

# Figure 14.1 Simplified version of the COMPANY relational database schema.

EMPLOYEE f.k.

ENAME	<u>SSN</u>	BDATE	ADDRESS	DNUMBER
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p.k.

DEPARTMENT f.k.

DNAME	<u>DNUMBER</u>	DMGRSSN
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p.k.

DEPT\_LOCATIONS f.k.

<u>DNUMBER</u>	<u>DLOCATION</u>
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p.k.

PROJECT f.k.

PNAME	<u>PNUMBER</u>	PLOCATION	DNUM
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p.k.

WORKS\_ON f.k.

<u>SSN</u>	<u>PNUMBER</u>	HOURS
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p.k.

**Figure 14.2** Example relations for the schema of Figure 14.1.

**EMPLOYEE**

ENAME	<u>SSN</u>	BDATE	ADDRESS	DNUMBER
Smith,John B.	123456789	1965-01-09	731 Fondren,Houston,TX	5
Wong,Franklin T.	333445555	1955-12-08	638 Voss,Houston,TX	5
Zelaya,Alicia J.	999887777	1968-07-19	3321 Castle,Spring,TX	4
Wallace,Jennifer S.	987654321	1941-06-20	291 Berry,Bellaire,TX	4
Narayan,Remesh K.	666884444	1962-09-15	975 Fire Oak,Humble,TX	5
English,Joyce A.	453453453	1972-07-31	5631 Rice,Houston,TX	5
Jabbar,Ahmad V.	987987987	1969-03-29	980 Dallas,Houston,TX	4
Borg,James E.	888665555	1937-11-10	450 Stone,Houston,TX	1

**DEPARTMENT**

DNAME	<u>DNUMBER</u>	DMGRSSN
Research	5	333445555
Administration	4	987654321
Headquarters	1	888665555

**DEPT\_LOCATIONS**

<u>DNUMBER</u>	<u>DLOCATION</u>
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

