Chapter 9:
Database Systems

Computer Science: An Overview
Twelfth Edition

by

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Chapter 9: Database Systems

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- 9.2 The Relational Model
- 9.3 Object-Oriented Databases
- 9.4 Maintaining Database Integrity
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Database

A collection of data that is multidimensional in the sense that internal links between its entries make the information accessible from a variety of perspectives

Figure 9.1 **A file versus a database organization**

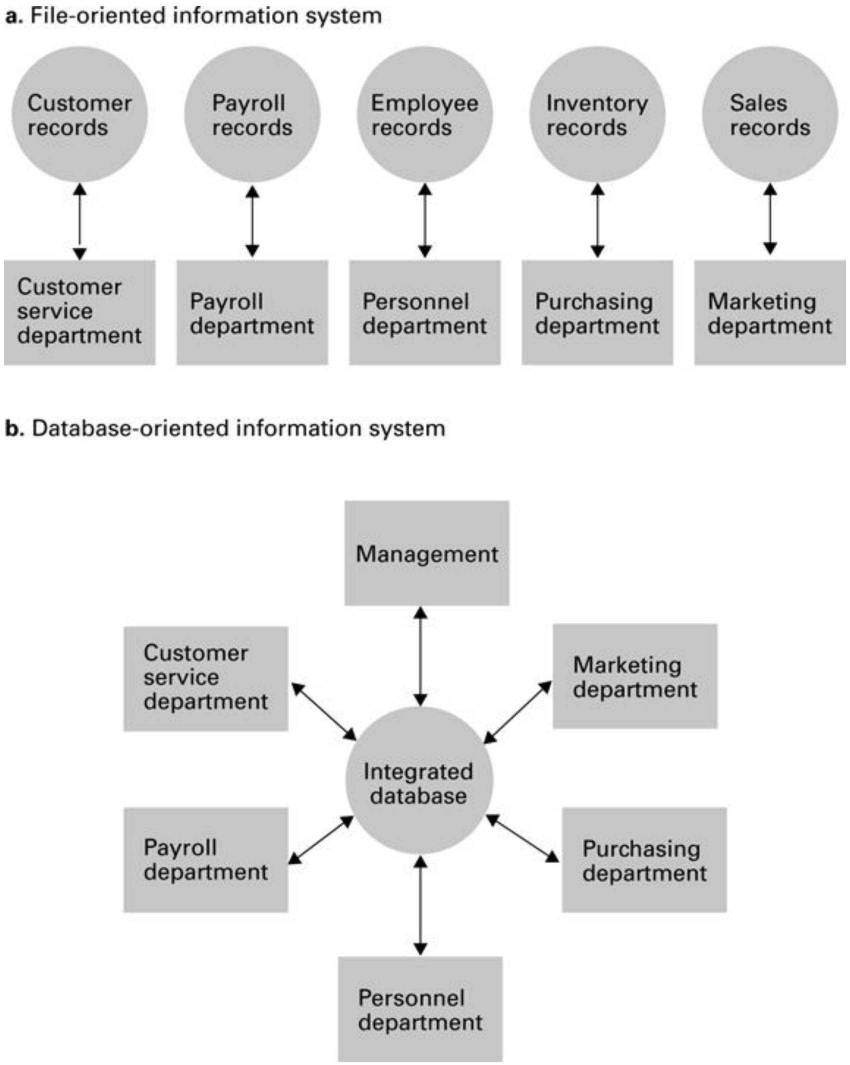
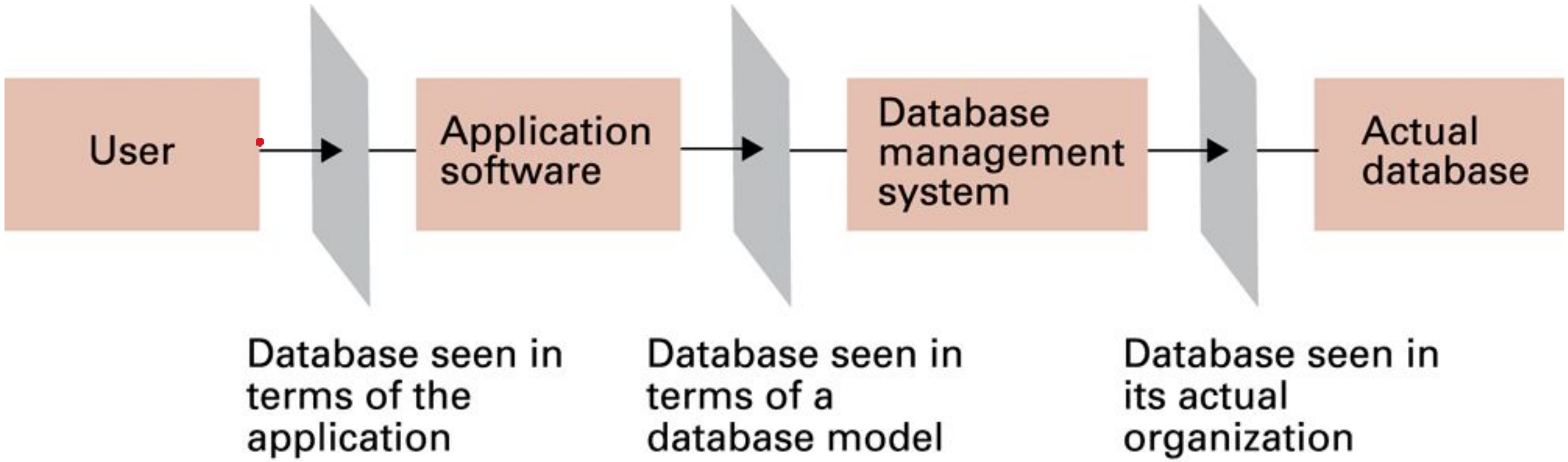


Figure 9.2 **The conceptual layers of a database implementation**


User
Application software
Database management system
Actual database
Database seen in terms of the application
Database seen in terms of a database model
Database seen in its actual organization

Schemas

- **Schema:** A description of the structure of an entire database, used by database software to maintain the database
- **Subschema:** A description of only that portion of the database pertinent to a particular user's needs, used to prevent sensitive data from being accessed by unauthorized personnel

Database Management Systems

- **Database Management System** (DBMS): A software layer that manipulates a database in response to requests from applications
- **Distributed Database:** A database stored on multiple machines
  - DBMS will mask this organizational detail from its users
- **Data independence:** The ability to change the organization of a database without changing the application software that uses it

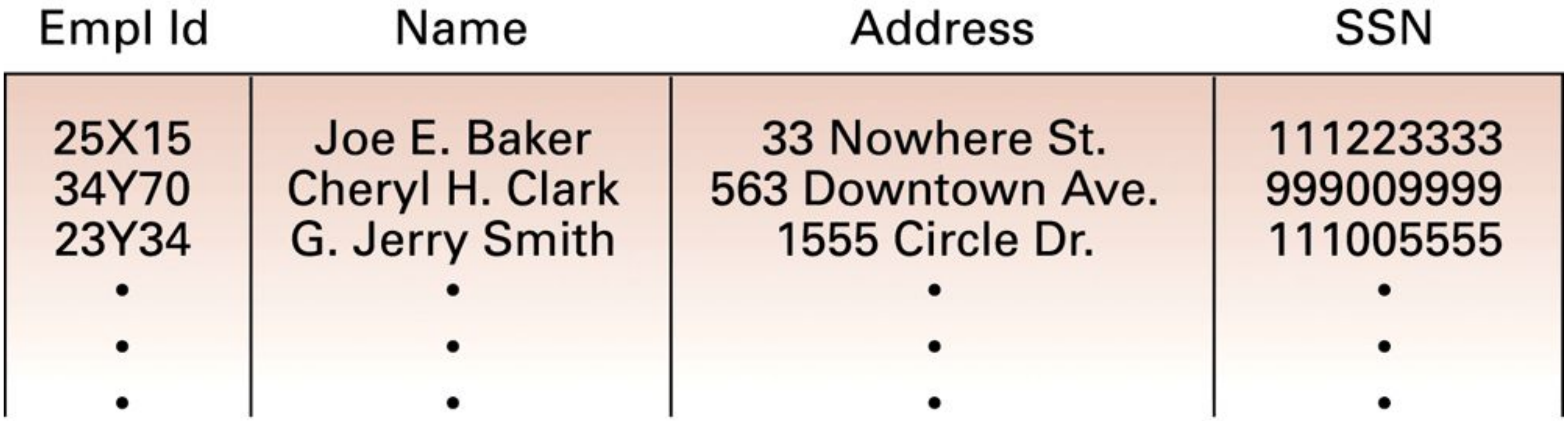
Database Models

- **Database model:** A conceptual view of a database
  - Relational database model
  - Object-oriented database model

