

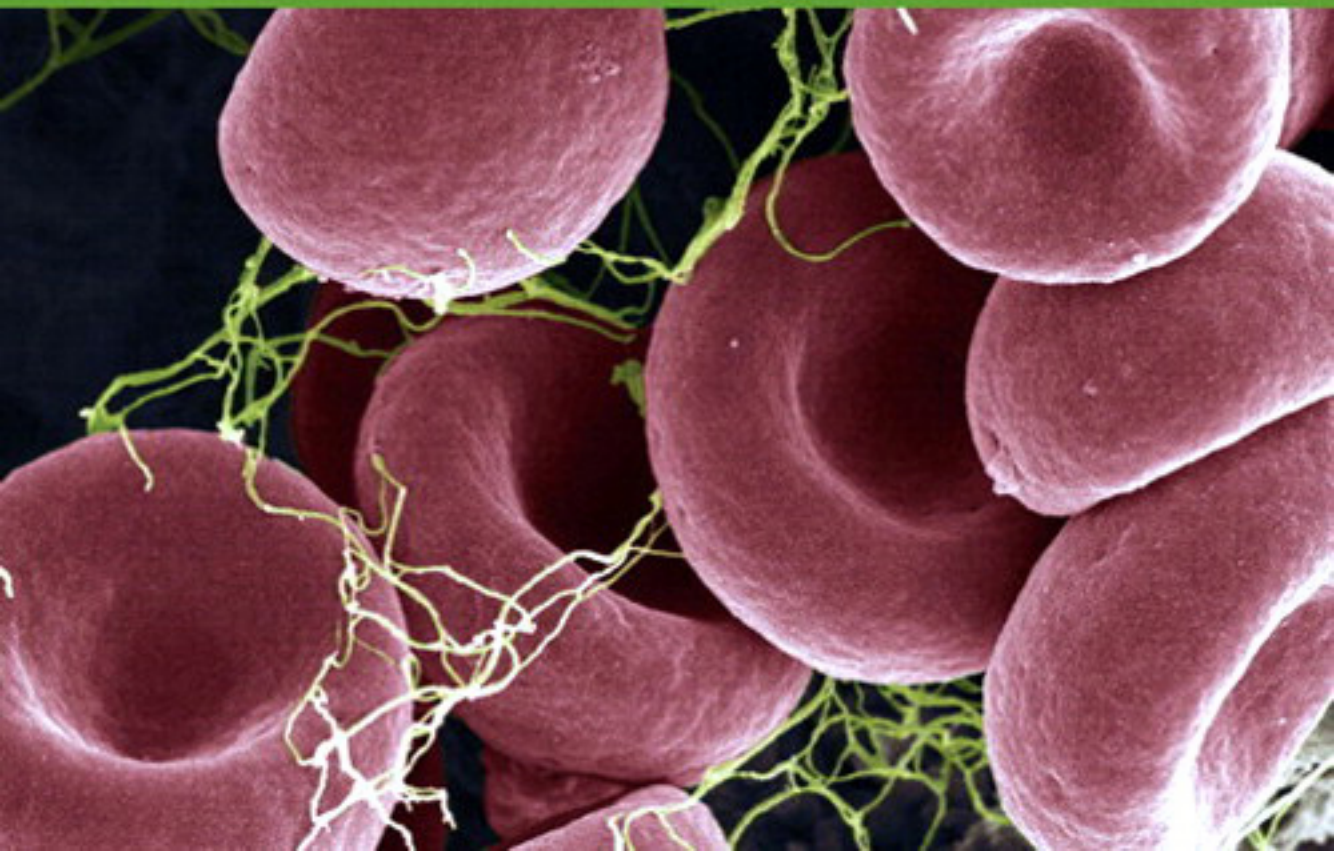
PEARSON CLINICAL LABORATORY SCIENCE SERIES

Clinical Laboratory Hematology

Third Edition

McKenzie | Williams

ELIZABETH A. GOCKEL-BLESSING, SERIES EDITOR



Data for reference values in these tables was compiled from multiple sources. These values will vary slightly among laboratories. Laboratories should derive reference intervals for their population and geographic location.

