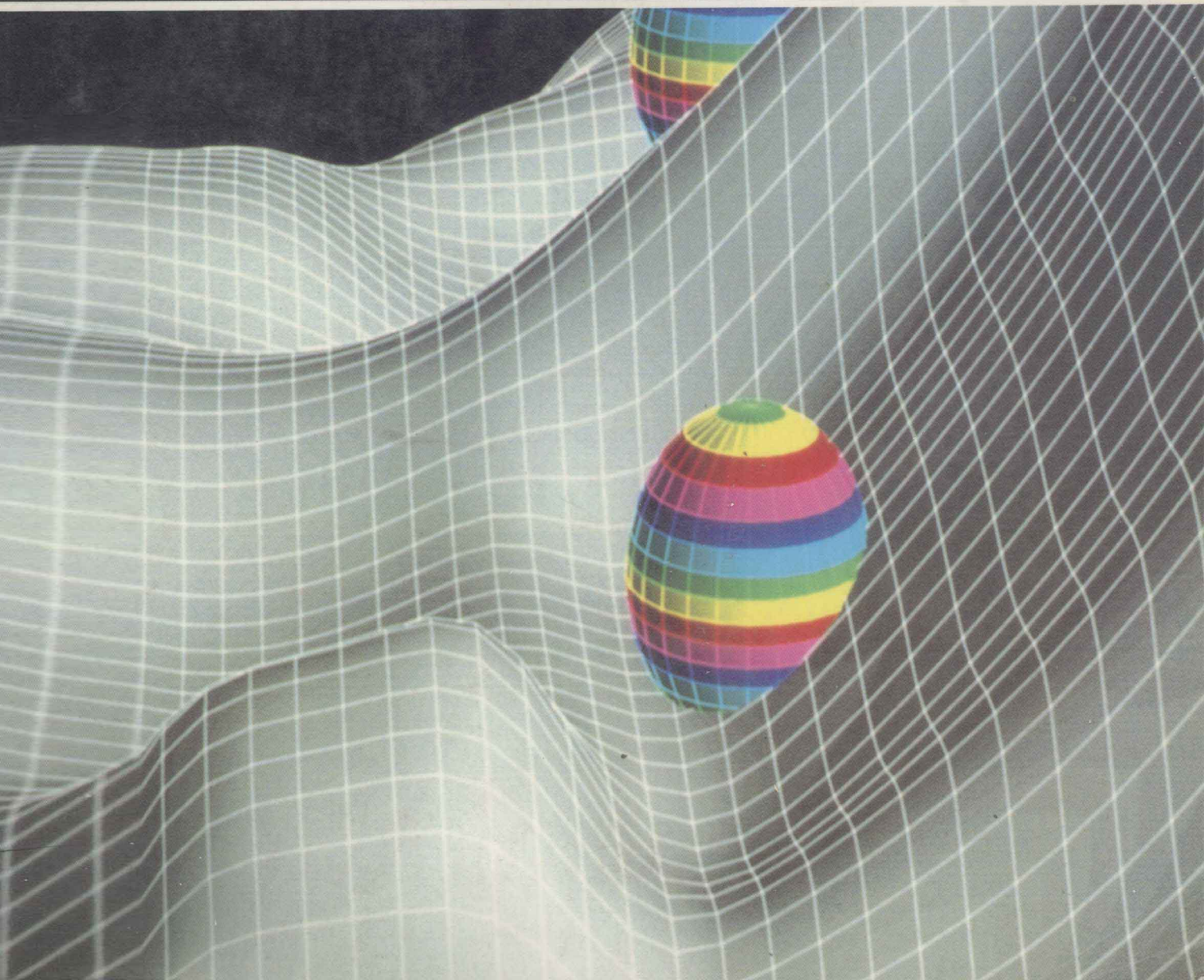


UNDERSTANDING COMPUTERS

Second Edition

Grace Murray Hopper

Steven L. Mandell





Copy Editor: Deborah Annan
Artwork: Barbara Barnett, John Foster, and David Pauly
Composition: Parkwood Composition Service, Inc.
Cover: Melvin L. Prueitt, Motion Picture/Video Production,
Los Alamos National Laboratory

COPYRIGHT © 1984 By WEST PUBLISHING COMPANY

COPYRIGHT © 1987 By WEST PUBLISHING COMPANY
50 W. Kellogg Boulevard
P.O. Box 64526
St. Paul, MN 55164-1003

All rights reserved

Printed in the United States of America

Library of Congress Cataloging-in-Publication Data

Hopper, Grace Murray.
Understanding computers.

