An Introduction to the Database Management Systems

By
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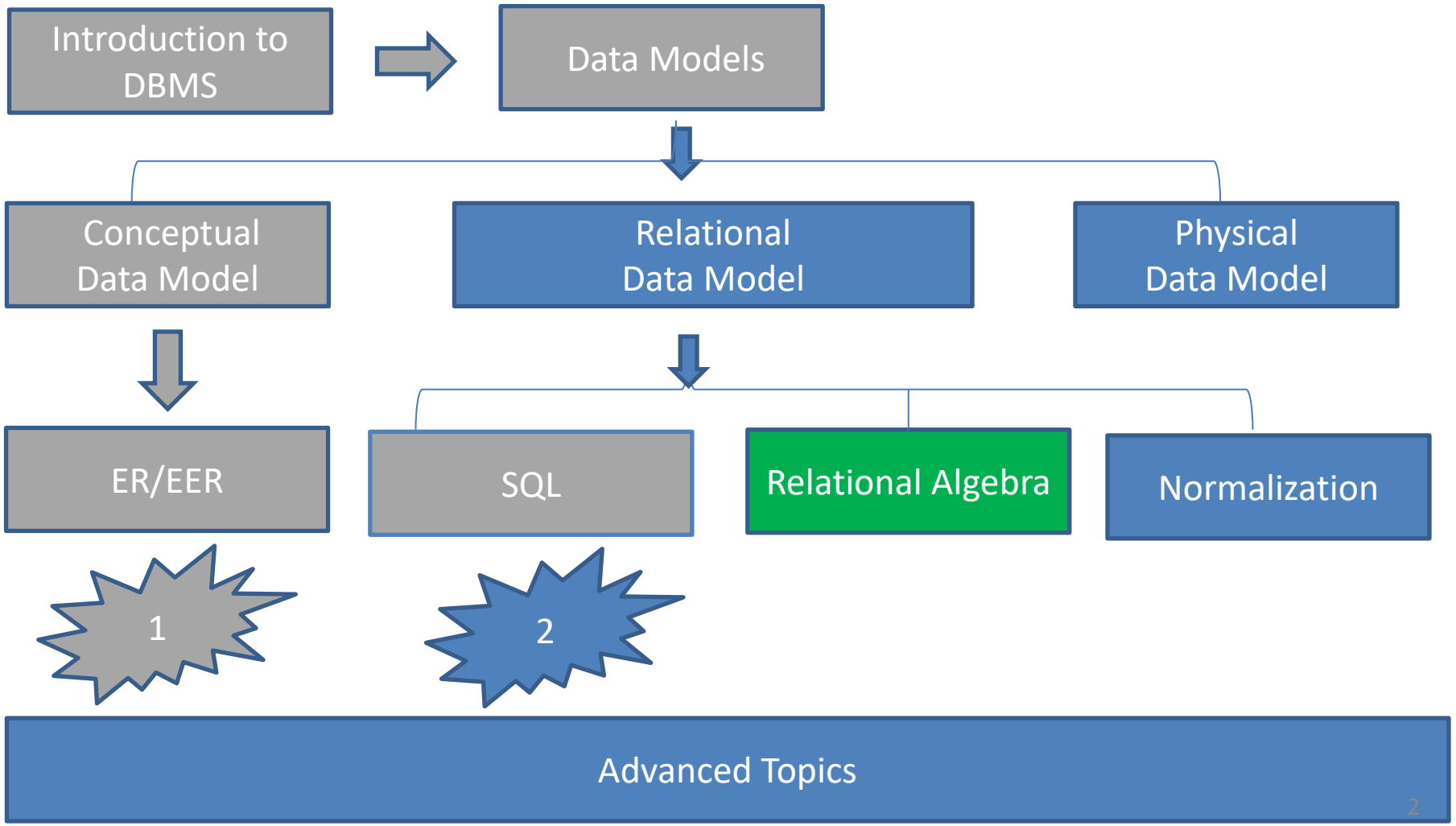
Slides originally by Book(s) Resources

Road Map

(Might change!)



Relational Algebra

- Unary Relational Operations: SELECT and PROJECT
- Relational Algebra Operations from Set Theory
- Binary Relational Operations: JOIN and DIVISION
- Additional Relational Operations

Unary Relational Operations: SELECT and PROJECT

- The SELECT Operation
  - Subset of the tuples from a relation that satisfies a selection condition:

$$\sigma_{<\text{selection condition}>}(R)$$

    - Boolean expression contains clauses of the form <attribute name> <comparison op> <constant value>

      or

    - <attribute name> <comparison op> <attribute name>

Unary Relational Operations: SELECT and PROJECT (cont'd.)

- Example:

$$\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000) \text{ OR } (\text{Dno}=5 \text{ AND } \text{Salary}>30000)}(\text{EMPLOYEE})$$

- <selection condition> applied independently to each individual tuple *t* in *R*
  - If condition evaluates to TRUE, tuple selected
- Boolean conditions **AND**, **OR**, and **NOT**
- **Unary**
  - Applied to a single relation

Unary Relational Operations: SELECT and PROJECT (cont'd.)