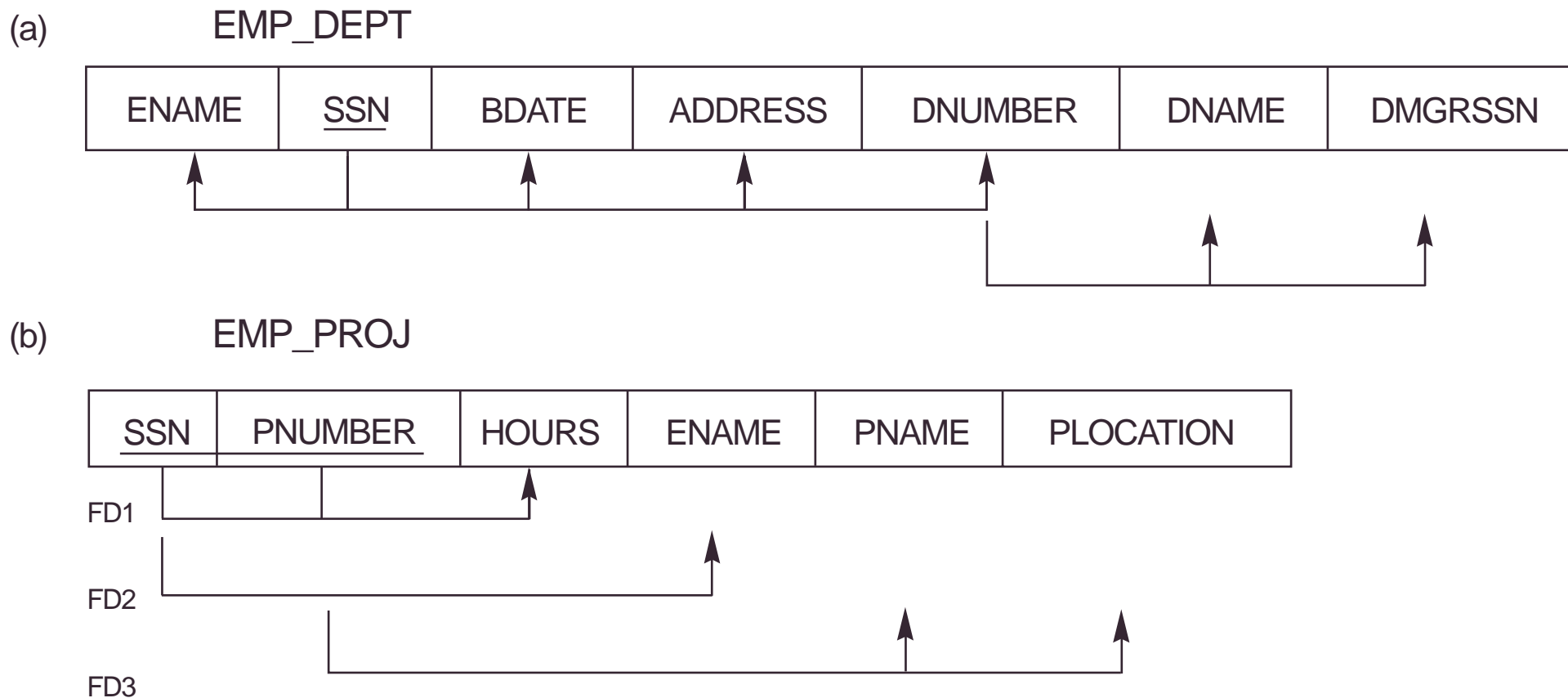
**WORKS\_ON**

<u>SSN</u>	<u>PNUMBER</u>	HOURS
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	null

**PROJECT**

PNAME	<u>PNUMBER</u>	PLOCATION	DNUM
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

**Figure 14.3** Two relation schemas and their functional dependencies. Both suffer from update anomalies. (a) The EMP\_DEPT relation schema. (b) The EMP\_PROJ relation schema.



**Figure 14.4** Example relations for the schemas in Figure 14.3 that result from applying NATURAL JOIN to the relations in Figure 14.2. These may be stored as base relations for performance reasons.

**EMP\_DEPT**

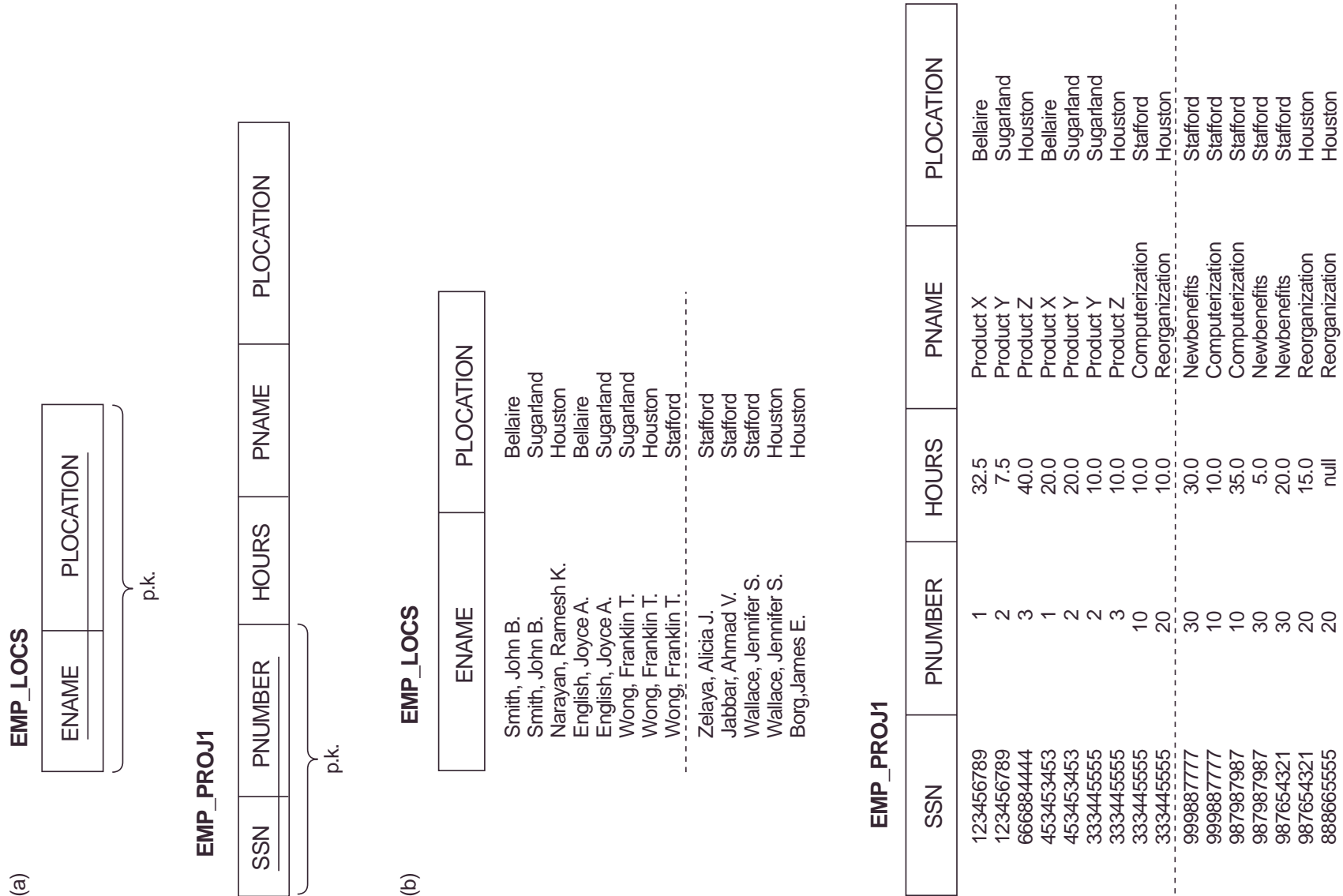
ENAME	<u>SSN</u>	BDATE	ADDRESS	DNUMBER	DNAME	DMGRSSN
Smith,John B.	123456789	1965-01-09	731 Fondren,Houston,TX	5	Research	333445555
Wong,Franklin T.	333445555	1955-12-08	638 Voss,Houston,TX	5	Research	333445555
Zelaya, Alicia J.	999887777	1968-07-19	3321 Castle,Spring,TX	4	Administration	987654321
Wallace,Jennifer S.	987654321	1941-06-20	291 Berry,Bellaire,TX	4	Administration	987654321
Narayan,Ramesh K.	666884444	1962-09-15	975 FireOak,Humble,TX	5	Research	333445555
English,Joyce A.	453453453	1972-07-31	5631 Rice,Houston,TX	5	Research	333445555
Jabbar,Ahmad V.	987987987	1969-03-29	980 Dallas,Houston,TX	4	Administration	987654321
Borg,James E.	888665555	1937-11-10	450 Stone,Houston,TX	1	Headquarters	888665555