Includes index.

1. Electronic digital computers. 2. Microcomputers.

I. Mandell, Steven L. II. Title.
QA76.5.H67 1986 004 86-15914

ISBN 0-314-30382-0

1st Reprint—1987

Photo Credits

1 Courtesy of Gould, Inc.; **3 (top)** Courtesy of Gould, Inc.; **3 (bottom)** Courtesy of Dennis Thurston, Albertson's, Inc.; **4** Courtesy of NYSE/Jeff Aranita; **5 (top)** Reproduced with permission of AT & T Corporate Archive; **5 (bottom)** Courtesy of International Business Machines Corporation; **6** Courtesy of AT & T Bell Laboratories; **7 (top)** Courtesy of International Business Machines Corporation; **7 (bottom)** Crown Copyright, Science Museum, London; **8** (all photos) Courtesy of International Business Machines Corporation; **9 (top)** Crown Copyright, Science Museum, London; **9 (bottom photos)** Courtesy of International Business Machines Corporation; **10 (top)** Culver Pictures; **10 (bottom photos)** Courtesy of International Business Machines Corporation; **11** Courtesy of International Business Machines Corporation; **12 (left)** Courtesy of International Business Machines Corporation; **12 (right)** Cruft Photo Lab, Harvard University; **13 (top)** Courtesy of Sperry Corporation; **13 (bottom photos)** Courtesy of Iowa State University Information Services; **14** Courtesy of The National Museum of American History; **15** Courtesy of The Institute for Advanced Study, Princeton, New Jersey; **16** Courtesy of International Business Machines Corporation; **17 (left)** Courtesy of Sperry Corporation; **17 (right)** US Navy Photo; **18 (both photos)** Courtesy of International Business Machines Corporation; **19** Courtesy of Hewlett-Packard Company; **20** Courtesy of Digital Equipment Corporation; **21 (left)** Courtesy of The Western Design Center; **21 (right)** Courtesy of CASE Communications, Inc.; **22** Courtesy of Gould, Inc.; **23** Photo reprinted by permission of Honeywell, Inc.; **29** Courtesy of Iowa State University Information Services; **30** Courtesy of Iowa State University Information Services; **32** Courtesy of AT & T Bell Laboratories; **33** Courtesy of Iowa State University Information Services; **34** Courtesy of Iowa State University Information Services; **36** Courtesy of Texas Instruments; **37** Courtesy of Motorola, Inc.; **38** Reproduced with permission of AT & T Corporate Archive; **42** Courtesy of BASF Systems Corporation; **43** Courtesy of BASF Systems Corporation;

(continued following index)



About the Authors



Rear Admiral Grace Murray Hopper

B.A. Vassar College, Phi Beta Kappa
M.A. Yale University
Ph.D. Yale University, 1934

Rear Admiral, retired, Special Consultant to the Secretary of the Navy, present

Special Consultant, Digital Equipment Corporation, present

Retired from active duty U.S. Navy, August 14, 1986, in ceremonies held aboard the USS Constitution

Active duty, U.S. Navy, 1944–46, when she assisted in programming the Mark I, the first large-scale digital computer, and 1977–present

Professional Lecturer in Management Sciences, George Washington University, 1971–78

Staff Scientist, Systems Programming, UNIVAC Division of Sperry Corporation, 1964–71

Visiting Lecturer to Adjunct Professor, Moore School of Electrical Engineering, University of Pennsylvania, 1959–present
 Systems Engineer, Director of Automatic Programming Development, UNIVAC Division of the Sperry Corporation, 1952–64
 Senior Mathematician, Eckert-Mauchly Computer Corporation, 1949–52
 Research Fellow in Engineering Sciences and Applied Physics, Computation Laboratory, Harvard University, 1946–49
 Assistant Professor of Mathematics, Barnard College, 1943
 Instructor to Associate Professor in Mathematics, Vassar College, 1931–43

