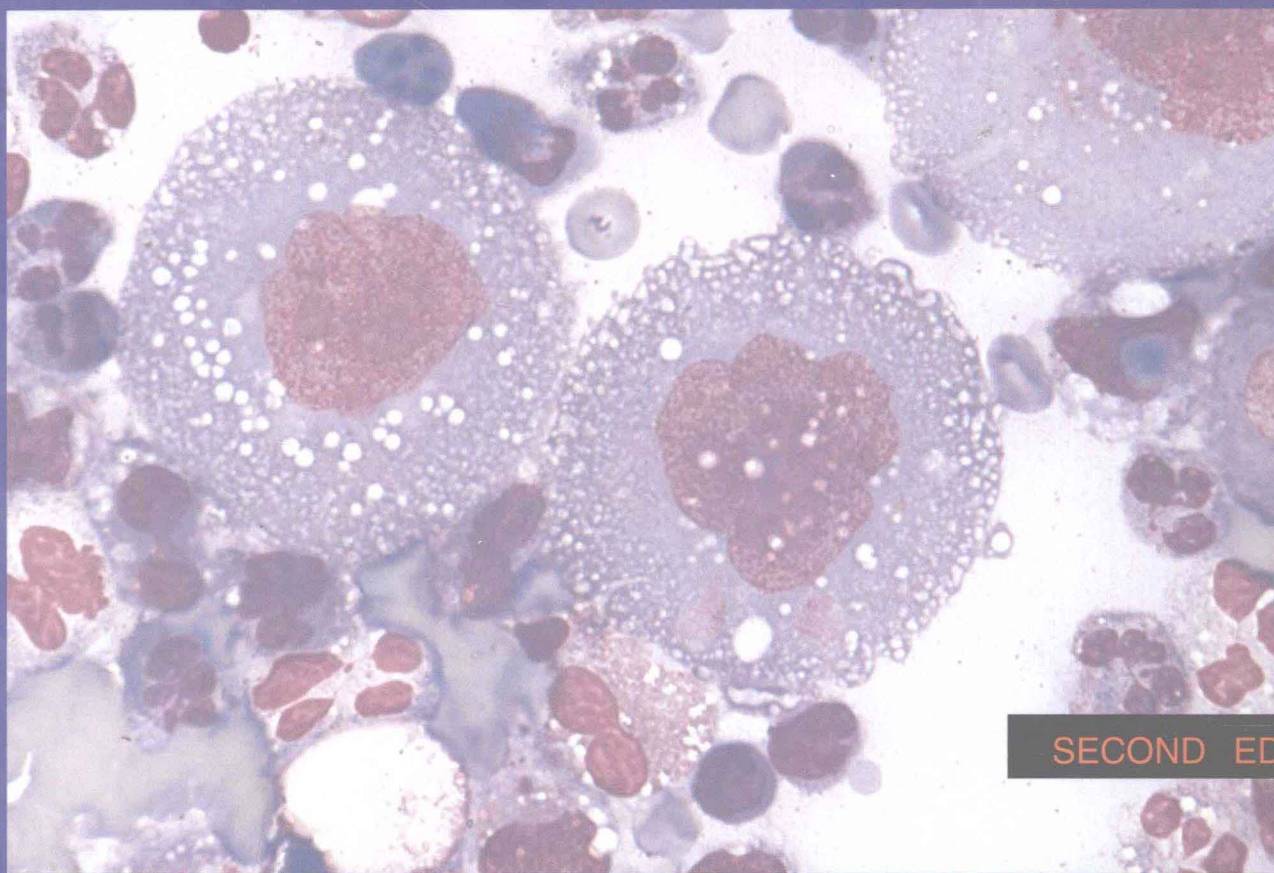


Pearson Clinical Laboratory Science Series

# Clinical Laboratory Hematology



SECOND EDITION

SHIRLYN B. MCKENZIE • J. LYNNE WILLIAMS

Elizabeth Zeibig Series Editor

# CLINICAL LABORATORY HEMATOLOGY

Second Edition

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## DEDICATION

Dedicated to my family, Gary, Scott, Shawn, Belynda, and Dora; my precious grandchildren, Lauren, Kristen, Weston, Waylon, and Wyatt, and to the memory of my parents, George and Helen Olson.