Relational Database Model

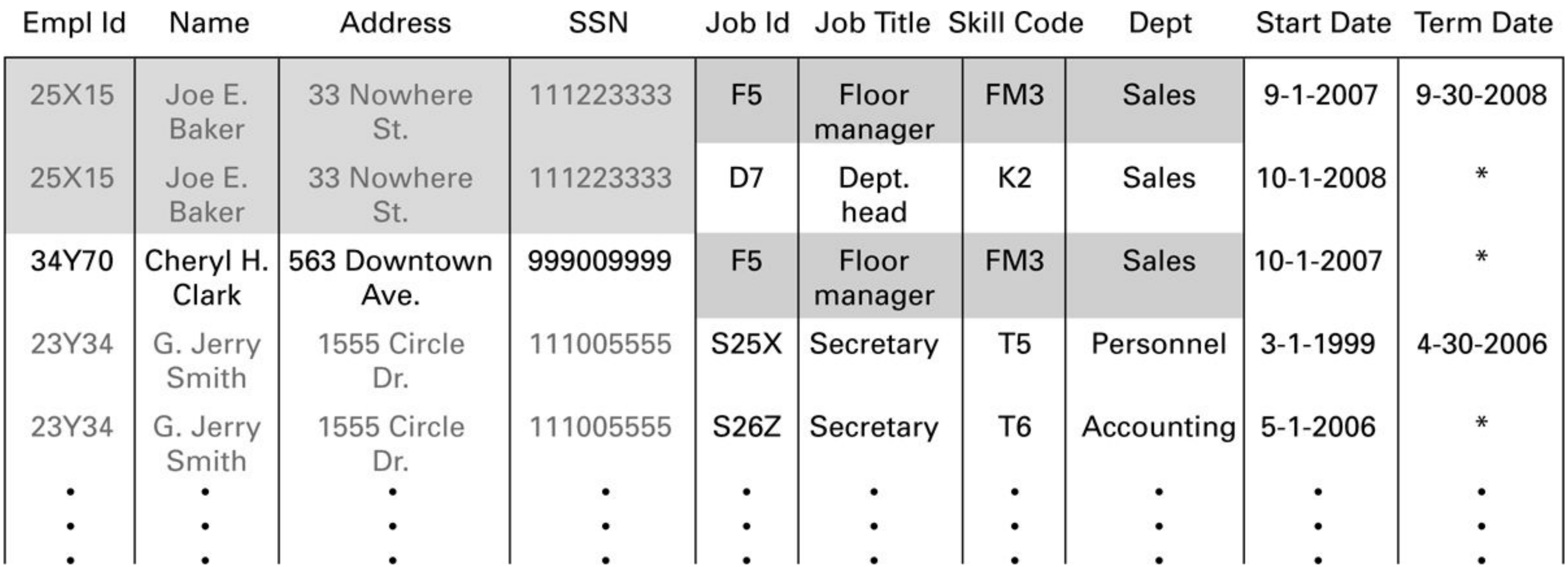
- **Relation:** A rectangular table
  - **Attribute:** A column in the table
  - **Tuple:** A row in the table

Figure 9.3 **A relation containing employee information**



Empl Id	Name	Address	SSN
25X15	Joe E. Baker	33 Nowhere St.	111223333
34Y70	Cheryl H. Clark	563 Downtown Ave.	999009999
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555
•	•	•	•
•	•	•	•
•	•	•	•

Figure 9.4 **A relation containing redundancy**



Empl Id	Name	Address	SSN	Job Id	Job Title	Skill Code	Dept	Start Date	Term Date
25X15	Joe E. Baker	33 Nowhere St.	111223333	F5	Floor manager	FM3	Sales	9-1-2007	9-30-2008
25X15	Joe E. Baker	33 Nowhere St.	111223333	D7	Dept. head	K2	Sales	10-1-2008	*
34Y70	Cheryl H. Clark	563 Downtown Ave.	999009999	F5	Floor manager	FM3	Sales	10-1-2007	*
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555	S25X	Secretary	T5	Personnel	3-1-1999	4-30-2006
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555	S26Z	Secretary	T6	Accounting	5-1-2006	*
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

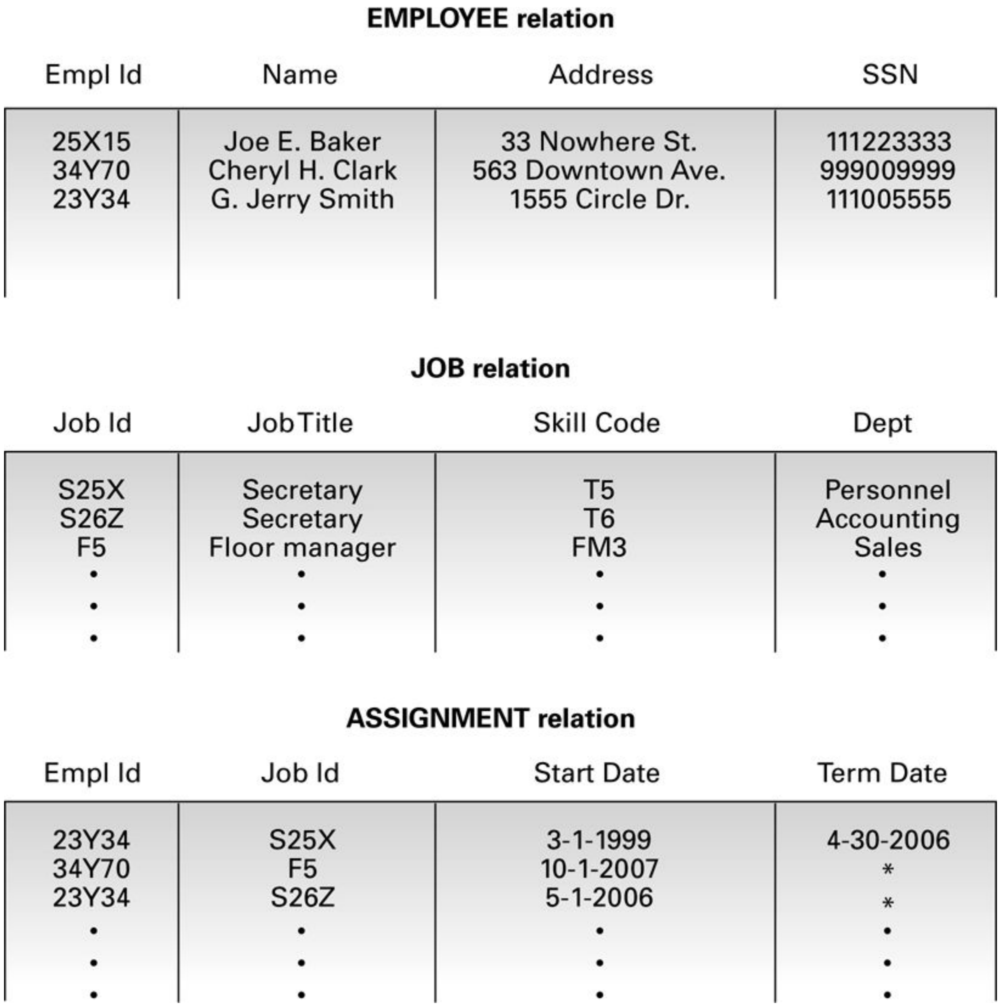
Relational Design

- Avoid multiple concepts within one relation
  - Can lead to redundant data
  - Deleting a tuple could also delete necessary but unrelated information

Improving a Relational Design

- **Decomposition:** Dividing the columns of a relation into two or more relations, duplicating those columns necessary to maintain relationships
  - **Lossless** or **nonloss** decomposition: A “correct” decomposition that does not lose any information

Figure 9.5 **An employee database consisting of three relations**



EMPLOYEE relation

Empl Id	Name	Address	SSN
25X15	Joe E. Baker	33 Nowhere St.	111223333
34Y70	Cheryl H. Clark	563 Downtown Ave.	999009999
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555