**EMP\_PROJ**

<u>SSN</u>	<u>PNUMBER</u>	HOURS	ENAME	PNAME	PLOCATION
123456789	1	32.5	Smith,John B.	ProductX	Bellaire
123456789	2	7.5	Smith,John B.	ProductY	Sugarland
666884444	3	40.0	Narayan,Ramesh K.	ProductZ	Houston
453453453	1	20.0	English,Joyce A.	ProductX	Bellaire
453453453	2	20.0	English,Joyce A.	ProductY	Sugarland
333445555	2	10.0	Wong,Franklin T.	ProductY	Sugarland
333445555	3	10.0	Wong,Franklin T.	ProductZ	Houston
333445555	10	10.0	Wong,Franklin T.	Computerization	Stafford
333445555	20	10.0	Wong,Franklin T.	Reorganization	Houston
999887777	30	30.0	Zelaya,Alicia J.	Newbenefits	Stafford
999887777	10	10.0	Zelaya,Alicia J.	Computerization	Stafford
987987987	10	35.0	Jabbar,Ahmad V.	Computerization	Stafford
987987987	30	5.0	Jabbar,Ahmad V.	Newbenefits	Stafford
987654321	30	20.0	Wallace,Jennifer S.	Newbenefits	Stafford
987654321	20	15.0	Wallace,Jennifer S.	Reorganization	Houston
888665555	20	null	Borg,James E.	Reorganization	Houston

**Figure 14.5** Alternative (bad) representation of the EMP\_PROJ relation.

(a) Representing EMP\_PROJ of Figure 14.3(b) by two relation schemas: EMP\_LOCS and EMP\_PROJ1. (b) Result of projecting the populated relation EMP\_PROJ of Figure 14.4 on the attributes of EMP\_LOCS and EMP\_PROJ1.



