_2$

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

Self join — assignment, renaming

- List instructors who teach more than one course



ID	*course_id*	*sec_id*	*semester*	*year*
10101	CS-101	1	Fall	2017
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45565	CS-101	1	Spring	2018
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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

Self join — assignment, renaming

- List instructors who teach more than one course

Let

$$\texttt{T1} \leftarrow \texttt{Teaches}$$
$$\texttt{T2} \leftarrow \texttt{Teaches}$$

in

$$\texttt{T1} \bowtie_\theta \texttt{T2}$$

where

$$\theta = \texttt{T1.ID} = \texttt{T2.ID} \wedge \texttt{T1.course\_id} \neq \texttt{T2.course\_id}$$

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
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22222	PHY-101	1	Fall	2017
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98345	EE-181	1	Spring	2017

Teaches

Self join — assignment, renaming

- List instructors who teach more than one course

$\rho_{T1}(\text{Teaches}) \bowtie_\theta \rho_{T2}(\text{Teaches})$

where

$\theta = \texttt{T1.ID} = \texttt{T2.ID} \wedge \texttt{T1.course\_id} \neq \texttt{T2.course\_id}$

ID	*course_id*	*sec_id*	*semester*	*year*
10101	CS-101	1	Fall	2017
10101	CS-315	1	Spring	2018
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15151	MU-199	1	Spring	2018
22222	PHY-101	1	Fall	2017
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45565	CS-101	1	Spring	2018
45565	CS-319	1	Spring	2018
76766	BIO-101	1	Summer	2017
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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 — set operations

- Union and intersection

$\sigma_{\theta_2}(\sigma_{\theta_1}(r))$

$\sigma_{\theta_2 \wedge \theta_1}(r)$

Tell me a course taught in 2 different semesters

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
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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

- Union and intersection

$\Pi_{ID}(\sigma_{sem,year = Fall,2017}(Teaches))$

$\Pi_{ID}(\sigma_{sem,year = Spring,2018}(Teaches))$

$\sigma_{sem,year = F,2017 \wedge sem,year = S,2018}(Teaches)$

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

Relational algebra — set operations

- Union and intersection

$$\sigma_{\theta_1}(r) \cup \sigma_{\theta_2}(r)$$
$$\equiv$$
$$\sigma_{\theta_1 \vee \theta_2}(r)$$

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
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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

- Union and intersection
- Complementation?

What is the universe

$sqrt \subseteq \mathbb{N} \times \mathbb{R}$

$\overline{sqrt} = \{(n, r) \mid r \neq \sqrt{n}\}$

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
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45565	CS-101	1	Spring	2018
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83821	CS-190	1	Spring	2017
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98345	EE-181	1	Spring	2017

Relational algebra — set operations

- Union and intersection
- Complementation?

relation

$\sigma_{\theta}(r)$ $\sigma_{\neg\theta}(r)$

$\overline{\sigma_{\theta}(r)}$ = Any combination of ids where

(sem, year) = (Fall, 2017)

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
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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

- Union and intersection
- Complementation?
- Set difference

$r \setminus \sigma_\theta(r)$

$S \setminus T$ all elements in S, not in T

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
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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

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

Instructor

Not same table

Same relation

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
83821	Brandt	Comp. Sci.	92000
15151	Mozart	Music	40000
33456	Gold	Physics	87000
76543	Singh	Finance	80000

Instructor, unsorted

Sets – duplicates

Π_{dept_name} (Instructor)

↓

Comp Sc
Financ
Music
Physics
History
Bio
EE

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
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98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra – describes "what" we want

"Declarative"

Python – describe "how" to compute

SQL

↳ Implementation

"Imperative" – giving orders

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find all faculty members from Physics who earn more than at least one faculty member from Comp.Sci.

Imperatively

Find min CS salary

∀ Physics above this min

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
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83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find all faculty members from Physics who earn more than at least one faculty member from Comp.Sci.

Witness

person 1, Physics

person 2, CS

P1.salary > P2.salary

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
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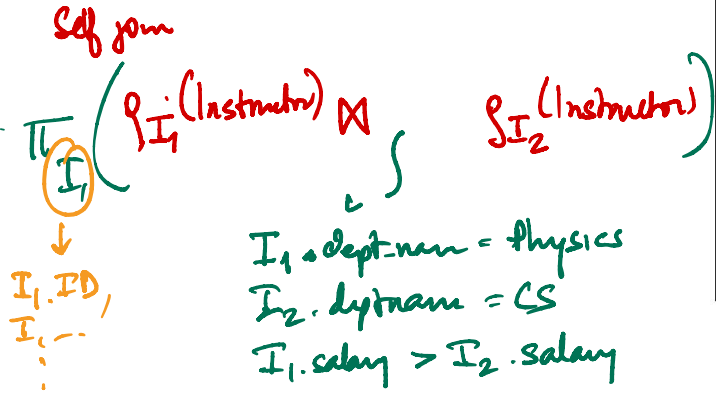
Instructor

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find all faculty members from Physics who earn more than at least one faculty member from Comp.Sci.