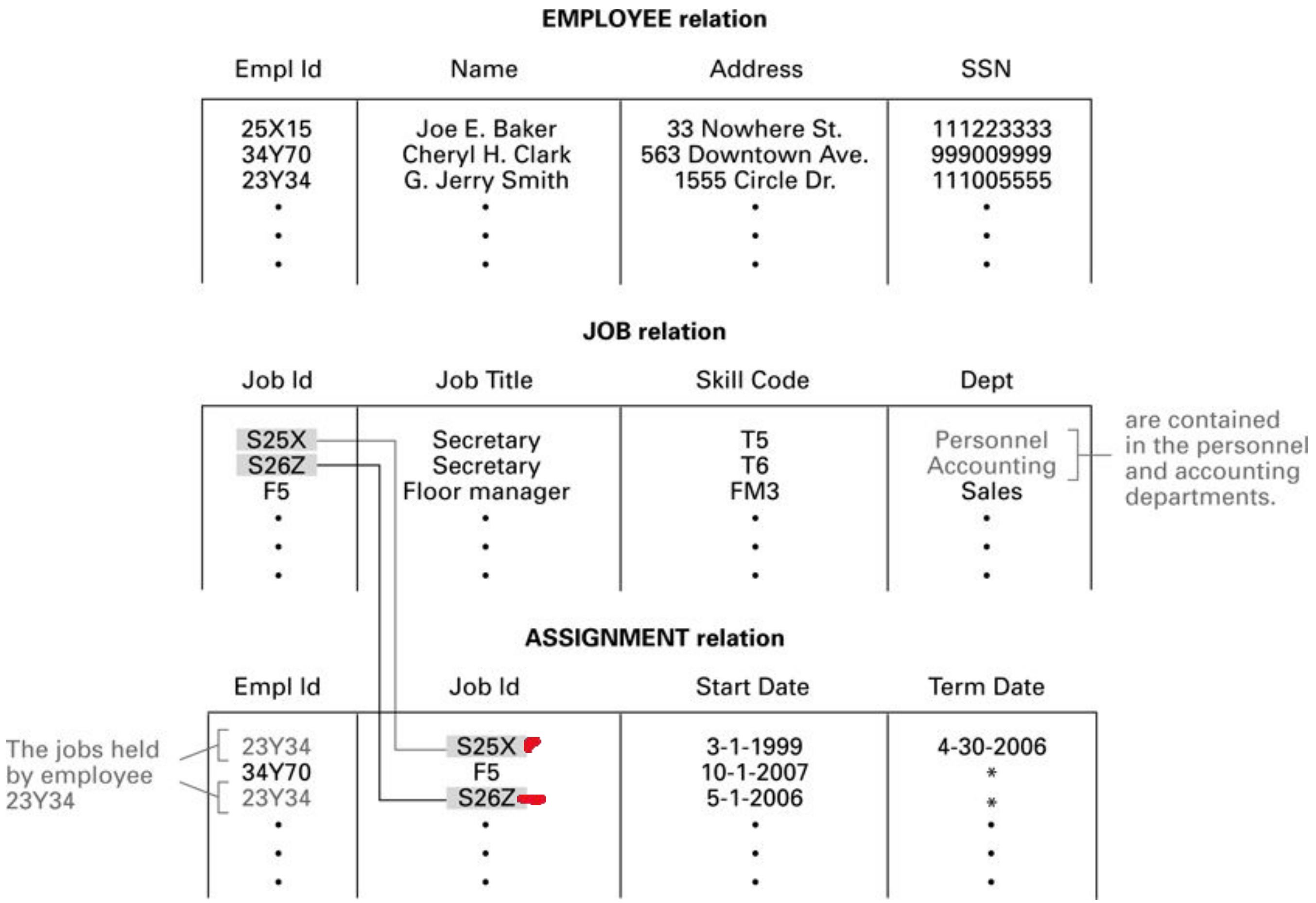
JOB relation

Job Id	JobTitle	Skill Code	Dept
S25X	Secretary	T5	Personnel
S26Z	Secretary	T6	Accounting
F5	Floor manager	FM3	Sales
•	•	•	•
•	•	•	•
•	•	•	•

ASSIGNMENT relation

Empl Id	Job Id	Start Date	Term Date
23Y34	S25X	3-1-1999	4-30-2006
34Y70	F5	10-1-2007	*
23Y34	S26Z	5-1-2006	*
•	•	•	•
•	•	•	•
•	•	•	•

Figure 9.6 Finding the departments in which employee 23Y34 has worked



EMPLOYEE relation

Empl Id	Name	Address	SSN
25X15	Joe E. Baker	33 Nowhere St.	111223333
34Y70	Cheryl H. Clark	563 Downtown Ave.	999009999
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555
•	•	•	•
•	•	•	•
•	•	•	•

JOB relation

Job Id	Job Title	Skill Code	Dept
S25X	Secretary	T5	Personnel
S26Z	Secretary	T6	Accounting
F5	Floor manager	FM3	Sales
•	•	•	•
•	•	•	•
•	•	•	•

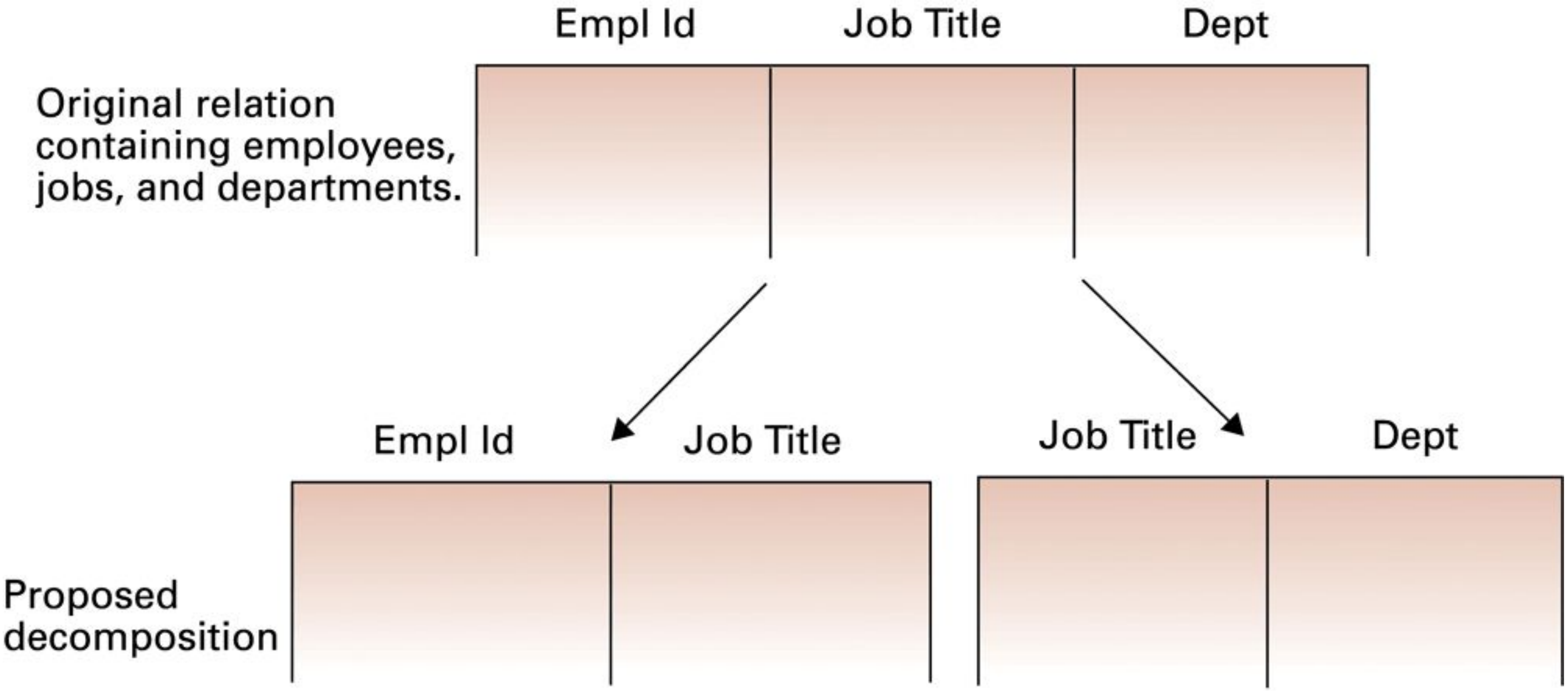
are contained in the personnel and accounting departments.

ASSIGNMENT relation

Empl Id	Job Id	Start Date	Term Date
23Y34	S25X	3-1-1999	4-30-2006
34Y70	F5	10-1-2007	*
23Y34	S26Z	5-1-2006	*
•	•	•	•
•	•	•	•
•	•	•	•

The jobs held by employee 23Y34

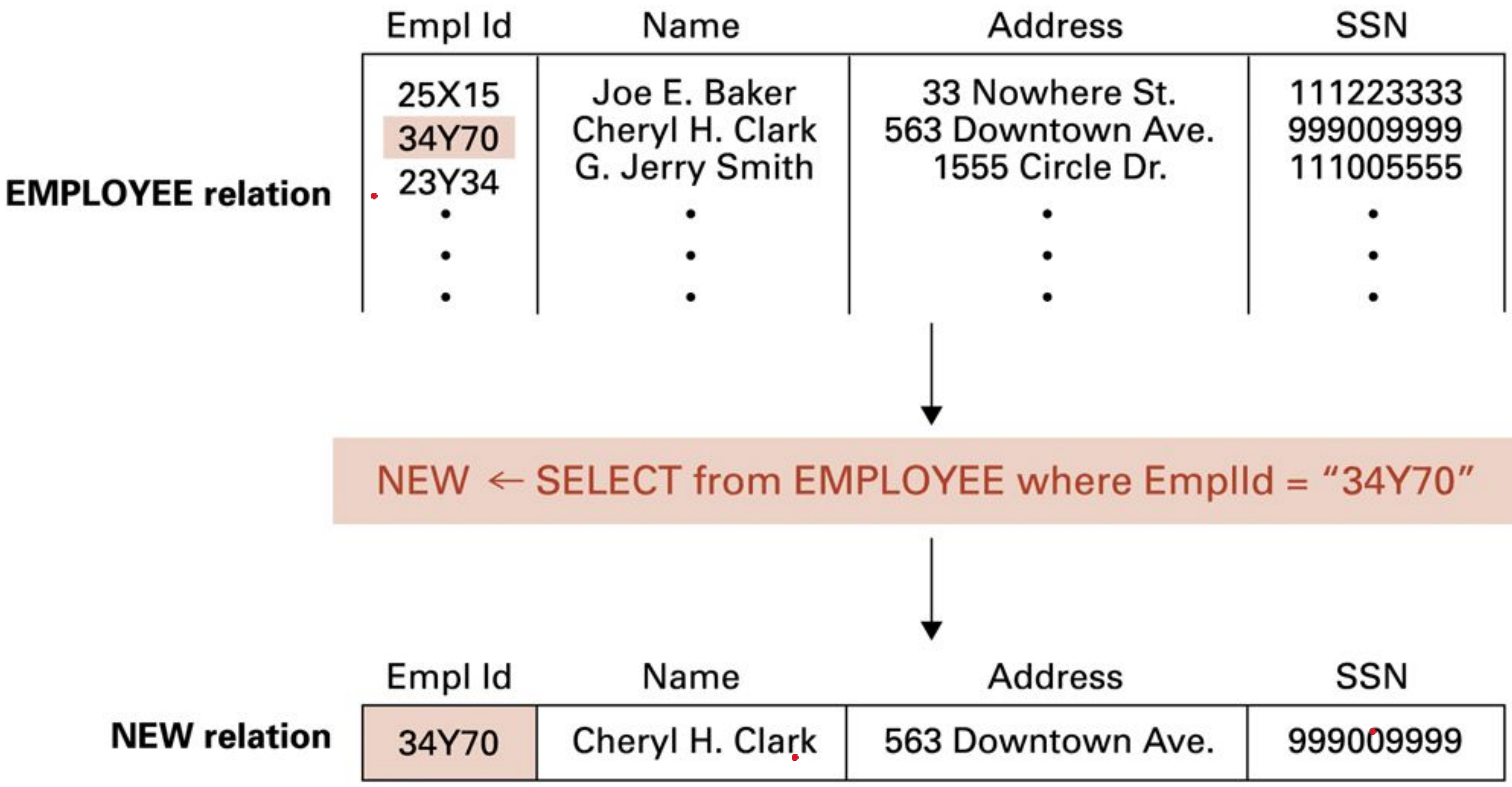
Figure 9.7 **A relation and a proposed decomposition**