*Shirlyn B. McKenzie*

For my parents, David and Mary Williams, who gave their children roots as well as wings; for Lee, Laurie, Roger, and Richard, who sustain my roots; and for Dulaney, Corie, Chris and Ava, whom I love as my own.

*J. Lynne Williams*

# FOREWORD

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*Clinical Laboratory Hematology* is part of Pearson's Clinical Laboratory Science series of textbooks, which is designed to balance theory and practical applications in a way that is engaging and useful to students. The authors of and contributors to *Clinical Laboratory Hematology* present highly detailed technical information and real-life case studies that will help learners envision themselves as members of the health care team, providing the laboratory services specific to hematology that assist in patient care. The mixture of theoretical and practical information relating to hematology provided in this text allows learners to analyze and synthesize this information and, ultimately, to answer questions and solve problems and cases. Additional applications and instructional resources are available at [www.pearsonhighered.com/mckenzie](http://www.pearsonhighered.com/mckenzie).

We hope that this book, as well as the entire series, proves to be a valuable educational resource.

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# PREFACE

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The second edition of *Clinical Laboratory Hematology* continues as a comprehensive, yet easy-to-read text of hematology and hemostasis written for students at all levels in clinical laboratory science programs, including clinical laboratory technicians (CLT)/medical laboratory technicians (MLT), clinical laboratory scientists (CLS)/medical technologists (MT). Other health professional students and practitioners may also benefit from this book, including pathology residents, medical students, physician assistants, and nurse practitioners. The team of authoritative contributing authors updated chapters with cutting edge advancements. The chapters have a striking design that will appeal to today's visually oriented student. To help readers grasp the content more easily, an exciting set of learning features is included in a repetitive format for each chapter. The book-specific online study guide is available at [www.pearsonhighered.com/mckenzie](http://www.pearsonhighered.com/mckenzie) with additional learning material and self-assessment items.

## ORGANIZATION OF THE BOOK

Understanding hematologic/hemostatic diseases is dependent on a thorough knowledge and understanding of normal processes. Thus, the book begins with a section on normal hematopoiesis and progresses through anemias, nonmalignant and malignant leukocyte disorders. Hemostasis adheres to a similar format with normal hemostasis function discussed first, followed by abnormalities in hemostasis. Hematology and hemostasis laboratory procedures comprise the last section of the book.

Each hematology instructor has his or her idea of the ideal content sequence in which to teach hematology/hemostasis. This edition has a different organization than the first, based on user feedback. The text is divided into sections and may be studied by section or chapter sequence. If the instructor decides to use a different sequence than is used in the book, the background basics that are included in each chapter may help to determine if students have the appropriate background to progress. This gives each instructor flexibility to fit the book to his or her specific course design.

Section One covers an introduction to hematology and hematopoiesis, including a discussion of cell morphology, cell cycle, and its regulation. The cellular processes involved in hematopoiesis and tissue homeostasis have been expanded from one chapter (Chapter 2) in the first edition, to two chapters (Chapters 2 and 3) in this edition. Included in these chapters are discussions of regulation of these processes at the molecular level. Not all educational programs will elect to include Chapter 2, Cellular Homeostasis; alternatively, some may teach it but exclude processes at the molecular level.

Section Two includes chapters on normal hematopoiesis, including a discussion of hematopoietic tissues and organs as well as leukopoiesis, erythropoiesis, and hemoglobin structure and function.

