

<b>Part I</b>	<b>Background</b>	<b>I</b>
<b>Chapter 1</b>	<b>Introduction to Databases</b>	<b>3</b>
1.1	Introduction	4
1.2	Traditional File-Based Systems	7
1.2.1	File-Based Approach	7
1.2.2	Limitations of the File-Based Approach	12
1.3	Database Approach	14
1.3.1	The Database	15
1.3.2	The Database Management System (DBMS)	16
1.3.3	(Database) Application Programs	17
1.3.4	Components of the DBMS Environment	18
1.3.5	Database Design: The Paradigm Shift	21
1.4	Roles in the Database Environment	21
1.4.1	Data and Database Administrators	21
1.4.2	Database Designers	22
1.4.3	Application Developers	23
1.4.4	End-Users	23
1.5	History of Database Management Systems	23
1.6	Advantages and Disadvantages of DBMSs	27
	<i>Chapter Summary</i>	31
	<i>Review Questions</i>	32
	<i>Exercises</i>	32
<b>Chapter 2</b>	<b>Database Environment</b>	<b>35</b>
2.1	The Three-Level ANSI-SPARC Architecture	36
2.1.1	External Level	37
2.1.2	Conceptual Level	38
2.1.3	Internal Level	38
2.1.4	Schemas, Mappings, and Instances	39
2.1.5	Data Independence	40
2.2	Database Languages	41
2.2.1	The Data Definition Language (DDL)	42

2.2.2	The Data Manipulation Language (DML)	42
2.2.3	Fourth-Generation Languages (4GLs)	44
2.3	Data Models and Conceptual Modeling	45
2.3.1	Object-Based Data Models	46
2.3.2	Record-Based Data Models	46
2.3.3	Physical Data Models	49
2.3.4	Conceptual Modeling	49
2.4	Functions of a DBMS	49
	<i>Chapter Summary</i>	54
	<i>Review Questions</i>	55
	<i>Exercises</i>	55
<b>Chapter 3</b>	<b>Database Architectures and the Web</b>	<b>57</b>
3.1	Multi-user DBMS Architectures	58
3.1.1	Teleprocessing	58
3.1.2	File-Server Architecture	59
3.1.3	Traditional Two-Tier Client–Server Architecture	60
3.1.4	Three-Tier Client–Server Architecture	63
3.1.5	N-Tier Architectures	64
3.1.6	Middleware	65
3.1.7	Transaction Processing Monitors	67
3.2	Web Services and Service-Oriented Architectures	69
3.2.1	Web Services	69
3.2.2	Service-Oriented Architectures (SOA)	70
3.3	Distributed DBMSs	72
3.4	Data Warehousing	74
3.5	Components of a DBMS	77
3.6	Oracle Architecture	80
3.6.1	Oracle’s Logical Database Structure	80
3.6.2	Oracle’s Physical Database Structure	82
	<i>Chapter Summary</i>	86
	<i>Review Questions</i>	87
	<i>Exercises</i>	87
<b>Part 2</b>	<b>The Relational Model and Languages</b>	<b>89</b>
<b>Chapter 4</b>	<b>The Relational Model</b>	<b>91</b>
4.1	Brief History of the Relational Model	92
4.2	Terminology	94
4.2.1	Relational Data Structure	94
4.2.2	Mathematical Relations	97

4.2.3 Database Relations	98
4.2.4 Properties of Relations	98
4.2.5 Relational Keys	100
4.2.6 Representing Relational Database Schemas	101
4.3 Integrity Constraints	103
4.3.1 Nulls	103
4.3.2 Entity Integrity	104
4.3.3 Referential Integrity	104
4.3.4 General Constraints	105
4.4 Views	105
4.4.1 Terminology	105
4.4.2 Purpose of Views	106
4.4.3 Updating Views	107
<i>Chapter Summary</i>	107
<i>Review Questions</i>	108
<i>Exercises</i>	108
<b>Chapter 5 Relational Algebra and Relational Calculus</b>	<b>109</b>
5.1 The Relational Algebra	110
5.1.1 Unary Operations	110
5.1.2 Set Operations	113
5.1.3 Join Operations	116
5.1.4 Division Operation	119
5.1.5 Aggregation and Grouping Operations	120
5.1.6 Summary of the Relational Algebra Operations	122
5.2 The Relational Calculus	123
5.2.1 Tuple Relational Calculus	123
5.2.2 Domain Relational Calculus	126
5.3 Other Languages	128
<i>Chapter Summary</i>	129
<i>Review Questions</i>	129
<i>Exercises</i>	130
<b>Chapter 6 SQL: Data Manipulation</b>	<b>133</b>
6.1 Introduction to SQL	134
6.1.1 Objectives of SQL	134
6.1.2 History of SQL	135
6.1.3 Importance of SQL	137
6.1.4 Terminology	137
6.2 Writing SQL Commands	137
6.3 Data Manipulation	138
6.3.1 Simple Queries	139
6.3.2 Sorting Results (ORDER BY Clause)	147