- **Selectivity**
  - Fraction of tuples selected by a selection condition
- **Cascade** SELECT operations into a single operation with **AND** condition

The PROJECT Operation

- Selects columns from table and discards the other columns:
  $\pi_{<\text{attribute list}>}(R)$
- **Degree**
  - Number of attributes in <attribute list>
- **Duplicate elimination**
  - Result of PROJECT operation is a set of distinct tuples

Sequences of Operations and the RENAME Operation

- **In-line** expression:

$$\pi_{\text{Fname, Lname, Salary}}(\sigma_{\text{Dno}=5}(\text{EMPLOYEE}))$$

- Sequence of operations:

$$\text{DEP5\_EMPS} \leftarrow \sigma_{\text{Dno}=5}(\text{EMPLOYEE})$$
$$\text{RESULT} \leftarrow \pi_{\text{Fname, Lname, Salary}}(\text{DEP5\_EMPS})$$

- **Rename** attributes in intermediate results
  - RENAME operation

$$\rho_{S(B1, B2, \ldots, Bn)}(R) \quad \text{or} \quad \rho_{S}(R) \quad \text{or} \quad \rho_{(B1, B2, \ldots, Bn)}(R)$$

Figure 6.1

Results of SELECT and PROJECT operations. (a) $\sigma_{(Dno=4\ \textbf{AND}\ Salary>25000)\ OR\ (Dno=5\ \textbf{AND}\ Salary>30000)}$ (EMPLOYEE). (b) $\pi_{Lname,\ Fname,\ Salary}$(EMPLOYEE). (c) $\pi_{Sex,\ Salary}$(EMPLOYEE).

(a)

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5

(b)

Lname	Fname	Salary
Smith	John	30000
Wong	Franklin	40000
Zelaya	Alicia	25000
Wallace	Jennifer	43000
Narayan	Ramesh	38000
English	Joyce	25000
Jabbar	Ahmad	25000
Borg	James	55000

(c)

Sex	Salary
M	30000
M	40000
F	25000
F	43000
M	38000
M	25000
M	55000

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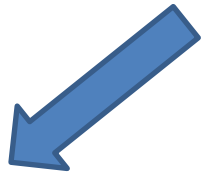

Relational Algebra Operations from Set Theory

- **UNION**, **INTERSECTION**, and **MINUS**
  - Merge the elements of two sets in various ways
  - Binary operations
  - Relations must have the same type of tuples
- UNION
  - $R \cup S$
  - Includes all tuples that are either in *R* or in *S* or in both *R* and *S*
  - Duplicate tuples eliminated

Relational Algebra Operations from Set Theory (cont'd.)

- INTERSECTION
  - $R \cap S$
  - Includes all tuples that are in both *R* and *S*
- SET DIFFERENCE (or MINUS)
  - $R - S$
  - Includes all tuples that are in *R* but not in *S*

Figure 6.4
The set operations UNION, INTERSECTION, and MINUS. (a) Two union-compatible relations. (b) STUDENT ∪ INSTRUCTOR. (c) STUDENT ∩ INSTRUCTOR. (d) STUDENT – INSTRUCTOR. (e) INSTRUCTOR – STUDENT.

(a) **STUDENT**

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

INSTRUCTOR

Fname	Lname
John	Smith
Ricardo	Browne
Susan	Yao
Francis	Johnson
Ramesh	Shah

(b)

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert
John	Smith
Ricardo	Browne
Francis	Johnson

(c)

Fn	Ln
Susan	Yao
Ramesh	Shah

(d)

Fn	Ln
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

(e)

Fname	Lname
John	Smith
Ricardo	Browne
Francis	Johnson

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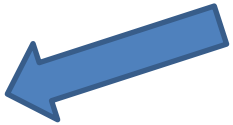

The CARTESIAN PRODUCT (CROSS PRODUCT) Operation

- **CARTESIAN PRODUCT**
  - **CROSS PRODUCT** or **CROSS JOIN**
  - Denoted by ×
  - Binary set operation
  - Relations do not have to be union compatible
  - Useful when followed by a selection that matches values of attributes

