**FIGURE 10.1** A simplified COMPANY relational database schema.

EMPLOYEE

ENAME	SSN	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, Ramesh 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	DNUMBER	DMGRSSN
Research	5	333445555
Administration	4	987654321
Headquarters	1	888665555

DEPT_LOCATIONS

DNUMBER	DLOCATION
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

SSN	PNUMBER	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	PNUMBER	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 10.2 Example database state for the relational database schema of Figure 10.1.

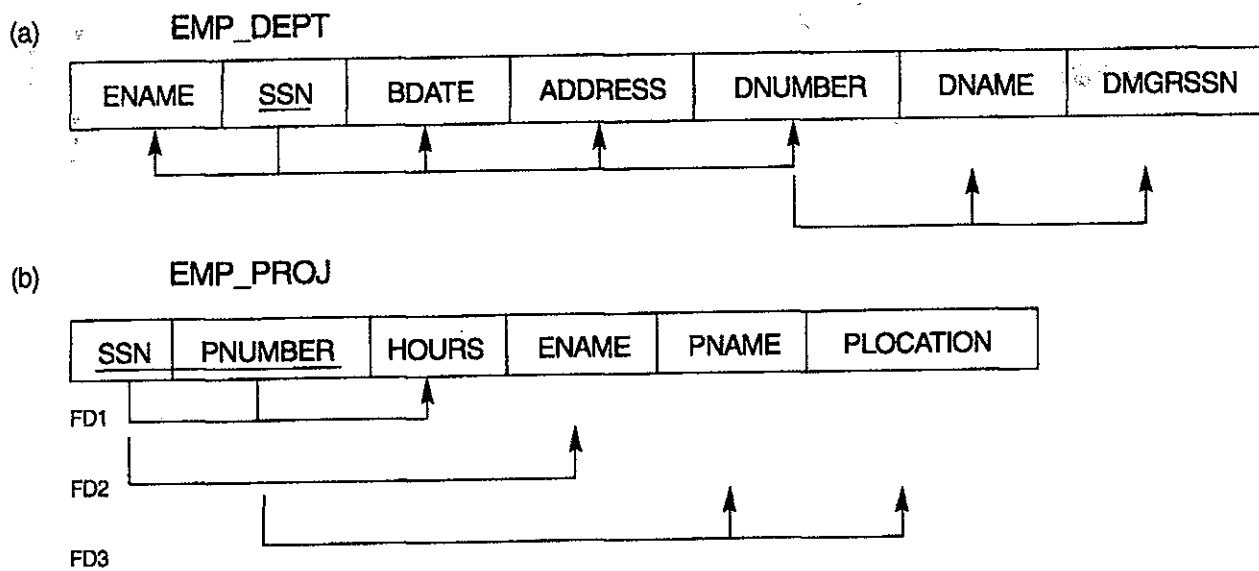


FIGURE 10.3 Two relation schemas suffering from update anomalies.

EMP_DEPT					redundancy	
ENAME	SSN	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			redundancy		redundancy	
SSN	PNUMBER	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 10.4 Example states for EMP_DEPT and EMP_PROJ resulting from applying NATURAL JOIN to the relations in Figure 10.2. These may be stored as base relations for performance reasons.

