DM534: Introduction to Relational Databases

(Part 2)

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Relational Query Languages

- Based on relational algebra
- For relational databases, i.e. relational data model
- Relational model supports simple, powerful QLs:
  - Strong formal foundation based on logic
  - Allows for much optimization
- **SQL** (Structured Query Language)
  - Most widely used relational query language

→ Understanding Relational Algebra is key to understanding SQL, query processing!

What is an “Algebra”?

- Mathematical system consisting of
  - **Operands:** Values from which new values can be constructed by applying operations
  - **Operators:** Procedures that construct new values from old values
  - **Symbols** for the operators
- Variables are letters that can represent values

Example of an Algebra

- Algebra of real numbers:
  - **Operands**: The set of real numbers
  - **Operators**: Addition, subtraction, multiplication, division, …
  - **Symbols for operators**: +, -, *, ⁄, …
- Examples of algebraic expressions:

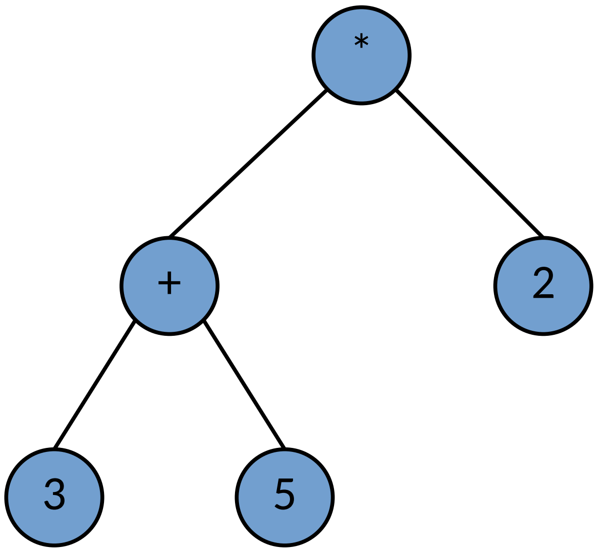
  (3 + 5) * 2

  5 – x / 3

Algebraic expressions

- Can be visualized as expression trees

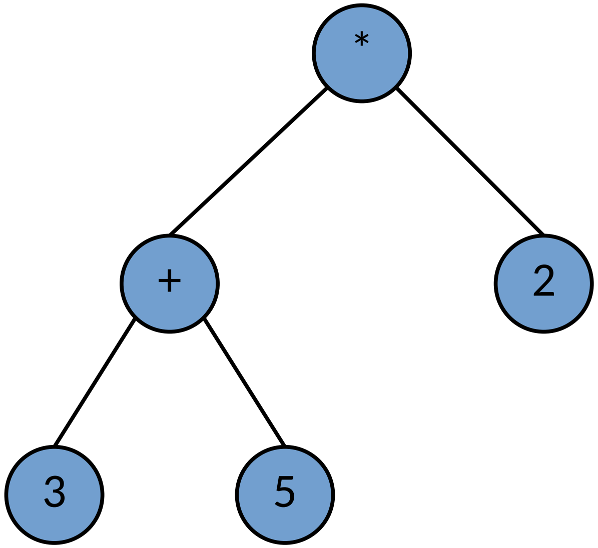
(3 + 5) * 2

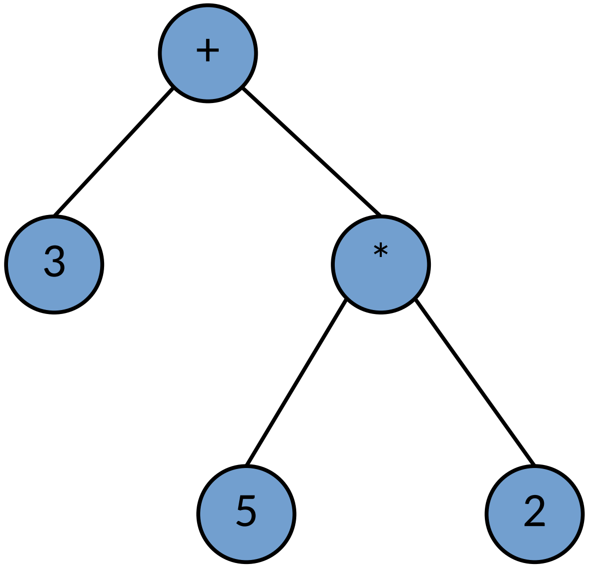


Algebraic expressions

- Can be visualized as expression trees

(3 + 5) * 2 vs. 3 + 5 * 2

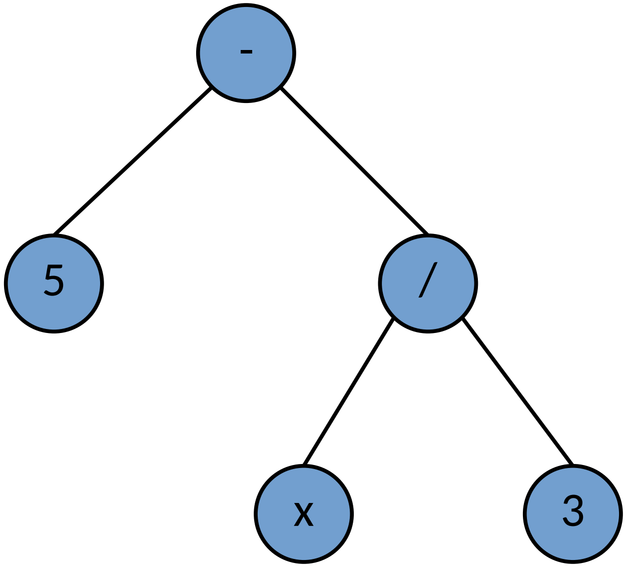




Algebraic expressions

- Can be visualized as expression trees

  5 – x / 3



Another Example of an Algebra

- Boolean algebra:
  - **Operands**: The values True and False
  - **Operators**: and, or, negation, xor, …
  - **Symbols for operators**: $\vee$, $\wedge$, $\neg$, …
- Examples of algebraic expressions:

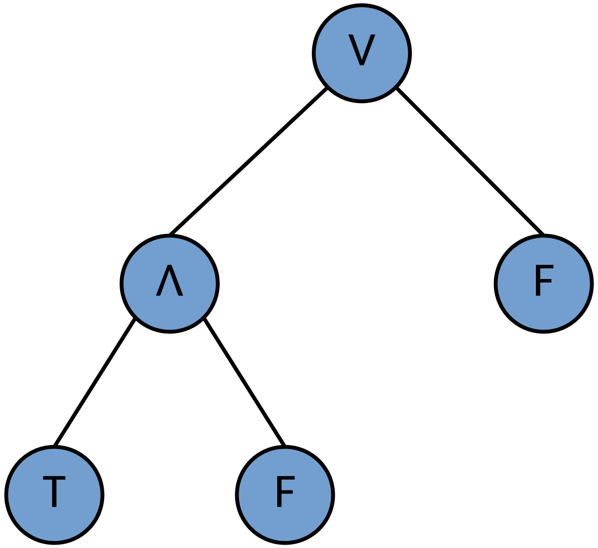
  $(T \wedge F) \vee F$

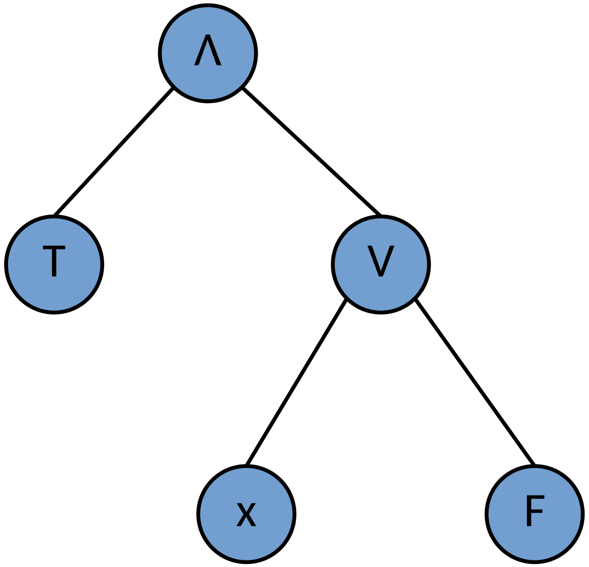
  $T \wedge (x \vee F)$

Algebraic expressions

- Can be visualized as expression trees

$(T \land F) \lor F$ vs. $T \land (a \lor F)$



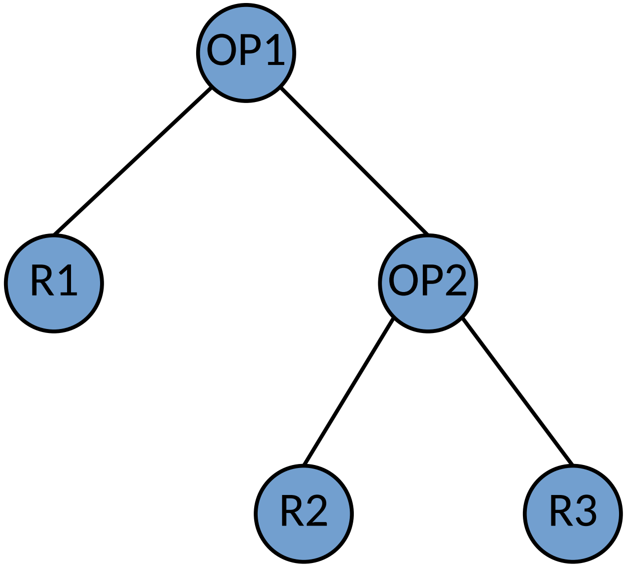


What is Relational Algebra?

- An algebra where
  - **operands** are relations (i.e., tables)
  - **operations** compute new relations (tables) from old relations (tables)
- Can be used as a query language for relations
  - The query “Language” of relational databases

What is Relational Algebra?

Expressions of relational algebra can also be visualized as trees



- OP1 and OP2 are relational operations
- R1, R2, R3 are variables for relations

Relational Algebra: 5 Basic Operations

- Selection: $\boldsymbol{\sigma}_{\boldsymbol{C}}(\boldsymbol{R})$

  Selects a subset of tuples from relation R, for which condition C holds (horizontal pruning)

- Projection: $\boldsymbol{\pi}_{\boldsymbol{A}_1,\ldots,\boldsymbol{A}_k}(\boldsymbol{R})$

  Retains attributes $A_1, \ldots, A_k$ from relation R (vertical pruning)

- Cross-product: **R1 x R2**

  Pairwise combination of tuples of relations R1 and R2

- Set-difference: **R1 – R2**

  Tuples in relation R1, but not in relation R2

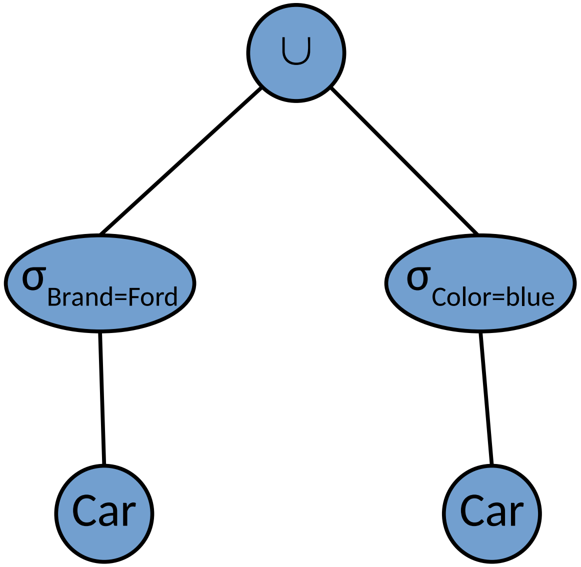
- Union: **R1** ∪ **R2**

  Tuples in relation R1 and/or in relation R2

- Since each operation returns a relation, operations can be composed (Algebra is “closed”)