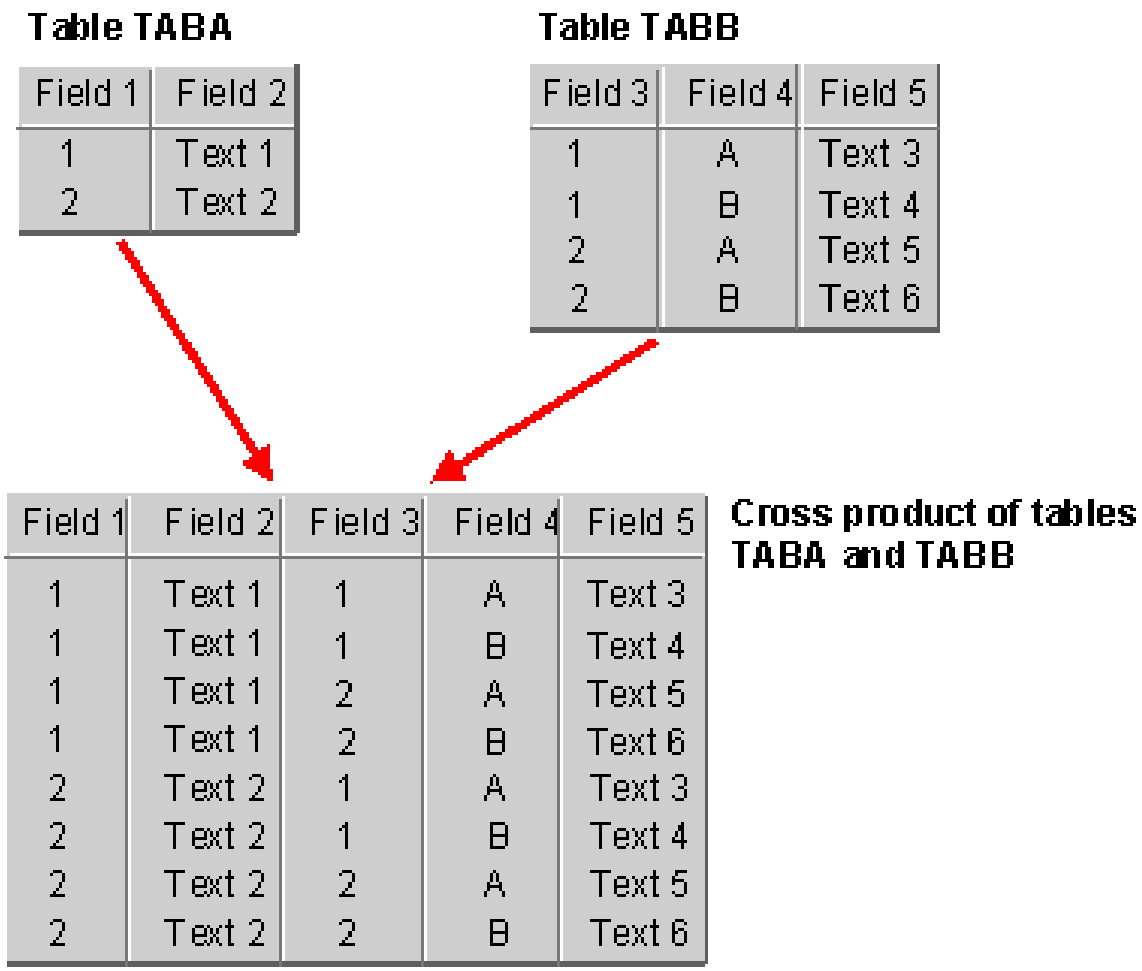
Table TABA
Field 1 Field 2
1 Text 1
2 Text 2
Table TABB
Field 3 Field 4 Field 5
1 A Text 3
1 B Text 4
2 A Text 5
2 B Text 6
Field 1 Field 2 Field 3 Field 4 Field 5
1 Text 1 1 A Text 3
1 Text 1 1 B Text 4
1 Text 1 2 A Text 5
1 Text 1 2 B Text 6
2 Text 2 1 A Text 3
2 Text 2 1 B Text 4
2 Text 2 2 A Text 5
2 Text 2 2 B Text 6
Cross product of tables TABA and TABB

Binary Relational Operations: JOIN and DIVISION

- The **JOIN** Operation
  - Denoted by ⋈
  - Combine related tuples from two relations into single "longer" tuples
  - General join condition of the form <condition> **AND** <condition> **AND**...**AND** <condition>
  - Example:

$$\text{DEPT\_MGR} \leftarrow \text{DEPARTMENT} \bowtie_{\text{Mgr\_ssn=Ssn}} \text{EMPLOYEE}$$
$$\text{RESULT} \leftarrow \pi_{\text{Dname, Lname, Fname}}(\text{DEPT\_MGR})$$

Binary Relational Operations: JOIN and DIVISION (cont'd.)

- **THETA** JOIN
  - Each <condition> of the form A_i θ B_j
  - A_i is an attribute of R
  - B_j is an attribute of S
  - A_i and B_j have the same domain
  - θ (theta) is one of the comparison operators:
    - {=, <, ≤, >, ≥, ≠}

Variations of JOIN: The EQUIJOIN and NATURAL JOIN

- **EQUIJOIN**
  - Only = comparison operator used
  - Always have one or more pairs of attributes that have identical values in every tuple
- **NATURAL JOIN**
  - Denoted by *
  - Removes second (superfluous) attribute in an EQUIJOIN condition

EQUI NATURAL

(both are inner joins)

Joined Enrollments				
SID	Name	SID	Course	Grade
1	Smith	1	Mgt280	A
1	Smith	1	Mgt284	B
1	Smith	1	Mgt287	A
2	Jones	2	Mgt280	B
2	Jones	2	Mgt284	A

Redundancy left in place in the equi-join

Joined Enrollments			
SID	Name	Course	Grade
1	Smith	Mgt280	A
1	Smith	Mgt284	B
1	Smith	Mgt287	A
2	Jones	Mgt280	B
2	Jones	Mgt284	A

Redundancy has been removed in the natural join

Variations of JOIN: The EQUIJOIN and NATURAL JOIN (cont'd.)

