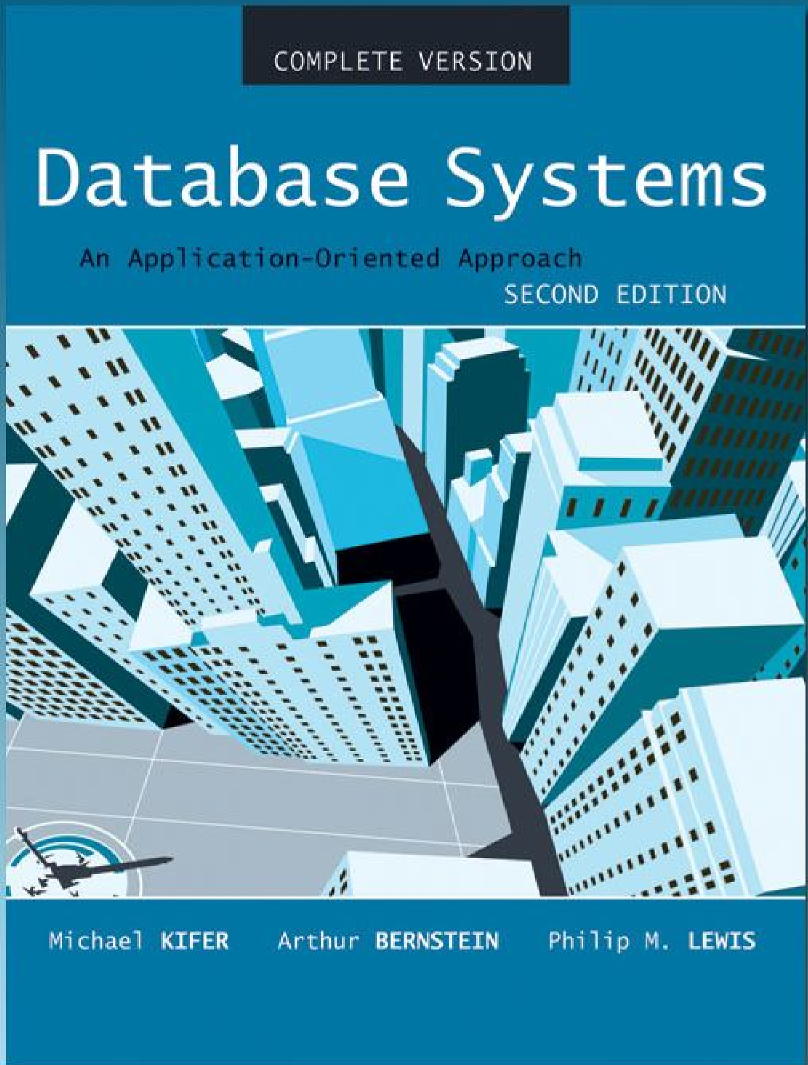
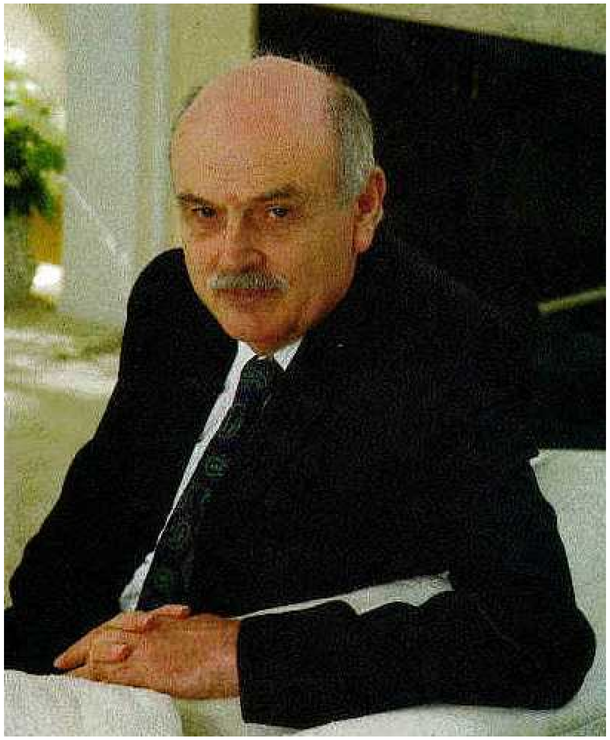


Chapter 5

Relational Algebra and SQL

Father of Relational Model Edgar F. Codd (1923-2003)



- PhD from U. of Michigan, Ann Arbor
- Received Turing Award in 1981.
- More see http://en.wikipedia.org/wiki/Edgar_Codd

Relational Query Languages

- Languages for describing queries on a relational database
- *Structured Query Language* (SQL)
  - Predominant application-level query language
  - Declarative
- *Relational Algebra*
  - Intermediate language used within DBMS
  - Procedural