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98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find all faculty members from Physics who earn more than every faculty member from Comp.Sci.

Complement

$I_1.\text{dept} = \text{Phy}$

$I_2.\text{dept} = \text{CS}$

$I_1.\text{salary} \leq I_2.\text{salary}$

Set difference

ID	*name*	*dept_name*	*salary*
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98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find all faculty members from Physics who earn more than every faculty member from Comp.Sci.

$\sigma_{dept\_name = Physics}(Instructor)$

$\Pi_{I_1}\left(\rho_{I_1}(Inst) \bowtie \rho_{I_2}(Inst)\right)$

left = Phy
right = CS
left salary ≤ right salary

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
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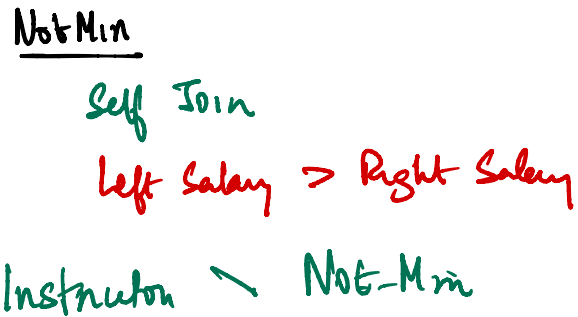
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find the faculty member(s) with the minimum salary.



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83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — Examples

`Instructor(ID,name,dept_name,salary)`

- Find the faculty member(s) with the maximum salary, department-wise.

Max = Instructor − NotMax

MaxCS ∪
MaxPhy ∪
MaxFin

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
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98345	Kim	Elec. Eng.	80000

Instructor

Relational algebra — Examples

`family(ID,name,gender)`
`parent(ID1,ID2)`

ID_1 is a parent of ID_2

- Compute the relation `sister(ID1,ID2)` — `ID1` is a sister of `ID2`

ID_1 gender is F

ID_1, ID_2 share a common parent

E. F. Codd

Relational algebra is all you need

What does this mean?

Family × Family → Parent × Parent

$(ID_1, Name_1, Gender_1, I_2, Name_2, G_2, P_1I_1, P_1I_2, P_2I_1, P_2I_2)$

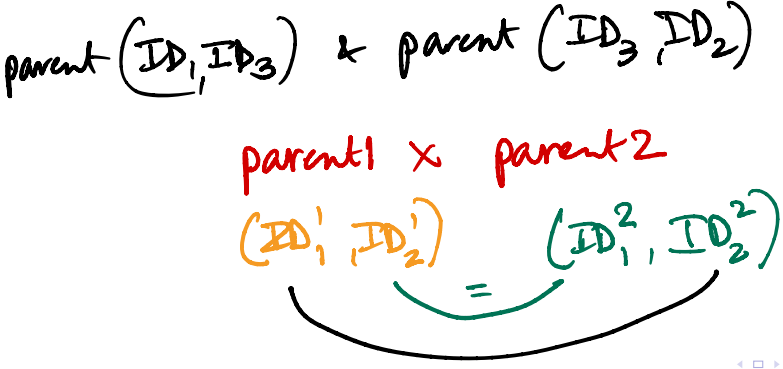
$Gender_1 = F$

$P_1I_1 = P_2I_1$

Relational algebra — Examples

`family(ID,name,gender)`
`parent(ID1,ID2)`

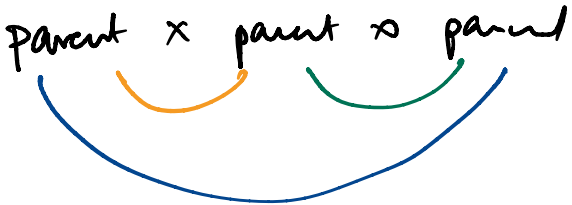
- Compute `grandparent(ID1,ID2)` — `ID1` is grandparent of `ID2`



Relational algebra — Examples

`family(ID,name,gender)`
`parent(ID1,ID2)`

- Compute
  `greatgrandparent(ID1,ID2)` — `ID1` is greatgrandparent of `ID2`



Relational algebra — Examples

`family(ID,name,gender)`
`parent(ID1,ID2)`

- Can you compute `ancestor(ID1,ID2)` in general?

"Transitive closure"

$R(a,b)$

$R(b,c)$

$\Rightarrow R^2(a,c)$

$R(a,b) \wedge R^2(b,c) = R^3(a,c)$

Relational algebra — Examples

`family(ID,name,gender)`
`parent(ID1,ID2)`

- Can you compute `ancestor(ID1,ID2)` in general?

$R(x,y)$ $\quad R^2(x,y) \stackrel{def}{=} \exists z.\, R(x,z) \wedge R(z,y)$

$\forall z$

First order logic
Predicate

Relational algebra — Examples

`family(ID,name,gender)`
`parent(ID1,ID2)`

- Can you compute `ancestor(ID1,ID2)` in general?

Codd's Thm Relational algebra ≡ First-Order Logic

Transitive closure cannot be expressed in First Order logic