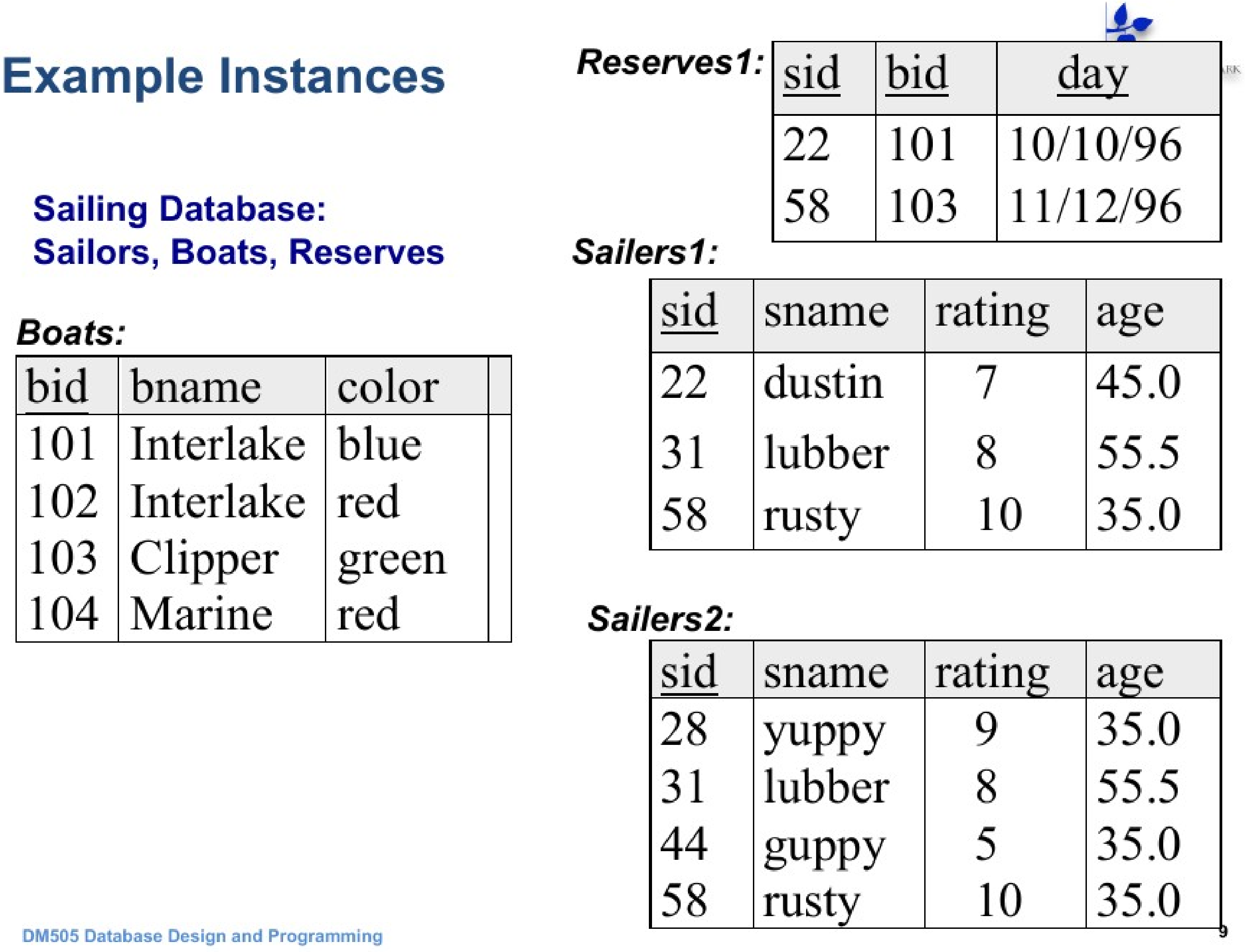
What is Relational Algebra?

=> An expression tree could like this



- What does this express?

Relational Algebra: Example Instances



Example Instances

Sailing Database:
Sailors, Boats, Reserves

Boats:

bid	bname	color
101	Interlake	blue
102	Interlake	red
103	Clipper	green
104	Marine	red

Reserves1:

sid	bid	day
22	101	10/10/96
58	103	11/12/96

Sailers1:

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

Sailers2:

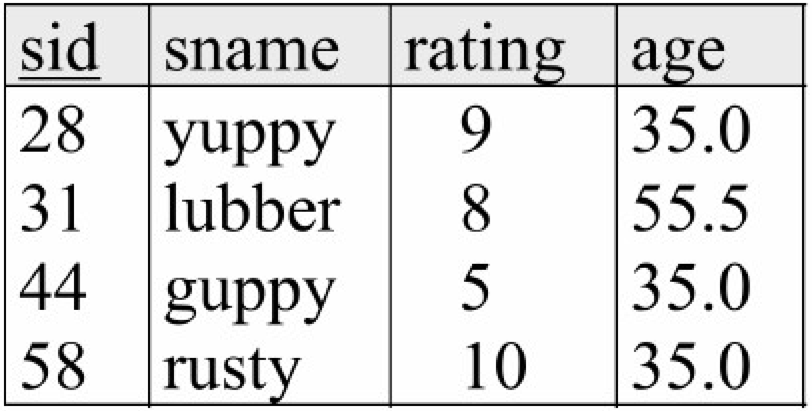
sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

Selection (σ)

Selects rows that satisfy *selection condition*.

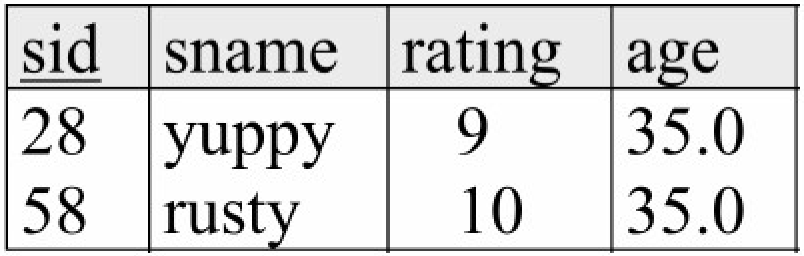
Result is a relation.

Schema of result is same as that of the input relation.



sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

$S2$



sid	sname	rating	age
28	yuppy	9	35.0
58	rusty	10	35.0

$\sigma_{rating>8}(S2)$

Projection (π)

Examples: $\pi_{age}(S2)$; $\pi_{sname,rating}(S2)$

Retains only attributes that are in the "*projection list*".