**Figure 14.6** Result of applying the NATURAL JOIN operation to the tuples above dotted lines in EMP\_PROJ1 and EMP\_LOCS, with generated spurious tuples marked by an asterisk.

SSN	PNUMBER	HOURS	PNAME	PLOCATION	
123456789	1	32.5	ProductX	Bellaire	Smith,John B.
* 123456789	1	32.5	ProductX	Bellaire	English,Joyce A.
123456789	2	7.5	ProductY	Sugarland	Smith,John B.
* 123456789	2	7.5	ProductY	Sugarland	English,Joyce A.
* 123456789	2	7.5	ProductY	Sugarland	Wong,Franklin T.
666884444	3	40.0	ProductZ	Houston	Narayan,Ramesh K.
* 666884444	3	40.0	ProductZ	Houston	Wong,Franklin T.
* 453453453	1	20.0	ProductX	Bellaire	Smith,John B.
453453453	1	20.0	ProductX	Bellaire	English,Joyce A.
* 453453453	2	20.0	ProductY	Sugarland	Smith,John B.
453453453	2	20.0	ProductY	Sugarland	English,Joyce A.
* 453453453	2	20.0	ProductY	Sugarland	Wong,Franklin T.
* 333445555	2	10.0	ProductY	Sugarland	Smith,John B.
* 333445555	2	10.0	ProductY	Sugarland	English,Joyce A.
333445555	2	10.0	ProductY	Sugarland	Wong,Franklin T.
* 333445555	3	10.0	ProductZ	Houston	Narayan,Ramesh K.
333445555	3	10.0	ProductZ	Houston	Wong,Franklin T.
333445555	10	10.0	Computerization	Stafford	Wong,Franklin T.
* 333445555	20	10.0	Reorganization	Houston	Narayan,Ramesh K.
333445555	20	10.0	Reorganization	Houston	Wong,Franklin T.

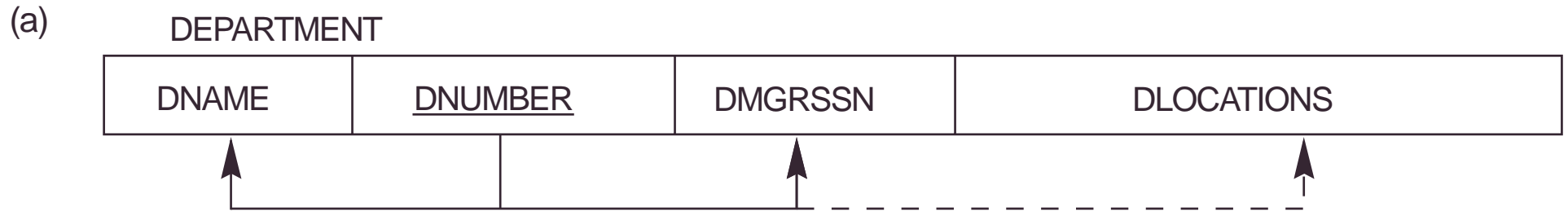
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**Figure 14.7** The teach relation state with an apparent functional dependency text  $\rightarrow$  COURSE. However, COURSE  $\rightarrow$  TEXT is ruled out.

### TEACH

TEACHER	COURSE	TEXT
Smith	Data Structures	Bartram
Smith	Data Management	Al-Nour
Hall	Compilers	Hoffman
Brown	Data Structures	Augenthaler

**Figure 14.8** Normalization into 1NF. (a) Relation schema that is not in 1NF. (b) Example relation instance. (c) 1NF relation with redundancy.



(b)