Relational Operations

- **Select:** Choose rows
- **Project:** Choose columns
- **Join:** Assemble information from two or more relations

Figure 9.8 The SELECT operation



EMPLOYEE relation

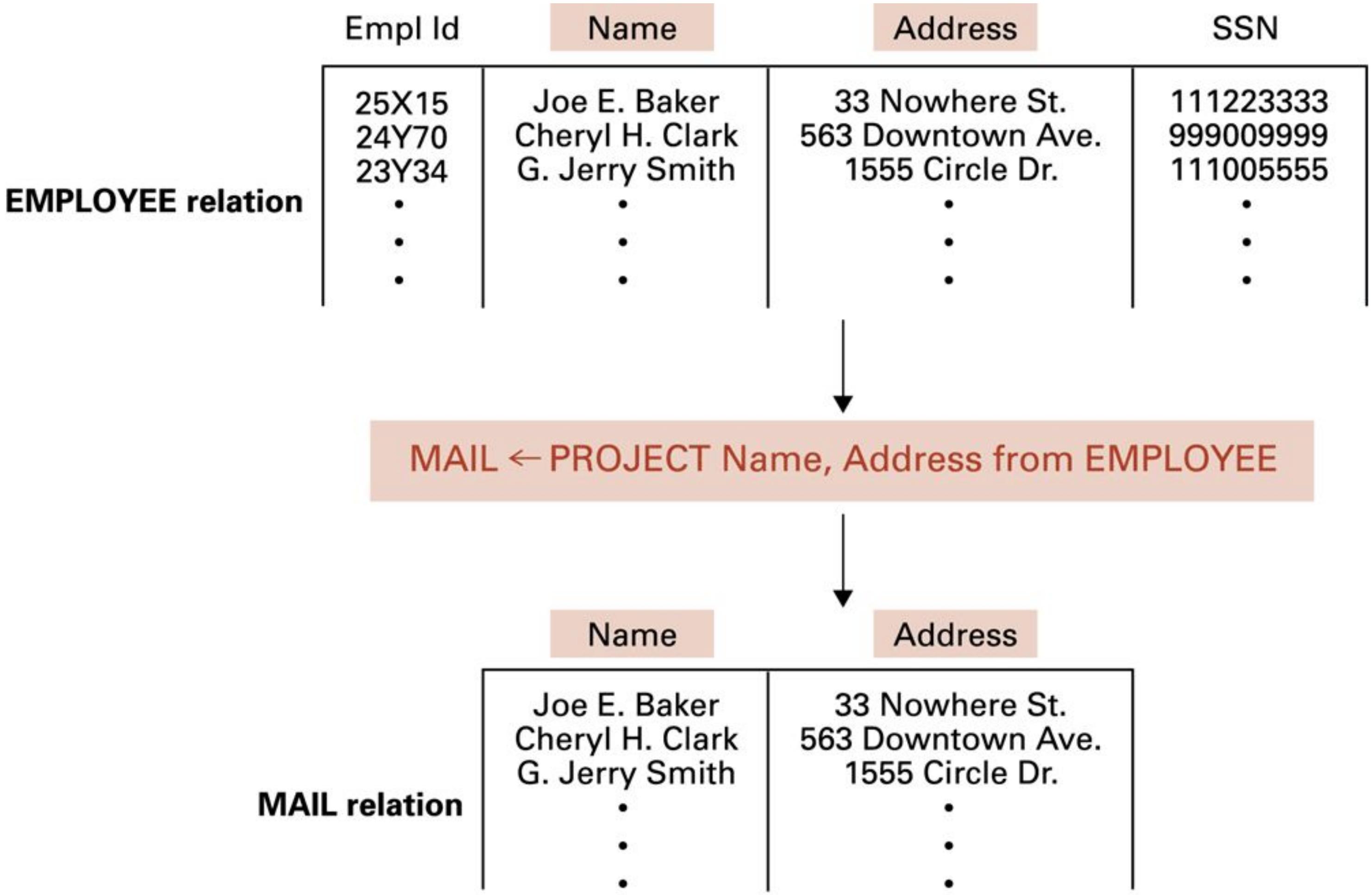
Empl Id	Name	Address	SSN
25X15	Joe E. Baker	33 Nowhere St.	111223333
34Y70	Cheryl H. Clark	563 Downtown Ave.	999009999
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555
•	•	•	•
•	•	•	•
•	•	•	•

NEW ← SELECT from EMPLOYEE where EmplId = "34Y70"

NEW relation

Empl Id	Name	Address	SSN
34Y70	Cheryl H. Clark	563 Downtown Ave.	999009999

Figure 9.9 **The PROJECT operation**



EMPLOYEE relation

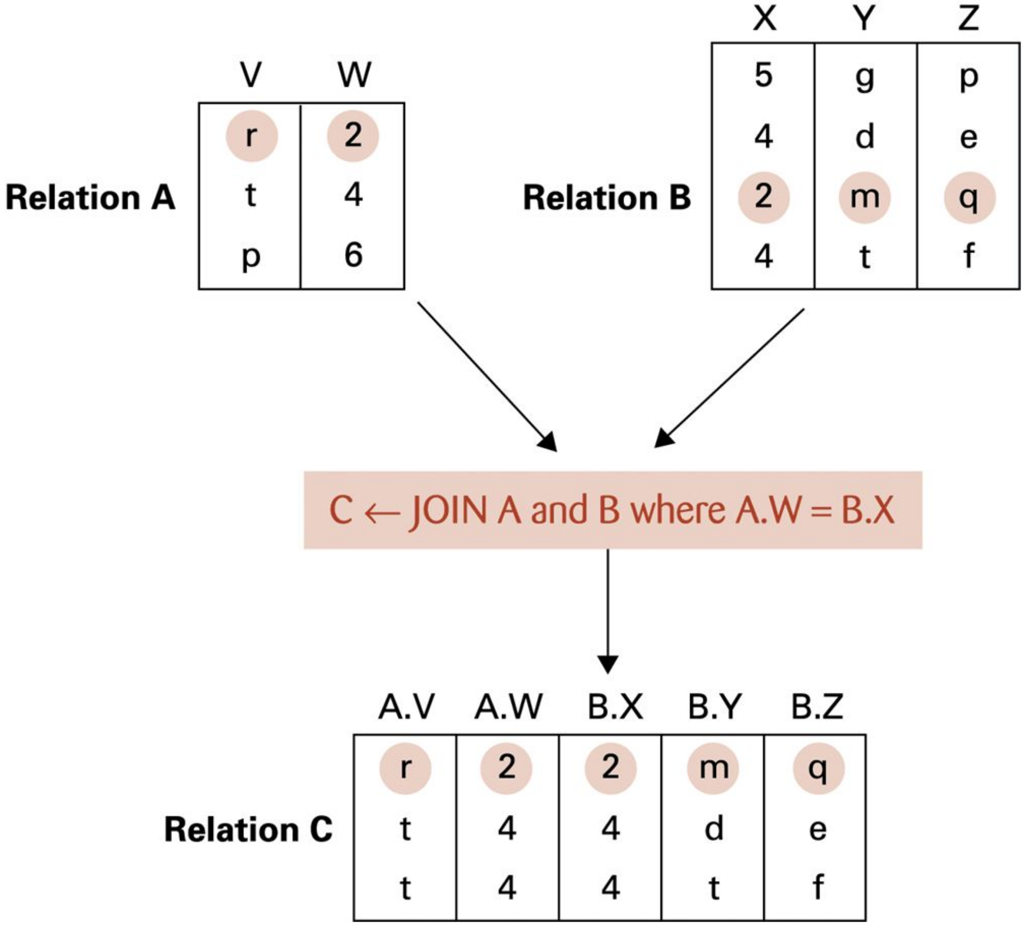
Empl Id	Name	Address	SSN
25X15	Joe E. Baker	33 Nowhere St.	111223333
24Y70	Cheryl H. Clark	563 Downtown Ave.	999009999
23Y34	G. Jerry Smith	1555 Circle Dr.	111005555
•	•	•	•
•	•	•	•
•	•	•	•