6.3.3	Using the SQL Aggregate Functions	149
6.3.4	Grouping Results (GROUP BY Clause)	151
6.3.5	Subqueries	154
6.3.6	ANY and ALL	156
6.3.7	Multi-table Queries	158
6.3.8	EXISTS and NOT EXISTS	164
6.3.9	Combining Result Tables (UNION, INTERSECT, EXCEPT)	165
6.3.10	Database Updates	167
	<i>Chapter Summary</i>	171
	<i>Review Questions</i>	172
	<i>Exercises</i>	172
<b>Chapter 7</b>	<b>SQL: Data Definition</b>	<b>175</b>
7.1	The ISO SQL Data Types	176
7.1.1	SQL Identifiers	176
7.1.2	SQL Scalar Data Types	177
7.1.3	Exact Numeric Data	178
7.2	Integrity Enhancement Feature	181
7.2.1	Required Data	182
7.2.2	Domain Constraints	182
7.2.3	Entity Integrity	183
7.2.4	Referential Integrity	184
7.2.5	General Constraints	185
7.3	Data Definition	185
7.3.1	Creating a Database	186
7.3.2	Creating a Table (CREATE TABLE)	187
7.3.3	Changing a Table Definition (ALTER TABLE)	190
7.3.4	Removing a Table (DROP TABLE)	191
7.3.5	Creating an Index (CREATE INDEX)	192
7.3.6	Removing an Index (DROP INDEX)	192
7.4	Views	193
7.4.1	Creating a View (CREATE VIEW)	193
7.4.2	Removing a View (DROP VIEW)	195
7.4.3	View Resolution	196
7.4.4	Restrictions on Views	197
7.4.5	View Updatability	197
7.4.6	WITH CHECK OPTION	198
7.4.7	Advantages and Disadvantages of Views	200
7.4.8	View Materialization	202
7.5	Transactions	203
7.5.1	Immediate and Deferred Integrity Constraints	204

7.6	Discretionary Access Control	204
7.6.1	Granting Privileges to Other Users (GRANT)	206
7.6.2	Revoking Privileges from Users (REVOKE)	207
	<i>Chapter Summary</i>	209
	<i>Review Questions</i>	210
	<i>Exercises</i>	210
<b>Chapter 8</b>	<b>Advanced SQL</b>	<b>213</b>
8.1	The SQL Programming Language	214
8.1.1	Declarations	214
8.1.2	Assignments	215
8.1.3	Control Statements	216
8.1.4	Exceptions in PL/SQL	218
8.1.5	Cursors in PL/SQL	219
8.2	Subprograms, Stored Procedures, Functions, and Packages	222
8.3	Triggers	223
8.4	Recursion	229
	<i>Chapter Summary</i>	230
	<i>Review Questions</i>	231
	<i>Exercises</i>	231
<b>Chapter 9</b>	<b>Query-By-Example</b>	<b>233</b>
9.1	Introduction to Microsoft Office Access Queries	234
9.2	Building Select Queries Using QBE	236
9.2.1	Specifying Criteria	237
9.2.2	Creating Multi-table Queries	239
9.2.3	Calculating Totals	242
9.3	Using Advanced Queries	242
9.3.1	Parameter Query	242
9.3.2	Crosstab Query	243
9.3.3	Find Duplicates Query	246
9.3.4	Find Unmatched Query	248
9.3.5	Autolookup Query	249
9.4	Changing the Content of Tables Using Action Queries	250
9.4.1	Make-Table Action Query	250
9.4.2	Delete Action Query	250
9.4.3	Update Action Query	253
9.4.4	Append Action Query	253
	<i>Exercises</i>	258

<b>Chapter 10 Database System Development Lifecycle</b>	<b>261</b>
10.1 The Information Systems Lifecycle	262
10.2 The Database System Development Lifecycle	263
10.3 Database Planning	263
10.4 System Definition	266
10.4.1 User Views	266
10.5 Requirements Collection and Analysis	266
10.5.1 Centralized Approach	268
10.5.2 View Integration Approach	268
10.6 Database Design	270
10.6.1 Approaches to Database Design	271
10.6.2 Data Modeling	271
10.6.3 Phases of Database Design	272
10.7 DBMS Selection	275
10.7.1 Selecting the DBMS	275
10.8 Application Design	279
10.8.1 Transaction Design	280
10.8.2 User Interface Design Guidelines	281
10.9 Prototyping	283
10.10 Implementation	283
10.11 Data Conversion and Loading	284
10.12 Testing	284
10.13 Operational Maintenance	285
10.14 CASE Tools	286
<i>Chapter Summary</i>	288
<i>Review Questions</i>	289
<i>Exercises</i>	290
<b>Chapter 11 Database Analysis and the DreamHome Case Study</b>	<b>291</b>
11.1 When Are Fact-Finding Techniques Used?	292
11.2 What Facts Are Collected?	293
11.3 Fact-Finding Techniques	294
11.3.1 Examining Documentation	294
11.3.2 Interviewing	294
11.3.3 Observing the Enterprise in Operation	295