Sections Three through Five cover hematologic disorders. Section Three covers the anemias and begins with an introduction to anemia. Section Four covers nonmalignant disorders of the leukocytes. Section Five is a study of the hematopoietic neoplasms. It begins with an introductory chapter that will help the student understand the classification, terminology, and pathophysiology of these disorders and the laboratory's role in diagnosis and treatment. Some instructors may want to cover the study of bone marrow (Chapter 35), flow cytometry (Chapter 37), cytogenetics (Chapter 38), and molecular genetics (Chapter 39) prior to teaching Section Five, or integrate this material with Section Five.

Section Six is a study of body fluids. Body fluid analysis is often a function of the hematology laboratory, since analysis includes cell counts and review of cell morphology. As much of the analysis includes identification of cells and differentiation of malignant cells from reactive or normal cells, this section has many excellent microphotographs.

Section Seven is a study of hemostasis. It begins with a study of normal hemostasis processes and proceeds to abnormalities associated with bleeding and thrombosis. Due to the high frequency of thrombotic disorders and the rapid discovery of mechanisms responsible for thrombosis, the laboratory's role in diagnosis of thrombotic disorders is expanding. Thus, an entire chapter is devoted to hypercoagulability (thrombophilia). Laboratory testing procedures for evaluation of hemostasis are included in Chapter 40, a chapter that has been expanded significantly from the first edition and written by a CLS coagulation laboratory specialist. Extensive additional material is included on the web page for this chapter, including links to educational videos and detailed laboratory procedures for download.

Section Eight covers hematology and hemostasis procedures. Section Nine is a thorough discussion of quality assessment in the hematology laboratory. Included in this chapter are common abnormal results and alert flags and corrective actions to take. Automation in hematology and hemostasis is supplemented on the Website with extensive use of graphics to illustrate abnormal results using various analyzers and to teach evaluation and interpretation of data.

The text incorporates ethical issues and management issues of test utilization and value, as well as critical testing pathways. This is the soft side of science, but addressing these topics alerts students to issues they will be facing in their work and communities. In many cases the laboratorian is the one who has the breadth of information needed to

help make critical decisions involving the laboratory and its effective, efficient, ethical use.

## SUITABLE FOR ALL LEVELS OF LEARNING

This book has been designed for both CLT/MLT and CLS/MT students. Using only one textbook is beneficial and economical in laboratory science programs offering both levels of instruction. Use of the book is also helpful to programs that design articulated curricula. The CLS/MT program can be confident of the CLT's/MLT's knowledge level in hematology without doing an extensive CLT/MLT course analysis.

Objectives are divided into two levels: Level I (basic) and Level II (advanced). CLT/MLT instructors reviewed the Level I objectives and generally agreed that most are appropriate for the CLT/MLT body of knowledge. These instructors also indicated that some Level II objectives were appropriate for CLT/MLT students. CLS/MT students should be able to meet both Level I and Level II objectives in most cases, but of course there may be differences among programs. Therefore, both CLT and CLS instructors are encouraged to review both levels of objectives to ensure their appropriateness for the course they teach. Although all chapters are appropriate for the CLS/MT student, if the program has two levels of hematology courses, Level I and Level II, instructors may choose to use the book as for a CLT/MLT program in the first course and the remainder of the book in the second course.

All instructors, regardless of discipline or level, will need to communicate to their students what is expected of them. They may want their students to find the information in the text that allows them to satisfy selected objectives, or they may assign particular sections to read. If not assigned specific sections to read, the CLT/MLT student may read more than expected, which is certainly not a bad thing! The two levels of questions at the end of each chapter are matched to the two levels of objectives.

The case study questions and checkpoints are not delineated by level. All students should try to answer as many of these as possible to assess their understanding of the previous material discussed.

Instructors should select appropriate chapters for their students based on the course goals. Some chapters, such as molecular techniques, cytogenetics, flow cytometry and body fluids may not be included in some hematology courses. Each program will need to assess what fits its particular curriculum.