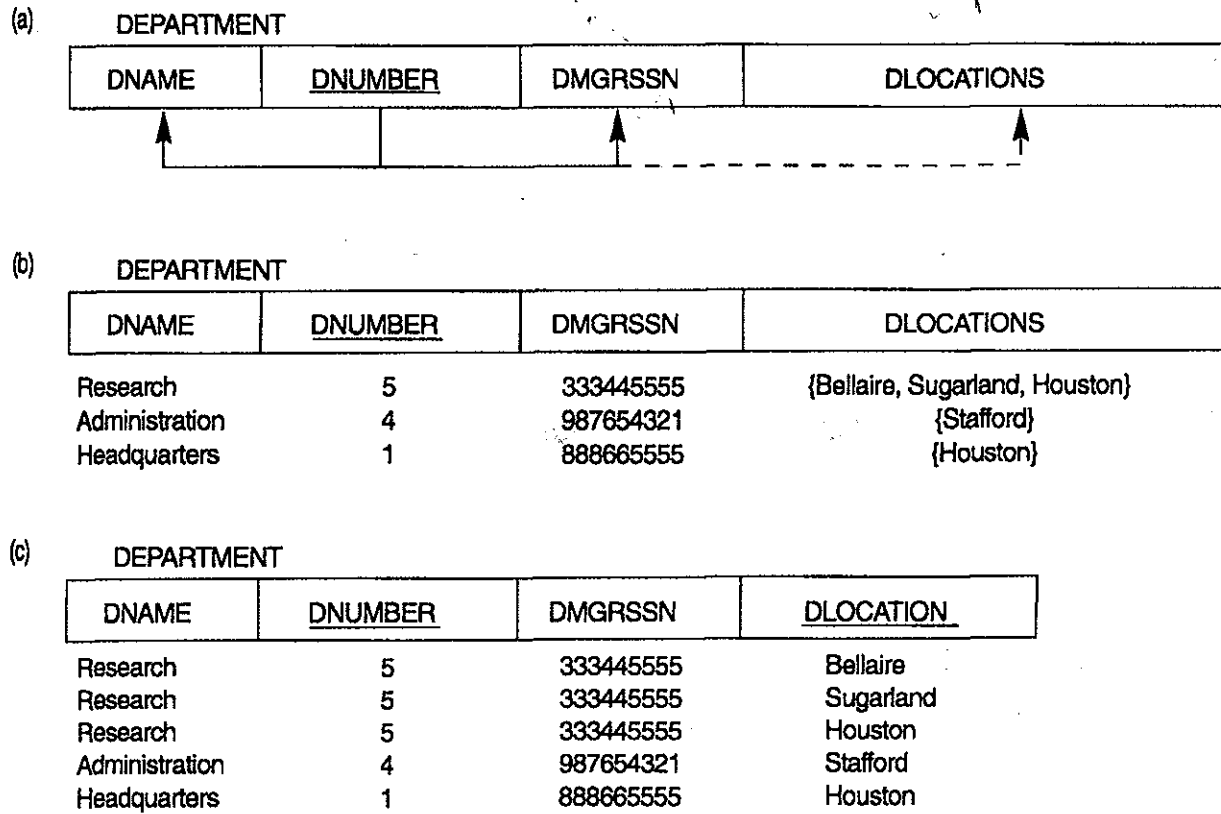


FIGURE 10.8 Normalization into 1NF. (a) A relation schema that is not in 1NF. (b) Example state of relation DEPARTMENT. (c) 1NF version of same relation with redundancy.

(a)

EMP_PROJ

SSN	ENAME	PROJS	
		PNUMBER	HOURS

(b)

EMP_PROJ

SSN	ENAME	PNUMBER	HOURS
123456789	Smith, John B.	1	32.5
		2	7.5
666884444	Narayan, Ramesh K.	3	40.0
453453453	English, Joyce A.	1	20.0
		2	20.0
333445555	Wong, Franklin T.	2	10.0
		3	10.0
		10	10.0
		20	10.0
999887777	Zelaya, Alicia J.	30	30.0
		10	10.0
987987987	Jabbar, Ahmad V.	10	35.0
		30	5.0
987654321	Wallace, Jennifer S.	30	20.0
		20	15.0
888665555	Borg, James E.	20	null

(c)

EMP_PROJ1

<u>SSN</u>	ENAME
------------	-------

EMP_PROJ2

<u>SSN</u>	<u>PNUMBER</u>	HOURS
------------	----------------	-------

FIGURE 10.9 Normalizing nested relations into 1NF. (a) Schema of the EMP_PROJ relation with a "nested relation" attribute PROJS. (b) Example extension of the EMP_PROJ relation showing nested relations within each tuple. (c) Decomposition of EMP_PROJ into relations EMP_PROJ1 and EMP_PROJ2 by propagating the primary key.