11.3.4	Research	296
11.3.5	Questionnaires	296
11.4	Using Fact-Finding Techniques: A Worked Example	297
11.4.1	The <i>DreamHome</i> Case Study—An Overview of the Current System	298
11.4.2	The <i>DreamHome</i> Case Study—Database Planning	302
11.4.3	The <i>DreamHome</i> Case Study—System Definition	308
11.4.4	The <i>DreamHome</i> Case Study—Requirements Collection and Analysis	309
11.4.5	The <i>DreamHome</i> Case Study—Database Design	317
	<i>Chapter Summary</i>	318
	<i>Review Questions</i>	318
	<i>Exercises</i>	318
<b>Chapter 12</b>	<b>Entity–Relationship Modeling</b>	<b>321</b>
12.1	Entity Types	322
12.2	Relationship Types	324
12.2.1	Degree of Relationship Type	326
12.2.2	Recursive Relationship	328
12.3	Attributes	329
12.3.1	Simple and Composite Attributes	329
12.3.2	Single-valued and Multi-valued Attributes	330
12.3.3	Derived Attributes	330
12.3.4	Keys	331
12.4	Strong and Weak Entity Types	333
12.5	Attributes on Relationships	334
12.6	Structural Constraints	335
12.6.1	One-to-One (1:1) Relationships	336
12.6.2	One-to-Many (1 :*) Relationships	337
12.6.3	Many-to-Many (*:*) Relationships	338
12.6.4	Multiplicity for Complex Relationships	339
12.6.5	Cardinality and Participation Constraints	340
12.7	Problems with ER Models	342
12.7.1	Fan Traps	342
12.7.2	Chasm Traps	344
	<i>Chapter Summary</i>	346
	<i>Review Questions</i>	346
	<i>Exercises</i>	347
<b>Chapter 13</b>	<b>Enhanced Entity–Relationship Modeling</b>	<b>349</b>
13.1	Specialization/Generalization	350
13.1.1	Superclasses and Subclasses	350

13.1.2	Superclass/Subclass Relationships	351
13.1.3	Attribute Inheritance	352
13.1.4	Specialization Process	352
13.1.5	Generalization Process	353
13.1.6	Constraints on Specialization/Generalization	356
13.1.7	Worked Example of using Specialization/ Generalization to Model the Branch View of the <i>DreamHome</i> Case Study	357
13.2	Aggregation	361
13.3	Composition	362
	<i>Chapter Summary</i>	363
	<i>Review Questions</i>	364
	<i>Exercises</i>	364
<b>Chapter 14</b>	<b>Normalization</b>	<b>365</b>
14.1	The Purpose of Normalization	366
14.2	How Normalization Supports Database Design	367
14.3	Data Redundancy and Update Anomalies	368
14.3.1	Insertion Anomalies	369
14.3.2	Deletion Anomalies	369
14.3.3	Modification Anomalies	370
14.4	Functional Dependencies	370
14.4.1	Characteristics of Functional Dependencies	370
14.4.2	Identifying Functional Dependencies	374
14.4.3	Identifying the Primary Key for a Relation Using Functional Dependencies	377
14.5	The Process of Normalization	378
14.6	First Normal Form (1NF)	380
14.7	Second Normal Form (2NF)	384
14.8	Third Normal Form (3NF)	385
14.9	General Definitions of 2NF and 3NF	387
	<i>Chapter Summary</i>	389
	<i>Review Questions</i>	389
	<i>Exercises</i>	390
<b>Chapter 15</b>	<b>Advanced Normalization</b>	<b>393</b>
15.1	More on Functional Dependencies	394
15.1.1	Inference Rules for Functional Dependencies	394
15.1.2	Minimal Sets of Functional Dependencies	396



15.2	Boyce–Codd Normal Form (BCNF)	397
	15.2.1 Definition of BCNF	397
15.3	Review of Normalization Up to BCNF	400
15.4	Fourth Normal Form (4NF)	405
	15.4.1 Multi-Valued Dependency	406
	15.4.2 Definition of Fourth Normal Form	407
15.5	Fifth Normal Form (5NF)	407
	15.5.1 Lossless-Join Dependency	408
	15.5.2 Definition of Fifth Normal Form	408
	<i>Chapter Summary</i>	410
	<i>Review Questions</i>	410
	<i>Exercises</i>	411

## **Part 4 Methodology 413**

### **Chapter 16 Methodology—Conceptual Database Design 415**

16.1	Introduction to the Database Design Methodology	416
	16.1.1 What Is a Design Methodology?	416
	16.1.2 Conceptual, Logical, and Physical Database Design	417
	16.1.3 Critical Success Factors in Database Design	417
16.2	Overview of the Database Design Methodology	418
16.3	Conceptual Database Design Methodology	420
	Step 1: Build Conceptual Data Model	420
	<i>Chapter Summary</i>	436
	<i>Review Questions</i>	436
	<i>Exercises</i>	437

### **Chapter 17 Methodology—Logical Database Design for the Relational Model 439**

17.1	Logical Database Design Methodology for the Relational Model	440
	Step 2: Build Logical Data Model	440
	<i>Chapter Summary</i>	468
	<i>Review Questions</i>	469
	<i>Exercises</i>	469

### **Chapter 18 Methodology—Physical Database Design for Relational Databases 471**

18.1	Comparison of Logical and Physical Database Design	472
18.2	Overview of the Physical Database Design Methodology	473