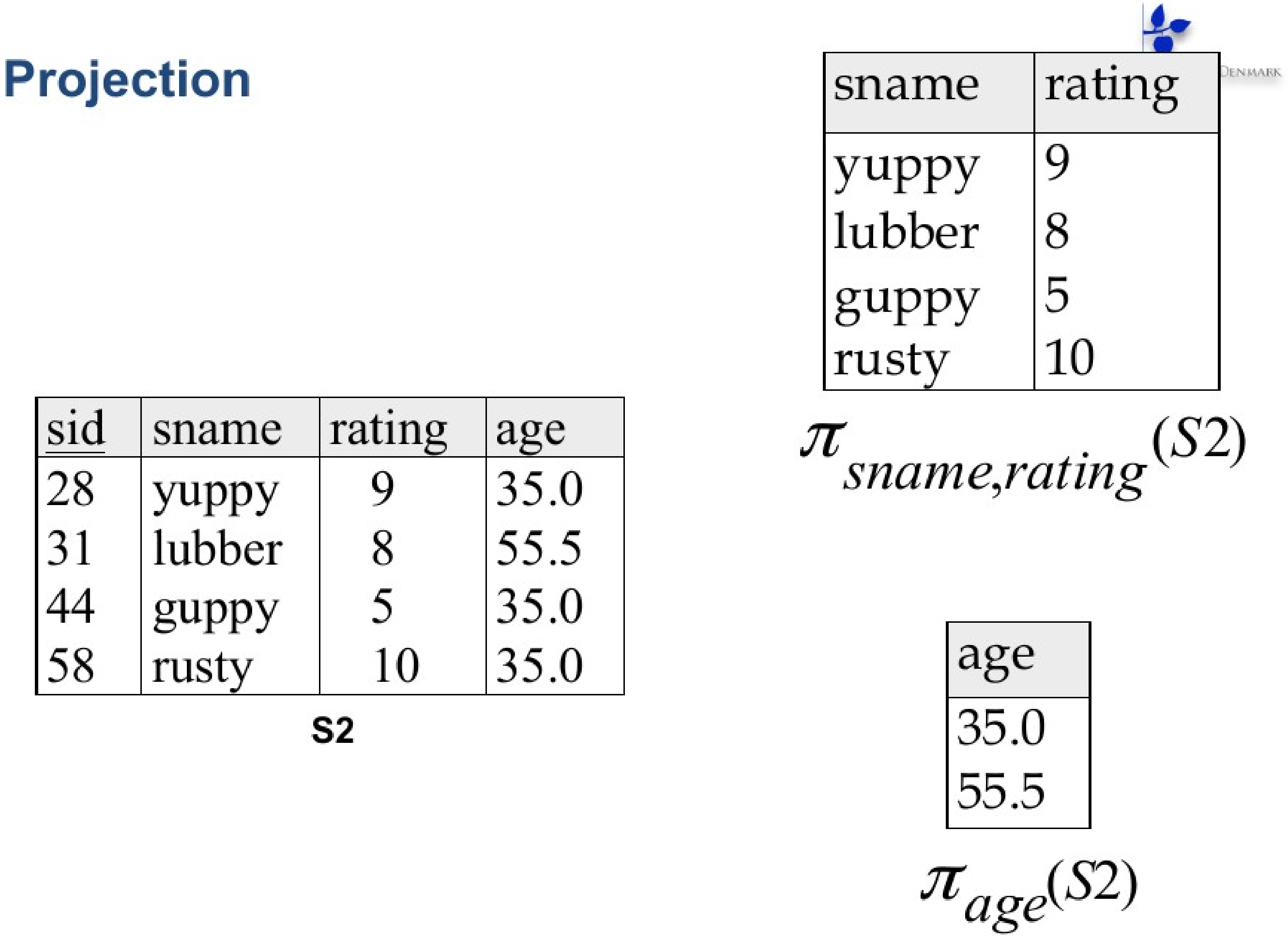
Schema **of result:**

- exactly the fields in the projection list,
- with the same names that they had in the input relation.

Projection operator has to *eliminate duplicates* (How do they arise? Why remove them?)

- Note: real systems typically don't do duplicate elimination unless the user explicitly asks for it. (Why not?)

Projection (π)



Projection

<u>sid</u>	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

sname	rating
yuppy	9
lubber	8
guppy	5
rusty	10

$\pi_{sname,rating}(S2)$

age
35.0
55.5

$\pi_{age}(S2)$

Cross Product

S1 x R1: Each row of S1 paired with each row of R1.

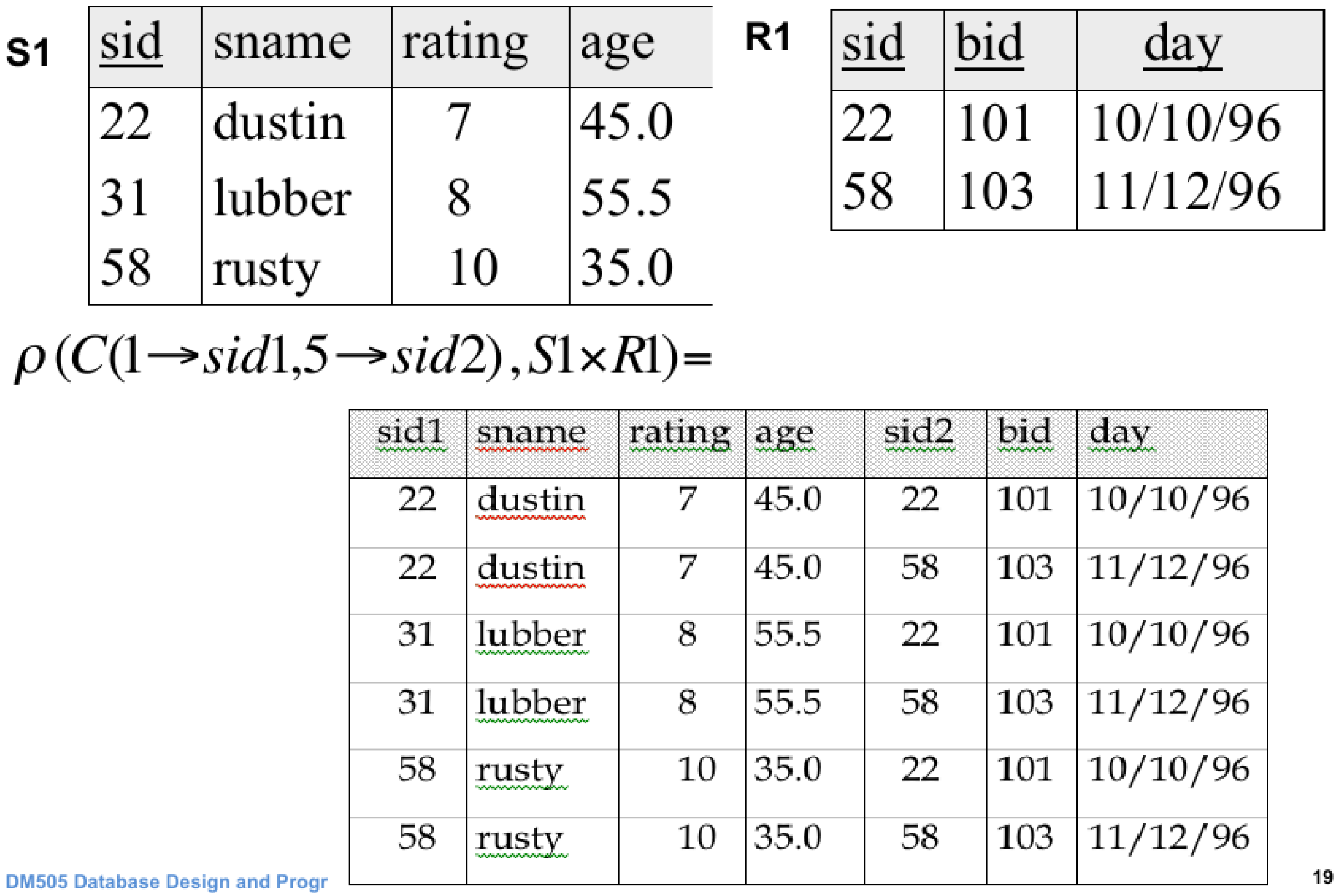
Q: How many rows in the result?