In all cases the instructor should begin the course with Sections One and Two. The remaining sections can be rearranged and used as the instructor desires. The "Background Basics" feature will help the instructor determine which concepts the student should have mastered before beginning a unit of study. This concept should help instructors customize their courses.

## UNIQUE PEDAGOGICAL FEATURES

This text has a number of unique pedagogical features that will help the student assimilate, organize, and understand the information. Each chapter begins with a group of components intended to set the stage for the content to follow.

- **Background Basics** alert students to material that should be learned or reviewed before starting the chapter. In most cases it refers readers to previous chapters to help them find the material if they want to review it.
- **Objectives** are comprised of two levels: Level I for basic or essential information and Level II for more advanced information. These objectives were reviewed by clinical (medical) laboratory technician (CLT/MLT) educators who made recommendations that aimed the Level I objectives to their students. Clinical laboratory science/medical technologist (CLS/MT) educators may expect their students to meet both Level I and Level II objective requirements.
- **Overview** gives the reader an idea of the chapter content and organization.
- **Key terms** alert the student to important terms used in the chapter and found in the glossary.

Each chapter offers students a variety of opportunities to assess their knowledge and ability to apply it.

- **Case Study** is a running case feature that first appears at the beginning of each chapter and focuses the student's attention on the subject matter that the chapter will cover. Throughout the chapter at appropriate places, additional information on the case may be given such as laboratory test results, and then questions are asked. The questions relate to the material presented in preceding sections. Appendix A provides the answers to the Case Study questions.
- **Checkpoints** are integrated throughout the chapter. These questions require the student to pause along the way to recall or apply information covered in preceding sections. The answers are provided in Appendix B.
- A **Summary** concludes the text portion of each chapter in order to help the student bring all the material together.
- **Review Questions** appear at the end of each chapter. The two sets of questions are referenced and organized to correspond to the Level I and Level II objectives. Answers are provided in Appendix C.

The page design features a number of enhancements intended to aid the learning process.

- **Colorful symbols** ★ ■ are used within the chapter text to help the student quickly cross-reference from the tables and figures to the text.
- A ∞ symbol is also used when referring the student to another chapter.
- **Figures and tables** are used liberally to help the student organize and conceptualize information. This is especially important to visual learners.

- **Algorithms** (critical pathways, reflex testing pathways) are used when appropriate to help illustrate effective, cost-efficient use of laboratory tests in diagnosis.
- The **microphotographs** displayed in the book are typical of those found in a particular disease or disorder. Students should be aware that cell variations occur and that blood and bone marrow findings will not always mimic those found in textbooks.

## A COMPLETE TEACHING AND LEARNING PACKAGE

The book is complemented by a variety of ancillary materials designed to help instructors be more effective and students more successful.

**Instructor's Resource Manual**—designed to equip faculty with necessary teaching resources, regardless of the level of instruction. Features include suggested learning activities for each chapter, test item writing guide, introduction to Bloom's taxonomy, crossword puzzles, word finds, sample syllabi, and a transition grid to assist instructors in correlating the content of other hematology texts to this text.

**Instructor's Resource DVD-ROM** (0-13-513737-3)—available upon adoption of the text and gives the instructor access to a number of powerful tools in an electronic format. The following materials are included on the DVD-ROM:

- **Test Bank** includes questions to allow instructors to design customized quizzes and exams using our award-winning TestGen 7.0 test building engine. The TestGen wizard guides you through the steps to create a simple test with drag-and-drop or point-and-click transfer. You can select test questions either manually or randomly and use online spellchecking and other tools to quickly

polish your test content and presentation. You can save your test in a variety of formats both locally and on a network, print up to 25 variations of a single test, and publish your tests in an online course.