★ **TABLE A** Hematology Reference Values in Adults and Children (Hb, Hct, and RBC shown in conventional units; SI units in parentheses)

Age	Hb g/dL (g/L)	Hct % (L/L)	RBC × 10 ⁶ /mCL (μL) (×10 ¹² /L)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Reticulocytes % (×10 ⁹ /L)
Adult							
Male	14–17.4 (140–174)	42–52 (0.42–0.52)	4.5–5.5 (4.5–5.5)	80–100	28–34	32–36	0.5–2.0 (25–75)
Female	12.0–16.0 (120–160)	36–46 (0.36–0.46)	4.0–5.0 (4.0–5.0)	80–100	28–34	32–36	0.5–2.0 (25–75)
Critical low limit	6.6 g/dL, 1.7 SD	18%, 5 SD					
Critical high limit	19.9 g/dL, 2.7 SD	61%, 6 SD					
Birth	135–200	0.42–0.60	3.9–5.9	98–123	31–37	30–36	1.7–7.0 (220–420)
2 weeks	130–200	0.39–0.65	3.6–5.9	88–123	30–37	28–35	1.0–3.0 (45–135) (same up to 1 year)
1 month	11–17 (110–170)	33–55 (0.33–0.55)	3.3–5.3	91–112	29–36	28–36	
2 months	9–13 (90–130)	28–42 (0.28–0.42)	3.1–4.3	84–106	27–34	28–35	
4 months	10–13 (100–130)	32–44 (0.32–0.44)	3.5–5.1	76–97	25–32	29–37	
6 months	11–14 (110–140)	31–41 (0.31–0.41)	3.9–5.5	68–85	24–30	33–37	
9 months	11–14 (110–140)	32–40 (0.32–0.40)	4.0–5.3	70–85	25–30	32–37	
1 year	13–14 (130–140)	33–41 (0.33–0.41)	4.1–5.3	71–84	24–30	32–37	
2–6 years	11.5–13.5 (115–135)	34–41 (0.34–0.41)	3.9–5.3	75–87	24–30	31–37	
6–12 years	11.5–15.5 (115–155)	35–45 (0.35–0.45)	4.0–5.2	77–95	25–33	31–37	

Reference intervals derived from combined data. Critical limits are the low and high boundaries of life-threatening values. Results that fall below the low critical limit and above the high critical limit are “panic values” or critical results that require emergency notification of physicians. These limits were derived by Dr. George Kost from a national survey of 92 institutions.

Source: Data from article by Kost GJ: Critical limits for urgent clinician notification at US Medical Centers. *JAMA*. 1990; 263:704.

★ **TABLE B** Age and Race-Specific Reference Intervals for Leukocyte Count and Differential^a

	Birth	6 Months	4 Years	Adult	Adult of African Descent
Total leukocyte count ($\times 10^9/L$)	9.0–30.0	6.0–18.0	4.5–13.5	4.5–11.0	3.0–9.0
Segmented neutrophil: percent (%)	50–60	25–35	35–45	40–80	45–55
Absolute ($\times 10^9/L$)	4.5–18.0	1.5–6.3	1.5–8.5	1.8–7.0	1.5–5.0
Band neutrophil percent (%)	5–14	0–5	0–5	0–5	0–5
Absolute ($\times 10^9/L$)	0.5–4.2	0–1.0	0–0.7	0–0.7	0–0.7
Lymphocyte percent (%)	25–35	55–65	50–65	25–35	35–45
Absolute ($\times 10^9/L$)	2.0–11.0	4.0–13.5	2.0–8.8	1.0–4.8	1.0–4.8
Monocyte percent (%)	2–10	2–10	2–10	2–10	2–10
Absolute ($\times 10^9/L$)	0.2–3.0	0.1–2.0	0.1–1.4	0.1–0.8	0.1–0.8
Eosinophil percent (%)	0–5	0–5	0–5	0–5	0–5
Absolute ($\times 10^9/L$)	0–1.5	0–0.9	0–0.7	0–0.4	0–0.4
Basophil percent (%)	0–1	0–1	0–1	0–1	0–1
Absolute ($\times 10^9/L$)	0–0.6	0–0.4	0–0.3	0–0.2	0–0.2

^aCompiled from multiple sources. Values may vary among sources and laboratories.