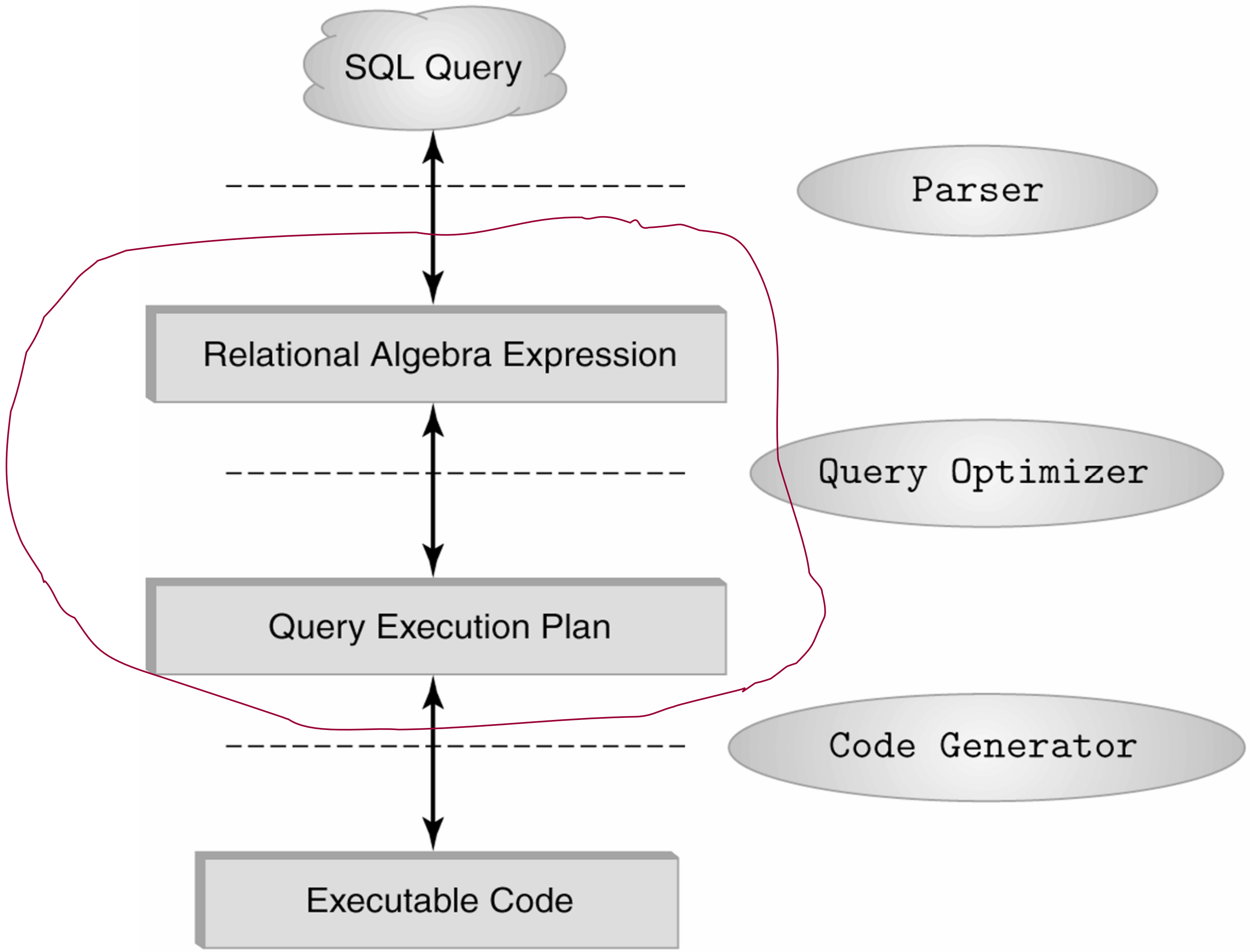
What is an Algebra?

- A language based on operators and a domain of values
- Operators map values taken from the domain into other domain values
- Hence, an expression involving operators and arguments produces a value in the domain
- When the domain is a set of all relations (and the operators are as described later), we get the *relational algebra*
- We refer to the expression as a *query* and the value produced as the *query result*

Relational Algebra

- *Domain*: set of relations
- *Basic operators*: select, project, union, set difference, Cartesian product
- *Derived operators*: set intersection, division, join
- *Procedural*: Relational expression specifies query by describing an algorithm (the sequence in which operators are applied) for determining the result of an expression

The Role of Relational Algebra in a DBMS



Select Operator

- Produce table containing subset of rows of argument table satisfying condition

$$\sigma_{condition}(relation)$$

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\sigma_{Hobby=\text{'stamps'}}(\text{Person})$

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
9876	Bart	5 Pine St	stamps

Selection Condition

- Operators: $<, \leq, \geq, >, =, \neq$
- Simple selection condition:
  - <*attribute*> *operator* <*constant*>
  - <*attribute*> *operator* <*attribute*>
- <*condition*> AND <*condition*>
- <*condition*> OR <*condition*>
- NOT <*condition*>

Selection Condition - Examples

- $\sigma_{Id>3000 \text{ OR } Hobby=\text{'hiking'}}$ (Person)
- $\sigma_{Id>3000 \text{ AND } Id<3999}$ (Person)
- $\sigma_{\text{NOT}(Hobby=\text{'hiking'})}$ (Person)
- $\sigma_{Hobby\neq\text{'hiking'}}$ (Person)

Project Operator

- Produces table containing subset of columns of argument table

$$\pi_{attribute\ list}(\mathit{relation})$$

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\pi_{Name,Hobby}$(Person)

Name	*Hobby*
John	stamps
John	coins
Mary	hiking
Bart	stamps

Project Operator

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\pi_{Name,Address}$(Person)

Name	*Address*
John	123 Main
Mary	7 Lake Dr
Bart	5 Pine St

Result is a table (no duplicates); can have fewer tuples than the original

Expressions

$$\pi_{\,Id,\ Name}\ (\sigma_{\,Hobby=\text{'stamps'}\ \text{OR}\ Hobby=\text{'coins'}}\ (\text{Person})\ )$$

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

Person

Id	*Name*
1123	John
9876	Bart

Result

Set Operators

- Relation is a set of tuples, so set operations should apply: $\cap$, $\cup$, – (set difference)
- Result of combining two relations with a set operator is a relation => all its elements must be tuples having same structure
- Hence, scope of set operations limited to *union compatible relations*

Union Compatible Relations

- Two relations are *union compatible* if
  - Both have same number of columns
  - Names of attributes are the same in both
  - Attributes with the same name in both relations have the same domain
- Union compatible relations can be combined using *union*, *intersection*, and *set difference*

Example

Tables:

Person (*SSN*, *Name*, *Address*, *Hobby*)

Professor (*Id*, *Name*, *Office*, *Phone*)

are <u>not</u> union compatible.

But

π_{Name} (Person) and π_{Name} (Professor)

<u>are</u> union compatible so

π_{Name} (Person) - π_{Name} (Professor)

makes sense.

Cartesian Product

- If *R* and *S* are two relations, $R \times S$ is the set of all concatenated tuples <*x*,*y*>, where *x* is a tuple in *R* and *y* is a tuple in *S*
  - *R* and *S* need not be union compatible.
  - *But R* and *S* must have distinct attribute names. Why?
- $R \times S$ is <u>expensive to compute. But why?</u>

A	*B*
x1	x2
x3	x4

R

C	*D*
y1	y2
y3	y4

S

A	*B*	*C*	*D*
x1	x2	y1	y2
x1	x2	y3	y4
x3	x4	y1	y2
x3	x4	y3	y4

$R \times S$

Renaming

- Result of expression evaluation is a relation
- Attributes of relation must have distinct names. This is not guaranteed with Cartesian product
  - e.g., suppose in previous example *A* and *C* have the same name
- Renaming operator tidies this up. To assign the names A_1, A_2,… A_n to the attributes of the *n* column relation produced by expression *expr* use

  $expr\ [A_1, A_2, \ldots A_n]$

Example

Transcript (*StudId*, *CrsCode*, *Semester*, *Grade*)

Teaching (*ProfId*, *CrsCode*, *Semester*)

$\pi_{StudId,\ CrsCode}$ (Transcript)[*StudId*, *CrsCode1*]

$\times$ $\pi_{ProfId,\ CrsCode}$(Teaching) [*ProfId*, *CrsCode2*]

This is a relation with 4 attributes:

StudId, *CrsCode1*, *ProfId*, *CrsCode2*

Derived Operation: Join

A (*general* or *theta*) *join* of R and S is the expression

$$R \bowtie_c S$$

where *join-condition* c is a *conjunction* of terms:

$$A_i \ oper \ B_i$$

in which A_i is an attribute of R; B_i is an attribute of S; and *oper* is one of =, <, >, ≥ ≠, ≤.