18.3	The Physical Database Design Methodology for Relational Databases	474
	Step 3: Translate Logical Data Model for Target DBMS	474
	Step 4	479
	Step 5: Design User Views	492
	Step 6: Design Security Mechanisms	492
	<i>Chapter Summary</i>	493
	<i>Review Questions</i>	494
	<i>Exercises</i>	494
<b>Chapter 19</b>	<b>Methodology—Monitoring and Tuning the Operational System</b>	<b>495</b>
19.1	Denormalizing and Introducing Controlled Redundancy	495
	Step 7: Consider the Introduction of Controlled Redundancy	495
19.2	Monitoring the System to Improve Performance	508
	Step 8: Monitor and Tune the Operational System	508
	<i>Chapter Summary</i>	512
	<i>Review Questions</i>	513
	<i>Exercises</i>	513
<b>Part 5</b>	<b>Selected Database Issues</b>	<b>515</b>
<b>Chapter 20</b>	<b>Security and Administration</b>	<b>517</b>
20.1	Database Security	518
	20.1.1 Threats	519
20.2	Countermeasures—Computer-Based Controls	521
	20.2.1 Authorization	522
	20.2.2 Access Controls	523
	20.2.3 Views	526
	20.2.4 Backup and Recovery	526
	20.2.5 Integrity	527
	20.2.6 Encryption	527
	20.2.7 RAID (Redundant Array of Independent Disks)	528
20.3	Security in Microsoft Office Access DBMS	531
20.4	Security in Oracle DBMS	533
20.5	DBMSs and Web Security	537
	20.5.1 Proxy Servers	538
	20.5.2 Firewalls	538

20.5.3	Message Digest Algorithms and Digital Signatures	539
20.5.4	Digital Certificates	539
20.5.5	Kerberos	540
20.5.6	Secure Sockets Layer and Secure HTTP	540
20.5.7	Secure Electronic Transactions and Secure Transaction Technology	541
20.5.8	Java Security	542
20.5.9	ActiveX Security	544
20.6	Data Administration and Database Administration	544
20.6.1	Data Administration	545
20.6.2	Database Administration	546
20.6.3	Comparison of Data and Database Administration	546
	<i>Chapter Summary</i>	547
	<i>Review Questions</i>	548
	<i>Exercises</i>	548

## **Chapter 21 Professional, Legal, and Ethical Issues in Data Management 549**

21.1	Defining Legal and Ethical Issues in IT	550
21.1.1	Defining Ethics in the Context of IT	550
21.1.2	The Difference Between Ethical and Legal Behavior	551
21.1.3	Ethical Behavior in IT	552
21.2	Legislation and Its Impact on the IT Function	553
21.2.1	Securities and Exchange Commission (SEC) Regulation National Market System (NMS)	553
21.2.2	The Sarbanes-Oxley Act, COBIT, and COSO	553
21.2.3	The Health Insurance Portability and Accountability Act	555
21.2.4	The European Union (EU) Directive on Data Protection of 1995	555
21.2.5	The United Kingdom's Data Protection Act of 1998	556
21.2.6	International Banking—Basel II Accords	557
21.3	Establishing a Culture of Legal and Ethical Data Stewardship	558
21.3.1	Developing an Organization-Wide Policy for Legal and Ethical Behavior	558
21.3.2	Professional Organizations and Codes of Ethics	559
21.3.3	Developing an Organization-Wide Policy for Legal and Ethical Behavior for <i>DreamHome</i>	561
21.4	Intellectual Property	563
21.4.1	Patent	563
21.4.2	Copyright	564
21.4.3	Trademark	564

21.4.4 Intellectual Property Rights Issues for Software	565
21.4.5 Intellectual Property Rights Issues for Data	566
<i>Chapter Summary</i>	566
<i>Review Questions</i>	567
<i>Exercises</i>	567
<b>Chapter 22 Transaction Management</b>	<b>569</b>
22.1 Transaction Support	570
22.1.1 Properties of Transactions	573
22.1.2 Database Architecture	573
22.2 Concurrency Control	574
22.2.1 The Need for Concurrency Control	574
22.2.2 Serializability and Recoverability	577
22.2.3 Locking Methods	585
22.2.4 Deadlock	591
22.2.5 Timestamping Methods	594
22.2.6 Multiversion Timestamp Ordering	597
22.2.7 Optimistic Techniques	598
22.2.8 Granularity of Data Items	599
22.3 Database Recovery	602
22.3.1 The Need for Recovery	602
22.3.2 Transactions and Recovery	603
22.3.3 Recovery Facilities	606
22.3.4 Recovery Techniques	609
22.3.5 Recovery in a Distributed DBMS	611
22.4 Advanced Transaction Models	611
22.4.1 Nested Transaction Model	613
22.4.2 Sagas	614
22.4.3 Multilevel Transaction Model	615
22.4.4 Dynamic Restructuring	616
22.4.5 Workflow Models	617
22.5 Concurrency Control and Recovery in Oracle	618
22.5.1 Oracle's Isolation Levels	619
22.5.2 Multiversion Read Consistency	619
22.5.3 Deadlock Detection	621
22.5.4 Backup and Recovery	621
<i>Chapter Summary</i>	624
<i>Review Questions</i>	625
<i>Exercises</i>	625
<b>Chapter 23 Query Processing</b>	<b>627</b>
23.1 Overview of Query Processing	629
23.2 Query Decomposition	632