Result schema has one field per field of S1 and R1, with field names `inherited' if possible.

- *May have a naming conflict*: Both S1 and R1 have a field with the same name.
- In this case, can use the *renaming operator*:

$$\rho\,(C(1 \rightarrow sid1, 5 \rightarrow sid2),\ S1 \times R1)$$

Cross Product



S1

sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

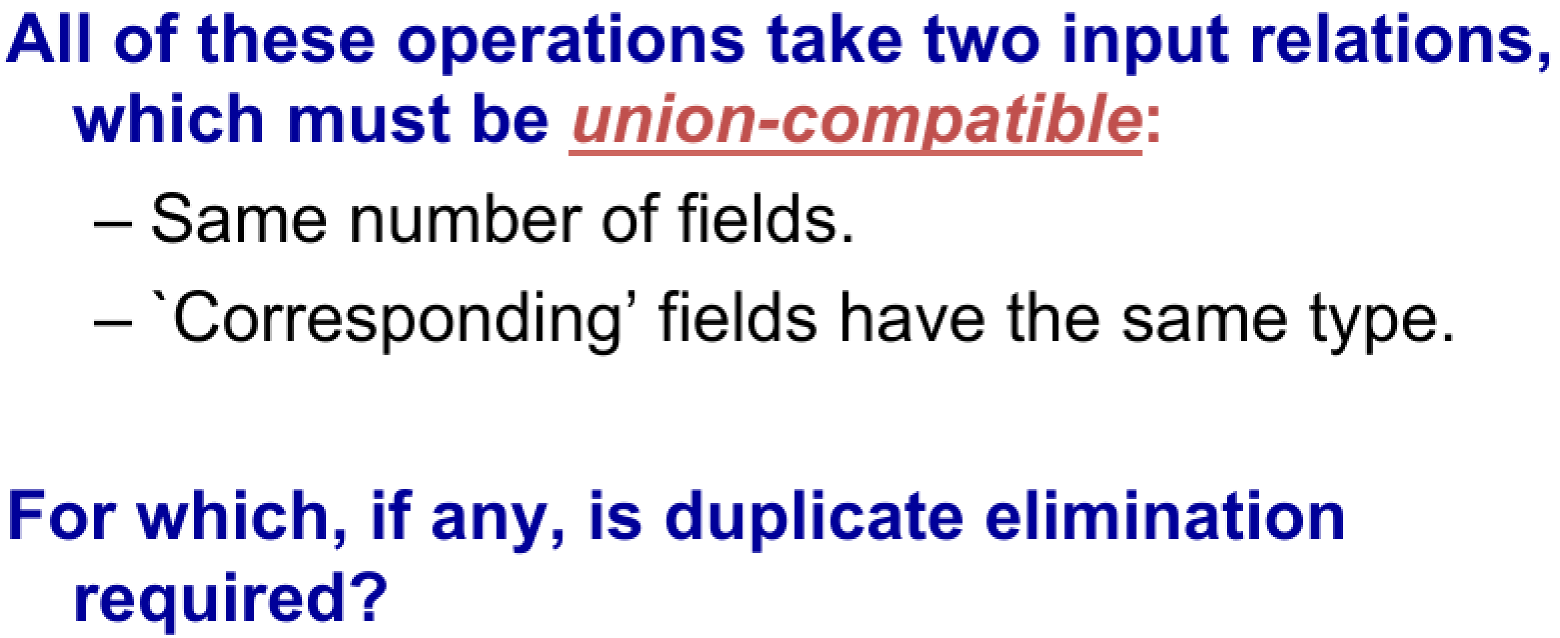
R1

sid	bid	day
22	101	10/10/96
58	103	11/12/96

$$\rho(C(1\rightarrow sid1, 5\rightarrow sid2), S1\times R1)=$$

sid1	sname	rating	age	sid2	bid	day
22	dustin	7	45.0	22	101	10/10/96
22	dustin	7	45.0	58	103	11/12/96
31	lubber	8	55.5	22	101	10/10/96
31	lubber	8	55.5	58	103	11/12/96
58	rusty	10	35.0	22	101	10/10/96
58	rusty	10	35.0	58	103	11/12/96

Union and Set Difference

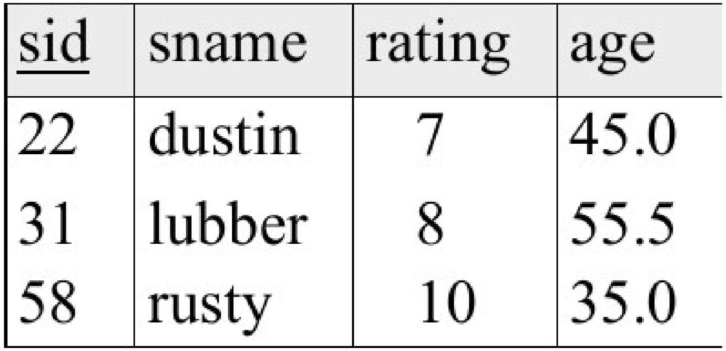


All of these operations take two input relations, which must be *union-compatible*:

- Same number of fields.
- `Corresponding' fields have the same type.