Q: Any difference between join condition and selection condition?

The meaning is:

$$\sigma_c (R \times S)$$

Where join-condition c becomes a select condition c except for possible renamings of attributes (next)

Join and Renaming

- **Problem**: *R* and *S* might have attributes with the same name – in which case the Cartesian product is not defined
- **Solutions**:
  1. Rename attributes prior to forming the product and use new names in *join-condition*´.
  2. Qualify common attribute names with relation names (thereby disambiguating the names). For instance: Transcript.*CrsCode* or Teaching.*CrsCode*
     – This solution is nice, but doesn't always work: consider

$$R \bowtie_{join\_condition} R$$

In *R*.*A*, how do we know which R is meant?

Theta Join – Example

Employee(*Name*,*Id*,*MngrId*,*Salary*)
Manager(*Name*,*Id*,*Salary*)

Output the names of all employees that earn more than their managers.

$\pi_{\text{Employee}.Name}(\text{Employee} \bowtie_{MngrId=Id \text{ AND } \text{Employee}.Salary > \text{Manager}.Salary} \text{Manager})$

The join yields a table with attributes:

Employee.*Name*, Employee.*Id*, Employee.*Salary*, *MngrId*
Manager.*Name*, Manager.*Id*, Manager.*Salary*

Equijoin Join - Example

Equijoin: Join condition is a conjunction of *equalities*.

$$\pi_{Name,CrsCode}(\text{Student} \bowtie_{Id=StudId} \sigma_{Grade=\text{'}A\text{'}}(\text{Transcript}))$$

Student

Id	*Name*	*Addr*	*Status*
111	John	…..	…..
222	Mary	…..	…..
333	Bill	…..	…..
444	Joe	…..	…..

Transcript

StudId	*CrsCode*	*Sem*	*Grade*
111	CSE305	S00	B
222	CSE306	S99	A
333	CSE304	F99	A

Mary	CSE306
Bill	CSE304

The equijoin is used very frequently since it combines related data in different relations.

Natural Join

- Special case of equijoin:
  - join condition equates *all* and *only* those attributes with the same name (condition doesn't have to be explicitly stated)
  - duplicate columns eliminated from the result

Transcript (*StudId*, *CrsCode*, *Sem*, *Grade*)
Teaching (*ProfId*, *CrsCode*, *Sem*)

$$\text{Transcript} \bowtie \text{Teaching} =$$

$$\pi_{StudId,\ Transcript.CrsCode,\ Transcript.Sem,\ Grade,\ ProfId}$$
$$(\text{Transcript} \bowtie_{Transcipt.CrsCode=Teaching.CrsCode \text{ AND } Transcirpt.Sem=Teaching.Sem} \text{Teaching})$$
$$[StudId,\ CrsCode,\ Sem,\ Grade,\ ProfId\ ]$$

Q: but why natural join is a derived operator? Because…

Natural Join (cont’d)

- More generally:

$$R \bowtie S = \pi_{attr\text{-}list} (\sigma_{join\text{-}cond} (R \times S))$$

where

$attr\text{-}list = attributes\ (R) \cup attributes\ (S)$

(duplicates are eliminated) and *join-cond* has the form:

$R.A_1 = S.A_1$ AND … AND $R.A_n = S.A_n$

where

$\{A_1 \ldots A_n\} = attributes(R) \cap attributes(S)$

Natural Join Example

- List all Ids of students who took at least two different courses:

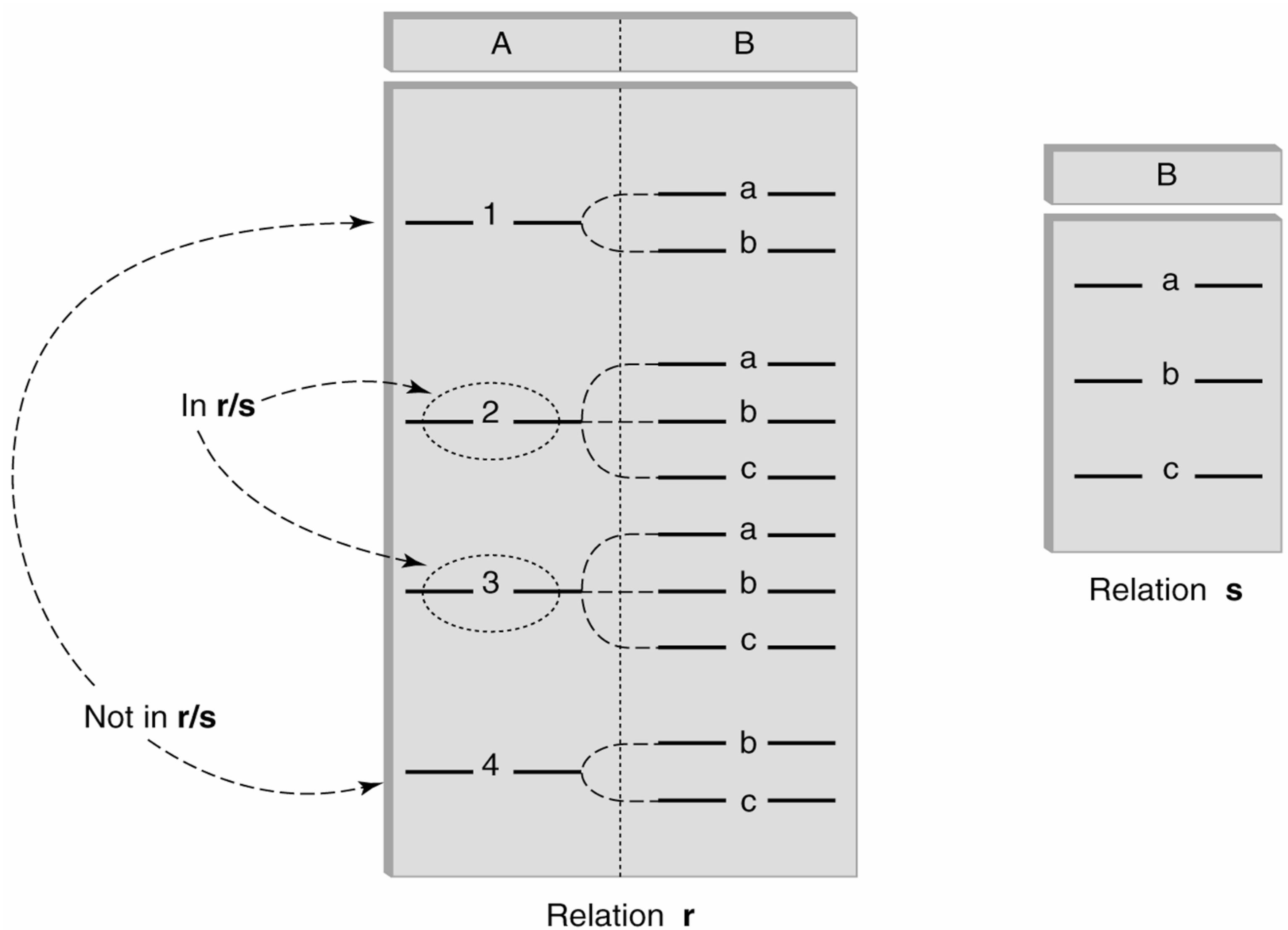
$$\pi_{StudId}\left(\sigma_{CrsCode \neq CrsCode2}\left(\text{Transcript} \bowtie \text{Transcript}\,[StudId, CrsCode2, Sem2, Grade2] \right)\right)$$