★ **TABLE C** Other Hematology Reference Values

Analyte	Reference Value
Immature reticulocyte fraction (IRF)	0.09–0.31
RDW	12–14.6
Platelet count	150–400 $\times 10^9/L$
MPV	6.8–10.2 fL
Sedimentation rate	
Male <50 years	0–15 mm/hr
>50 years	0–20 mm/hr
Female <50 years	0–20 mm/hr
>50 years	0–30 mm/hr
Zeta sedimentation rate	
Male	40–52
Female	40–52
Cerebrospinal fluid	
Erythrocytes	0
Leukocytes	<5/mcL

Clinical Laboratory Hematology

Third Edition

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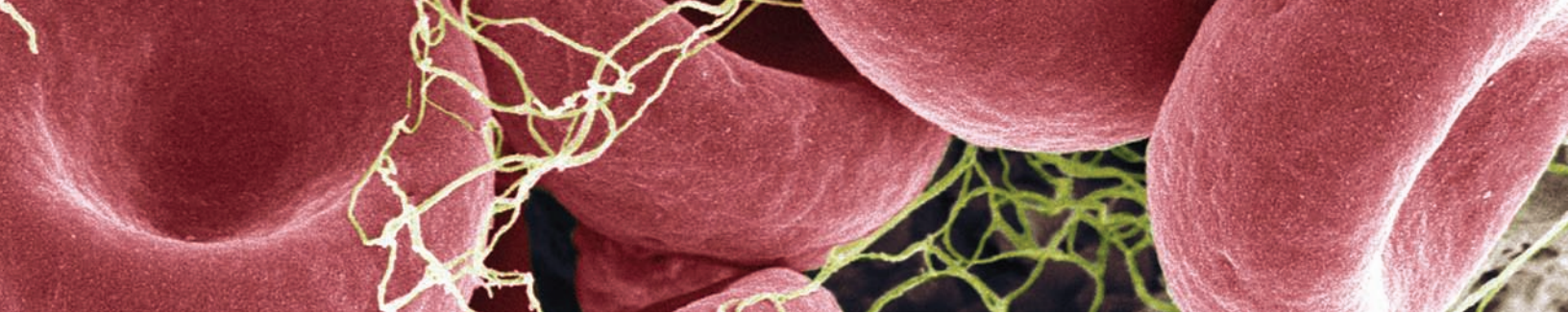
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To my family, the wind beneath my wings, Gary, Scott, Shawn, Belynda, and Dora; my special grandchildren Lauren, Kristen, Weston, Waylon, and Wyatt; to the memory of my parents, George and Helen Olson.

Shirlyn B. McKenzie

For my mother, Mary Williams, who gave her children roots as well as wings; for Lee, Laurie, Roger, and Richard, who sustain my roots; for Dulaney, Corie, Chris, Ava, and Holden, whom I love as my own; and to the memory of my father, David Williams.

J. Lynne Williams



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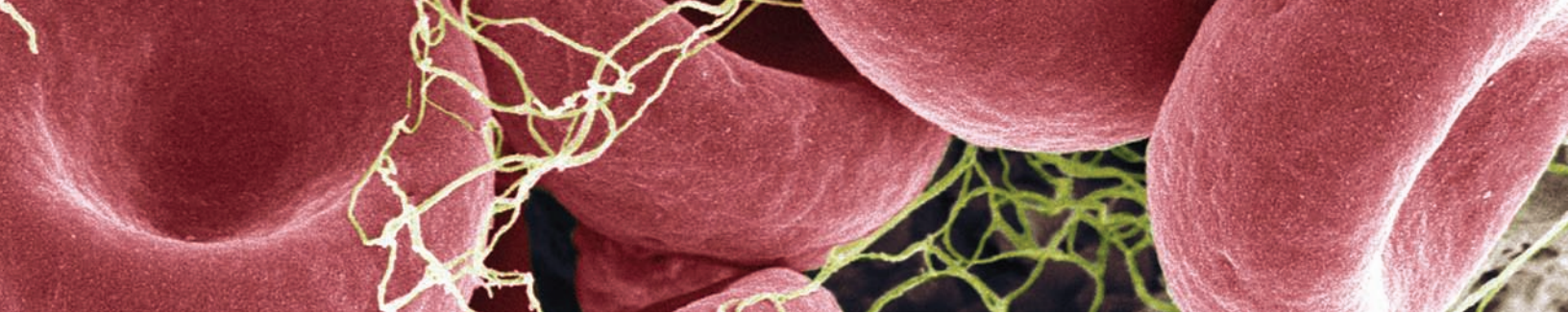
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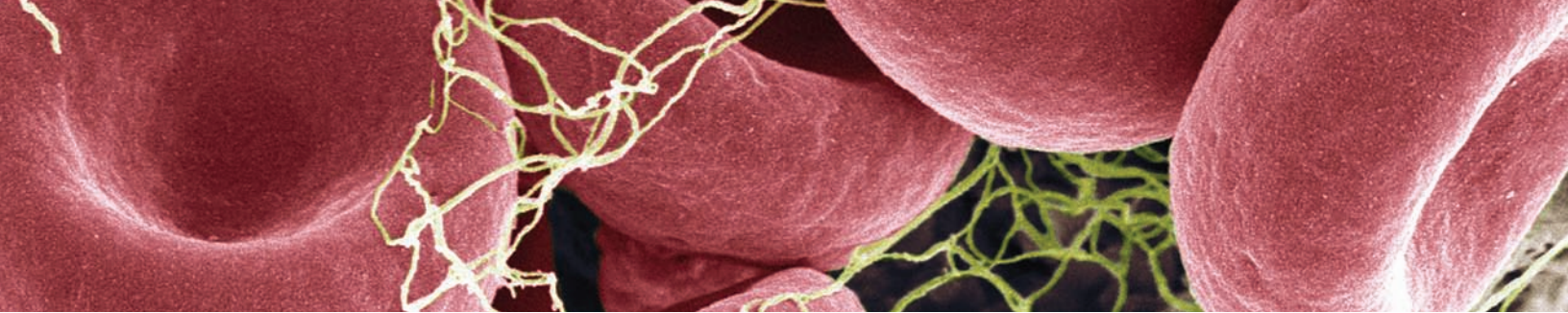
Foreword