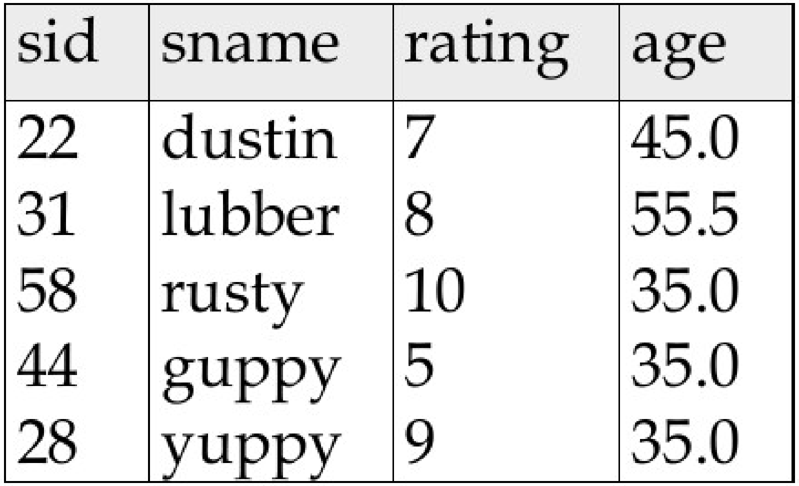
For which, if any, is duplicate elimination required?

Union



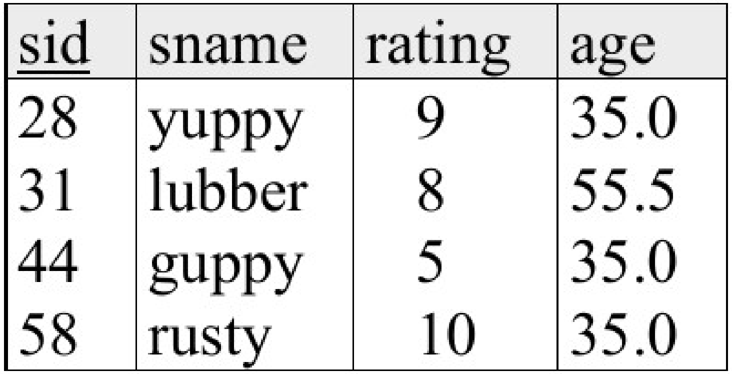
sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1



sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0
44	guppy	5	35.0
28	yuppy	9	35.0

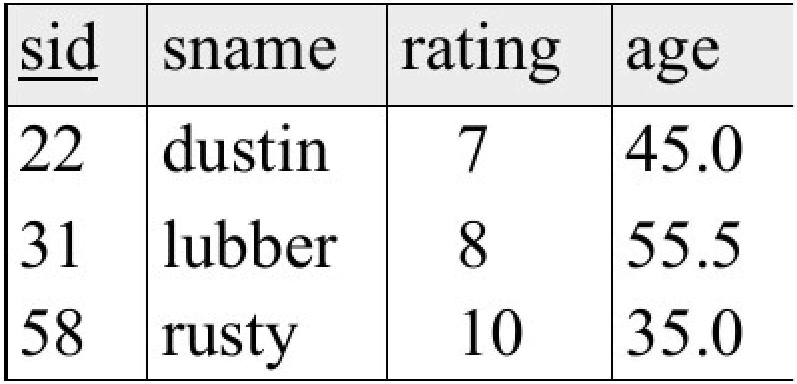
$S1 \cup S2$



sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

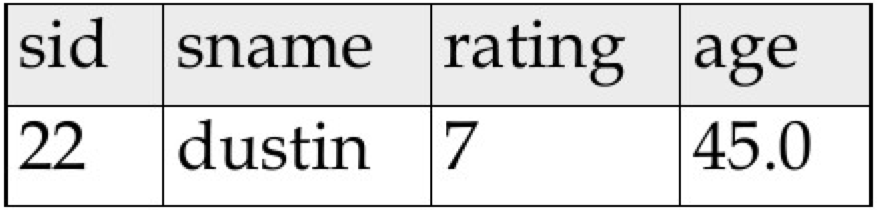
S2

Set Difference



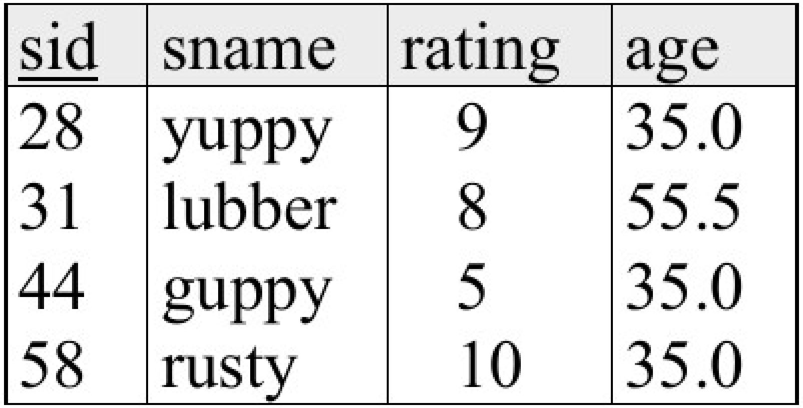
sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1