Has received twenty honorary doctorates
 Published over 50 papers and articles on software and programming
 Member ANSI Committee on standardization of computer languages, and presently serving on the CODASYL Executive Committee.
 Received Department of Defense Service Medal (the highest honor accorded in peacetime), 1986
 Received Navy Meritorious Service Medal
 Legion of Merit, 1973
 Distinguished Fellow of the British Computer Society, 1973
 Elected to membership in the National Academy of Engineering, 1973
 Chosen by the Data Processing Management Association as the first Computer Sciences “Man-of-the-Year,” 1969
 Received the 1964 Achievement Award by the Society of Women Engineers

Professor Steven L. Mandell

B.S. Lehigh University
 B.S. Ch.E. Lehigh University
 M.B.A. Wharton School, University of Pennsylvania, IBM Fellow
 D.B.A. George Washington University
 Juris Doctorate, University of Toledo Law School

Professor, Bowling Green State University, 1975–present
 Special Counsel, Marshall & Melborn, Attorneys at Law, Toledo, Ohio
 Director, Management Information Systems Institute, Bowling Green State University, 1977–81
 Associate Director, ADP Management Training Center, U.S. Civil Service Commission, 1972–75
 Captain, U.S. Army, ADP Plans and Operations Officer, 1970–72
 Systems Engineer, IBM Corporation, 1969–1970
 Financial Analyst, TWA, 1968
 Engineer, U.S. Navy, 1967
 Engineer, RCA, 1966

Published numerous textbooks in computers and data processing, and law
 Holds Certificate in Data Processing from the Institute for Certification of Computer Professionals
 Holds Certificate in Data Processing Education
 Served as consultant to Bureau of Land Management
 Served as consultant to the Agency for International Development
 Member of Ohio Bar



Preface



Grace Hopper and Steven Mandell first worked together in 1972 in Washington, D.C. As associate director of computer specialist training with the U.S. Civil Service Commission, Mr. Mandell was responsible for interagency government training programs in advanced computer technology. Commander Hopper became the featured guest lecturer at the sessions and was an advisor to the program.

At George Washington University, Dr. Hopper served as the important link between Mr. Mandell and his dissertation research committee. Her active participation insured the success of the research project and led to a highly successful report published at international conferences on multi-national corporate computer systems.

Together in 1974 Captain Hopper and Dr. Mandell organized the first government-wide conference on minicomputers and microcomputers. It was their belief that this new emerging technology was an important direction for future development. Some of the brightest young individuals in the country participated in this conference. For example, an instructor for the Naval postgraduate school demonstrated one of the first portable computers with a 4-bit Intel chip and a modified operating system. This instructor was Gary Kildall (see chapter 5) who is now president of Digital Research, and the operating system was the beginning of the current standard CP/M.

During the past several years, Commodore Hopper and Professor Mandell have appeared together on several panels at professional meetings. Her trips to Bowling Green to address his students have been a high point for many in their academic experiences. She is continuing her pioneering work in the computer field as a consultant to Digital Equipment Corporation and is a special consultant to the Secretary of the Navy. The nation-wide acclaim received by Rear Admiral Hopper and the success experienced by many of the textbooks authored by Professor Mandell provide the basis for this current project.

The computer revolution continues to have a profound impact upon us as individuals and as members of society. Like the first edition, the second edition of *Understanding Computers* focuses on presenting information that will help people become computer literate so that they may make knowledgeable decisions regarding computers and their use. The book is designed to bridge the computer technology gap in an informative, exciting, and challenging manner. The material covered in the second edition has a

broad scope of coverage and there is a balance among technology, applications, society, and programming.

The basic pedagogical format found in this book is designed to aid in the clear straightforward presentation of the material while including motivational real-world examples. Each chapter begins with an outline that presents a frame of reference for the material that follows. An article with high interest appeal introduces each chapter. Each article was carefully selected, with the intent of maintaining reader interest, from a current periodical. A brief introductory section provides a link to earlier chapters. Easy to locate marginal definitions appear in each chapter for the students' convenience. Summary points at the conclusion of each chapter help students quickly review key topics covered in the material. Review and discussion questions are designed to promote recall of chapter material and stimulate creative thinking.

