CSE532
Relational Algebra and SQL

CSE 532, Theory of Database Systems

Stony Brook University

http://www.cs.stonybrook.edu/~cse532

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

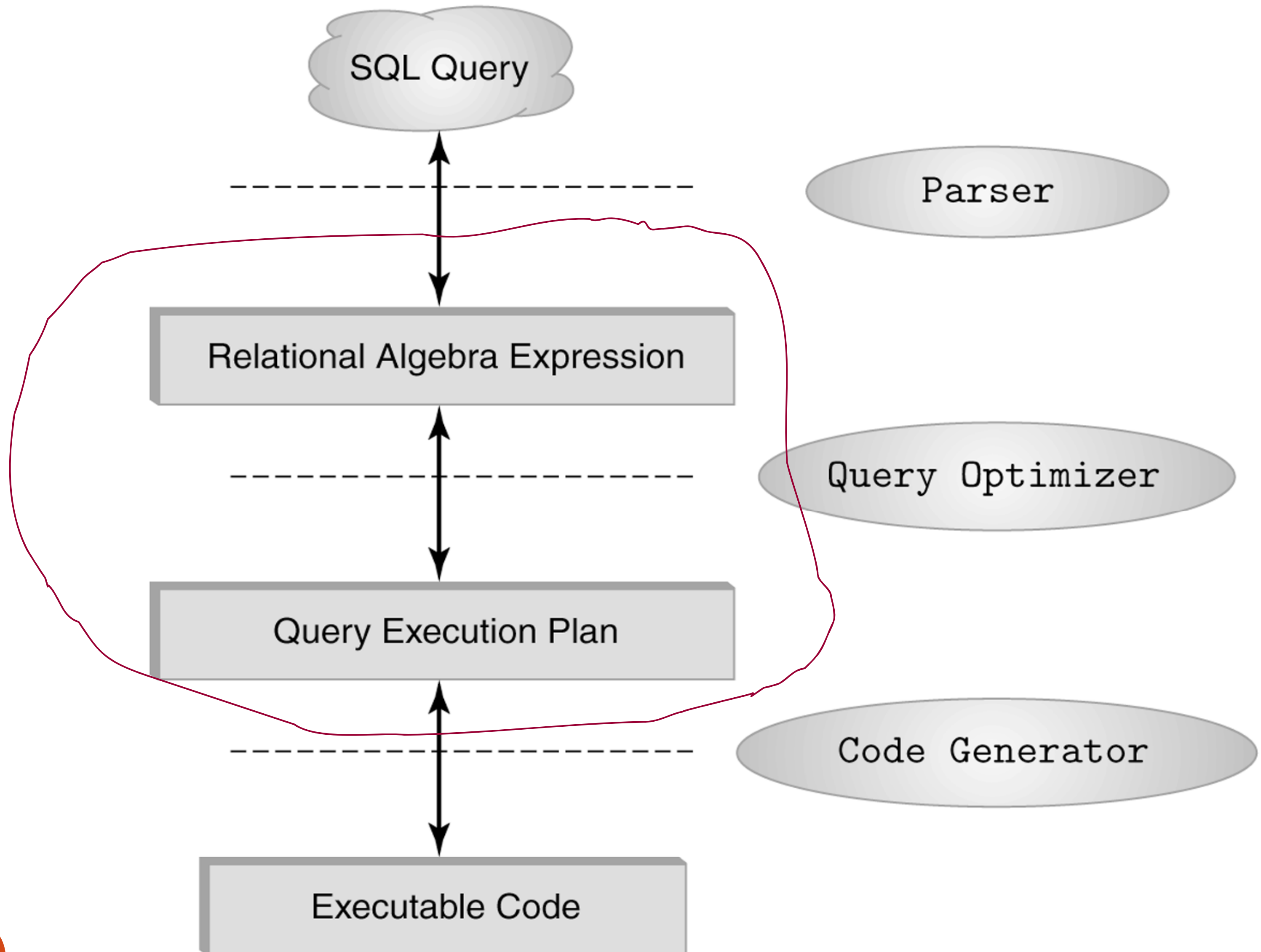
What is an Algebra?

- 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: <, ≤, ≥, >, =, ≠
- Simple selection condition:
  - <*attribute*> *operator* <*constant*>
  - <*attribute*> *operator* <*attribute*>
- <*condition*> AND <*condition*>
- <*condition*> OR <*condition*>
- NOT <*condition*>

Selection Condition - Examples

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

Project Operator

- Produces table containing subset of columns of argument table

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

- 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

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

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 not union compatible.