- **Join selectivity**
  - Expected size of join result divided by the maximum size $n_R * n_S$
- **Inner joins**
  - Type of match and combine operation
  - Defined formally as a combination of CARTESIAN PRODUCT and SELECTION

A Complete Set of Relational Algebra Operations

- Set of relational algebra operations {σ, π, ∪, ρ, –, ×} is a **complete set**
  - Any relational algebra operation can be expressed as a sequence of operations from this set

The DIVISION Operation

- Denoted by ÷
- Example: retrieve the names of employees who work on all the projects that 'John Smith' works on
- Apply to relations $R(Z) \div S(X)$

SSN_PNOS

Essn	Pno
123456789	1
123456789	2
666884444	3
453453453	1
453453453	2
333445555	2
333445555	3
333445555	10
333445555	20
999887777	30
999887777	10
987987987	10
987987987	30
987654321	30
987654321	20
888665555	20

SMITH_PNOS

Pno
1
2

SSNS

Ssn
123456789
453453453

R

A	B
a1	b1
a2	b1
a3	b1
a4	b1
a1	b2
a3	b2
a2	b3
a3	b3
a4	b3
a1	b4
a2	b4
a3	b4

S

A
a1
a2
a3

$T \leftarrow R \div S.$

?

R

A	B
a1	b1
a2	b1
a3	b1
a4	b1
a1	b2
a3	b2
a2	b3
a3	b3
a4	b3
a1	b4
a2	b4
a3	b4

S

A
a1
a2
a3

T

B
b1
b4

$$T \leftarrow R \div S.$$

Operations of Relational Algebra

Table 6.1 Operations of Relational Algebra

OPERATION	PURPOSE	NOTATION
SELECT	Selects all tuples that satisfy the selection condition from a relation R.	$\sigma_{\text{<selection condition>}}(R)$
PROJECT	Produces a new relation with only some of the attributes of R, and removes duplicate tuples.	$\pi_{\text{<attribute list>}}(R)$
THETA JOIN	Produces all combinations of tuples from R_1 and R_2 that satisfy the join condition.	$R_1 \bowtie_{\text{<join condition>}} R_2$
EQUIJOIN	Produces all the combinations of tuples from R_1 and R_2 that satisfy a join condition with only equality comparisons.	$R_1 \bowtie_{\text{<join condition>}} R_2$, OR $R_1 \bowtie_{(\text{<join attributes 1>}),\ (\text{<join attributes 2>})} R_2$
NATURAL JOIN	Same as EQUIJOIN except that the join attributes of R_2 are not included in the resulting relation; if the join attributes have the same names, they do not have to be specified at all.	$R_1 *_{\text{<join condition>}} R_2$, OR $R_1 *_{(\text{<join attributes 1>}),\ (\text{<join attributes 2>})} R_2$ OR $R_1 * R_2$

Operations of Relational Algebra (cont'd.)

Table 6.1 Operations of Relational Algebra

UNION	Produces a relation that includes all the tuples in R_1 or R_2 or both R_1 and R_2; R_1 and R_2 must be union compatible.	$R_1 \cup R_2$
INTERSECTION	Produces a relation that includes all the tuples in both R_1 and R_2; R_1 and R_2 must be union compatible.	$R_1 \cap R_2$
DIFFERENCE	Produces a relation that includes all the tuples in R_1 that are not in R_2; R_1 and R_2 must be union compatible.	$R_1 - R_2$
CARTESIAN PRODUCT	Produces a relation that has the attributes of R_1 and R_2 and includes as tuples all possible combinations of tuples from R_1 and R_2.	$R_1 \times R_2$
DIVISION	Produces a relation $R(X)$ that includes all tuples $t[X]$ in $R_1(Z)$ that appear in R_1 in combination with every tuple from $R_2(Y)$, where $Z = X \cup Y$.	$R_1(Z) \div R_2(Y)$

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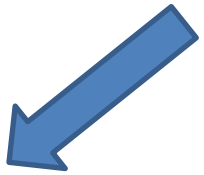


OUTER JOIN Operations

- **Outer joins**
  - Keep all tuples in *R*, or all those in *S*, or all those in both relations regardless of whether or not they have matching tuples in the other relation
  - **Types**
    - **LEFT OUTER JOIN, RIGHT OUTER JOIN, FULL OUTER JOIN**