23.3	Heuristical Approach to Query Optimization	636
23.3.1	Transformation Rules for the Relational Algebra Operations	636
23.3.2	Heuristical Processing Strategies	641
23.4	Cost Estimation for the Relational Algebra Operations	642
23.4.1	Database Statistics	642
23.4.2	Selection Operation ( $S = \sigma_p(R)$ )	643
23.4.3	Join Operation ( $T = (R \bowtie_F S)$ )	650
23.4.4	Projection Operation ( $S = \Pi_{A_1, A_2, \dots, A_m}(R)$ )	657
23.4.5	The Relational Algebra Set Operations ( $T = R \cup S, T = R \cap S, T = R - S$ )	659
23.5	Enumeration of Alternative Execution Strategies	660
23.5.1	Pipelining	661
23.5.2	Linear Trees	661
23.5.3	Physical Operators and Execution Strategies	662
23.5.4	Reducing the Search Space	664
23.5.5	Enumerating Left-Deep Trees	665
23.5.6	Semantic Query Optimization	666
23.5.7	Alternative Approaches to Query Optimization	667
23.5.8	Distributed Query Optimization	668
23.6	Query Optimization in Oracle	668
23.6.1	Rule-Based and Cost-Based Optimization	668
23.6.2	Histograms	672
23.6.3	Viewing the Execution Plan	674
	<i>Chapter Summary</i>	675
	<i>Review Questions</i>	676
	<i>Exercises</i>	676

## **Part 6 Distributed DBMSs and Replication 679**

<b>Chapter 24</b>	<b>Distributed DBMSs—Concepts and Design</b>	<b>681</b>
24.1	Introduction	682
24.1.1	Concepts	683
24.1.2	Advantages and Disadvantages of DDBMSs	687
24.1.3	Homogeneous and Heterogeneous DDBMSs	690
24.2	Overview of Networking	693
24.3	Functions and Architectures of a DDBMS	697
24.3.1	Functions of a DDBMS	697
24.3.2	Reference Architecture for a DDBMS	697
24.3.3	Reference Architecture for a Federated MDBS	699
24.3.4	Component Architecture for a DDBMS	700
24.4	Distributed Relational Database Design	701
24.4.1	Data Allocation	702
24.4.2	Fragmentation	703

24.5	Transparencies in a DDBMS	712
24.5.1	Distribution Transparency	712
24.5.2	Transaction Transparency	715
24.5.3	Performance Transparency	718
24.5.4	DBMS Transparency	720
24.5.5	Summary of Transparencies in a DDBMS	720
24.6	Date's Twelve Rules for a DDBMS	721
	<i>Chapter Summary</i>	723
	<i>Review Questions</i>	724
	<i>Exercises</i>	724
<b>Chapter 25</b>	<b>Distributed DBMSs—Advanced Concepts</b>	<b>727</b>
25.1	Distributed Transaction Management	728
25.2	Distributed Concurrency Control	729
25.2.1	Objectives	729
25.2.2	Distributed Serializability	730
25.2.3	Locking Protocols	730
25.2.4	Timestamp Protocols	733
25.3	Distributed Deadlock Management	733
25.4	Distributed Database Recovery	737
25.4.1	Failures in a Distributed Environment	737
25.4.2	How Failures Affect Recovery	738
25.4.3	Two-Phase Commit (2PC)	739
25.4.4	Three-Phase Commit (3PC)	745
25.4.5	Network Partitioning	749
25.5	The X/Open Distributed Transaction Processing Model	750
25.6	Distributed Query Optimization	753
25.6.1	Data Localization	754
25.6.2	Distributed Joins	758
25.6.3	Global Optimization	759
25.7	Distribution in Oracle	763
25.7.1	Oracle's DDBMS Functionality	763
	<i>Chapter Summary</i>	768
	<i>Review Questions</i>	769
	<i>Exercises</i>	770
<b>Chapter 26</b>	<b>Replication and Mobile Databases</b>	<b>771</b>
26.1	Introduction to Database Replication	772
26.1.1	Synchronous Versus Asynchronous Replication	773
26.1.2	Applications of Replication	774

26.2	Replication Servers	774
26.2.1	Replication Server Functionality	775
26.2.2	Data Ownership	775
26.2.3	Implementation Issues	779
26.3.	Introduction to Mobile Databases	782
26.3.1	Mobile DBMSs	784
26.3.2	Issues with Mobile DBMSs	784
26.4	Oracle Replication	790
26.4.1	Oracle's Replication Functionality	790
	<i>Chapter Summary</i>	796
	<i>Review Questions</i>	797
	<i>Exercises</i>	797

## **Part 7 Object DBMSs 799**

### **Chapter 27 Object-Oriented DBMSs—Concepts and Design 801**

27.1	Advanced Database Applications	803
27.2	Weaknesses of RDBMSs	807
27.3	Storing Objects in a Relational Database	812
27.3.1	Mapping Classes to Relations	813
27.3.2	Accessing Objects in the Relational Database	814
27.4	Next-Generation Database Systems	816
27.5	Introduction to OODBMSs	817
27.5.1	Definition of Object-Oriented DBMSs	818
27.5.2	Functional Data Models	819
27.5.3	Persistent Programming Languages	824
27.5.4	<i>The Object-Oriented Database System Manifesto</i>	825
27.5.5	Alternative Strategies for Developing an OODBMS	828
27.6	Persistence in OODBMSs	829
27.6.1	Pointer Swizzling Techniques	831
27.6.2	Accessing an Object	834
27.6.3	Persistence Schemes	836
27.6.4	Orthogonal Persistence	837
27.7	Issues in OODBMSs	839
27.7.1	Transactions	839
27.7.2	Versions	840
27.7.3	Schema Evolution	841
27.7.4	Architecture	844
27.7.5	Benchmarking	846