Two other pedagogical devices that appeared in the first edition also are present in the second edition. Profiles of individuals who have made significant contributions to the computer industry are interspersed throughout the material. Because the computer industry is dynamic, many new profiles appear in the second edition. The issues, a popular feature in the first edition, are located at the conclusion of each chapter. Each issue presents the pros and cons of a controversial societal problem that is related to computers. This approach encourages students to analyze some extremely important problems. Issues from the first edition have been updated and several new issues appear in the second edition.

The appendices cover three highly important subject areas. "Careers" provides students with insight into computer-related job opportunities. "A Consumer's Guide to Microcomputers, Software, and Accessing Networks" gives students the basic information needed for purchasing microcomputers and software as well as using network services. "Flowcharting" supports the use of a programming module with the book.

The BASIC supplement has been entirely rewritten to reflect an emphasis on structured programming and top-down design. The supplement was written with a microcomputer orientation. While all programs were run on the IBM/PC, difference boxes detail any changes necessary to run the programs on other microcomputer systems.

■ Supplementary Educational Material

The Study Guide to accompany this text includes numerous materials for student reinforcement. Each chapter in the Study Guide includes the following: a narrative Summary of the chapter; a Structured Learning section; an extensive set of Questions and Answers (True/False, Matching, Short Answers); and an Answer Key. Each section in the BASIC supplement includes the following: a Summary, Structured Learning, a Worksheet, Programming Problems, and an Answer Key.

A complete instructor resource package has been designed to reduce administrative efforts. The manual provides classroom support and includes: Learning Objectives, Lecture Outline, Answers to Review and Discussion

Questions, and Additional Review and Discussions with Answers. For each section of the BASIC supplement there are four Programming Problems with solutions. There are also answers to Review Questions that appear in the supplement and solutions to debugging exercises and Programming Problems. A Test Bank with hundreds of new multiple choice questions is also included in the Instructor's Manual.

Transparency Masters (an average of four per chapter) present chapter material in a visual form. Most of the transparencies are new and are not merely reproductions of artwork found in the text. A set of color acetate transparencies is also available to qualified adopters.

■ Acknowledgments

I wish to again express my thanks to those people who reviewed the manuscript for the first edition of this text. Their thoughtful comments and suggestions were instrumental to the success of *Understanding Computers*.

George Beekman
Oregon State University

Beverly Bilshausen
College of DuPage, Illinois

Donald H. Cooley
Utah State University

Bill Griffith
College of San Mateo, California

Earl Jackson
North Texas State University

Ed Morris
Highline Community College, Washington

Perry Sanders
Indiana University, Northwest

Robert Schmiederer
Los Angeles Valley College

Michael Ward
Willamette University, Oregon

Susan P. White
Catonsville Community College, Maryland

Jean Wirsig
University of Wisconsin, River Falls

Louis Wolff
Moorpark College, California

In preparation of this second edition, the following people provided invaluable comments based on their experience using *Understanding Computers*. My sincere thanks to each of them.

Alan Broyles
York Technical College, South Carolina

Rhonda Cotton
Mississippi State University

Ralph W. Ewton Jr.
University of Texas, El Paso

Lawrence Turner
Andrews University, Michigan

Baldwin van der Bijl
Clackamas Community College, Oregon

Frank J. Wiggins
University of Arkansas

Dick A. Wood
Seattle Pacific University

Many individuals and companies have been involved in the development of the material for this book. Numerous corporations and government agencies provided the color pictures found in this book. Many professionals provided the assistance required for completing a text of this magnitude: Susan Moran on content development; Sarah Basinger on Issues; Laura Bores on Profiles; Alan Johnson on student and instructor material; Melissa Landon on photos; Norma Morris, Meredith Flynn, and Donna Pulchen on manuscript development; Sue Baumann, Irene Bulas, and Sara Fetterman on the BASIC Supplement; Dave Biesiada on student material; Sally Oates, Shannon Benschoter, Linda Cupp, and Ann Bressler on manuscript preparation. The design of the book is a tribute to the many talents of William Stryker. One final acknowledgment goes to my publisher and valued friend, Clyde Perlee, Jr., for his encouragement and ideas.