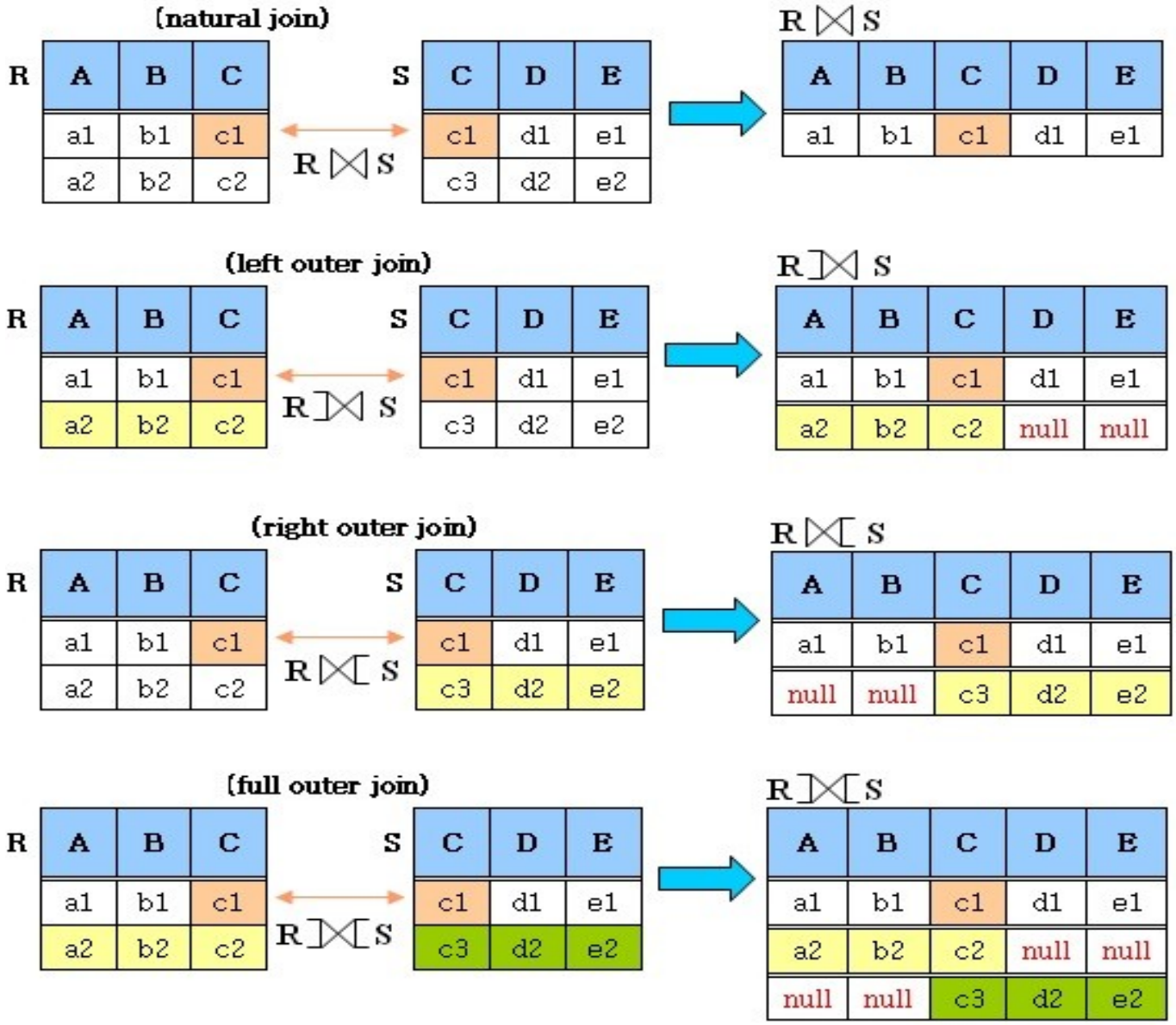
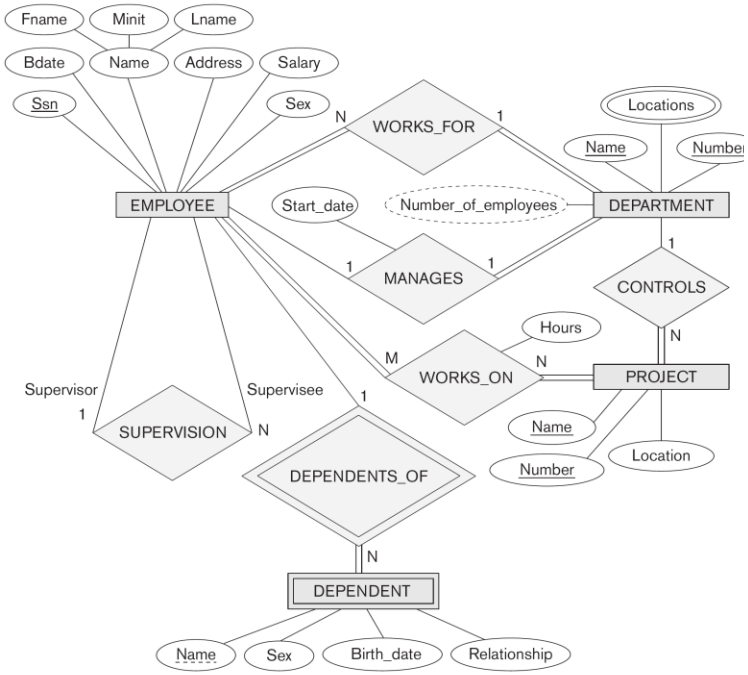