We don't want to join on *CrsCode*, *Sem*, and *Grade* attributes, hence renaming!

Division

- Goal: Produce the tuples in one relation, r, that match *all* tuples in another relation, s
  - $r\ (A_1, \ldots A_n, B_1, \ldots B_m)$
  - $s\ (B_1 \ldots B_m)$
  - *r/s*, with attributes $A_1, \ldots A_n$, is the set of all tuples <*a*> such that for every tuple <*b*> in *s*, <*a*,*b*> is in *r*
- Can be expressed in terms of projection, set difference, and cross-product

Division (cont'd)



Division - Example

- List the Ids of students who have passed <u>*all*</u> courses that were taught in spring 2000
- *Numerator*:
  - *StudId* and *CrsCode* for every course passed by every student:

$$\pi_{StudId,\ CrsCode}(\sigma_{Grade \neq \text{'F'}}(\text{Transcript}))$$

- *Denominator*:
  - *CrsCode* of all courses taught in spring 2000

$$\pi_{CrsCode}(\sigma_{Semester = \text{'S2000'}}(\text{Teaching}))$$

- Result is *numerator/denominator*

Schema for Student Registration System

Student (<u>*Id*</u>, *Name*, *Addr*, *Status*)
Professor (<u>*Id*</u>, *Name*, *DeptId*)
Course (*DeptId*, <u>*CrsCode*</u>, *CrsName*, *Descr*)
Transcript (<u>*StudId*, *CrsCode*, *Semester*</u>, *Grade*)
Teaching (*ProfId*, <u>*CrsCode*, *Semester*</u>)
Department (<u>*DeptId*</u>, *Name*)

Query Sublanguage of SQL

```
SELECT  C.CrsName
FROM  Course C
WHERE  C.DeptId = 'CS'
```

- *Tuple variable* C ranges over rows of Course.
- Evaluation strategy:
  – FROM clause produces Cartesian product of listed tables
  – WHERE clause assigns rows to C in sequence and produces table containing only rows satisfying condition
  – SELECT clause retains listed columns
- Equivalent to: $\pi_{CrsName}\sigma_{DeptId=\text{'CS'}}(\text{Course})$

Join Queries

SELECT C.*CrsName*
FROM Course C, Teaching T
WHERE C.*CrsCode*=T.*CrsCode* AND T.*Semester*='S2000'

- List CS courses taught in S2000
- Tuple variables clarify meaning.
- Join condition "C.*CrsCode*=T.*CrsCode*"
  - relates facts to each other
- Selection condition " T.*Semester*='S2000' "
  - eliminates irrelevant rows
- Equivalent (using natural join) to:

$$\pi_{CrsName}(\text{Course} \bowtie \sigma_{Semester=\text{'S2000'}}(\text{Teaching}))$$

$$\pi_{CrsName}(\sigma_{Sem=\text{'S2000'}}(\text{Course} \bowtie \text{Teaching}))$$

Correspondence Between SQL and Relational Algebra

SELECT C.*CrsName*
FROM Course C, Teaching T
WHERE C.*CrsCode* = T.*CrsCode* AND T.*Semester* = 'S2000'

Also equivalent to:

$$\pi_{CrsName}\, \sigma_{C\_CrsCode = T\_CrsCode \text{ AND } Semester = \text{'S2000'}} (\text{Course}\, [C\_CrsCode, DeptId, CrsName, Desc] \times \text{Teaching}\, [ProfId, T\_CrsCode, Semester])$$

- This is the simplest evaluation algorithm for SELECT.
- Relational algebra expressions are procedural.
  - Which of the two equivalent expressions is more easily evaluated?

Self-join Queries

Find Ids of all professors who taught at least two courses in the same semester:

```
SELECT  T1.ProfId
FROM    Teaching T1, Teaching T2
WHERE   T1.ProfId = T2.ProfId
    AND T1.Semester = T2.Semester
    AND T1.CrsCode <> T2.CrsCode
```

Tuple variables are essential in this query!

Equivalent to:

$$\pi_{ProfId}\,(\sigma_{T1.CrsCode \neq T2.CrsCode}(\text{Teaching}[\mathit{ProfId, T1.CrsCode, Semester}] \bowtie \text{Teaching}[\mathit{ProfId, T2.CrsCode, Semester}]))$$

Duplicates

- Duplicate rows not allowed in a relation
- However, duplicate elimination from query result is costly and not done by default; must be explicitly requested:

```
SELECT DISTINCT …..
FROM …..
```

Use of Expressions

Equality and comparison operators apply to strings (based on lexical ordering)

WHERE S.*Name* < 'P'

Concatenate operator applies to strings

WHERE S.*Name* || '--' || S.*Address* = ….

Expressions can also be used in SELECT clause:

SELECT S.*Name* || '--' || S.*Address* AS *NmAdd*
FROM Student S

Set Operators

- SQL provides UNION, EXCEPT (set difference), and INTERSECT for union compatible tables
- Example: Find all professors in the CS Department and all professors that have taught CS courses

```
(SELECT   P.Name
 FROM   Professor P, Teaching T
 WHERE  P.Id=T.ProfId AND T.CrsCode LIKE 'CS%')
UNION
(SELECT  P.Name
 FROM  Professor P
 WHERE  P.DeptId = 'CS')
```

Nested Queries

List all courses that were not taught in S2000

```
SELECT C.CrsName
FROM Course C
WHERE C.CrsCode NOT IN
    (SELECT T.CrsCode      --subquery
     FROM Teaching T
     WHERE T.Sem = 'S2000')
```

Evaluation strategy: subquery evaluated once to produces set of courses taught in S2000. Each row (as C) tested against this set.