MAIL ← PROJECT Name, Address from EMPLOYEE

MAIL relation

Name	Address
Joe E. Baker	33 Nowhere St.
Cheryl H. Clark	563 Downtown Ave.
G. Jerry Smith	1555 Circle Dr.
•	•
•	•
•	•

Figure 9.10 **The JOIN operation**



Relation A

V	W
r	2
t	4
p	6

Relation B

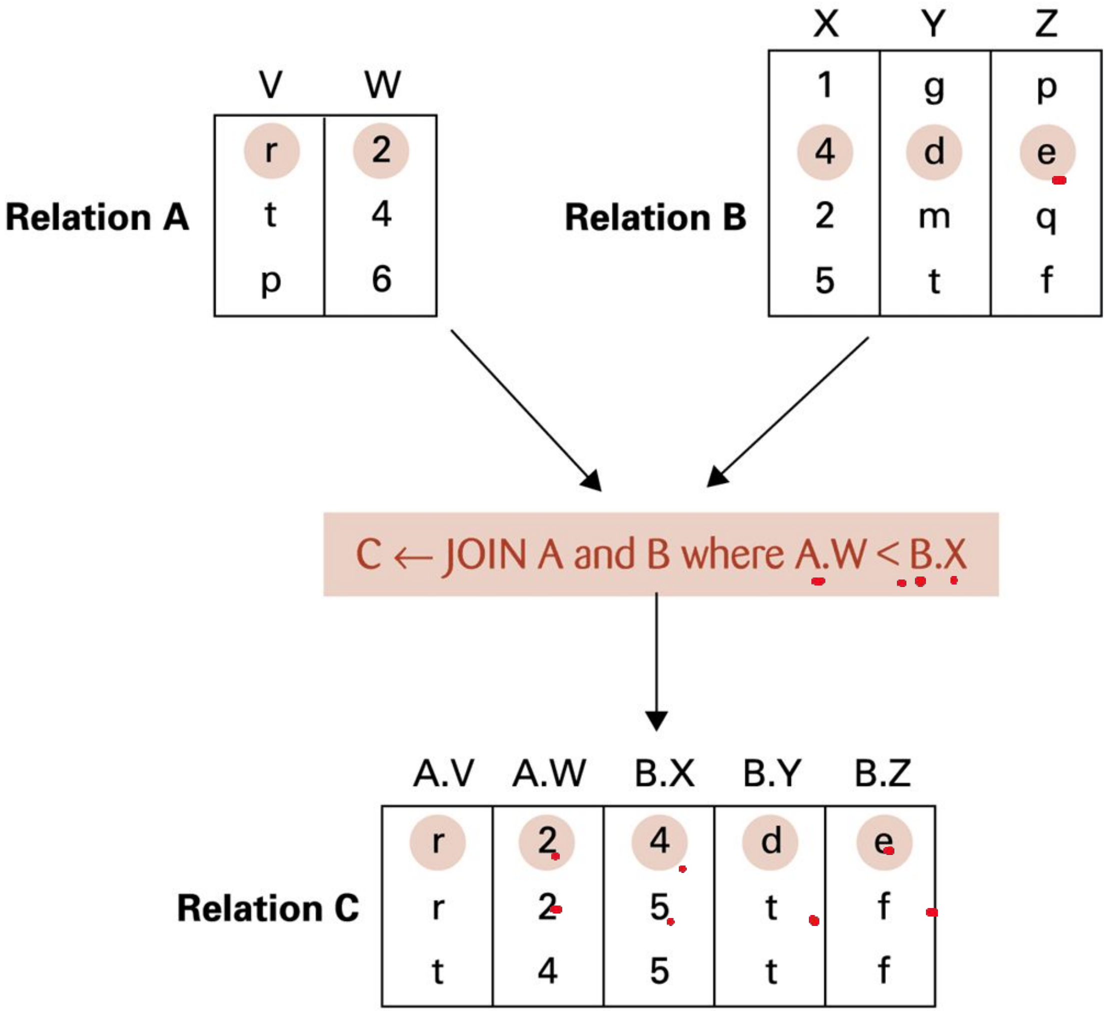
X	Y	Z
5	g	p
4	d	e
2	m	q
4	t	f

C ← JOIN A and B where A.W = B.X

Relation C

A.V	A.W	B.X	B.Y	B.Z
r	2	2	m	q
t	4	4	d	e
t	4	4	t	f

Figure 9.11 **Another example of the JOIN operation**



Relation A

V	W
r	2
t	4
p	6

Relation B

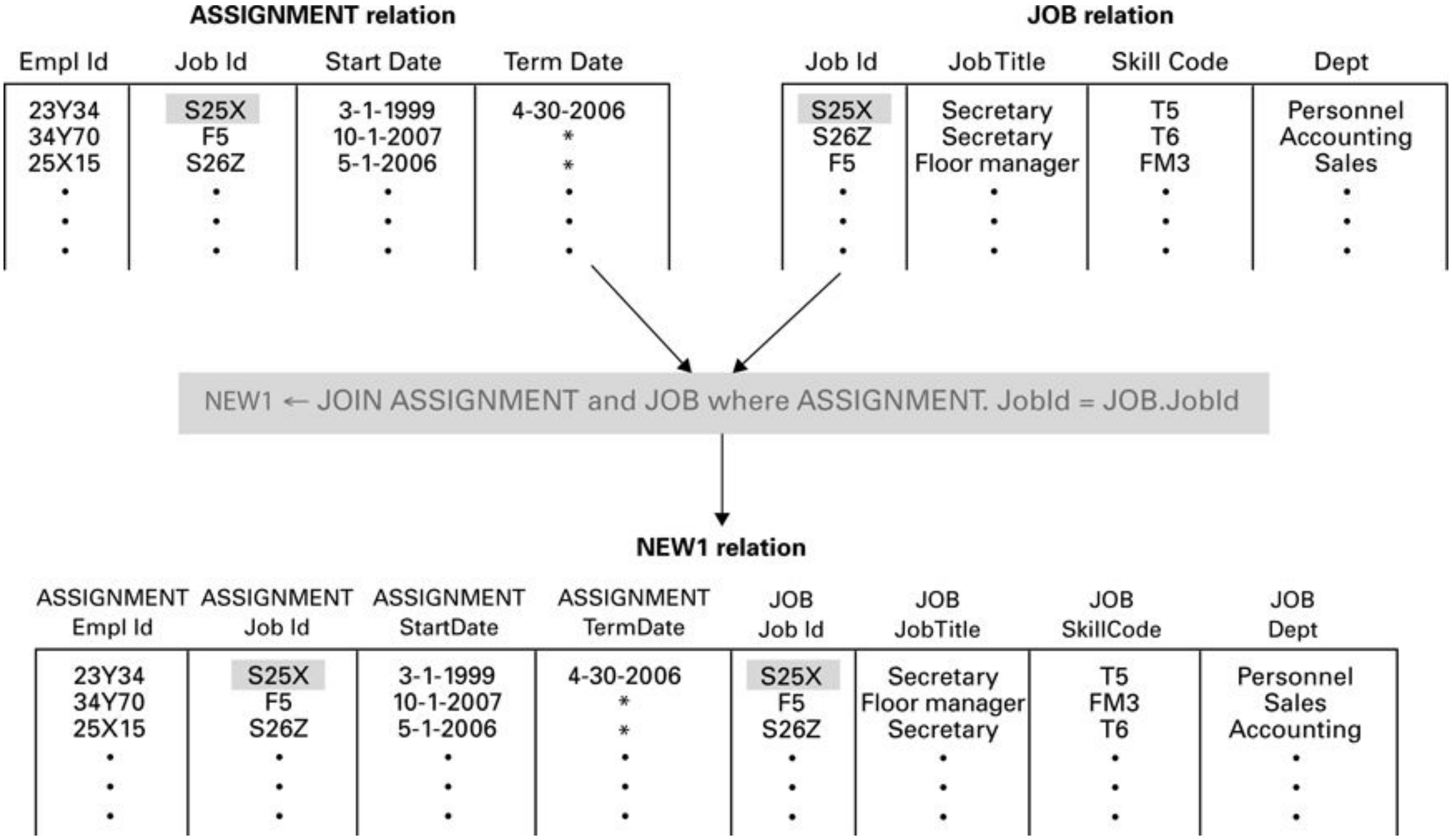
X	Y	Z
1	g	p
4	d	e
2	m	q
5	t	f

C ← JOIN A and B where A.W < B.X

Relation C

A.V	A.W	B.X	B.Y	B.Z
r	2	4	d	e
r	2	5	t	f
t	4	5	t	f

Figure 9.12 **An application of the JOIN operation**



ASSIGNMENT relation

Empl Id	Job Id	Start Date	Term Date
23Y34	S25X	3-1-1999	4-30-2006
34Y70	F5	10-1-2007	*
25X15	S26Z	5-1-2006	*
•	•	•	•
•	•	•	•
•	•	•	•