But

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

are 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
- $R \times S$ is <u>expensive to compute</u>:
  - Factor of two in the size of each row
  - Quadratic in the number of rows

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 $A_1, A_2, \ldots A_n$ 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

$$R \bowtie_{join\text{-}condition} S$$

where *join-condition* 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 =, <, >, ≥ ≠, ≤.

The meaning is:

$$\sigma_{join\text{-}condition'}(R \times S)$$

where *join-condition* and *join-condition*′ are the same, 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.

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

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*.

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

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 relatio

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*)

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

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

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:

$A_1 = A_1$ AND … AND $A_n = A_n$

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:

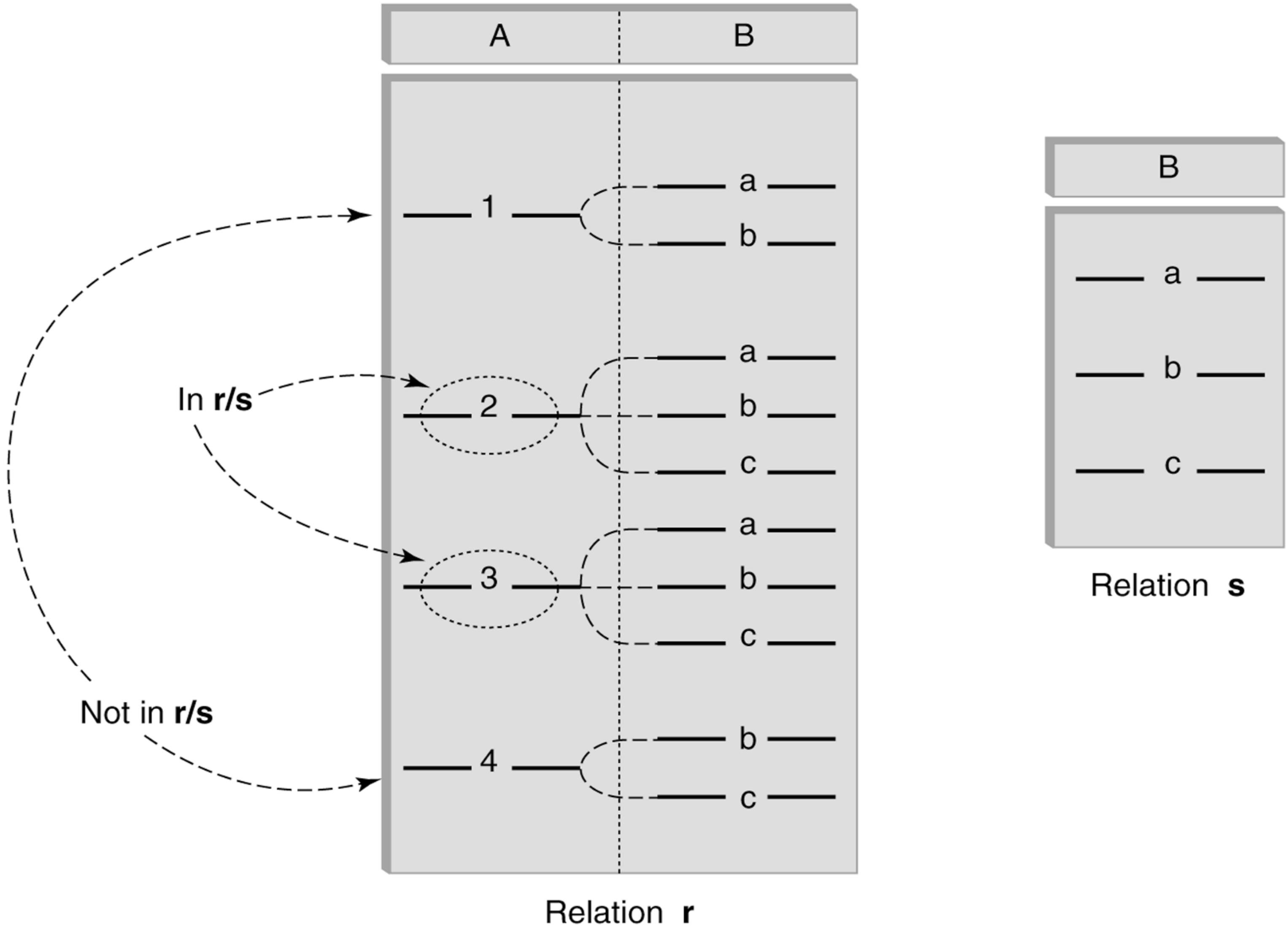
$$\pi_{StudId} (\sigma_{CrsCode \neq CrsCode2} (\text{Transcript} \bowtie \text{Transcript} [StudId, CrsCode2, Sem2, Grade2]))$$