Clinical Laboratory Hematology is part of Pearson's Clinical Laboratory Science (CLS) series of textbooks, which is designed to balance theory and practical applications in a way that is engaging and useful to students. The authors 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/healthprofessionsresources.

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

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Preface

As with the first two editions, the third edition of *Clinical Laboratory Hematology* is designed to be a comprehensive resource that medical laboratory technician (MLT) and medical laboratory science (MLS) students can use in all their hematology courses. Laboratory practitioners will find the book a welcome resource to help them keep up with advances in the field. The book also is suited for use by students in other health care professions including pathology, medicine, physician assistant, and nursing. This edition is thoroughly updated to include the latest in advances in laboratory medicine. Each chapter has a similar format; the striking visual design makes it easy for readers to find information on each topic. Multiple supplemental learning tools for students and teaching resources for the instructor, including a website with resources available by chapter, are available. In summary, the book is not just a book but a package of learning tools.

ORGANIZATION

We believe that students must have a thorough knowledge of normal hematopoiesis and cell processes to understand the pathophysiology of hematologic/hemostatic diseases, evaluate and correlate laboratory test results, and ensure the appropriate utilization of the laboratory in diagnosis and patient follow-up. Thus, this book is organized so that the first 10 chapters give the students a comprehensive base of knowledge about blood cell proliferation, maturation, and differentiation and the processes that control hematopoiesis. Section One (Chapters 1–2) includes an introduction to hematology and hematopoiesis, including cell morphology and the cell cycle and its regulation. This introduction includes a description of cellular processes at the molecular level, which could be new material for some students and a basic review for others. The reader might want to review these chapters before beginning a study of neoplastic disorders. Section Two (Chapters 3–10) includes chapters on normal hematopoiesis, including a description of the structure and function of hematopoietic tissue and organs, erythropoiesis, leukopoiesis, and hemoglobin. In this third edition, the chapter on leukocytes is divided into two separate chapters: granulocytes/monocytes (Chapter 7) and lymphocytes (Chapter 8). An introductory chapter on platelets (Chapter 9) was added to this section to complete the discussion of normal blood cells. Details of platelet function and physiology are found in Section Eight,

“Hemostasis.” Chapter 10, “The Complete Blood Count and Peripheral Blood Smear Examination” is a new chapter that describes the information that can be gained about blood cells from these frequently ordered laboratory tests. Most of the remaining chapters refer to the tests that are described in this chapter.