Steven L. Mandell



Contents In Brief



Chapter 1 ■ An Invitation to Computers 1

- Article: When the Computer is Down 2
Issue: Man the Thinkist, Woman the Typist? 24

Chapter 2 ■ The Machine Itself: Hardware 29

- Article: Light Beam Focuses on Counterfeiting 30
Issue: Japan or Us? 58

Chapter 3 ■ The Computer: How It Processes and Communicates Data 63

- Article: Electronic "Noise" Makes Trouble 64
Issue: Computer Mistakes: Who Is Responsible? 87

Chapter 4 ■ Communicating with the Computer: Programming 93

- Article: Forty Days and Forty Nights 94
Issue: Programming: Art or Science? 123

Chapter 5 ■ The Microcomputer Revolution 129

- Article: A Comedy Writer's Portable Sidekick 130
Issue: Who Should Monitor Bulletin Boards? 153

Chapter 6 ■ Application Software 157

- Article: Moving the Ship of State a Little Faster 158
Issue: Software Piracy: Justified or Not? 179

Chapter 7 ■ Solving Problems Using Computers: System Analysis 183

Article: Taking Conventional Programs Beyond Intended Limits 184
Issue: It's Midnight. Do You Know Where Your Data Is? 205

Chapter 8 ■ Computers in Education 211

Article: The Kids Who Teach Teachers to Compute 212
Issue: BASIC or Pascal? 234

Chapter 9 ■ The Automated Office 239

Article: Designing a Computer Workplace 240
Issue: Are Computers Breaking Down Interpersonal Relationships? 258

Chapter 10 ■ Computers in Business and Industry 263

Article: The Business of Brokering Information 264
Issue: Industrial Robots: Improving Work or Eliminating Workers? 282

Chapter 11 ■ Computers in Science, Medicine, and Research and Design 287

Article: One Big Step for Mageir 288
Issue: No House Calls for this Doc 309

Chapter 12 ■ Computers in Society: Art, Entertainment, and Sports 315

Article: Computer Designing Ski Slopes 316
Issue: Creative Computers: Is Michelangelo Threatened? 334

Chapter 13 ■ Government, Legislation, Privacy, and Crime 339

Article: Employees Are Biggest Computer-File Criminals 340
Issue: Privacy and the Computer: The Demise of Confidentiality? 360

Chapter 14 ■ The Future 365

Article: What Will "Smart" Robots Mean to You? 366
Issue: Artificial Intelligence—Stepping Stone to Computerized Life? 384

Appendix A ■ Careers 389

**Appendix B ■ A Consumer's Guide to Microcomputers, Software
and Networks 395**

Appendix C ■ Flowcharting 419

BASIC Supplement 425

Glossary 507

Index 517



Contents



An Invitation to Computers

1

- ## Chapter 2

29

- ix

■ Understanding Computers

- **Profile: John Vincent Atanasoff** 34
 - Primary Storage 35
- **Profile: Jack Kilby** 36
 - Secondary Storage 38
- **Hardware for Input and Output** 45
 - Input Devices 46
 - Specialized Input Devices 50
 - Specialized Output Devices 56
- **Issue: Japan or Us?** 58
- **Summary Points** 61
- **Review Questions** 63
- **Discussion Questions** 63

■ Chapter 3

The Computer: How It Processes and Communicates Data

63

-
- **Article: Electronic “Noise” Makes Trouble** 64
 - **Introduction** 65
 - **Digital and Analog Computers** 65
 - **Machine Language** 65
 - **Data Representation** 66
 - Binary Representation 66
 - Octal Number System 67
 - **Profile: Gene Amdahl** 68
 - Computer Codes 68
 - Code Checking 70
 - **Electronic Data Processing (EDP)** 70
 - **Profile: Clive Sinclair** 71
 - **How Computers Process Data** 74
 - **Data Communication** 78
 - Communication Channels 79
 - Message Transmission 80
 - **Communication Networks** 85
 - **Issue: Computer Mistakes: Who Is Responsible?** 87
 - **Summary Points** 89
 - **Review Questions** 90
 - **Discussion Questions** 91

■ Chapter 4

Communicating with the Computer: Programming

93

-
- **Article: Forty Days and Forty Nights** 94
 - **Introduction** 95
 - **Solving Problems with the Computer** 95
 - Define the Problem 96