Third normal form (3NF) is based on the concept of *transitive dependency*. A functional dependency $X \rightarrow Y$ in a relation schema R is a **transitive dependency** if there is a set of

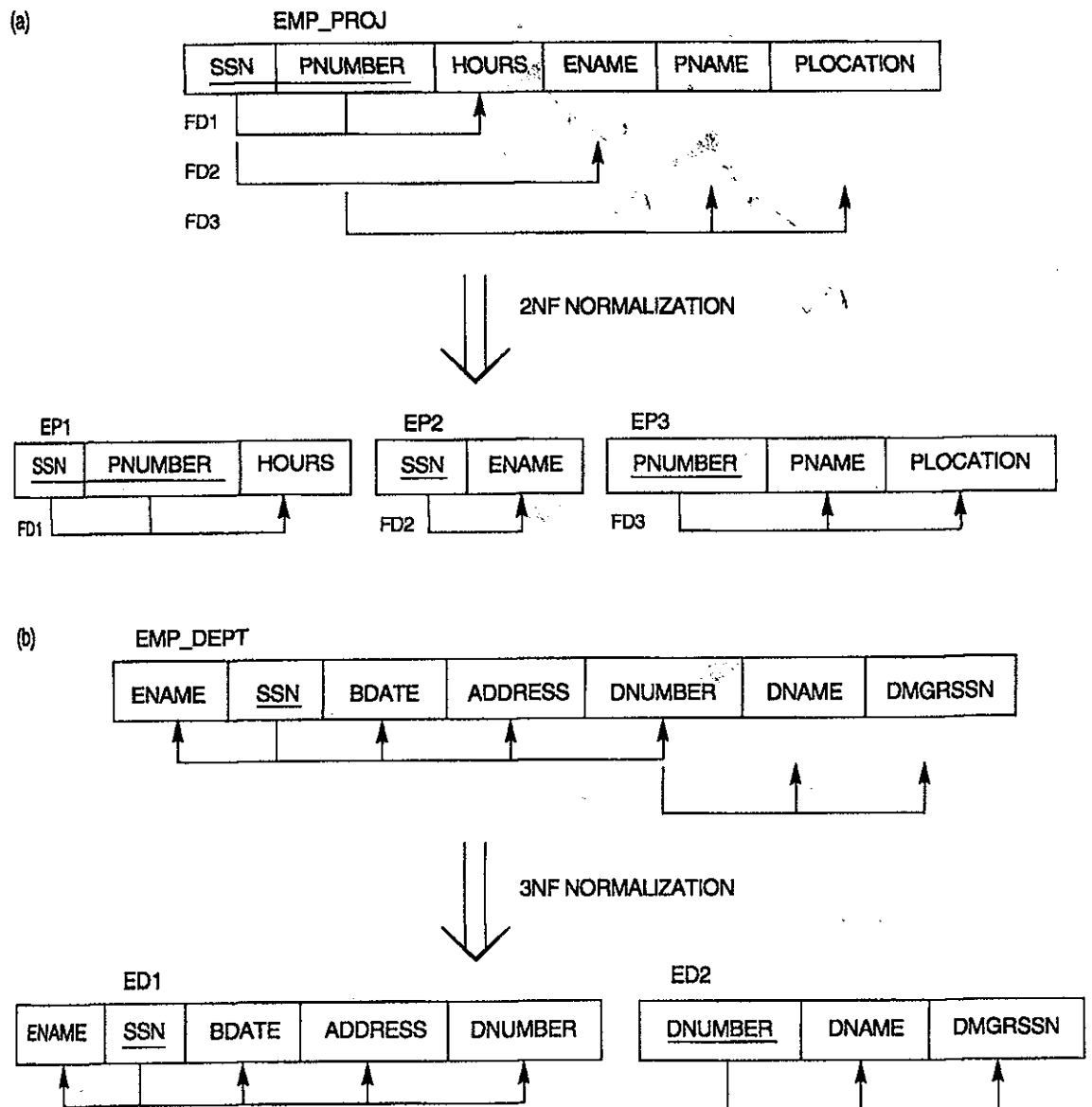


FIGURE 10.10 Normalizing into 2NF and 3NF. (a) Normalizing EMP_PROJ into 2NF relations. (b) Normalizing EMP_DEPT into 3NF relations.