The next three sections include discussions of hematologic disorders. Section Three (Chapters 11–20) begins with an introduction to anemia (Chapter 11). In this edition, we combined the introduction to anemia and the introduction to hemolytic anemia into one chapter because many anemias have a hemolytic component. This chapter is followed by chapters on the various anemias. Each anemia is discussed in the following manner: introduction, etiology, pathophysiology, clinical findings, laboratory findings, and therapy. This format helps readers understand what laboratory tests can help in diagnosis and how to interpret the results of these tests. Section Four (Chapters 21 and 22) covers the nonmalignant disorders of leukocytes. Section Five (Chapters 23–29) is a study of hematopoietic neoplasms. This section begins with an overview of these disorders to help students understand the classification, terminology, and pathophysiology of neoplasms and the laboratory’s role in diagnosis and therapy. As a part of this section, we included a chapter on stem cell therapy (Chapter 29) because it is a frequently used therapy for these neoplasms and the laboratory plays a critical role in harvesting the stem cells and preparing them for transplant. Molecular studies are becoming a major diagnostic tool for neoplastic disorders and are discussed within each chapter as well as in the chapter devoted to molecular diagnostics (Chapter 42). Some instructors might prefer to cover Section Eight, the study of bone marrow (Chapter 38), flow cytometry (Chapter 40), cytogenetics (Chapter 41), and molecular diagnostics (Chapter 42) before teaching Section Five or integrate this material with Section Five. Some hematology courses do not include these topics, or instructors might not want to cover them in the depth presented in this book.

Section Six (Chapter 30) is a study of body fluids from a hematologic perspective and thus includes a large number of photographs of cells found in body fluids. This chapter has been reorganized and revised extensively to give a more complete perspective on body fluid analysis. Discussions of semen analysis and amniotic fluid lamellar body counts have been added. Additional photographs have been added to the online resources. Not all hematology courses include

this topic, but the chapter is written in such a way that it can be used separately in a body fluid course.

Section Seven (Chapters 31–36) is a study of hemostasis. Chapters on normal hemostasis include primary and secondary hemostasis and fibrinolysis. They are followed by three chapters on disorders of hemostasis. Chapter 36 describes the testing procedures for hemostasis, including information on automation. This chapter has been revised by laboratory coagulation specialists and describes an extensive collection of coagulation procedures; additional detailed information on hemostasis testing is available on the chapter's website. These procedures can be downloaded and used as is or adapted for use in student laboratories.

Section Eight (Chapters 37–42) includes chapters on test procedures that help in the diagnosis of hematologic disorders. Automation in hematology is included in Chapter 39. Extensive additional information is included on the book's website and includes step-by-step procedures for some tests, graphs, tables, figures, and printouts of abnormal results using various hematology analyzers. Chapter 42 is designed to introduce molecular procedures and their use in detecting various hematologic and hemostatic disorders. A background in genetics is suggested before students begin this chapter.

Section Nine (Chapter 43) is a thorough discussion of quality assessment in the hematology laboratory. Problems discussed include common abnormal results, errors, and alert flags. Corrective action to take to resolve these problems is described. Several excellent tables help to quickly find needed information. We suggest that these tables be read early in the course of study because they can be used periodically when attempting to interpret and correlate laboratory test results. Chapter 10 refers the reader to these tables because it discusses interpretation of test results and abnormalities in the CBC.

The text emphasizes the effective, efficient, and ethical use of laboratory tests. The clinical laboratory professional is in an ideal position to assist physicians in interpreting laboratory test results and choosing the best reflex tests to arrive at a diagnosis or evaluate therapy. Many laboratories develop algorithms to assist in these tasks. This text includes several algorithms that some laboratories use. To save page space in the text, some algorithms are on the website.

SUITABLE FOR ALL LEVELS OF LEARNING

The book is designed for both MLT and MLS students. Using only one textbook for both levels is beneficial and economic for laboratory science programs that offer both levels of instruction. It also is helpful for programs that have developed articulated MLT to MLS curricula. The MLS program can be confident of the MLT's knowledge in hematology without doing a time-consuming analysis of the MLT course.

Objectives are divided into two levels: Level I (basic) and Level II (advanced). MLT instructors who reviewed the objectives for this text generally agreed that most Level I objectives are appropriate for the MLT body of knowledge. They also indicated that some Level II objectives are appropriate for MLTs. MLS students should be able to

meet both Level I and Level II objectives in most cases. If the MLS program has two levels of hematology courses—Level I and Level II—this book can be used for both.

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

The Case Study questions and the Checkpoints are not delineated by level. All students should try to answer as many of them as possible to assess their understanding of the material.