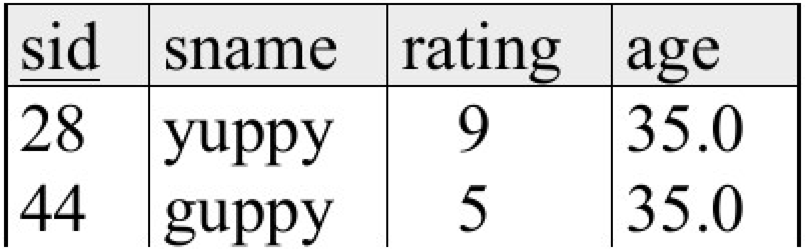
sid	sname	rating	age
22	dustin	7	45.0

S1 – S2



sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2

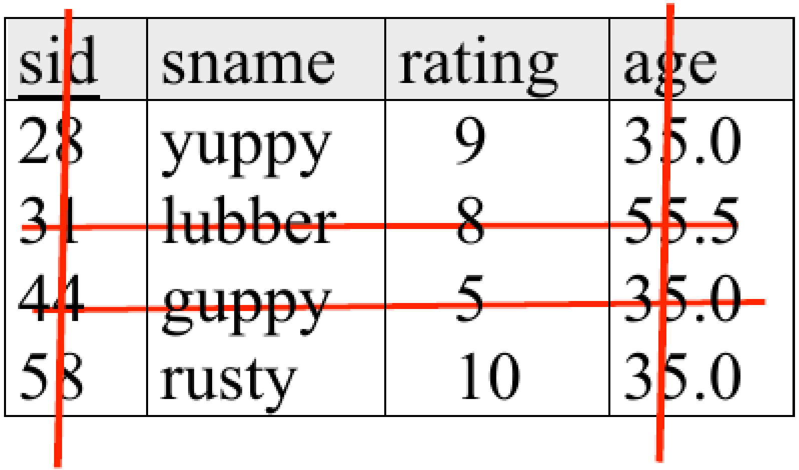


sid	sname	rating	age
28	yuppy	9	35.0
44	guppy	5	35.0

S2 – S1

Nesting Operators

- Result of a relational algebra operator is a relation
- It can be used as input to another relational algebra operator



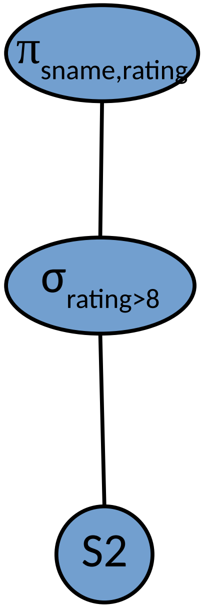
~~sid~~	sname	rating	~~age~~
~~28~~	yuppy	9	~~35.0~~
~~31~~	~~lubber~~	~~8~~	~~55.5~~
~~44~~	~~guppy~~	~~5~~	~~35.0~~
~~58~~	rusty	10	~~35.0~~

sname	rating
yuppy	9
rusty	10

$$\pi_{sname,rating}(\sigma_{rating>8}(S2))$$

Nesting Operators

- As expression tree:

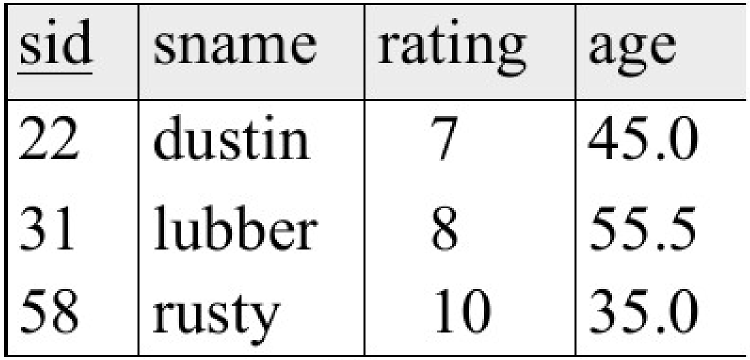


Compound Operator: Intersection

- In addition to the 5 basic operators, there are several additional “Compound Operators”
  - Do not add computational power to the language
  - Useful shorthands
  - Can be expressed with basic operations
- Example: **Intersection**
  - Takes two input relations that are union-compatible

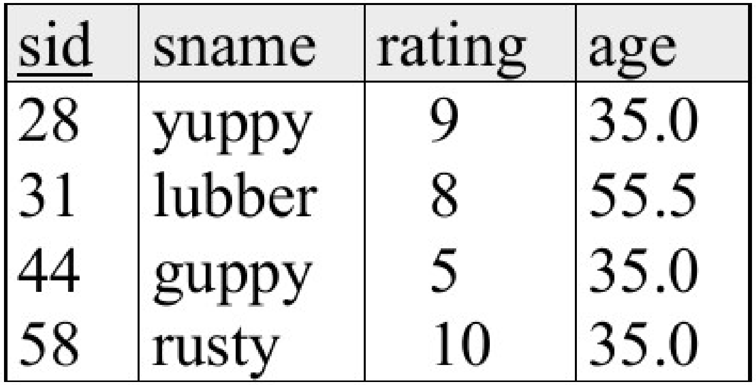
$$R \cap S = R - (R - S)$$

Compound Operator: Intersection



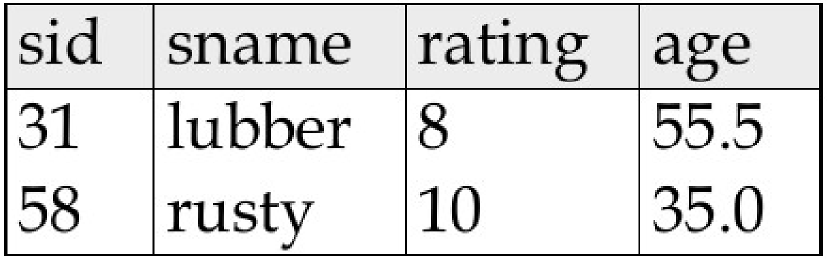
sid	sname	rating	age
22	dustin	7	45.0
31	lubber	8	55.5
58	rusty	10	35.0

S1



sid	sname	rating	age
28	yuppy	9	35.0
31	lubber	8	55.5
44	guppy	5	35.0
58	rusty	10	35.0

S2



sid	sname	rating	age
31	lubber	8	55.5
58	rusty	10	35.0

S1 ∩ S2

SQL - A language for Relational DBs

SQL - A language for Relational DBs

- Say: “ess-cue-ell” or “sequel”
  - But spelled “SQL”
- Data Definition Language (DDL) part
  - create, modify, delete relations
  - specify constraints
  - administer users, security, etc.
- Data Manipulation Language (DML) part
  - Specify queries to find tuples that satisfy criteria
  - add, modify, remove tuples
- The DBMS is responsible for efficient execution. “Declarative programming” – specify what, not how. Note the similarity to SAT-solving.