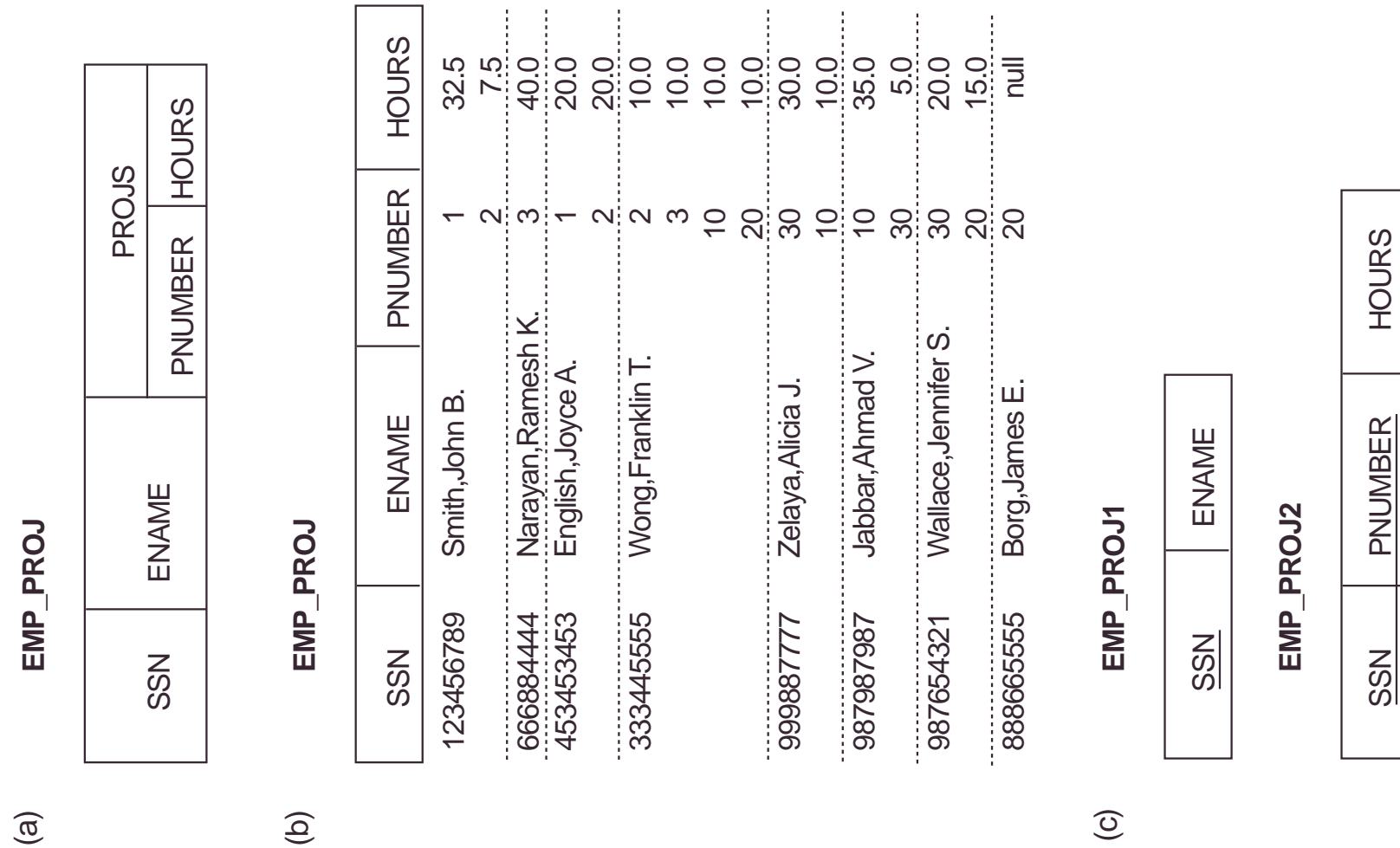
DEPARTMENT			
DNAME	<u>DNUMBER</u>	DMGRSSN	DLOCATIONS
Research	5	333445555	{Bellaire, Sugarland, Houston}
Administration	4	987654321	{Stafford}
Headquarters	1	888665555	{Houston}

(c)