- **PowerPoint Lectures** contain key discussion points and color images for each chapter. This feature provides dynamic, fully designed, integrated lectures that are ready to use, allowing instructors to customize the materials to meet their specific course needs. These ready-made lectures will save you time and ease the transition into use of *Clinical Laboratory Hematology*.
- **Image Library** contains all of the images from the text. You have permission to copy and paste these images into PowerPoint lectures, printed documents, or website, as long as you are using *Clinical Laboratory Hematology* as your course textbook.
- Electronic version of the Instructor's Resource Manual in PDF and Word formats can be accessed.
- Bonus image library contains microphotographs of normal and abnormal blood cells filed by chapter. These can be downloaded into your digital presentations or used on password protected course Websites.

**Companion Website** ([www.pearsonhighered.com/mckenzie](http://www.pearsonhighered.com/mckenzie))—This online study guide is completely unique to the market. In addition to providing an array of assessment quizzes, critical thinking questions, and case studies corresponding to each chapter of the book, the website presents additional figures, tables, and information. The quizzes and critical thinking questions have been developed within an automatic grading system that provides users with instant scoring once users submit their answers. Each student's quiz results can be emailed directly to the educator if desired. For procedure chapters, the website also includes detailed laboratory procedures that can be printed for use in the laboratory.



# ACKNOWLEDGMENTS

---

I am grateful to the many contributors who gave their expertise to make this book a comprehensive source of current knowledge in hematology and hemostasis for clinical laboratory science. I am honored to work with so many hematology and hemostasis experts. Thank you for sharing your expertise and for your patience.

We had a great panel of clinical laboratory educators review every chapter for appropriate content. Their reviews were invaluable in helping assure that this book met the needs of both clinical laboratory technicians (medical laboratory technicians) and clinical laboratory scientists (medical technologists) and that it reflects current laboratory practice.

Those who assisted in other tasks are invaluable members of the book's team.

Thank you, Linda Comeaux for updating the accompanying instructor's manual to this book. Thank you to Lynne Williams and Barbara Russell for providing many PowerPoints; to Venus Ward and Karen Brown for reviewing and revising questions, case studies and critical thinking questions on the Website; to Demetra Castillo, Victoria Norbury, and John Landis for writing the questions for the test bank. Thank you to my dear friend, Keila Paulsen, for reviewing chapters, providing excellent cell images for the book and Instructor's Resource DVD-ROM, and for offering many helpful suggestions to improve the book. A project of this size benefits greatly from the many contributions of these experts.

A very special thanks is due to my co-editor, Lynne Williams, for her assistance with this edition. She not only edited many chapters but extensively revised chapters she authored. Her knowledge of hematologic disease at the molecular level was invaluable in assuring this new edition is at the cutting edge of hematology.

I am fortunate to have family members who directly or indirectly support all that I take on. A special thanks to my

devoted husband who made many sacrifices while providing enormous support during the years it took me to complete this project. He put up with my nights and weekends in isolation to finish this project. Thank you also to the rest of my family who help me appreciate what is really important in life: my sons, Scott and Shawn; their wives, Belynda and Dora; my precious grandchildren who make everything worthwhile, Lauren, Kristen, Weston, Waylon, and Wyatt. I owe a great deal of my success to my parents, George and Helen Olson, who gave me the confidence to do anything I put my mind to. During my writing of this edition, they entered their heavenly home.

Thank you also to Mark Cohen, Melissa Kerian, Nicole Ragonese, and Christina Zingone for their assistance in putting this book together. They provided many of the new ideas on the book's design as well as encouragement along the way that it could be done. Melissa and Nicole provided the gentle prodding and follow through to get the job done. Thank you to Linda Duarte and Jessica Balch for their editorial assistance. You are a great team. And finally, a special thanks to Pearson Health Science for publishing this creation.

*SBM*

I would like to extend a special "thank-you" to my colleagues in the Medical Laboratory Sciences Program at Oakland University, Wanda Reygaert and Sumit Dinda, who kept the MLS program moving forward and allowed me to focus on the writing and editing of this new edition. Also to the MLS students of the past two years, who tolerated a distracted and often absent-minded professor—you've been my inspiration to try to create a meaningful and useful book to support your educational endeavors.