SQL - A language for Relational DBs

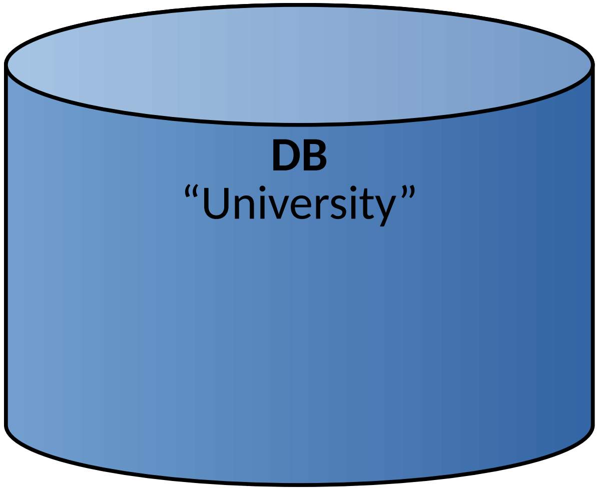
- SQL commands have to be terminated with ‘;’
- SQL is standardized
  - some DBMS include their own extra SQL commands

Creating Databases in SQL

- Create a new, empty database ‘University’:

  ```
  CREATE DATABASE University;
  ```

  - Does not contain any relations upon creation

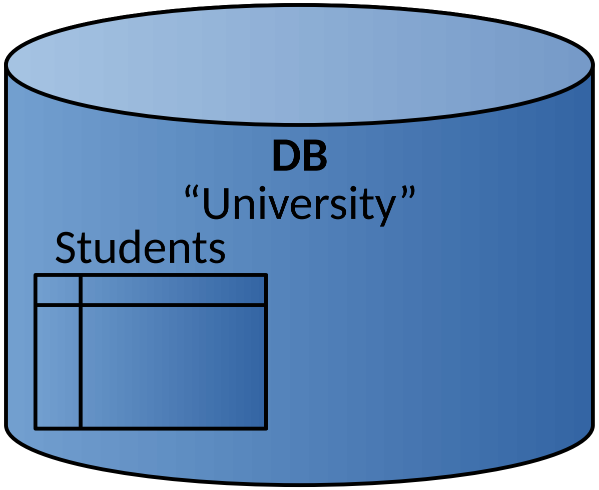


Creating Relations in SQL

- Create a new, empty relation ‘Students’:

  CREATE TABLE Students (sid CHAR(20) PRIMARY KEY, name CHAR(20), login CHAR(10), age INTEGER, gpa FLOAT);

  - Does not contain any tuples upon creation
  - Note: the type (domain) of each field is specified, and enforced by the DBMS whenever tuples are added or modified.

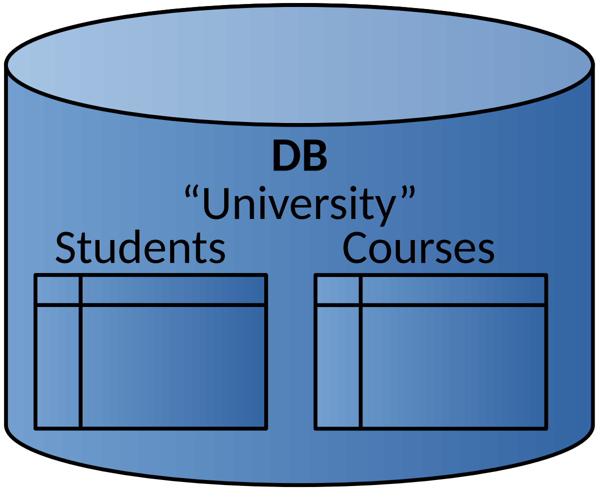


sid	name	login	age	gpa

Creating Relations in SQL

- Similarly:

```
CREATE TABLE Courses
( cid CHAR(20) PRIMARY KEY, cname CHAR(20), credits
INTEGER);
```



Adding and Deleting Tuples

- Insert a single tuple:

```
INSERT INTO Students (sid, name, login, age, gpa)
VALUES ('53688', 'Smith', 'smith@ee', 18, 3.2);
```

sid	name	login	age	gpa
53688	Smith	smith@ee	18	3.2

- Delete all tuples satisfying some condition (e.g., name = Smith):

```
DELETE FROM Students S WHERE S.name = 'Smith';
```

sid	name	login	age	gpa

Selecting Tuples in SQL

- Find tuples for all 18 year old students with gpa's above 2.0:

  SELECT * FROM Students S WHERE S.age=18 AND S.gpa > 2.0;

sid	name	login	age	gpa
53688	Smith	smith@ee	18	3.2

- To get just names and logins:

  SELECT S.name, S.login FROM Students S WHERE S.age=18 AND S.gpa > 2.0;

name	login
Smith	smith@ee

Relational Algebra Operators in SQL

- Relational algebra operators can be expressed with SQL
- Selection operator (σ):

```
SELECT * FROM Students S
    WHERE S.age=18 AND S.gpa > 2.0;
```

- Projection operator (π):

```
SELECT S.age,S.gpa FROM Students S;
```

- Union:

```
SELECT * FROM Students S
    WHERE S.age=18 AND S.gpa > 2.0
UNION
SELECT * FROM Students S
    WHERE S.age=20 AND S.gpa > 2.3;
```

Relational Algebra Operators in SQL

- Set Difference:

```
SELECT * FROM Students S
    WHERE S.gpa > 2.0
EXCEPT
SELECT * FROM Students S
    WHERE S.age=19;
```

- Cross Product:

```
SELECT * FROM Students S, Enrolled E;
```

Primary Keys in SQL

- Single attribute primary key:

```
CREATE TABLE Students (sid CHAR(20) PRIMARY KEY,
name CHAR(20), login CHAR(10), age INTEGER, gpa
FLOAT)
```

- Multi-attribute primary key:

```
CREATE TABLE Enrolled (sid CHAR(20) cid CHAR(20),
grade CHAR(2), PRIMARY KEY (sid,cid))
```

Foreign Keys in SQL

- Only students listed in the Students relation should be allowed to enroll for courses

  → sid is a foreign key referring to Students

- Students can only enroll for registered courses

  → cid is a foreign key referring to Courses

```
CREATE TABLE Enrolled
    (sid CHAR(20),cid CHAR(20),grade CHAR(2),
    PRIMARY KEY (sid,cid),
    FOREIGN KEY (sid) REFERENCES Students,
    FOREIGN KEY (cid) REFERENCES Courses);
```

Thank you for your attention!