We recognize that there are many approaches to organizing a hematology course and that not all instructors teach in the same topic sequence or at the same depth. Thus, we encourage instructors to use the book by selecting appropriate chapters and objectives for their students based on their course goals. Each program should assess what content fits its particular curriculum. The layout of the book is such that instructors can select the sequence of chapters in an order that fits their course design, which might not necessarily be the sequence in the book. However, we recommend that the course begin with Sections One and Two and that the chapters "Introduction to Anemia" and "Introduction to Hematopoietic Neoplasms" be studied before the individual chapters that follow on these topics. The Background Basics sections help the instructor determine which concepts students should master before beginning each chapter. This feature helps instructors customize their courses. Some hematology courses might not include some chapters on subjects such as molecular techniques, cytogenetics, flow cytometry, and body fluids but they might be helpful in other courses.

As a note, this text uses mc as an abbreviation for micro, which replaces μ . Thus abbreviations of mcg, mL, mM replace those that use the Greek letter "mu" (μ g, μ L, μ M).

UNIQUE PEDAGOGICAL FEATURES

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

- The **Objectives** comprise two levels: Level I for basic or essential information and Level II for more advanced information. Each instructor must decide what to expect their students to know.
- The **Key Terms** feature alerts students to important terms used in the chapter and found in the glossary.
- The **Background Basics** component alerts students to material that they should have learned or reviewed before starting the chapter. In most cases, these features refer readers to previous chapters to help them find the material if they want to review it.
- The **Overview** gives readers an idea of the chapter content and organization.

- The **Case Study** is a running case feature that first appears at the beginning of a chapter and focuses the students' attention on the subject matter that the chapter covers.
- Appropriate places throughout the chapter provide additional information on the case, such as additional laboratory test results followed by questions that relate to the material presented in preceding sections. The book's website provides the answers to Case Study questions.
- The **Checkpoints** components are integrated throughout the chapter. They are questions that require students to pause along the way to recall or apply information covered in preceding sections. The answers are provided on the book's website.
- A **Summary** concludes the text portion of each chapter to help students bring all the material together.
- **Review Questions** appear at the end of each chapter. The two sets of questions, Level I and Level II, are referenced and organized to correspond to the Level I and Level II objectives. Answers are provided in the Appendix.

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

- **Colorful symbols** are used to identify callouts for tables (★) and figures (■) within the chapter text to help students quickly cross-reference from the tables and figures to the text.
- **Figures and tables** are used liberally to help students organize and conceptualize information. This is especially important for visual learners.
- **Microphotographs** are displayed liberally in the book and 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 do not always mimic those found in textbooks. The legend for each microphotograph gives the original magnification but sometimes the image was zoomed to enhance detail.

WHAT'S NEW

Major changes in the text organization are listed here as a quick reference for instructors. In addition to updating, the following changes have been made:

- The leukocyte chapter has been split into two chapters (7 and 8). Chapter 7 includes granulocytes and monocytes; chapter 8 includes lymphocytes.
- An introductory chapter on platelets (Chapter 9) was added to complete the section on blood cells. More detailed information is included in Section Seven, Hemostasis.
- A chapter was added (Chapter 10, The Complete Blood Count and Peripheral Blood Smear Evaluation) to introduce the student to the results and interpretation of two of the most common laboratory tests in hematology.
- Section Five, Hematopoietic Neoplasms, is thoroughly updated using the WHO 2008 classification.

- The body fluid chapter (Chapter 30) was expanded to include more information on procedures and additional body fluids including semen and amniotic fluid. Additional photos of cells are available on the chapter's website.
- Automation in hemostasis testing was moved to the chapter about hemostasis procedures (Chapter 36).
- Chapter 39 includes automation in the hematology laboratory.
- Appendix A contains the answers to chapter review questions. The answers to the case study questions and checkpoints are available on the website.
- Two new comprehensive tables were added to the appendices. The table in Appendix B was developed through a collaborative effort of several authors. It lists hematopoietic neoplasms with the following information on each: immunophenotype using CD markers, cytogenetic abnormalities, and genotypic findings. This table provides a ready reference for information from the chapters in Section Five (Neoplastic Hematologic Disorders) and Section 8 (Hematology Procedures). The table in Appendix C is a comprehensive classification of hematopoietic, lymphopoietic, and histiocytic/dendritic neoplasms using the 2008 WHO classification system.

A COMPLETE TEACHING AND LEARNING PACKAGE

A variety of ancillary materials designed to help instructors be more efficient and effective and students more successful complements this book.