*JWL*

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# ABBREVIATIONS

ADCC – Antibody dependent cell-mediated cytotoxicity  
 AHG – Antihuman globulin  
 AIDS – Acquired immune deficiency syndrome  
 AIHA – Autoimmune hemolytic anemia  
 AL – Acute leukemia  
 ALL – Acute lymphoblastic leukemia  
 AML – Acute myeloid leukemia  
 ANLL – Acute nonlymphocytic leukemia  
 APTT – Activated partial thromboplastin time  
 ARC – AIDS related complex  
 Band – Nonsegmented neutrophil  
 BT – Bleeding time  
 CBC – Complete blood count  
 CD – Cluster of differentiation  
 cDNA – Complementary DNA  
 CFU – Colony forming unit  
 CGL – Chronic granulocytic leukemia  
 CLL – Chronic lymphocytic leukemia  
 CML – Chronic myeloid leukemia  
 CMML – Chronic myelomonocytic leukemia  
 CMV – Cytomegalovirus  
 DAF – Decay accelerating factor  
 DAT – Direct antiglobulin test  
 DIC – Disseminated intravascular coagulation  
 dL – Deciliter  
 DNA – Deoxyribonucleic acid  
 DVT – Deep vein thrombosis  
 EBV – Epstein-Barr virus  
 EPO – Erythropoietin  
 ER – Endoplasmic reticulum  
 FA – Fanconi's anemia  
 FAB – French-American-British  
 FFP – Fresh frozen plasma  
 G6PD – Glucose-6-phosphate dehydrogenase  
 Hb or Hgb – Hemoglobin  
 Hct – Hematocrit  
 HDN – Hemolytic disease of the newborn  
 HPFH – Hereditary persistence of fetal hemoglobin  
 HUS – Hemolytic uremic syndrome  
 IAT – Indirect antiglobulin test  
 Ig – Immunoglobulin  
 INR – International normalized ratio  
 IRF – Immature reticulocyte fraction  
 ISC – Irreversibly sickled cells  
 ISI – International sensitivity index  
 ITP – Immune (formerly idiopathic) thrombocytopenic purpura

L – Liter  
 LAP – Leukocyte alkaline phosphatase  
 LCAT – Lecithin:cholesterol acyl transferase  
 LD – Lactic dehydrogenase  
 Lymph – Lymphocyte  
 MAHA – Microangiopathic hemolytic anemia  
 MCH – Mean corpuscular hemoglobin  
 MCHC – Mean corpuscular hemoglobin concentration  
 MCV – Mean corpuscular volume  
 MDS – Myelodysplastic syndrome  
 MHC – Major histocompatibility complex  
 mL – Milliliter  
 Mono – Monocyte  
 MPD – Myeloproliferative disorders  
 MW – Molecular weight  
 NRBC – Nucleated red blood cell  
 PAS – Periodic-acid-Schiff  
 PCH – Paroxysmal cold hemoglobinuria  
 PCR – Polymerase chain reaction  
 PDW – Platelet distribution width  
 PIVKA – Protein-induced by vitamin-K absence (or antagonist)  
 PK – Pyruvate kinase  
 PMN – Polymorphonuclear neutrophil  
 PNH – Paroxysmal nocturnal hemoglobinuria  
 PT – Prothrombin time  
 RA – Refractory anemia  
 RAEB – Refractory anemia with excess blasts  
 RARS – Refractory anemia with ringed sideroblasts  
 RBC – Red blood cell  
 RDW – Red cell distribution width  
 RER – Rough endoplasmic reticulum  
 RNA – Ribonucleic acid  
 RPI – Reticulocyte production index  
 SCIDS – Severe combined immunodeficiency syndrome  
 Seg – Segmented neutrophil  
 SER – Smooth endoplasmic reticulum  
 SLL – Small lymphocytic lymphoma  
 TCR – T cell receptor  
 TIBC – Total iron binding capacity  
 TRAP – Tartrate resistant acid phosphatase  
 TTP – Thrombotic thrombocytopenic purpura  
 VWF – von Willebrand factor  
 WBC – White blood cell  
 WHO – World Health Organization