27.8	Advantages and Disadvantages of OODBMSs	849
27.8.1	Advantages	849
27.8.2	Disadvantages	851
27.9	Object-Oriented Database Design	853
27.9.1	Comparison of Object-Oriented Data Modeling and Conceptual Data Modeling	853
27.9.2	Relationships and Referential Integrity	854
27.9.3	Behavioral Design	856
27.10	Object-Oriented Analysis and Design with UML	858
27.10.1	UML Diagrams	859
27.10.2	Usage of UML in the Methodology for Database Design	864
	<i>Chapter Summary</i>	866
	<i>Review Questions</i>	867
	<i>Exercises</i>	868

## **Chapter 28 Object-Oriented DBMSs—Standards and Systems 871**

28.1	Object Management Group	872
28.1.1	Background	872
28.1.2	The Common Object Request Broker Architecture	875
28.1.3	Other OMG Specifications	880
28.1.4	Model-Driven Architecture	883
28.2	Object Data Standard ODMG 3.0, 1999	883
28.2.1	Object Data Management Group	885
28.2.2	The Object Model	886
28.2.3	The Object Definition Language	894
28.2.4	The Object Query Language	897
28.2.5	Other Parts of the ODMG Standard	903
28.2.6	Mapping the Conceptual Design to a Logical (Object-Oriented) Design	906
28.3	ObjectStore	907
28.3.1	Architecture	907
28.3.2	Building an ObjectStore Application	910
28.3.3	Data Definition in ObjectStore	911
28.3.4	Data Manipulation in ObjectStore	915
	<i>Chapter Summary</i>	918
	<i>Review Questions</i>	919
	<i>Exercises</i>	919

## **Chapter 29 Object-Relational DBMSs 921**

29.1	Introduction to Object-Relational Database Systems	922
29.2	The Third-Generation Database Manifestos	925
29.2.1	The <i>Third-Generation Database System Manifesto</i>	926
29.2.2	The <i>Third Manifesto</i>	926



29.3	Postgres—An Early ORDBMS	929
29.3.1	Objectives of Postgres	929
29.3.2	Abstract Data Types	929
29.3.3	Relations and Inheritance	930
29.3.4	Object Identity	931
29.4	SQL:2008	932
29.4.1	Row Types	933
29.4.2	User-Defined Types	934
29.4.3	Subtypes and Supertypes	936
29.4.4	User-Defined Routines	939
29.4.5	Polymorphism	940
29.4.6	Reference Types and Object Identity	941
29.4.7	Creating Tables	942
29.4.8	Querying Data	945
29.4.9	Collection Types	946
29.4.10	Typed Views	950
29.4.11	Persistent Stored Modules	950
29.4.12	Triggers	951
29.4.13	Large Objects	954
29.4.14	Recursion	955
29.5	Query Processing and Optimization	955
29.5.1	New Index Types	959
29.6	Object-Oriented Extensions in Oracle	959
29.6.1	User-Defined Data Types	960
29.6.2	Manipulating Object Tables	965
29.6.3	Object Views	966
29.6.4	Privileges	967
29.7	Comparison of ORDBMS and OODBMS	968
	<i>Chapter Summary</i>	969
	<i>Review Questions</i>	969
	<i>Exercises</i>	970

## **Part 8 The Web and DBMSs 971**

### **Chapter 30 Web Technology and DBMSs 973**

30.1	Introduction to the Internet and the Web	974
30.1.1	Intranets and Extranets	976
30.1.2	e-Commerce and e-Business	977
30.2	The Web	978
30.2.1	HyperText Transfer Protocol	979
30.2.2	HyperText Markup Language	981
30.2.3	Uniform Resource Locators	982
30.2.4	Static and Dynamic Web Pages	982

30.2.5	Web Services	984
30.2.6	Requirements for Web–DBMS Integration	985
30.2.7	Advantages and Disadvantages of the Web–DBMS Approach	986
30.2.8	Approaches to Integrating the Web and DBMSs	990
30.3	Scripting Languages	991
30.3.1	JavaScript and JScript	991
30.3.2	VBScript	992
30.3.3	Perl and PHP	993
30.4	Common Gateway Interface (CGI)	993
30.4.1	Passing Information to a CGI Script	995
30.4.2	Advantages and Disadvantages of CGI	997
30.5	HTTP Cookies	998
30.6	Extending the Web Server	999
30.6.1	Comparison of CGI and API	1000
30.7	Java	1000
30.7.1	JDBC	1004
30.7.2	SQLJ	1010
30.7.3	Comparison of JDBC and SQLJ	1010
30.7.4	Container-Managed Persistence (CMP)	1011
30.7.5	Java Data Objects (JDO)	1015
30.7.6	JPA (Java Persistence API)	1022
30.7.7	Java Servlets	1030
30.7.8	JavaServer Pages	1030
30.7.9	Java Web Services	1031
30.8	Microsoft’s Web Platform	1032
30.8.1	Universal Data Access	1034
30.8.2	Active Server Pages and ActiveX Data Objects	1035
30.8.3	Remote Data Services	1036
30.8.4	Comparison of ASP and JSP	1039
30.8.5	Microsoft .NET	1039
30.8.6	Microsoft Web Services	1044
30.9	Oracle Internet Platform	1044
30.9.1	Oracle Application Server (OracleAS)	1045
	<i>Chapter Summary</i>	<i>1051</i>
	<i>Review Questions</i>	<i>1052</i>
	<i>Exercises</i>	<i>1053</i>