Design the Solution	96
Write the Program	98
Compile, DeBug, and Test the Program	100
■ Profile: Ted Hoff	101
■ Structured Problem Solving	101
Top-Down Design	102
Documentation	102
Program Testing	103
The Programming Team	104
■ Types of Programs	104
■ Operating Systems	106
Control Programs	107
Processing Programs	108
■ Increasing Programming Efficiency	108
■ Programming Languages	109
Low-Level Languages	110
High-Level Languages	110
■ Profile: John Backus	116
■ Natural Languages	121
■ Issue: Programming: Art or Science?	123
■ Summary Points	125
■ Review Questions	127
■ Discussion Questions	128

■ Chapter 5

The Microcomputer Revolution

129

■ Article: A Comedy Writer's Portable Sidekick	130
■ Introduction	131
■ The Microcomputer Explosion	131
The New Technology	132
Historical Overview	133
■ Profile: Steven Jobs	134
■ Software and Hardware	136
The Microprocessor	136
Operating Systems	137
■ Profile: Gary Kildall	138
Compatibility	140
Microcomputer Peripherals	141
■ Special Microcomputers	145
Portables and Transportables	145
Supermicrocomputers	147
■ Microcomputers and Society	148
Applications	148
Telecommunications	149
User Groups	151
Computer Stores	152
■ Issue: Who Should Monitor Bulletin Boards?	153
■ Summary Points	155
■ Review Questions	156
■ Discussion Questions	156

■ **Chapter 6****Application Software****157**

-
- **Article: Moving the Ship of State a Little Faster** 158
 - **Introduction** 159
 - **Word-Processing Software** 159
 - Uses 163
 - Features 163
 - **Data-Management Software** 164
 - **Profile: Mitchell Kapor** 166
 - Uses 167
 - Features 168
 - **Modeling Software** 169
 - Uses 169
 - Features 170
 - **Graphics Software** 171
 - Uses 171
 - Features 173
 - **Integrated Software** 174
 - Vertical and Horizontal Integration 174
 - Windows 176
 - **Profile: William H. Gates** 177
 - **Issue: Software Piracy: Justified or Not?** 178
 - **Summary Points** 180
 - **Review Questions** 181
 - **Discussion Questions** 181

■ **Chapter 7****Solving Problems Using Computers: System Analysis****183**

-
- **Article: Taking Conventional Programs Beyond Intended Limits** 184
 - **Introduction** 185
 - **System Theory** 185
 - System Analysis 187
 - System Design 190
 - System Implementation 193
 - **Management Information Systems** 195
 - Levels of Management 195
 - **Profile: William Norris** 196
 - Decision-Oriented Reporting 197
 - Management and MIS 198
 - **Data Organization** 198
 - File Organization 200
 - Data-Base Systems 200
 - Data-Base Management System 201
 - **Distributed Computing** 202
 - **Profile: George Tate and Hal Lashlee** 203

- **Issue: It's Midnight. Do You Know Where Your Data Is?** 205
- **Summary Points** 207
- **Review Questions** 208
- **Discussion Questions** 209

■ Chapter 8

Computers in Education

211

- **Article: The Kids Who Teach Teachers to Compute** 212
- **Introduction** 213
- **Computer Literacy** 213
- **Teacher Training** 215
- **Computers in the Classroom** 216
 - Computer-Assisted Instruction 217
 - Networks 219
 - Videodisks 220
 - Programming 220
- **Profile: John G. Kemeny** 221
- **Profile: Seymour Papert** 223
- **Software Support** 223
- **Case Study** 227
- **Computers on Campus** 228
- **Issue: BASIC or Pascal?** 234
- **Summary Points** 236
- **Review Questions** 237
- **Discussion Questions** 238

■ Chapter 9

The Automated Office

239

- **Article: Designing a Computer Workplace** 240
- **Introduction** 241
- **The Electronic Office** 242
 - Local Area Networks 242
- **Profile: Adam Osborne** 244
 - Word Processing 244
 - Electronic Mail 245
- **Profile: John Opel** 246
 - Teleconferencing 247
 - Telecommuting 248
 - Information Retrieval 251
- **Ergonomics** 252
- **Case Study** 255
- **Issue: Are Computers Breaking Down Interpersonal Relationships?** 258
- **Summary points** 260
- **Review Questions** 261
- **Discussion Questions** 262