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 *all* 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 (*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*)

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:

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

- 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:

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

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
        )
```

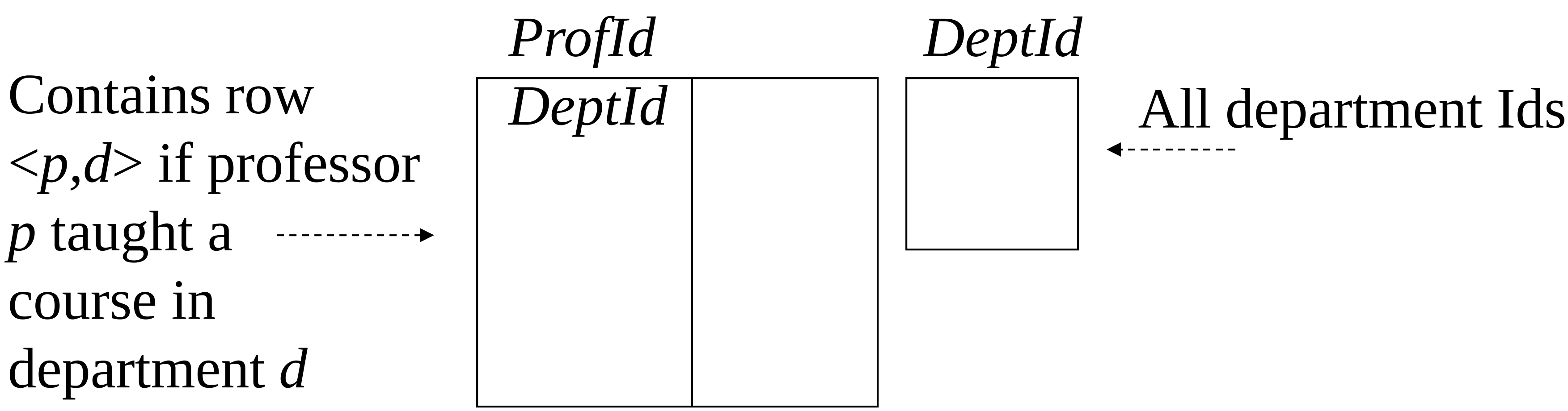
Correlated Nested Queries (con't)

- 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?



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

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

Division – SQL Solution

```
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)
- 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