## **Chapter 31 Semistructured Data and XML 1055**

31.1	Semistructured Data	1056
31.1.1	Object Exchange Model (OEM)	1058
31.1.2	Lore and Lorel	1059

31.2	Introduction to XML	1063
	31.2.1 Overview of XML	1066
	31.2.2 Document Type Definitions (DTDs)	1068
31.3	XML-Related Technologies	1071
	31.3.1 DOM and SAX Interfaces	1072
	31.3.2 Namespaces	1073
	31.3.3 XSL and XSLT	1073
	31.3.4 XPath (XML Path Language)	1074
	31.3.5 XPointer (XML Pointer Language)	1075
	31.3.6 XLink (XML Linking Language)	1076
	31.3.7 XHTML	1076
	31.3.8 Simple Object Access Protocol (SOAP)	1077
	31.3.9 Web Services Description Language (WSDL)	1077
	31.3.10 Universal Discovery, Description and Integration (UDDI)	1078
31.4	XML Schema	1081
	31.4.1 Resource Description Framework (RDF)	1087
31.5	XML Query Languages	1091
	31.5.1 Extending Lore and Lorel to Handle XML	1092
	31.5.2 XML Query Working Group	1093
	31.5.3 XQuery—A Query Language for XML	1094
	31.5.4 XML Information Set	1104
	31.5.5 XQuery 1.0 and XPath 2.0 Data Model (XDM)	1105
	31.5.6 XQuery Update Facility 1.0	1111
	31.5.7 Formal Semantics	1113
31.6	XML and Databases	1121
	31.6.1 Storing XML in Databases	1121
	31.6.2 XML and SQL	1124
	31.6.3 Native XML Databases	1135
31.7	XML in Oracle	1136
	<i>Chapter Summary</i>	1139
	<i>Review Questions</i>	1141
	<i>Exercises</i>	1142

## **Part 9 Business Intelligence**

**1143**

### **Chapter 32 Data Warehousing Concepts**

**1145**

32.1	Introduction to Data Warehousing	1146
	32.1.1 The Evolution of Data Warehousing	1146
	32.1.2 Data Warehousing Concepts	1147
	32.1.3 Benefits of Data Warehousing	1148
	32.1.4 Comparison of OLTP Systems and Data Warehousing	1148
	32.1.5 Problems of Data Warehousing	1150
	32.1.6 Real-Time Data Warehouse	1152

32.2	Data Warehouse Architecture	1153
32.2.1	Operational Data	1153
32.2.2	Operational Data Store	1153
32.2.3	ETL Manager	1154
32.2.4	Warehouse Manager	1154
32.2.5	Query Manager	1155
32.2.6	Detailed Data	1155
32.2.7	Lightly and Highly Summarized Data	1155
32.2.8	Archive/Backup Data	1155
32.2.9	Metadata	1156
32.2.10	End-User Access Tools	1156
32.3	Data Warehousing Tools and Technologies	1157
32.3.1	Extraction, Transformation, and Loading (ETL)	1158
32.3.2	Data Warehouse DBMS	1159
32.3.3	Data Warehouse Metadata	1162
32.3.4	Administration and Management Tools	1164
32.4	Data Mart	1164
32.4.1	Reasons for Creating a Data Mart	1165
32.5	Data Warehousing Using Oracle	1165
32.5.1	New Warehouse Features in Oracle 10g/11g	1168
	<i>Chapter Summary</i>	<i>1169</i>
	<i>Review Questions</i>	<i>1170</i>
	<i>Exercise</i>	<i>1171</i>

## **Chapter 33 Data Warehousing Design 1173**

33.1	Designing a Data Warehouse Database	1174
33.2	Data Warehouse Development Methodologies	1174
33.3	Kimball's Business Dimensional Lifecycle	1176
33.4	Dimensionality Modeling	1177
33.4.1	Comparison of DM and ER models	1180
33.5	The Dimensional Modeling Stage of Kimball's Business Dimensional Lifecycle	1181
33.5.1	Create a High-Level Dimensional Model (Phase I)	1181
	Step 1: Select Business Process	1181
	Step 2: Declare Grain	1183
	Step 3: Choose Dimensions	1183
	Step 4: Identify Facts	1185
33.5.2	Identify All Dimension Attributes for the Dimensional Model (Phase II)	1186
33.6	Data Warehouse Development Issues	1189
33.7	Data Warehousing Design Using Oracle	1190
33.7.1	Oracle Warehouse Builder Components	1190

33.7.2 Using Oracle Warehouse Builder	1191
33.7.3 New Warehouse Builder Features in Oracle 10g/11g	1195
<i>Chapter Summary</i>	1196
<i>Review Questions</i>	1197
<i>Exercises</i>	1198