(natural join)
R
A B C
a1 b1 c1
a2 b2 c2
S
C D E
c1 d1 e1
c3 d2 e2
R ⋈ S
R ⋈ S
A B C D E
a1 b1 c1 d1 e1
(left outer join)
R
A B C
a1 b1 c1
a2 b2 c2
S
C D E
c1 d1 e1
c3 d2 e2
R ⟕ S
R ⟕ S
A B C D E
a1 b1 c1 d1 e1
a2 b2 c2 null null
(right outer join)
R
A B C
a1 b1 c1
a2 b2 c2
S
C D E
c1 d1 e1
c3 d2 e2
R ⟖ S
R ⟖ S
A B C D E
a1 b1 c1 d1 e1
null null c3 d2 e2
(full outer join)
R
A B C
a1 b1 c1
a2 b2 c2
S
C D E
c1 d1 e1
c3 d2 e2
R ⟗ S
R ⟗ S
A B C D E
a1 b1 c1 d1 e1
a2 b2 c2 null null
null null c3 d2 e2

Figure 9.1
The ER conceptual schema diagram for the COMPANY database.



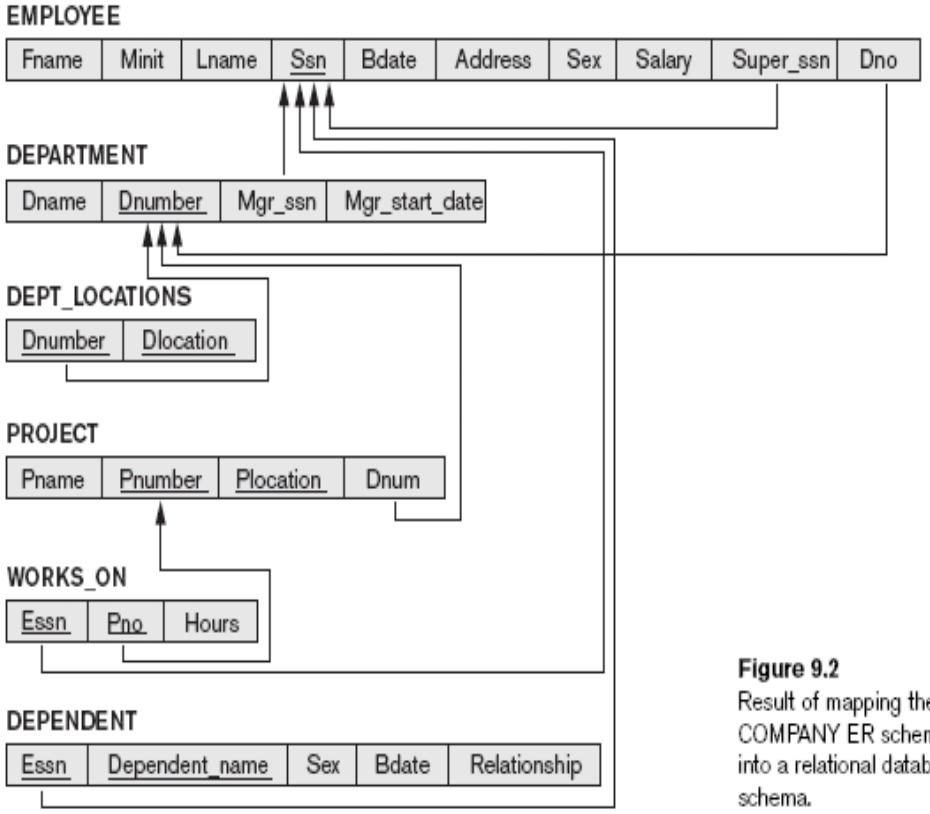
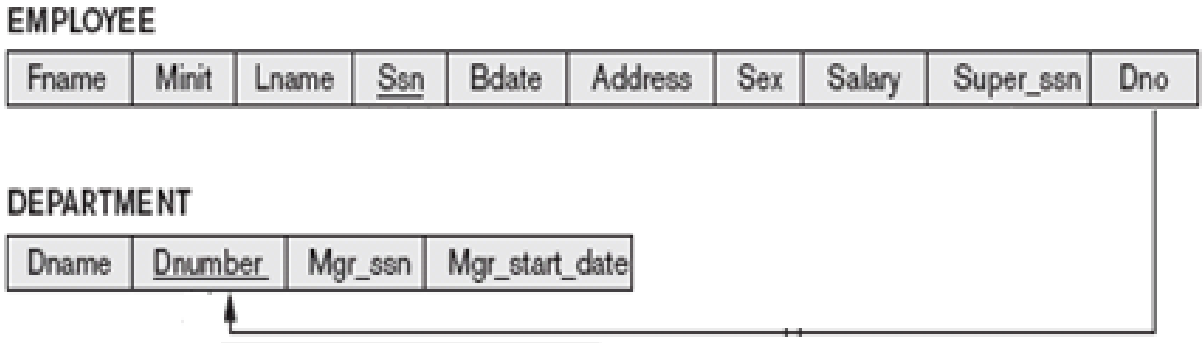