# CONTENTS

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FOREWORD	vii	CHAPTER 17	Hemolytic Anemia: Immune Anemias	339
PREFACE	ix	CHAPTER 18	Hemolytic Anemia: Nonimmune Defects	367
ACKNOWLEDGMENTS	xiii			
REVIEWERS	xiv	►	<b>Four NONMALIGNANT DISORDERS OF LEUKOCYTES</b>	
CONTRIBUTORS	xvii			
ABBREVIATIONS	xix	CHAPTER 19	Nonmalignant Granulocyte and Monocyte Disorders	383
		CHAPTER 20	Nonmalignant Lymphocyte Disorders	404
►		►	<b>Five NEOPLASTIC HEMATOLOGIC DISORDERS</b>	
► <b>One INTRODUCTION TO HEMATOLOGY</b>				
CHAPTER 1	1	CHAPTER 21	Introduction to Hematopoietic Neoplasms	421
CHAPTER 2	9	CHAPTER 22	Myeloproliferative Disorders	444
CHAPTER 3	31	CHAPTER 23	Myelodysplastic Syndromes	481
►		CHAPTER 24	Acute Myeloid Leukemias	504
► <b>Two THE HEMATOPOIETIC SYSTEM</b>		CHAPTER 25	Acute Lymphoblastic Leukemias	528
CHAPTER 4	50	CHAPTER 26	Lymphoid Malignancies: Chronic Lymphoid Leukemias, Lymphomas, and Plasma Cell Neoplasms	544
CHAPTER 5	62	CHAPTER 27	Hematopoietic Stem Cell Transplantation	568
CHAPTER 6	85	►	<b>Six BODY FLUIDS</b>	
CHAPTER 7	104	CHAPTER 28	Morphologic Analysis of Body Fluids in the Hematology Laboratory	583
►		►	<b>Seven HEMOSTASIS</b>	
► <b>Three THE ANEMIAS</b>		CHAPTER 29	Primary Hemostasis	612
CHAPTER 8	146	CHAPTER 30	Secondary Hemostasis and Fibrinolysis	639
CHAPTER 9	174	CHAPTER 31	Disorders of Primary Hemostasis	671
CHAPTER 10	211	CHAPTER 32	Disorders of Secondary Hemostasis	699
CHAPTER 11	231	CHAPTER 33	Thrombophilia	731
CHAPTER 12	257			
CHAPTER 13	283			
CHAPTER 14	298			
CHAPTER 15	308			
CHAPTER 16	326			

► **Eight HEMATOLOGY PROCEDURES**

CHAPTER 34	Hematology Procedures	762
CHAPTER 35	Bone Marrow Examination	797
CHAPTER 36	Automation in Hematology and Hemostasis	812
CHAPTER 37	Flow Cytometry	836
CHAPTER 38	Chromosome Analysis of Hematopoietic and Lymphoid Disorders	852
CHAPTER 39	Molecular Analysis of Hematologic Diseases	873
CHAPTER 40	Laboratory Testing in Coagulation	889

► **Nine HEMATOLOGY PROCEDURES AND QUALITY ASSESSMENT**

CHAPTER 41	Quality Assessment in the Hematology Laboratory	923
APPENDIX A	ANSWERS TO CASE STUDY QUESTIONS	A-1
APPENDIX B	ANSWERS TO CHECKPOINTS	A-28
APPENDIX C	ANSWERS TO REVIEW QUESTIONS	A-58
GLOSSARY		G-1
INDEX		I-1

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