Correlated Nested Queries

Output a row <*prof*, *dept*> if *prof* has taught a course in *dept*.

```
SELECT P.Name, D.Name                    --outer query
  FROM Professor P, Department D
  WHERE P.Id IN
        -- set of all ProfId's who have taught a course in D.DeptId
        (SELECT T.ProfId                       --subquery
         FROM Teaching T, Course C
         WHERE T.CrsCode=C.CrsCode AND
               C.DeptId=D.DeptId        --correlation
        )
```

Correlated Nested Queries (con't)

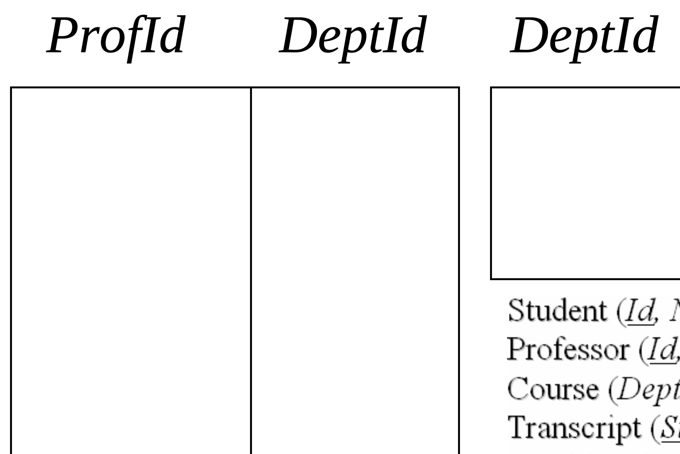
- Tuple variables T and C are *local* to subquery
- Tuple variables P and D are *global* to subquery
- *Correlation*: subquery uses a global variable, D
- The value of D.*DeptId* parameterizes an evaluation of the subquery
- Subquery must (at least) be re-evaluated for each distinct value of D.*DeptId*

- *Correlated queries can be expensive to evaluate*

Division in SQL

- *Query type*: Find the subset of items in one set that are related to *all* items in another set
- *Example*: Find professors who taught courses in *all* departments
  - Why does this involve division?

Contains row <*p*,*d*> if professor *p* taught a course in department *d*



All department Ids

Student (*Id*, *Name*, *Addr*, *Status*)
Professor (*Id*, *Name*, *DeptId*)
Course (*DeptId*, *CrsCode*, *CrsName*, *Descr*)
Transcript (*StudId*, *CrsCode*, *Semester*, *Grade*)
Teaching (*ProfId*, *CrsCode*, *Semester*)
Department (*DeptId*, *Name*)

$$\pi_{\text{ProfId,DeptId}}(\text{Teaching} \bowtie \text{Course}) \ / \ \pi_{\text{DeptId}}(\text{Department})$$

Division in SQL

- *Strategy for implementing division in SQL*:
  - Find set, A, of all departments in which a particular professor, *p*, has taught a course
  - Find set, B, of all departments
  - Output *p* if A $\supseteq$ B, or, equivalently, if B–A is empty
- *But how to do this exactly in SQL?*

Division Solution Sketch (1)

SELECT P.*Id*
FROM Professor P
WHERE P taught courses in all departments

⇩

SELECT P.*Id*
FROM Professor P
WHERE there does not exist any department that P has never taught a course

⇩

SELECT P.*Id*
FROM Professor P
WHERE NOT EXISTS(the departments that P has never taught a course)

Division Solution Sketch (1)

SELECT P.*Id*
FROM Professor P
WHERE NOT EXISTS(the departments that P has never taught a course)

⇩

SELECT P.*Id*
FROM Professor P
WHERE NOT EXISTS(
  B: All departments
  EXCEPT
  A: the departments that P has ever taught a course)

But how do we formulate A and B?

Division – SQL Solution in details

```
SELECT  P.Id
FROM  Professor P
WHERE NOT EXISTS
   (SELECT  D.DeptId            -- set B of all dept Ids
    FROM  Department D
        EXCEPT
    SELECT  C.DeptId             -- set A of dept Ids of depts in
                                 -- which P taught a course
    FROM  Teaching T, Course C
    WHERE  T.ProfId=P.Id         -- global variable
           AND  T.CrsCode=C.CrsCode)
```

Aggregates

- Functions that operate on sets:
  - COUNT, SUM, AVG, MAX, MIN
- Produce numbers (not tables)
- Aggregates over multiple rows into one row
- Not part of relational algebra (but not hard to add)

```
SELECT COUNT(*)
FROM   Professor P
```

```
SELECT MAX (Salary)
FROM   Employee E
```

Aggregates (cont'd)

Count the number of courses taught in S2000

SELECT COUNT (T.*CrsCode*)
FROM Teaching T
WHERE T.*Semester* = 'S2000'

But if multiple sections of same course are taught, use:

SELECT COUNT (DISTINCT T.*CrsCode*)
FROM Teaching T
WHERE T.*Semester* = 'S2000'