## **Chapter 34 OLAP 1199**

34.1 Online Analytical Processing	1200
34.1.1 OLAP Benchmarks	1201
34.2 OLAP Applications	1201
34.3 Multidimensional Data Model	1203
34.3.1 Alternative Multidimensional Data Representations	1203
34.3.2 Dimensional Hierarchy	1205
34.3.3 Multidimensional Operations	1207
34.3.4 Multidimensional Schemas	1207
34.4 OLAP Tools	1207
34.4.1 Codd's Rules for OLAP Tools	1208
34.4.2 OLAP Server—Implementation Issues	1209
34.4.3 Categories of OLAP Server	1210
34.5 OLAP Extensions to the SQL Standard	1214
34.5.1 Extended Grouping Capabilities	1214
34.5.2 Elementary OLAP Operators	1219
34.6 Oracle OLAP	1221
34.6.1 Oracle OLAP Environment	1221
34.6.2 Platform for Business Intelligence Applications	1222
34.6.3 Oracle Database	1222
34.6.4 Oracle OLAP	1224
34.6.5 Performance	1225
34.6.6 System Management	1226
34.6.7 System Requirements	1226
34.6.8 New OLAP Features in Oracle 11g	1226
<i>Chapter Summary</i>	1226
<i>Review Questions</i>	1227
<i>Exercises</i>	1227

## **Chapter 35 Data Mining 1229**

35.1 Data Mining	1230
35.2 Data Mining Techniques	1230
35.2.1 Predictive Modeling	1232
35.2.2 Database Segmentation	1233

35.2.3	Link Analysis	1234
35.2.4	Deviation Detection	1235
35.3	The Data Mining Process	1236
35.3.1	The CRISP-DM Model	1236
35.4	Data Mining Tools	1237
35.5	Data Mining and Data Warehousing	1238
35.6	Oracle Data Mining (ODM)	1239
35.6.1	Data Mining Capabilities	1239
35.6.2	Enabling Data Mining Applications	1239
35.6.3	Predictions and Insights	1240
35.6.4	Oracle Data Mining Environment	1240
35.6.5	New Data Mining Features in Oracle 11g	1241
	<i>Chapter Summary</i>	1241
	<i>Review Questions</i>	1242
	<i>Exercises</i>	1242

## Appendices

**1243**

<b>A</b>	<b>Users' Requirements Specification for <i>DreamHome</i> Case Study</b>	<b>A-1</b>
A.1	Branch User Views of <i>DreamHome</i>	A-1
A.1.1	Data Requirements	A-1
A.1.2	Transaction Requirements (Sample)	A-3
A.2	Staff User Views of <i>DreamHome</i>	A-4
A.2.1	Data Requirements	A-4
A.2.2	Transaction Requirements (Sample)	A-5
<b>B</b>	<b>Other Case Studies</b>	<b>B-1</b>
B.1	The <i>University Accommodation Office</i> Case Study	B-1
B.1.1	Data Requirements	B-1
B.1.2	Query Transactions (Sample)	B-3
B.2	The <i>EasyDrive School of Motoring</i> Case Study	B-4
B.2.1	Data Requirements	B-4
B.2.2	Query Transactions (Sample)	B-5
B.3	The <i>Wellmeadows Hospital</i> Case Study	B-5
B.3.1	Data Requirements	B-5
B.3.2	Transaction Requirements (Sample)	B-12
<b>C</b>	<b>Alternative ER Modeling Notations</b>	<b>C-1</b>
C.1	ER Modeling Using the Chen Notation	C-1
C.2	ER Modeling Using the Crow's Feet Notation	C-1

<b>D Summary of the Database Design Methodology for Relational Databases</b>	<b>D-I</b>
Step 1: Build Conceptual Data Model	D-1
Step 2: Build Logical Data Model	D-2
Step 3: Translate Logical Data Model for Target DBMS	D-5
Step 4: Design File Organizations and Indexes	D-5
Step 5: Design User Views	D-5
Step 6: Design Security Mechanisms	D-5
Step 7: Consider the Introduction of Controlled Redundancy	D-6
Step 8: Monitor and Tune the Operational System	D-6
<b>E Introduction to Pyrrho: A Lightweight RDBMS</b>	<b>E-I</b>
E.1 Pyrrho Features	E-2
E.2 Download and Install Pyrrho	E-2
E.3 Getting Started	E-3
E.4 The Connection String	E-3
E.5 Pyrrho's Security Model	E-4
E.6 Pyrrho SQL Syntax	E-4
<b>F File Organizations and Indexes (Online)</b>	<b>F-I</b>
<b>G When Is a DBMS Relational? (Online)</b>	<b>G-I</b>
<b>H Commercial DBMSs: Access and Oracle (Online)</b>	<b>H-I</b>
<b>I Programmatic SQL (Online)</b>	<b>I-I</b>
<b>J Estimating Disk Space Requirements (Online)</b>	<b>J-I</b>
<b>K Introduction to Object-Orientation (Online)</b>	<b>K-I</b>
<b>L Example Web Scripts (Online)</b>	<b>L-I</b>
<b>References</b>	<b>R-I</b>
<b>Further Reading</b>	<b>FR-I</b>
<b>Index</b>	<b>In-I</b>