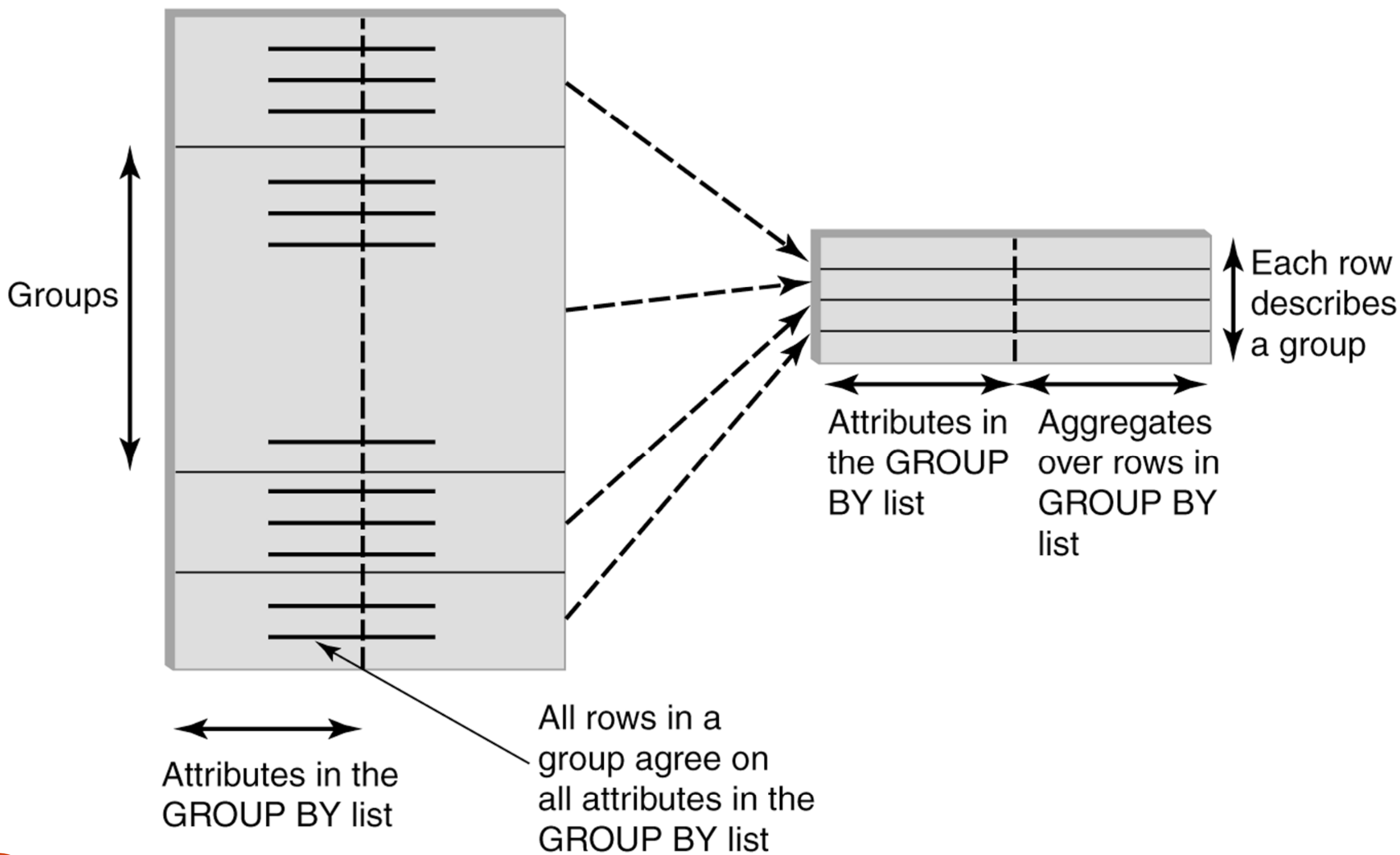
- But how do we compute the number of courses taught in S2000 *per professor*?
  - Strategy 1: Fire off a separate query for <u>each</u> professor:

```
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*:

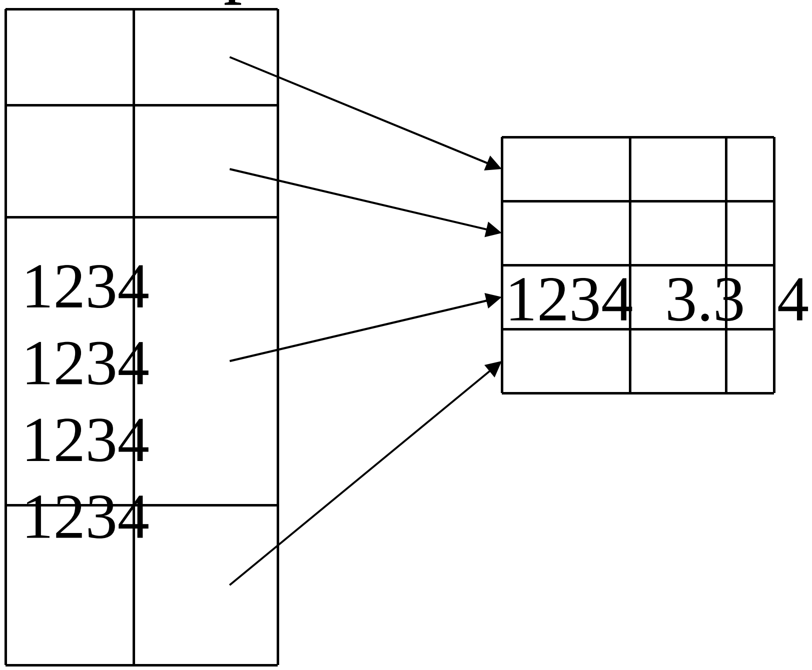
```
SELECT    T.ProfId,  COUNT(T.CrsCode)
FROM      Teaching  T
WHERE     T.Semester = 'S2000'
GROUP BY  T.ProfId
```

GROUP BY


Groups
Each row describes a group
Attributes in the GROUP BY list
Aggregates over rows in GROUP BY list
Attributes in the GROUP BY list
All rows in a group agree on all attributes in the GROUP BY list

GROUP BY - Example

Transcript



Attributes:

- –student's *Id*
- –avg grade
- –number of courses