Third normal form (3NF) is based on the concept of *transitive dependency*. A functional dependency $X \rightarrow Y$ in a relation schema R is a **transitive dependency** if there is a set of

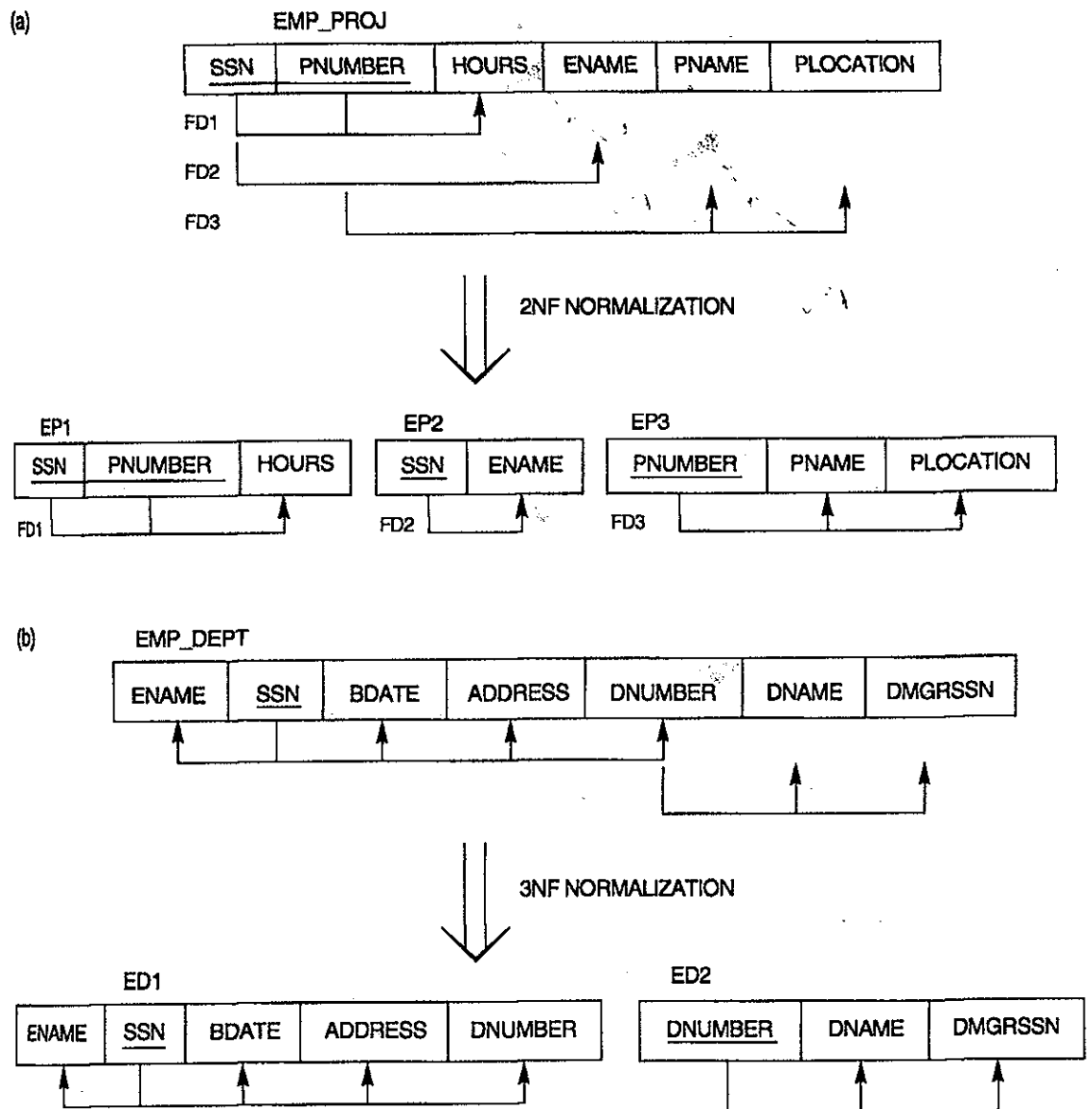


FIGURE 10.10 Normalizing into 2NF and 3NF. (a) Normalizing EMP_PROJ into 2NF relations. (b) Normalizing EMP_DEPT into 3NF relations.