Contents

Foreword xv
About the Author xvii
About the Technical Reviewer xix
Acknowledgments xxi

CHAPTER 1 Introducing SQLite 1

An Embedded Database 1
A Developer's Database 2
An Administrator's Database 3
SQLite History 3
Who Uses SQLite 4
Architecture 5
The Interface 6
The Compiler 6
The Virtual Machine 6
The Back-end 7
Utilities and Test Code 8
SQLite's Features and Philosophy 8
Zero Configuration 8
Portability 8
Compactness 8
Simplicity 9
Flexibility 9
Liberal Licensing 9
Reliability 10
Convenience 10
Performance and Limitations 11
Who Should Read This Book 14
How This Book Is Organized 14
Additional Information 16
Summary 16

CHAPTER 2 Getting Started 17

Where to Get SQLite 17
SQLite on Windows 18
Getting the Command-Line Program 18
Getting the SQLite DLL 20
Compiling the SQLite Source Code on Windows 21
Building the SQLite DLL with Microsoft Visual C++ 25
Building a Dynamically Linked SQLite Client with Visual C++ 28
Building SQLite with MinGW 29
SQLite on POSIX Systems 31
Binaries and Packages 31
Compiling SQLite from Source 33
Working with SQLite Databases 34
The CLP in Shell Mode 34
The CLP in Command-Line Mode 41
Database Administration 42
Creating, Backing Up, and Dropping Databases 42
Getting Database File Information 43
Other SQLite Tools 45
Summary 45

CHAPTER 3 The Relational Model 47

Background 47
The Three Components 48
SQL and the Relational Model 48
The Structural Component 49
The Information Principle 49
The Sanctity of the Logical Level 50
The Anatomy of the Logical Level 51
Tuples 52
Relations 52
Tables: Relation Variables 56
Views: Virtual Tables 58
The System Catalog 59

The Integrity Component 60
Primary Keys 60
Foreign Keys 61
Constraints 62
Null Values 63
Normalization 63
Normal Forms 64
First Normal Form 64
Functional Dependencies 64
Second Normal Form 65
Third Normal Form 67
The Manipulative Component 68
Relational Algebra and Calculus 68
Relational Query Language 69
The Advent of SQL 70
The Meaning of Relational 71
Summary 71
References 72

CHAPTER 4 SQL 73

The Relational Model 73
Query Languages 74
The Growth of SQL 74
The Example Database 75
Installation 76
Running the Examples 76
Syntax 77
Commands 79
Literals 79
Keywords and Identifiers 80
Comments 80
Creating a Database 80
Creating Tables 80
Altering Tables 82

Querying the Database 82
Relational Operations 82
The Operational Pipeline 84
Filtering 87
Limiting and Ordering 93
Functions and Aggregates 94
Grouping 97
Removing Duplicates 101
Joining Tables 101
Names and Aliases 109
Subqueries 111
Compound Queries 114
Conditional Results 117
The Thing Called Null 119
Set Operations 122
Modifying Data 123
Inserting Records 123
Updating Records 127
Deleting Records 128
Data Integrity 128
Entity Integrity 128
Domain Integrity 133
Storage Classes 136
Manifest Typing 139
Type Affinity 141
Transactions 147
Transaction Scopes 147
Conflict Resolution 148
Database Locks 151
Deadlocks 151
Transaction Types 152
Database Administration 153
Views 153
Indexes 155
Triggers 158
Attaching Databases 163
Cleaning Databases 164
Database Configuration 165
The System Catalog 168
Viewing Query Plans 168
Summary 169

CHAPTER 5 Design and Concepts 171

The API 171
What's New in SQLite Version 3 172
The Principal Data Structures 172
The Core API 174
Operational Control 182
The Extension API 183
Transactions 186
Transaction Lifecycles 186
Lock States 187
Read Transactions 188
Write Transactions 189
Tuning the Page Cache 192
Waiting for Locks 194
Code 197
Using Multiple Connections 197
Table Locks 198
Fun with Temporary Tables 199
The Importance of Finalizing 201
Shared Cache Mode 202
Summary 203

CHAPTER 6 The Core C API 205

Wrapped Queries 205
Connecting and Disconnecting 206
The exec Query 207
String Handling 211
The Get Table Query 213
Prepared Queries 214
Compilation 216
Execution 216
Finalization and Reset 217
Fetching Records 219
Parameterized Queries 224
Errors and the Unexpected 229
Handling Errors 229
Handling Busy Conditions 232
Handling Schema Changes 233

Operational Control 235
Commit Hooks 235
Rollback Hooks 236
Update Hooks 236
Authorizer Functions 237
Threads 246
Shared Cache Mode 247
Threads and Memory Management 252
Summary 253

CHAPTER 7 The Extension C API 255

The API 256
Registering Functions 256
The Step Function 258
Return Values 258
Functions 259
Return Values 262
A Complete Example 264
A Practical Application 267
Aggregates 278
A Practical Example 280
Collating Sequences 283
Collation Defined 284
A Simple Example 286
Collation on Demand 291
A Practical Application 292
Summary 299

CHAPTER 8 Language Extensions 301

Selecting an Extension 302
Perl 303
Installation 303
Connecting 304
Query Processing 304
Parameter Binding 306
User-Defined Functions and Aggregates 307
Python 310
PySQLite 310
APSW 316

Ruby 319
Installation 319
Connecting 319
Query Processing 320
User-Defined Functions and Aggregates 322
Java 324
Installation 325
Connecting 325
Query Processing 326
User-Defined Functions and Aggregates 328
JDBC 329
Tcl 331
Installation 331
Connecting 331
Query Processing 332
User-Defined Functions 334
PHP 335
Installation 336
Connections 336
Queries 336
User-Defined Functions and Aggregates 339
Summary 340

CHAPTER 9 SQLite Internals 341

The Virtual Database Engine 341
The Stack 343
Program Body 343
Program Startup and Shutdown 345
Instruction Types 347
The B-Tree and Pager Modules 349
Database File Format 349
The B-Tree API 353
The Compiler 355
The Tokenizer 355
The Parser 357
The Code Generator 358
The Optimizer 360
Summary 362

APPENDIX A SQL Reference 365

APPENDIX B C API Reference 395

APPENDIX C Codd's 12 Rules 423

INDEX 425