Figure 9.2
Result of mapping the COMPANY ER schema into a relational database schema.

Retrieve the name and address of all employees who work for the 'Research' department.

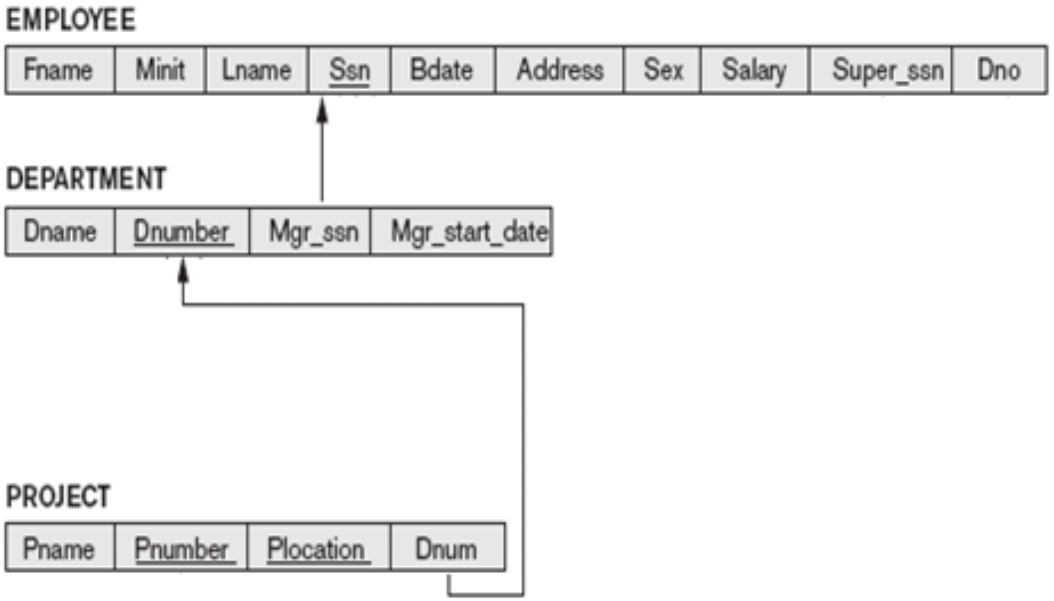


$$RESEARCH\_DEPT \leftarrow \sigma_{Dname='Research'}(DEPARTMENT)$$
$$RESEARCH\_EMPS \leftarrow (RESEARCH\_DEPT \bowtie_{Dnumber=Dno} EMPLOYEE)$$
$$RESULT \leftarrow \pi_{Fname,\ Lname,\ Address}(RESEARCH\_EMPS)$$

As a single in-line expression, this query becomes:

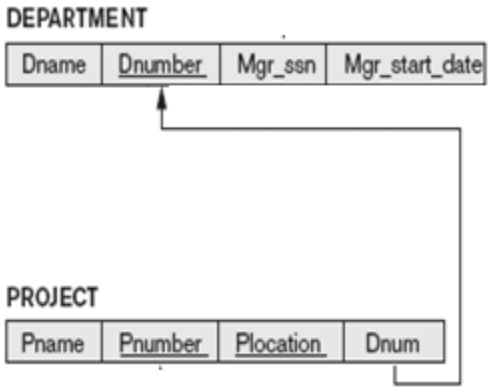
$$\pi_{Fname,\ Lname,\ Address}\ (\sigma_{Dname='Research'}(DEPARTMENT \bowtie_{Dnumber=Dno}(EMPLOYEE)))$$

For every project located in 'Stafford', list the project number, the controlling department number, and the department manager's last name, address, and birth date.