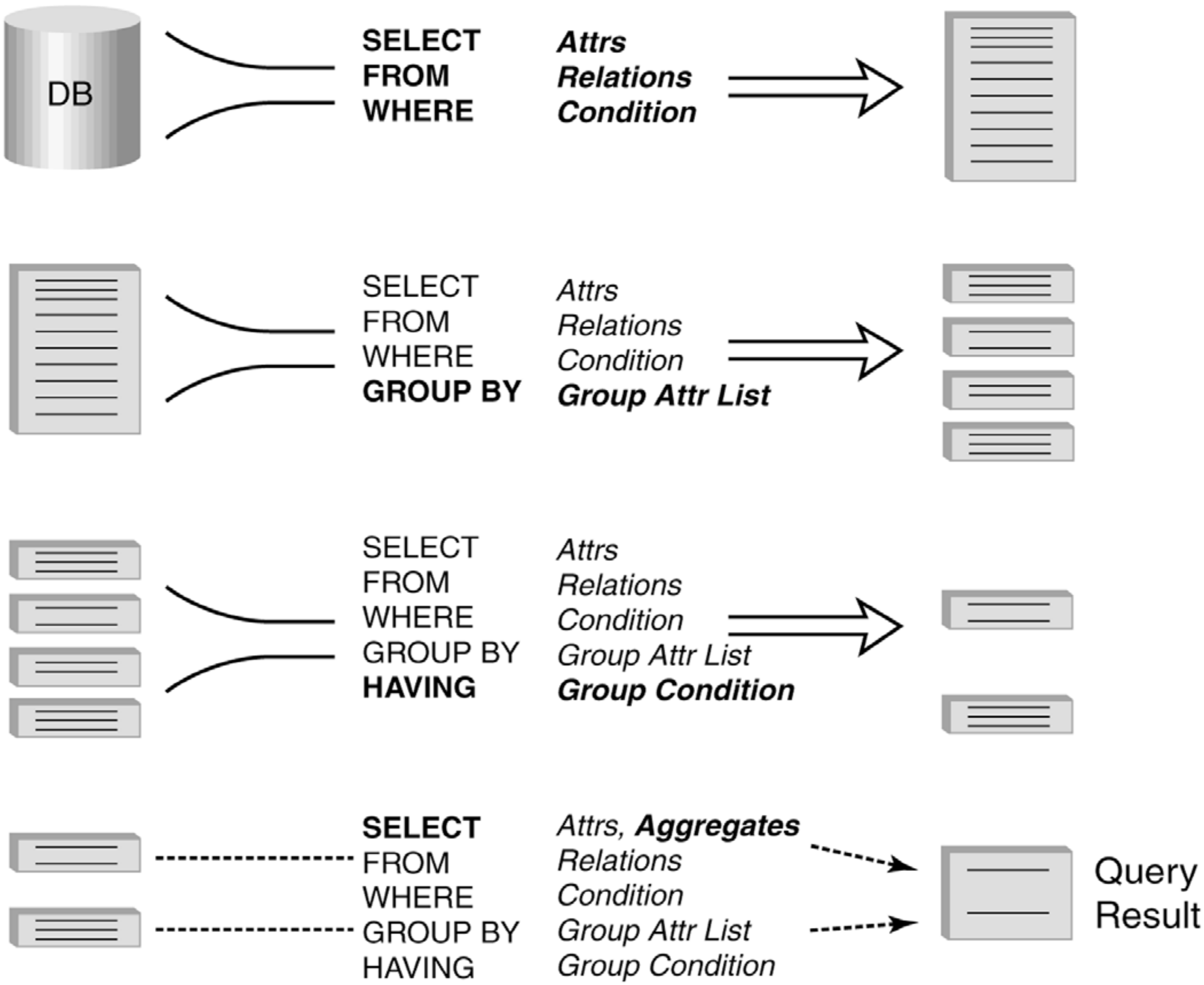
SELECT T.*StudId*, AVG(T.*Grade*), COUNT (*)
FROM Transcript T
GROUP BY T.*StudId*

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
```

Evaluation of GroupBy with Having



Example

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

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

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

Ascending

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
- 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 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

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’)

- **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
  - 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
```