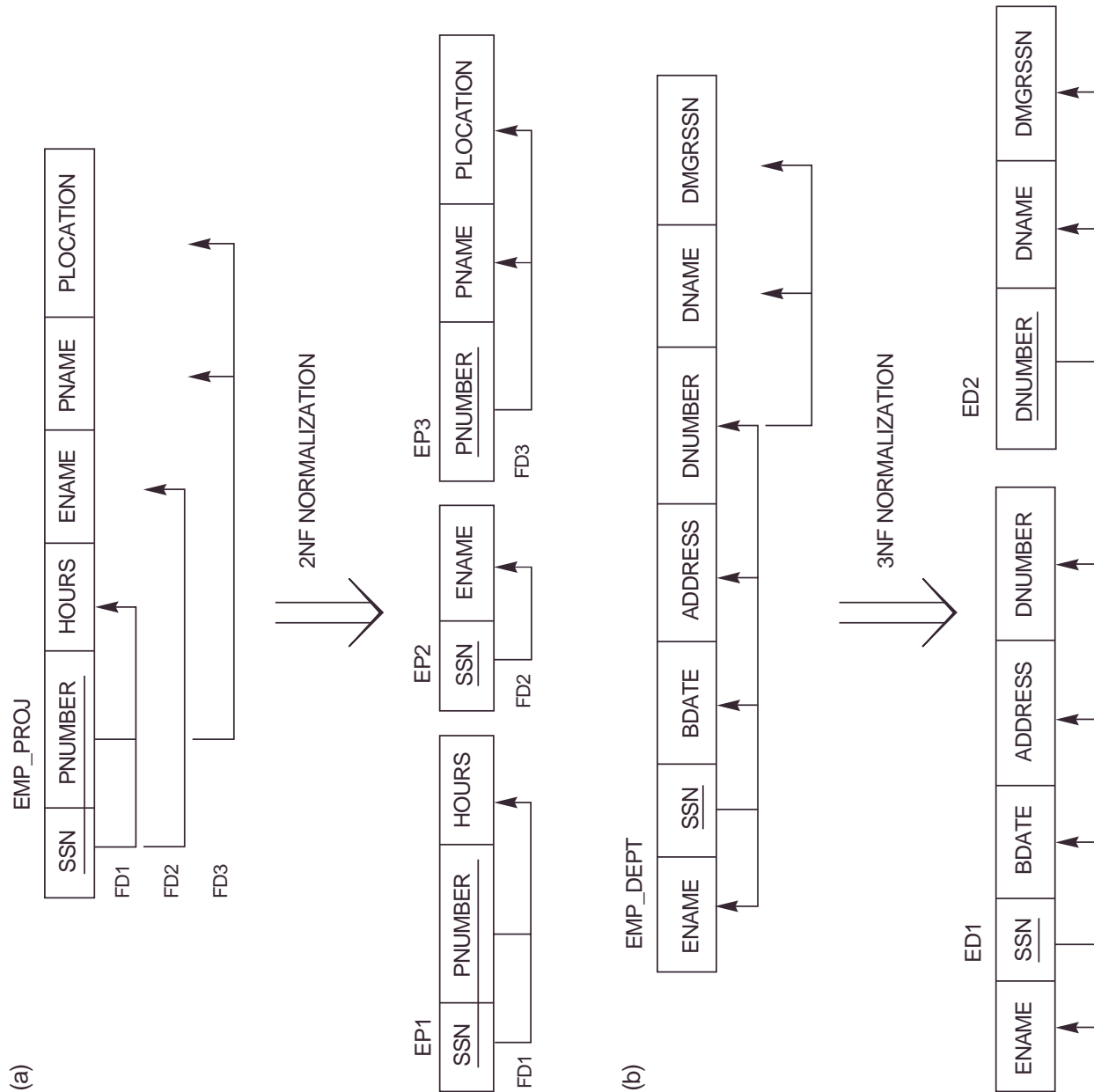
DEPARTMENT			
DNAME	<u>DNUMBER</u>	DMGRSSN	<u>DLOCATION</u>
Research	5	333445555	Bellaire
Research	5	333445555	Sugarland
Research	5	333445555	Houston
Administration	4	987654321	Stafford
Headquarters	1	888665555	Houston