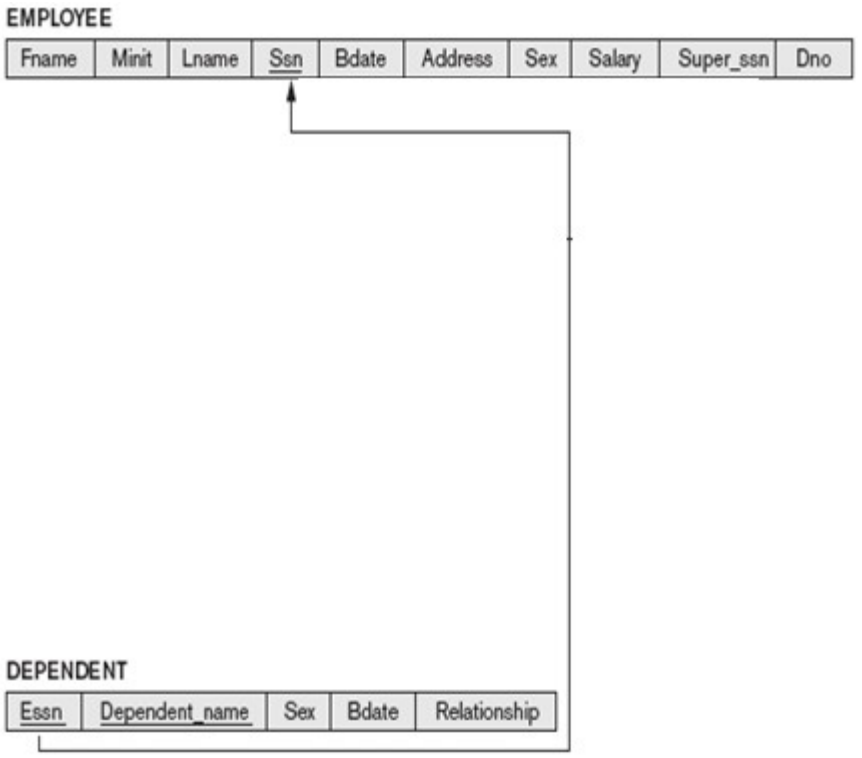
$$\text{STAFFORD\_PROJS} \leftarrow \sigma_{\text{Plocation='Stafford'}}(\text{PROJECT})$$
$$\text{CONTR\_DEPTS} \leftarrow (\text{STAFFORD\_PROJS} \bowtie_{\text{Dnum=Dnumber}} \text{DEPARTMENT})$$
$$\text{PROJ\_DEPT\_MGRS} \leftarrow (\text{CONTR\_DEPTS} \bowtie_{\text{Mgr\_ssn=Ssn}} \text{EMPLOYEE})$$
$$\text{RESULT} \leftarrow \pi_{\text{Pnumber, Dnum, Lname, Address, Bdate}}(\text{PROJ\_DEPT\_MGRS})$$

Find the names of employees who work on *all* the projects controlled by department number 5.



$$DEPT5\_PROJS \leftarrow \rho_{(Pno)}(\pi_{Pnumber}(\sigma_{Dnum=5}(PROJECT)))$$
$$EMP\_PROJ \leftarrow \rho_{(Ssn,\ Pno)}(\pi_{Essn,\ Pno}(WORKS\_ON))$$
$$RESULT\_EMP\_SSNS \leftarrow EMP\_PROJ \div DEPT5\_PROJS$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(RESULT\_EMP\_SSNS * EMPLOYEE)$$

Retrieve the names of employees who have no dependents.



$$ALL\_EMPS \leftarrow \pi_{Ssn}(EMPLOYEE)$$
$$EMPS\_WITH\_DEPS(Ssn) \leftarrow \pi_{Essn}(DEPENDENT)$$
$$EMPS\_WITHOUT\_DEPS \leftarrow (ALL\_EMPS - EMPS\_WITH\_DEPS)$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(EMPS\_WITHOUT\_DEPS * EMPLOYEE)$$

List the names of managers who have at least one dependent.

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship

Query 7. List the names of managers who have at least one dependent.

$$MGRS(Ssn) \leftarrow \pi_{Mgr\_ssn}(DEPARTMENT)$$
$$EMPS\_WITH\_DEPS(Ssn) \leftarrow \pi_{Essn}(DEPENDENT)$$
$$MGRS\_WITH\_DEPS \leftarrow (MGRS \cap EMPS\_WITH\_DEPS)$$
$$RESULT \leftarrow \pi_{Lname,\ Fname}(MGRS\_WITH\_DEPS * EMPLOYEE)$$

Quiz 1

Relation R

A	B
1	1
2	1
2	2
3	4
4	1
4	4
5	1
5	2
5	3

S

B
1
2

R ÷ S

?

Quiz 2

TABLE T1

P	Q	R
10	a	5
15	b	8
25	a	6

TABLE T2

A	B	C
10	b	6
25	c	3
10	b	5

a. $T1 \bowtie_{T1.P = T2.A} T2$

b. $T1 \bowtie_{T1.Q = T2.B} T2$

c. $T1 \bowtie_{T1.P = T2.A} T2$

d. $T1 \bowtie_{T1.Q = T2.B} T2$

e. $T1 \cup T2$

f. $T1 \bowtie_{(T1.P = T2.A \text{ AND } T1.R = T2.C)} T2$