Grouping

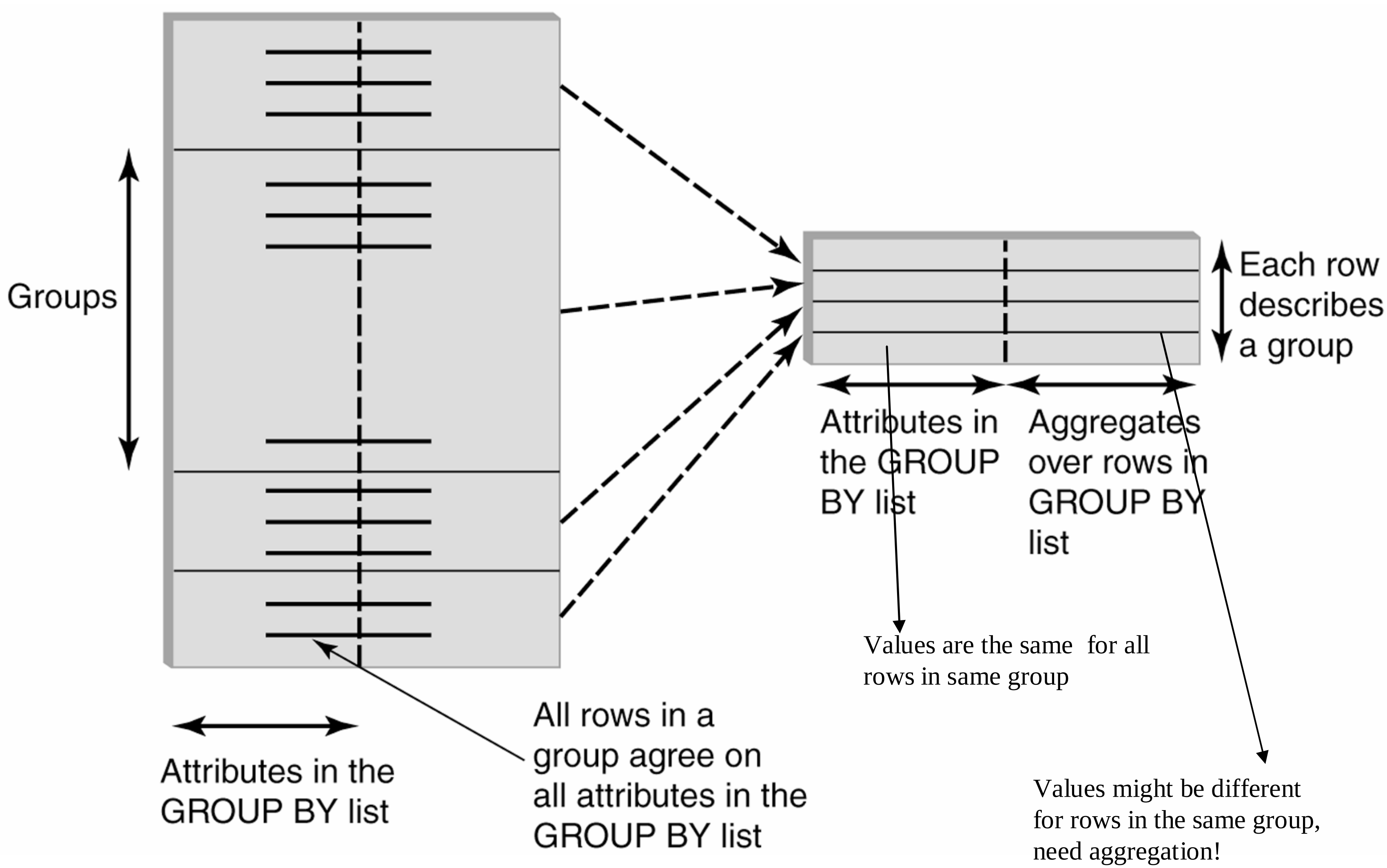
- But how do we compute the number of courses taught in S2000 *per professor*?
  - Strategy 1: Fire off a separate query for <u>each</u> professor:

```
SELECT   COUNT(T.CrsCode)
FROM     Teaching T
WHERE    T.Semester = 'S2000' AND T.ProfId = 123456789
```

    - Cumbersome
    - What if the number of professors changes? Add another query?
  - Strategy 2: define a special ***grouping operator***:

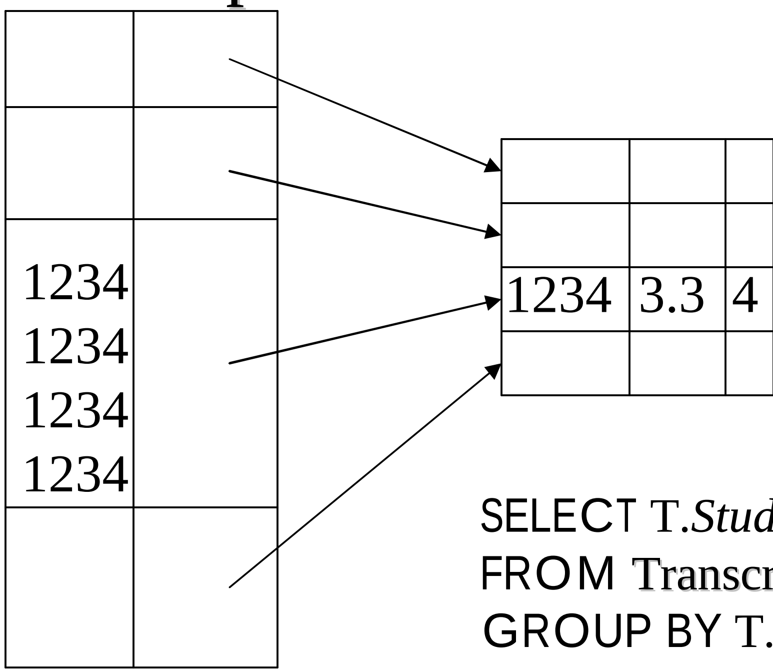
```
SELECT     T.ProfId,  COUNT(T.CrsCode)
FROM       Teaching  T
WHERE      T.Semester = 'S2000'
GROUP BY   T.ProfId
```

GROUP BY


Groups
Each row describes a group
Attributes in the GROUP BY list
Aggregates over rows in GROUP BY list
Values are the same for all rows in same group
Attributes in the GROUP BY list
All rows in a group agree on all attributes in the GROUP BY list
Values might be different for rows in the same group, need aggregation!

GROUP BY - Example

Transcript



Attributes:

–student's *Id*

–avg grade

–number of courses

```
SELECT T.StudId, AVG(T.Grade), COUNT (*)
FROM Transcript T
GROUP BY T.StudId
```