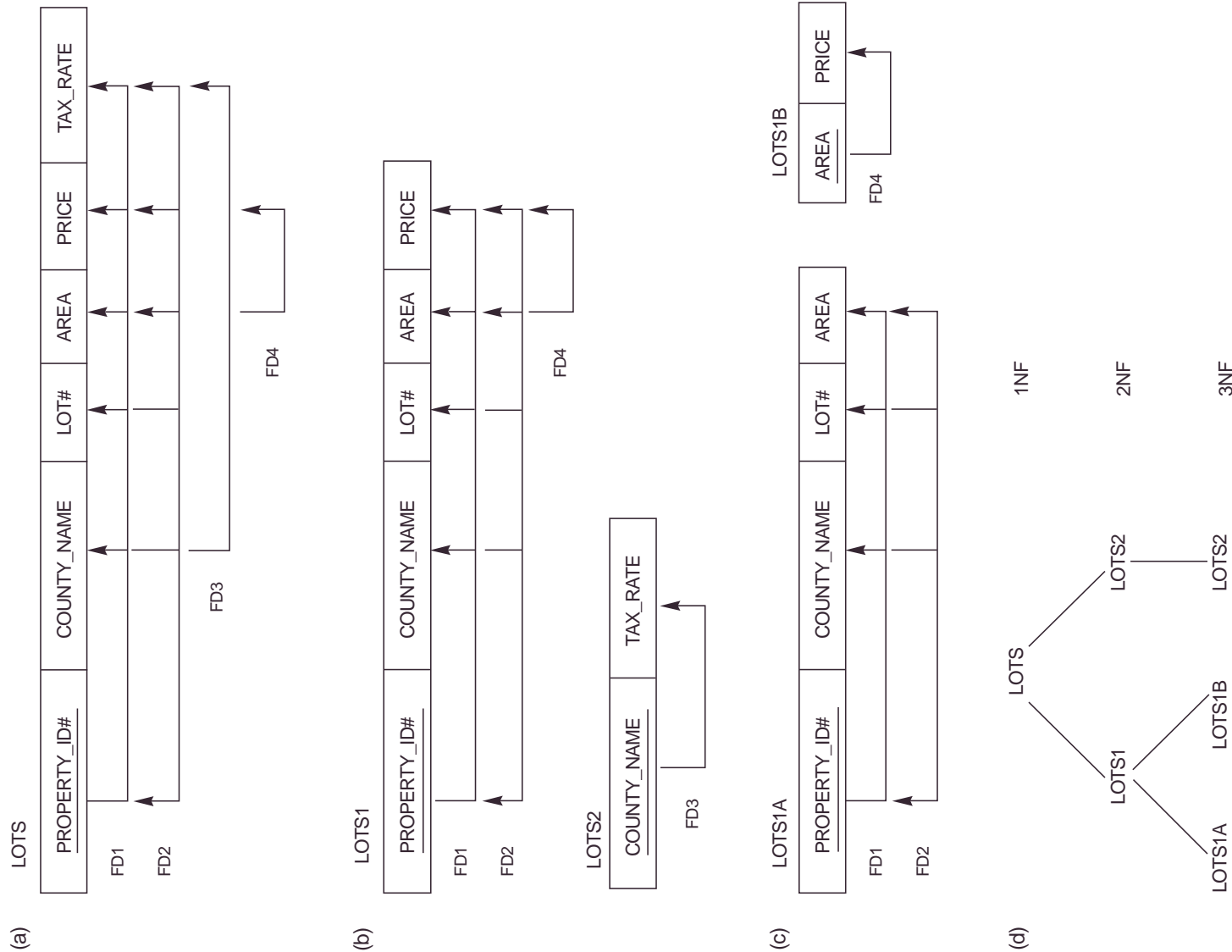
**Figure 14.9** Normalizing nested relations into 1NF. (a) Schema of the EMP\_PROJ relation with a “nested relation” PROJS. (b) Example extension of the EMP\_PROJ relation showing nested relations within each tuple. (c) Decomposing EMP\_PROJ into 1NF relations EMP\_PROJ1 and EMP\_PROJ2 by propagating the primary key.