JOB relation

Job Id	JobTitle	Skill Code	Dept
S25X	Secretary	T5	Personnel
S26Z	Secretary	T6	Accounting
F5	Floor manager	FM3	Sales
•	•	•	•
•	•	•	•
•	•	•	•

NEW1 ← JOIN ASSIGNMENT and JOB where ASSIGNMENT. JobId = JOB.JobId

NEW1 relation

ASSIGNMENT Empl Id	ASSIGNMENT Job Id	ASSIGNMENT StartDate	ASSIGNMENT TermDate	JOB Job Id	JOB JobTitle	JOB SkillCode	JOB Dept
23Y34	S25X	3-1-1999	4-30-2006	S25X	Secretary	T5	Personnel
34Y70	F5	10-1-2007	*	F5	Floor manager	FM3	Sales
25X15	S26Z	5-1-2006	*	S26Z	Secretary	T6	Accounting
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•

Structured Query Language (SQL)

- Operations to manipulate tuples
  - insert
  - update
  - delete
  - select

SQL Examples

-
  ```
  SELECT EmplId, Dept
  FROM Assignment, Job
  WHERE Assignment.JobId = Job.JobId
      AND Assignment.TermData = '*';
  ```

-
  ```
  INSERT INTO Employee
  VALUES ('43212', 'Sue A. Burt',
      '33 Fair St.', '444661111');
  ```

SQL Examples (continued)

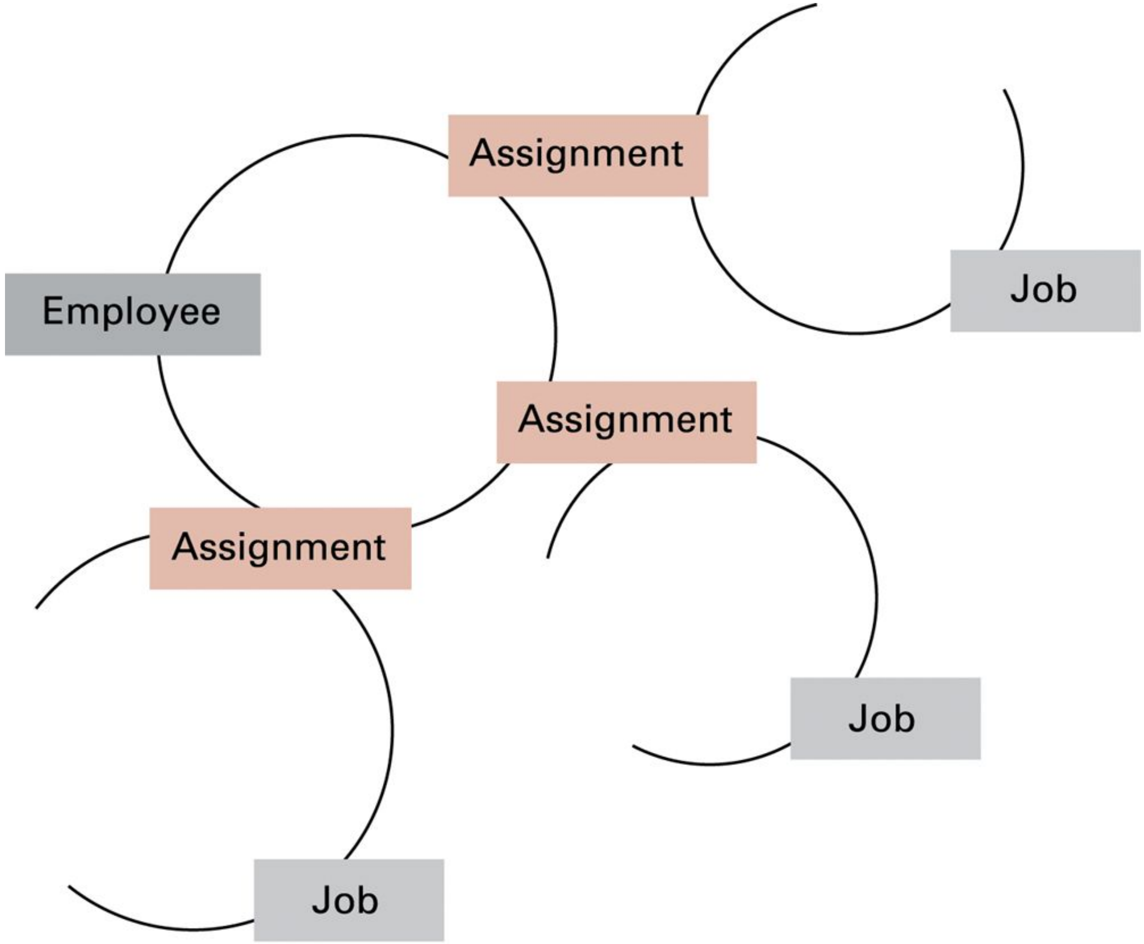
-
  ```
  DELETE FROM Employee
  WHERE Name = 'G. Jerry Smith';
  ```

-
  ```
  UPDATE Employee
  SET Address = '1812 Napoleon Ave.'
  WHERE Name = 'Joe E. Baker';
  ```

Object-oriented Databases

- **Object-oriented Database:** A database constructed by applying the object-oriented paradigm
  - Each entity stored as a persistent object
  - Relationships indicated by links between objects
  - DBMS maintains inter-object links

Figure 9.13 **The associations between objects in an object-oriented database**



Advantages of Object-oriented Databases

- Matches design paradigm of object-oriented applications
- Intelligence can be built into attribute handlers
- Can handle exotic data types
  - Example: multimedia

Maintaining Database Integrity

- **Transaction:** A sequence of operations that must all happen together
  - Example: transferring money between bank accounts
- **Transaction log:** A non-volatile record of each transaction’s activities, built before the transaction is allowed to execute
  - **Commit point:** The point at which a transaction has been recorded in the log
  - **Roll-back:** The process of undoing a transaction

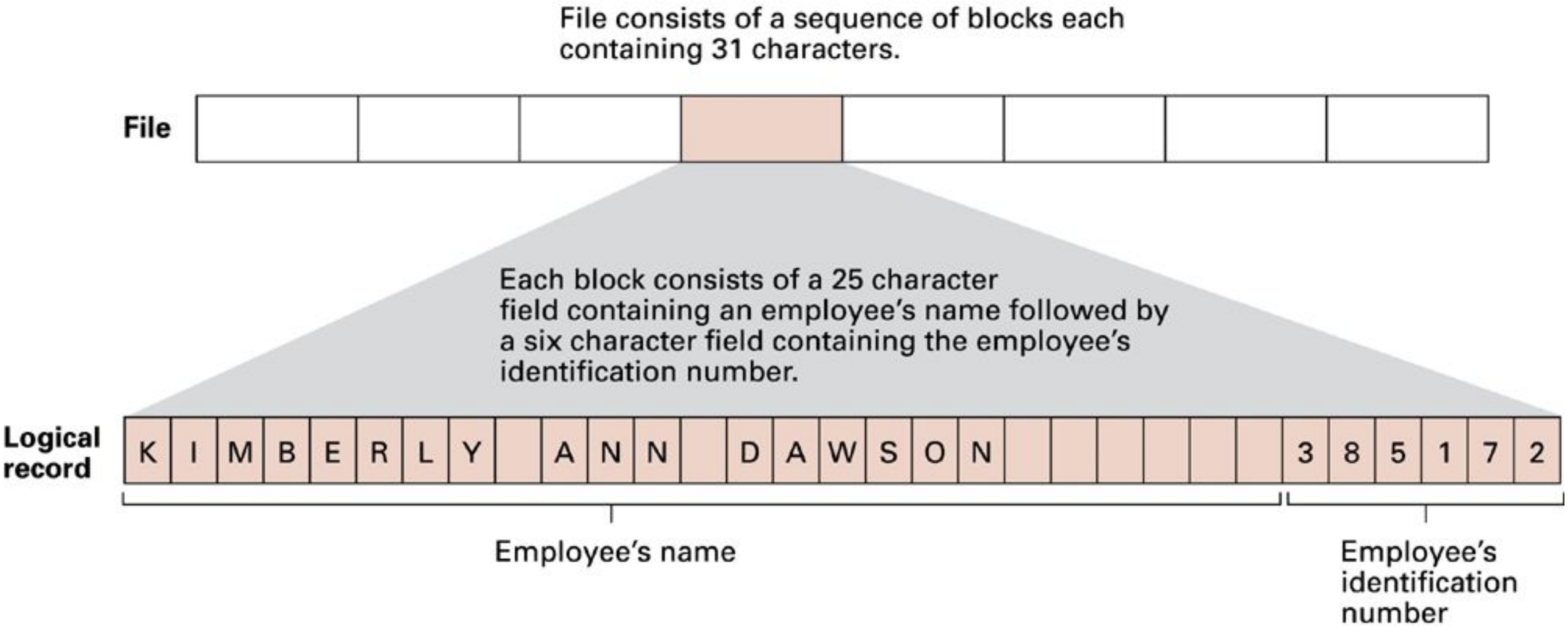
Maintaining database integrity (continued)