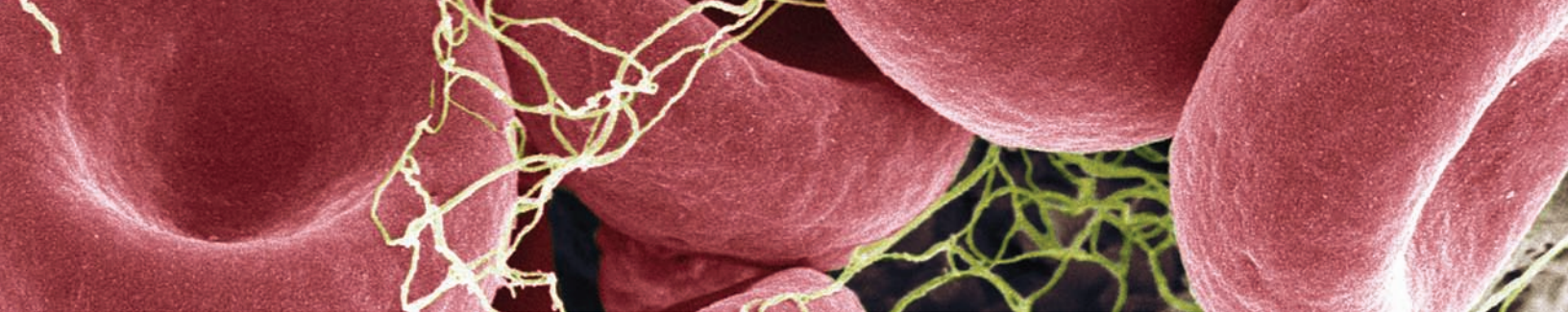
An **Instructor's Resource Center** is available upon adoption of the text and gives the instructor access to a number of powerful tools in an electronic format. The following materials are downloadable:

- The **MyTest** feature includes questions to allow instructors to design customized quizzes and exams. The MyTest guides instructors through the steps to create a simple test with drag-and-drop or point-and-click transfer. Test questions are available either manually or randomly and use online spell checking and other tools to quickly polish the test content and presentation. Instructors can save their tests in a variety of formats both local and network, print as many as 25 variations of a single test, and publish the tests in an online course.
- The **PowerPoint Lectures** tool contains 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 instructors time and allow an easy transition into using *Clinical Laboratory Hematology*.
- The **Image Library** feature contains all of the images from the text. Instructors have permission to copy and paste these images into PowerPoint lectures, printed documents, or website as long as they are using *Clinical Laboratory Hematology* as their course textbook.

- The **Instructor's Resource Manual** tool in PDF and Word formats can be accessed.
- The **Bonus Image Library** feature contains microphotographs of normal and abnormal blood cells filed by chapter. These can be downloaded into instructors' digital presentations or used on password-protected course websites.

COMPANION RESOURCES ([WWW.PEARSONHIGHERED.COM/ HEALTHPROFESSIONSRESOURCES](http://WWW.PEARSONHIGHERED.COM/HEALTHPROFESSIONSRESOURCES))

This online resource page is completely unique to the market. The website presents additional figures, tables, and information for readers. For procedure chapters, the website includes detailed laboratory procedures that can be adapted and printed for use in the laboratory.



Acknowledgments

Writing a textbook is a complicated task that requires a team of dedicated authors, editors, copy editors, artists, permission researchers, educators, practitioners, content reviewers, project and program managers, and many other individuals behind the scenes. The team that Pearson and the editors put together to make the third edition of this book an excellent hematology and hemostasis resource for students and health care practitioners worked tirelessly over several years to bring the project to completion. The new and returning authors ensured that their chapters were up to date and accurate. Content reviewers and users of the second edition provided helpful suggestions that were incorporated into the chapters. Dr. Brooke Solberg had an important role in reviewing the body fluid chapter and making recommendations that enhanced the chapter's content and organization. We offer our thanks to this group who ensured a quality textbook for a wide audience.

Andrea Klingler was our daily contact who kept us on track even though it meant multiple deadline revisions. She was understanding when our mistakes meant more work for her. Her gentle prodding was evident and appreciated. Her editing was superb.

Rebecca Lazure came into the picture later in the process and played an important role in final copyediting. Patty Gutierrez was instrumental in working with permission researchers to obtain permission for use of copyright works.