-Finally, each group of rows is aggregated into one row

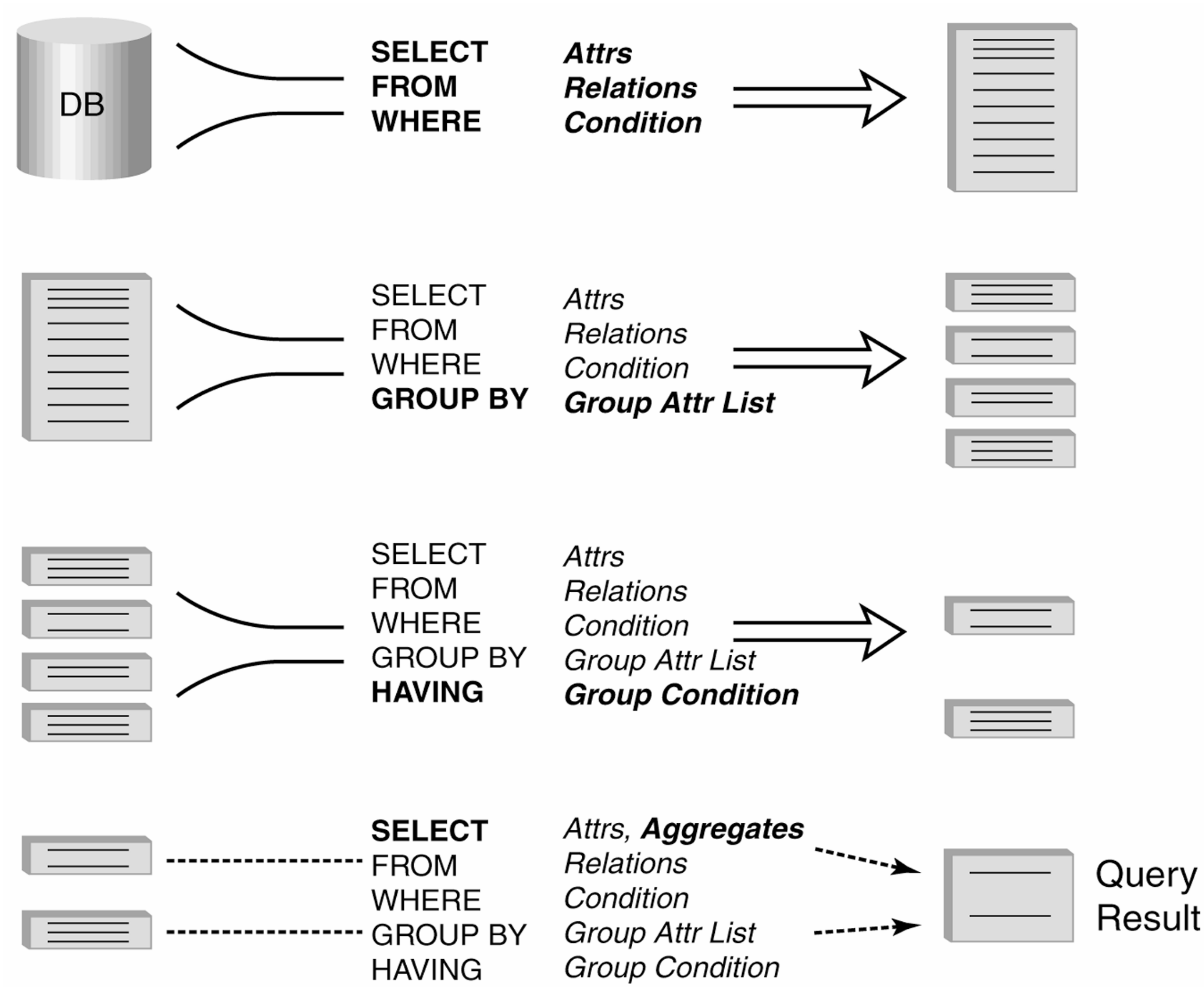
HAVING Clause

- Eliminates unwanted groups (analogous to WHERE clause, but works on groups instead of individual tuples)
- HAVING condition is constructed from attributes of GROUP BY list and aggregates on attributes not in that list

```
SELECT   T.StudId,
         AVG(T.Grade)  AS  CumGpa,
         COUNT (*)  AS  NumCrs
FROM   Transcript  T
WHERE   T.CrsCode  LIKE  'CS%'
GROUP BY  T.StudId
HAVING  AVG (T.Grade) > 3.5
```

Apply to each group not to the whole table

Evaluation of GroupBy with Having



Example

- Output the name and address of all seniors on the Dean's List

Student (*Id*, *Name*, *Addr*, *Status*)
Professor (*Id*, *Name*, *DeptId*)
Course (*DeptId*, *CrsCode*, *CrsName*, *Descr*)
Transcript (*StudId*, *CrsCode*, *Semester*, *Grade*)
Teaching (*ProfId*, *CrsCode*, *Semester*)
Department (*DeptId*, *Name*)

SELECT S.*Id*, S.*Name*
FROM Student S, Transcript T
WHERE S.*Id* = T.*StudId* AND S.*Status* = 'senior'

GROUP BY
- S.*Id* -- *wrong*
- S.*Id*, S.*Name* -- *right*

Every attribute that occurs in SELECT *clause must also occur in* GROUP BY *or it must be an aggregate. S.Name does not.*

HAVING AVG (T.*Grade*) > 3.5 AND SUM (T.*Credit*) > 90

> The DB has not used the information that "S.Id → S.Name".

Aggregates: Proper and Improper Usage

SELECT COUNT (T.*CrsCode*), T. *ProfId*

– *makes no sense (in the absence of* GROUP BY *clause)*

SELECT COUNT (*), AVG (T.*Grade*)

– *but this is OK*

WHERE T.*Grade* > COUNT (SELECT ….)

– *aggregate cannot be applied to result of* SELECT *statement*

ORDER BY Clause

- Causes rows to be output in a specified order

```
SELECT  T.StudId, COUNT (*) AS NumCrs,
              AVG(T.Grade) AS CumGpa
FROM    Transcript T
WHERE  T.CrsCode LIKE ‘CS%’
GROUP BY  T.StudId
HAVING  AVG (T.Grade) > 3.5
ORDER BY  DESC  CumGpa,  ASC StudId
```

Descending (DESC) — *Ascending* (ASC)

Query Evaluation with GROUP BY, HAVING, ORDER BY

As before

1. Evaluate FROM: produces Cartesian product, A, of tables in FROM list
2. Evaluate WHERE: produces table, B, consisting of rows of A that satisfy WHERE condition
3. Evaluate GROUP BY: partitions B into groups that agree on attribute values in GROUP BY list
4. Evaluate HAVING: eliminates groups in B that do not satisfy HAVING condition
5. Evaluate SELECT: produces table C containing a row for each group. Attributes in SELECT list limited to those in GROUP BY list and aggregates over group
6. Evaluate ORDER BY: orders rows of C

Views

- Used as a relation, but rows are not physically stored.
  - The contents of a view is *computed* when it is used within an SQL statement
  - Each time it is used (thus computed), the content might different as underlying base tables might have changed
- View is the result of a SELECT statement over other views and base relations
- When used in an SQL statement, the view definition is substituted for the view name in the statement
  - As SELECT statement nested in FROM clause

View - Example

CREATE VIEW CumGpa (*StudId*, *Cum*) AS
  SELECT T.*StudId*, AVG (T.*Grade*)
  FROM Transcript T
  GROUP BY T.*StudId*

SELECT S.*Name*, C.*Cum*
FROM CumGpa C, Student S
WHERE C.*StudId* = S.*StudId* AND C.*Cum* > 3.5