- Simultaneous access problems
  - Incorrect summary problem
  - Lost update problem
- **Locking** = preventing others from accessing data being used by a transaction
  - **Shared** lock: used when reading data
  - **Exclusive** lock: used when altering data

Sequential Files

- **Sequential file:** A file whose contents can only be read in order
  - Reader must be able to detect end-of-file (EOF)
  - Data can be stored in logical records, sorted by a key field
    - Greatly increases the speed of batch updates

Figure 9.14 **The structure of a simple employee file implemented as a text file**

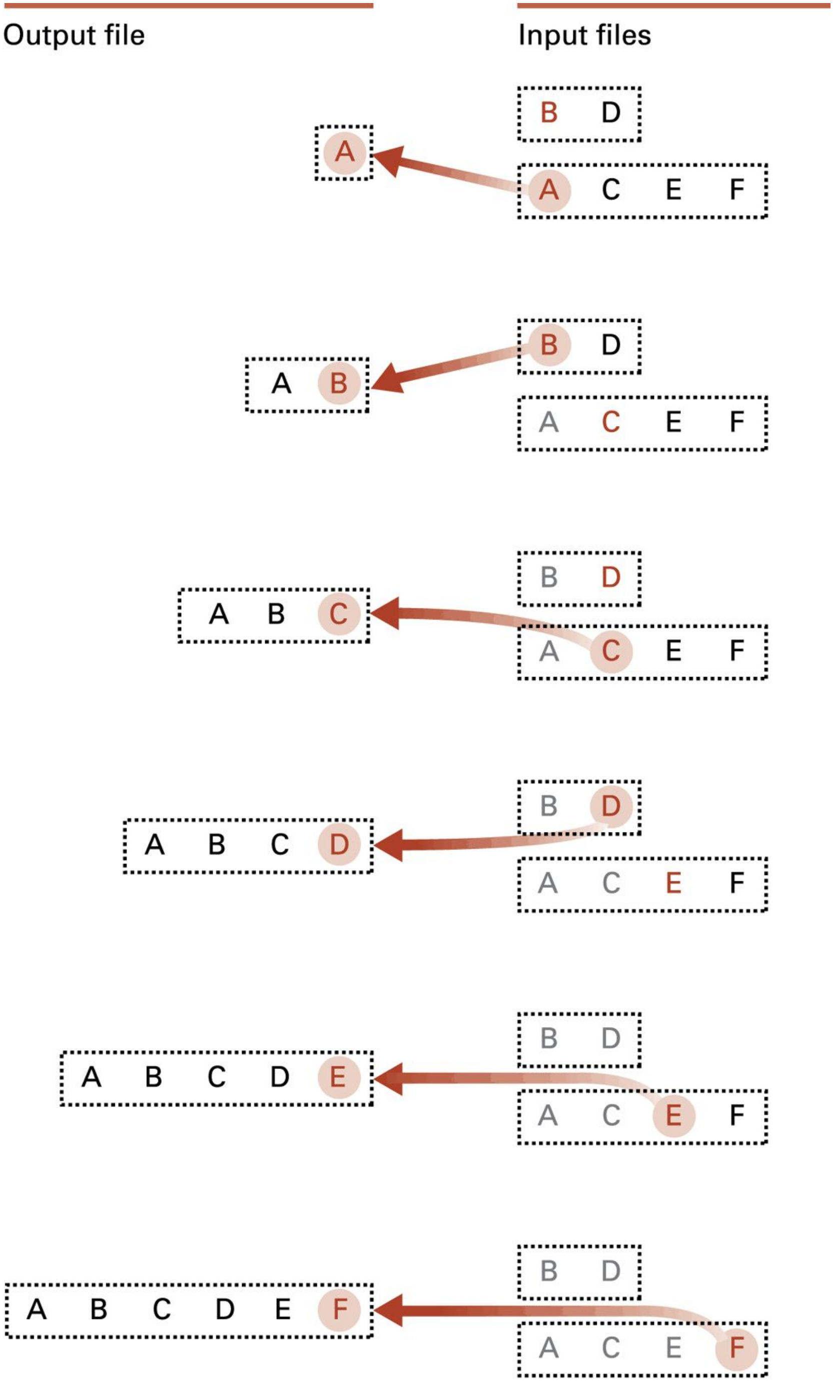


File consists of a sequence of blocks each containing 31 characters.
File
Each block consists of a 25 character field containing an employee's name followed by a six character field containing the employee's identification number.
Logical record
K I M B E R L Y A N N D A W S O N
3 8 5 1 7 2
Employee's name
Employee's identification number

Figure 9.15 **A function for merging two sequential files**

```
def MergeFiles (InputFileA, InputFileB, OutputFile):
    if (both input files at EOF):
        Stop, with OutputFile empty
    if (InputFileA not at EOF):
        Declare its first record to be its current record
    if (InputFileB not at EOF):
        Declare its first record to be its current record
    while (neither input file at EOF):
        Put the current record with the “smaller” key field value in OutputFile
        if (that current record is the last record in its corresponding input file):
            Declare that input file to be at EOF
        else:
            Declare the next record in that input file to be the file’s current record
    Starting with the current record in the input file that is not at EOF,
    copy the remaining records to OutputFile
```

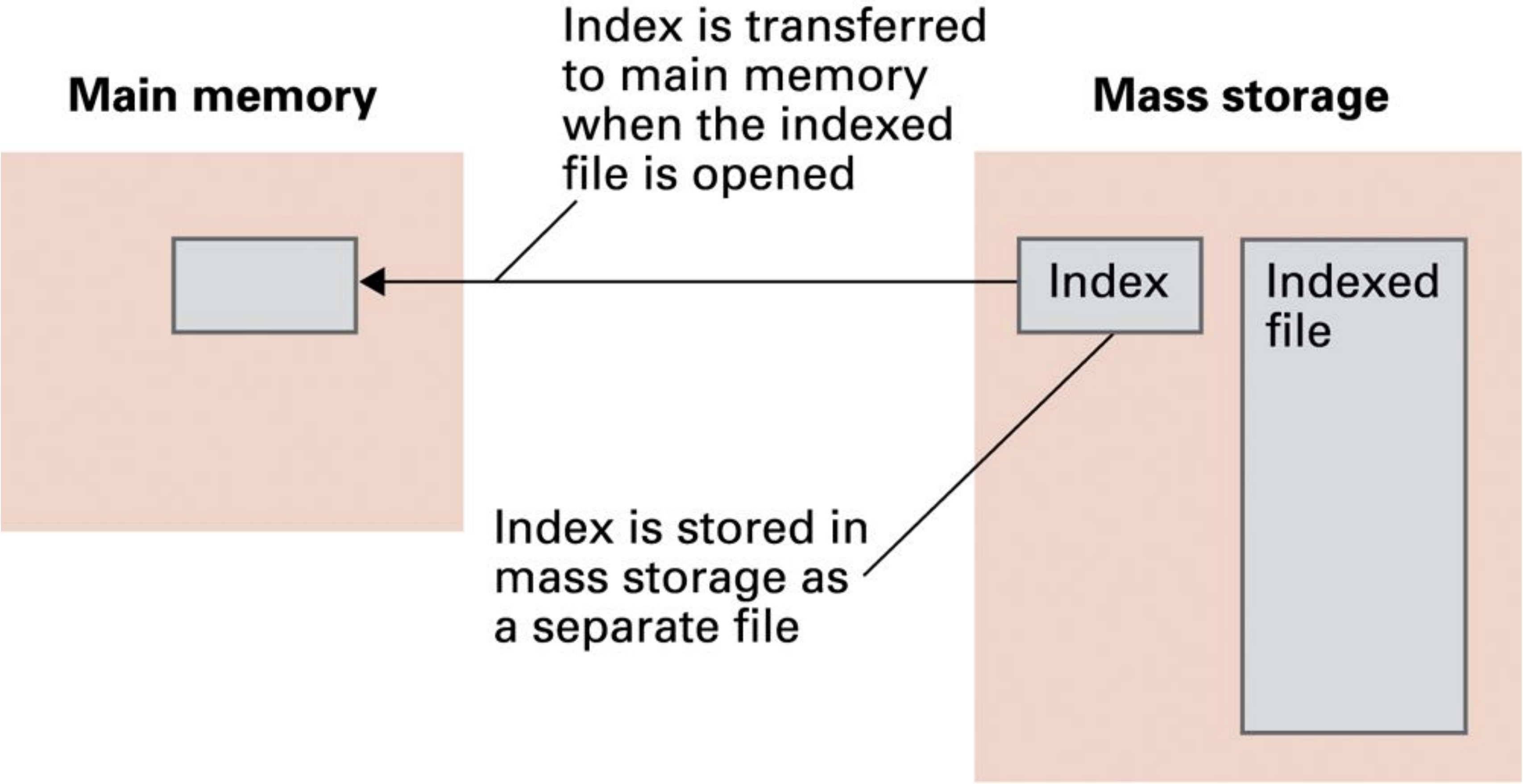
Figure 9.16 **Applying the merge algorithm (Letters are used to represent entire records. The particular letter indicates the value of the record's key field.)**