John Goucher started the ball moving on the third edition. He had faith in us and provided support and encouragement for another edition of *Clinical Laboratory Hematology*. Jonathan Cheung and Nicole Rangone were essential in finding authors for support materials including PowerPoints, test questions, and the instructor's guide. This group of author educators contributed behind the scenes to enhance the instructors' use of this book.

A very special thanks goes to Dr. Kristin Landis-Piwowar, Consulting Editor, who accepted a critical editing role late in our process. Her knowledge and expertise in molecular diagnostics proved invaluable. Her attention to detail, writing ability, and suggestions for organization are evident in her editing. Most notably, she was always willing and able to take additional tasks to help keep us on track.

Although he wasn't involved in producing this edition, Mark Cohen was responsible for the creation of the first edition of this text. His keen insights into developing a unique textbook design with pedagogical enhancements has helped *Clinical Laboratory Hematology* become a leading textbook in the field of clinical laboratory science.

Thank you, Pearson, for having faith in us to publish a third edition. Thank you for providing the special team of experts to help us accomplish this task. We recognize that the job is not over but will require the efforts of sales and marketing to ensure widespread use and adoption.

SBM and JLW

The reason I took the task of writing my first hematology textbook was that as an instructor for medical laboratory science students, I could not find a suitable text for them. Thus, my former students were the inspiration for this book. Thank you for your feedback to help make each edition better.

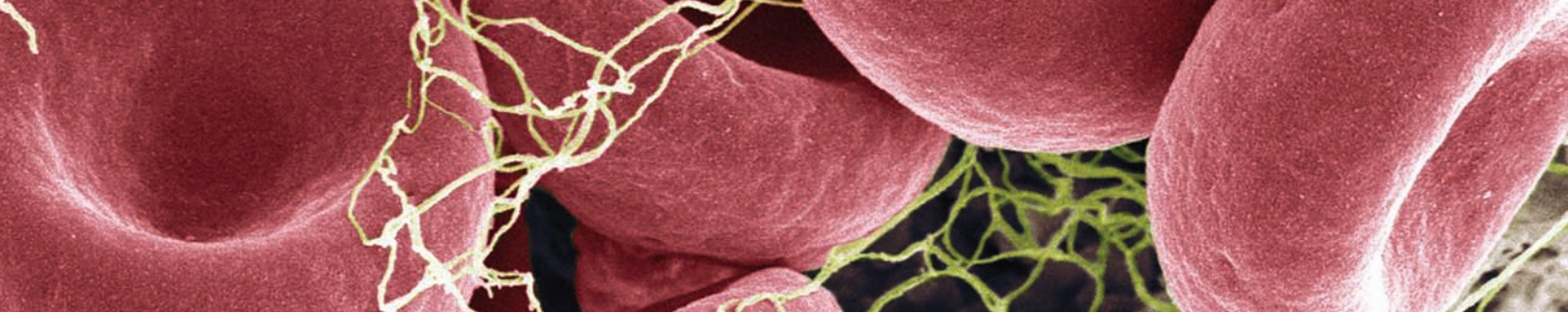
Writing and editing a text of this size is a monumental job. I am privileged to work with my brilliant fellow coeditor and friend, Dr. J. Lynne Williams, who spent many hours of research on topics before editing to ensure that the chapters are up to date and accurate. Her ability to recognize errors is without equal. She spent many late hours at the office to complete editing tasks. We have similar philosophies about teaching hematology and often discussed how to best present the information in this book.

During the time this book was under development, my professional life took over many hours of my personal life. Many thanks to my husband and best friend for his support, sacrifices, and understanding during some very stressful times so this book could become a reality. My parents, George and Helen Olson, instilled in me the confidence that I could accomplish anything I set my heart to. This mind-set has stuck with me through life, especially in this task. I hope that through example I have provided the same to my children and grandchildren.

SBM

I extend a special thank you to my colleagues in the Biomedical Diagnostic and Therapeutic Sciences program at Oakland University—Dr. Kristin Landis-Piwowar, Dr. Sumit Dinda, Lisa DeCeuninck, and our many part-time instructors—who kept the programs moving forward while I was working on this new edition—and to the BDTS students of the past 2 years who tolerated a distracted and often absent-minded professor. To all my former students: You have been my inspiration to try to create a meaningful and useful book to support your educational endeavors. But especially to my coeditor, Dr. Shirlyn McKenzie: thank you for the privilege of accompanying you on this wonderful journey.

JLW



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