View - Substitution

When used in an SQL statement, the view definition is substituted for the view name in the statement. As SELECT statement nested in FROM clause

SELECT S.*Name*, C.*Cum*
FROM (SELECT T.*StudId*, AVG (T.*Grade*)
FROM Transcript T
GROUP BY T.*StudId*) C, Student S
WHERE C.*StudId* = S.*StudId* AND C.*Cum* > 3.5

View Benefits

- *Access Control*: Users not granted access to base tables. Instead they are granted access to the view of the database appropriate to their needs.
  - *External schema* is composed of views.
  - View allows owner to provide SELECT access to a subset of columns (analogous to providing UPDATE and INSERT access to a subset of columns)

Views – Limiting Visibility

Grade projected out

CREATE VIEW PartOfTranscript (*StudId*, *CrsCode*, *Semester*) AS
SELECT T. *StudId*, T.*CrsCode*, T.*Semester* -- *limit columns*
FROM Transcript T
WHERE T.*Semester* = 'S2000' -- *limit rows*

Give permissions to access data through view:

GRANT SELECT ON PartOfTranscript TO joe

This would have been analogous to:

GRANT SELECT (*StudId*,*CrsCode*,*Semester*)
ON Transcript TO joe

on regular tables, <u>if</u> SQL allowed attribute lists in GRANT SELECT

View Benefits (cont'd)

- *Customization*: Users need not see full complexity of database. View creates the illusion of a simpler database customized to the needs of a particular category of users
- A view is *similar in many ways to a subroutine* in standard programming
  - Can be reused in multiple queries

Nulls

- *Conditions*: *x op y* (where *op* is <, >, <>, =, etc.) has value *unknown* (*U*) when either x or y is null
  - WHERE T.*cost* > T.*price*
- *Arithmetic expression*: x *op y* (where *op* is +, –, *, etc.) has value NULL if x or y is NULL
  - WHERE (T. *price*/T.*cost*) > 2
- *Aggregates*: COUNT counts NULLs like any other value; other aggregates ignore NULLs

```
SELECT  COUNT (T.CrsCode), AVG (T.Grade)
FROM    Transcript T
WHERE   T.StudId = '1234'
```

Nulls (cont'd)

- WHERE clause uses a *three-valued logic – T, F, U(ndefined) –* to filter rows. Portion of truth table:

C1	*C2*	*C1* AND *C2*	*C1* OR *C2*
T	U	U	T
F	U	F	U
U	U	U	U

- Rows are discarded if WHERE condition is *F(alse)* or U(*nknown)*
- Ex: WHERE T.*CrsCode* = 'CS305' AND T.*Grade* > 2.5
- Q: Why not simply replace each "U" to "F"?

Modifying Tables – Insert

- Inserting a single row into a table
  - Attribute list can be omitted if it is the same as in CREATE TABLE (but do not omit it)
  - NULL and DEFAULT values can be specified

INSERT INTO Transcript(*StudId*, *CrsCode*, *Semester*, *Grade*)
VALUES (12345, 'CSE305', 'S2000', NULL)

Bulk Insertion

- Insert the rows output by a SELECT

```
CREATE TABLE DeansList (
        StudId      INTEGER,
        Credits     INTEGER,
        CumGpa      FLOAT,
        PRIMARY KEY StudId )

INSERT INTO  DeansList (StudId, Credits, CumGpa)
SELECT       T.StudId, 3 * COUNT (*),  AVG(T.Grade)
FROM         Transcript T
GROUP BY     T.StudId
HAVING  AVG (T.Grade) > 3.5  AND  COUNT(*) > 30
```

Modifying Tables – Delete

- Similar to SELECT except:
  - No project list in DELETE clause
  - No Cartesian product in FROM clause (only 1 table name)
  - Rows satisfying WHERE clause (general form, including subqueries, allowed) are deleted instead of output

DELETE FROM Transcript T
WHERE T.*Grade* IS NULL AND T.*Semester* <> 'S2000'

Modifying Data - Update

```
UPDATE  Employee E
SET     E.Salary = E.Salary * 1.05
WHERE   E.Department = ‘R&D’
```

- Updates rows in a single table
- All rows satisfying WHERE clause (general form, including subqueries, allowed) are updated

Updating Views

- Question: Since views look like tables to users, can they be updated?
- Answer: Yes – a view update changes the underlying base table to produce the requested change to the view

CREATE VIEW CsReg (*StudId*, *CrsCode*, *Semester*) AS
SELECT T.*StudId*, T. *CrsCode*, T.*Semester*
FROM Transcript T
WHERE T.*CrsCode* LIKE 'CS%' AND T.*Semester*='S2000'

Updating Views - Problem 1

INSERT INTO CsReg (*StudId*, *CrsCode*, *Semester*)
VALUES (1111, 'CSE305', 'S2000')
Tuple is in the VIEW

- **Question**: What value should be placed in attributes of underlying table that have been projected out (e.g., *Grade*)?
- **Answer**: NULL (assuming null allowed in the missing attribute) or DEFAULT

Updating Views - Problem 2

INSERT INTO CsReg (*StudId*, *CrsCode*, *Semester*)
VALUES (1111, 'ECO105', 'S2000')

- **Problem**: New tuple not in view
- **Solution**: Allow insertion (assuming the WITH CHECK OPTION clause has not been appended to the CREATE VIEW statement)

Updating Views - Problem 3

- Update to a view might *__not__* *__uniquely__* specify the change to the base table(s) that results in the desired modification of the view (ambiguity)

CREATE VIEW ProfDept (*PrName*, *DeName*) AS
SELECT P.*Name*, D.*Name*
FROM Professor P, Department D
WHERE P.*DeptId* = D.*DeptId*

Updating Views - Problem 3 (cont’d)

- Tuple <Smith, CS> can be deleted from ProfDept by:
  - Deleting row for Smith from Professor (but this is inappropriate if he is still at the University)
  - Deleting row for CS from Department (not what is intended)
  - Updating row for Smith in Professor by setting *DeptId* to null (seems like a good idea, but how would the computer know?)

Updating Views – Restrictions

- Updatable views are restricted to those in which
  - No Cartesian product in FROM clause, single table
  - no aggregates, GROUP BY, HAVING
  - …

For example, if we allowed:

```
CREATE VIEW AvgSalary (DeptId, Avg_Sal ) AS
   SELECT  E.DeptId, AVG(E.Salary)
   FROM    Employee E
   GROUP BY E.DeptId
```

then how do we handle:

```
UPDATE AvgSalary
   SET Avg_Sal = 1.1 * Avg_Sal
```