Indexed Files

- **Index:** A list of key values and the location of their associated records

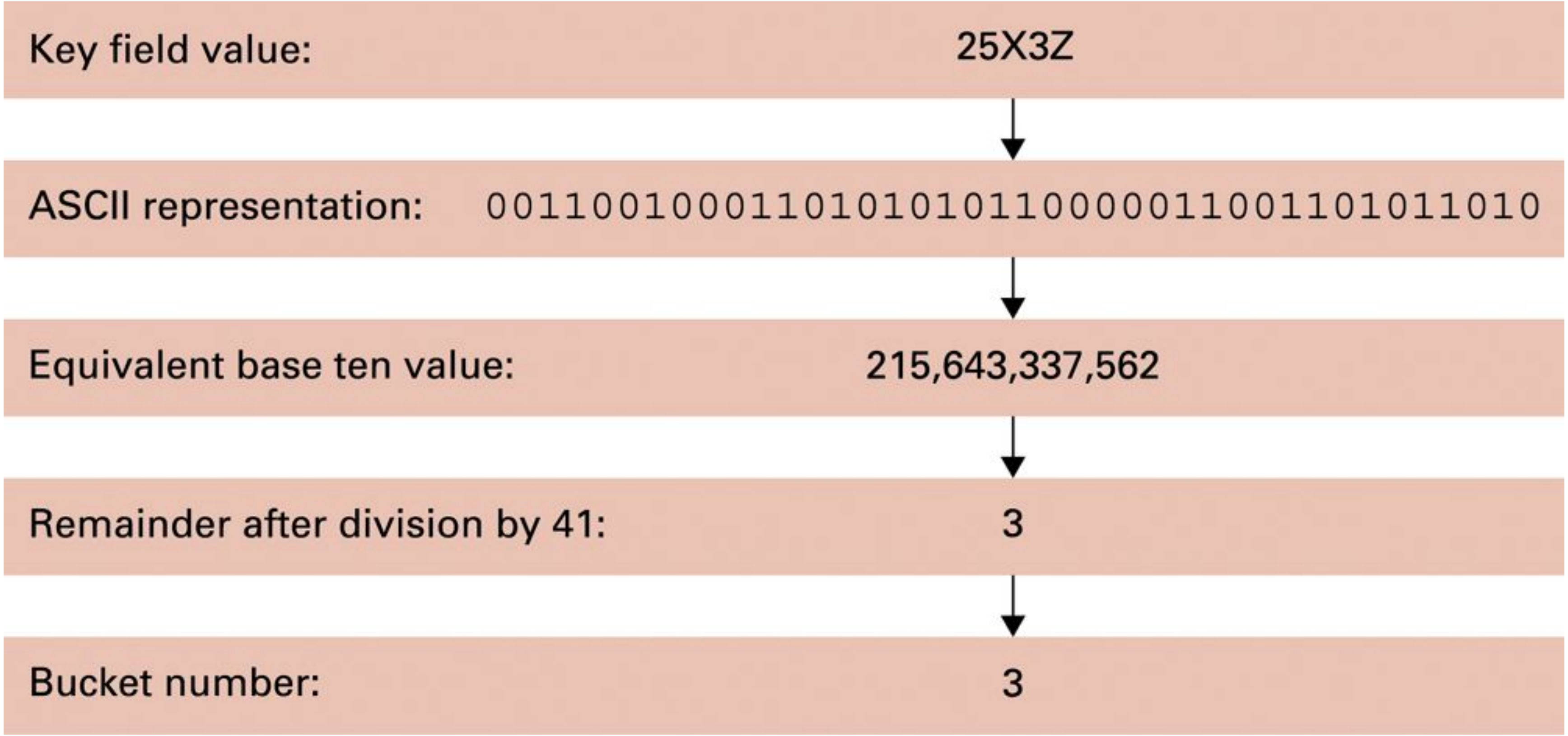
Figure 9.17 Opening an indexed file


Main memory
Index is transferred to main memory when the indexed file is opened
Mass storage
Index
Indexed file
Index is stored in mass storage as a separate file

Hashing

- Each record has a key field
- The storage space is divided into **buckets**
- A **hash function** computes a bucket number for each key value
- Each record is stored in the bucket corresponding to the hash of its key

Figure 9.18 **Hashing the key field value 25X3Z to one of 41 buckets**



Key field value: 25X3Z

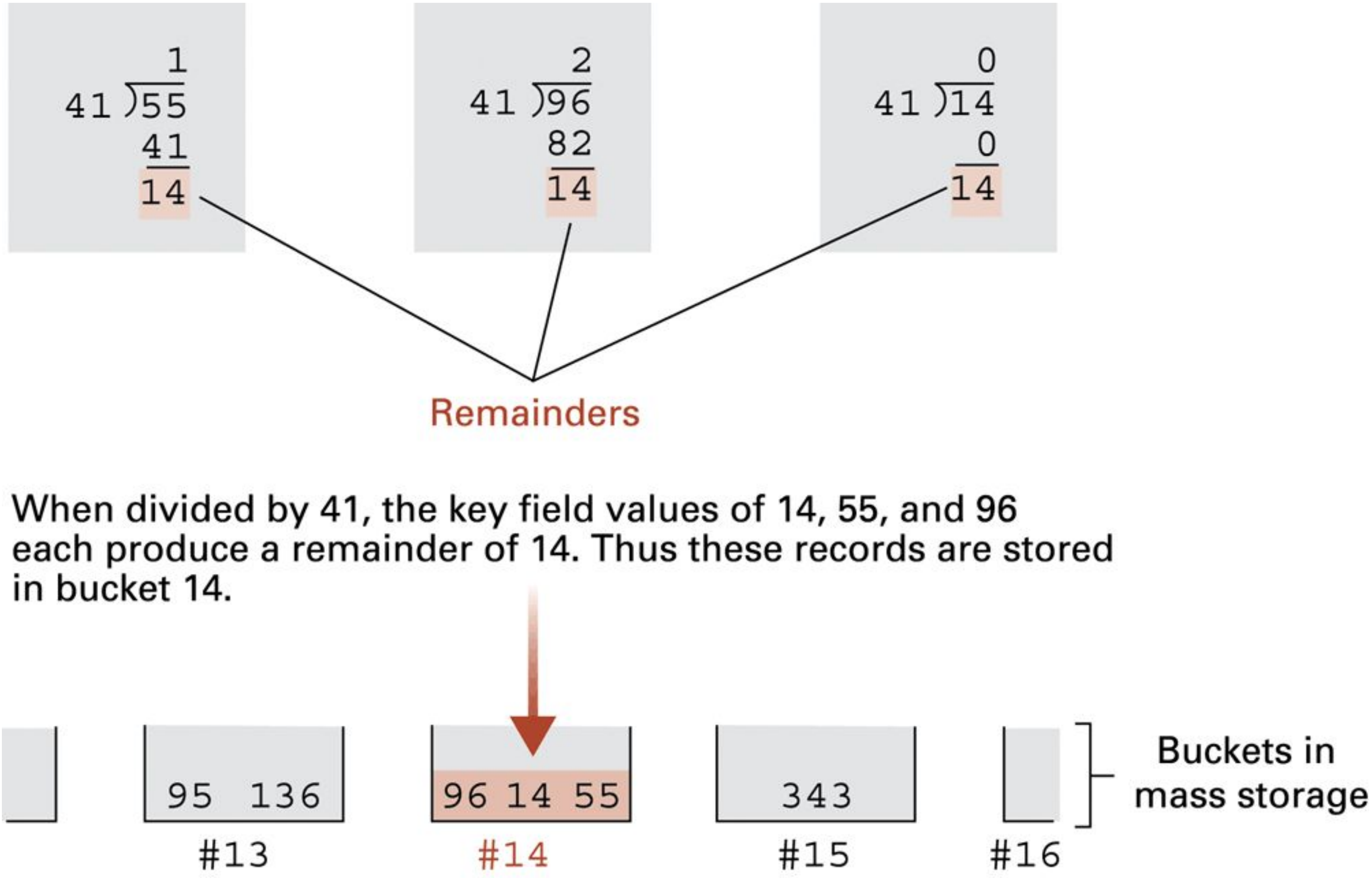
ASCII representation: 0011001000110101010110000011001101011010

Equivalent base ten value: 215,643,337,562

Remainder after division by 41: 3

Bucket number: 3

Figure 9.19 **The rudiments of a hashing system**



When divided by 41, the key field values of 14, 55, and 96 each produce a remainder of 14. Thus these records are stored in bucket 14.

Collisions in Hashing

- **Collision:** The case of two keys hashing to the same bucket
  - Major problem when table is over 75% full
  - Solution: increase number of buckets and rehash all data

Data Mining

- **Data Mining:** The area of computer science that deals with discovering patterns in collections of data
- **Data warehouse:** A static data collection to be mined
  - **Data cube:** Data presented from many perspectives to enable mining

Data Mining Strategies

- Class description
- Class discrimination
- Cluster analysis
- Association analysis
- Outlier analysis
- Sequential pattern analysis

Social Impact of Database Technology

- Problems
  - Massive amounts of personal data are being collected
    - Often without knowledge or meaningful consent of affected people
  - Data merging produces new, more invasive information
  - Errors are widely disseminated and hard to correct
- Remedies
  - Existing legal remedies often difficult to apply
  - Negative publicity may be more effective