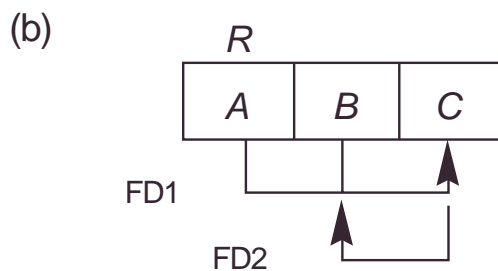
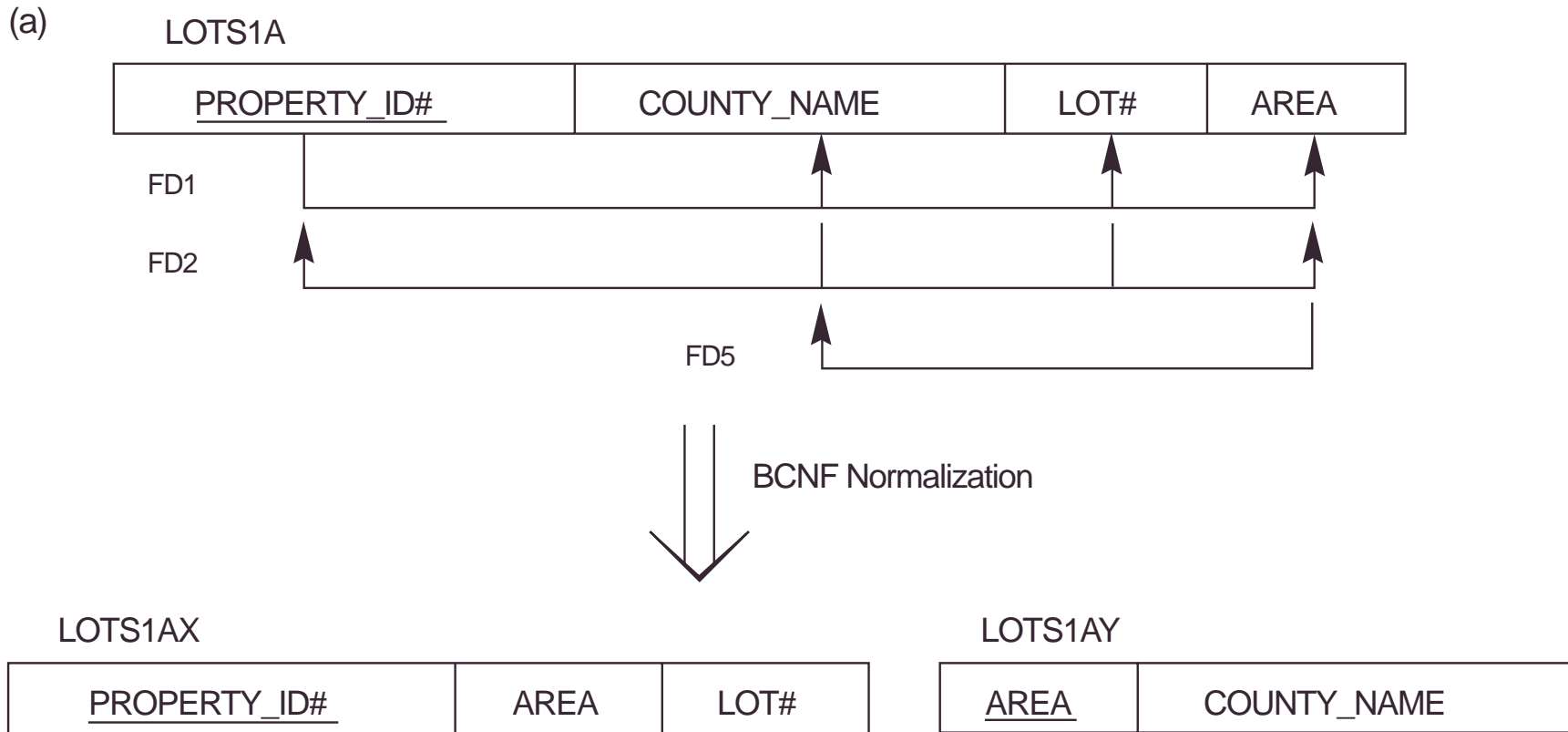
**Figure 14.10** The normalization process. (a) Normalizing EMP\_PROJ into 2NF relations. (b) Normalizing EMP\_DEPT into 3NF relations.



**Figure 14.11** Normalization to 2NF and 3NF. (a) The lots relation schema and its functional dependencies fd1 through FD4. (b) Decomposing lots into the 2NF relations LOTS1 and LOTS2. (c) Decomposing LOTS1 into the 3NF relations LOTS1A and LOTS1B. (d) Summary of normalization of lots.



**Figure 14.12** Boyce-Codd normal form. (a) BCNF normalization with the dependency of FD2 being “lost” in the decomposition. (b) A relation  $R$  in 3NF but not in BCNF.



**Figure 14.13** A relation TEACH that is in 3NF but not in BCNF.

TEACH

STUDENT	COURSE	INSTRUCTOR
Narayan	Database	Mark
Smith	Database	Navathe
Smith	Operating Systems	Ammar
Smith	Theory	Schulman
Wallace	Database	Mark
Wallace	Operating Systems	Ahamad
Wong	Database	Omiecinski
Zelaya	Database	Navathe