KATHY D. BLANEY • PAULA R. HOWARD

BASIC & APPLIED CONCEPTS of BLOOD BANKING and TRANSFUSION PRACTICES

Third Edition

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BASIC & APPLIED CONCEPTS *of*

BLOOD BANKING and TRANSFUSION PRACTICES

Third Edition

Kathy D. Blaney, MS, BB(ASCP)SBB
Tissue Typing Laboratory
Florida Hospital
Orlando, Florida;
LifeSouth Community Blood Centers
Gainesville, Florida

Paula R. Howard, MS, MPH, MT(ASCP)SBB
Community Blood Centers of Florida
A Division of OneBlood, Inc.
Lauderhill, Florida

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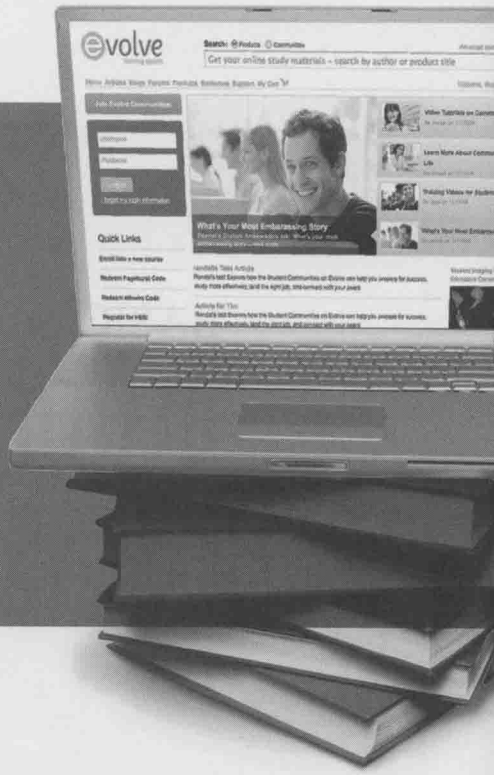

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This book is dedicated to my family, ***Tommy*** *and* ***Sean****, for their support.*
And to all the students and professionals
I have worked with throughout my career in
immunohematology.
KDB

This third edition is dedicated in loving memorium to my parents,
William and Olga Juda,
who encouraged my individuality and desire for continuous learning
and to my partner,
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for his perpetual belief and support of my professional goals.
And as always to all of my
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PRH

Reviewers

Charlotte Bates, MEd, MT(ASCP)
Instructor
Medical Laboratory Science Department
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Clinical Laboratory Science Program
Department of Medical Laboratory Science
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North Dartmouth, Massachusetts

Kim Boyd, MS, MT(AMT)
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Medical Laboratory Technology Program
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Cara Calvo, MS, MT(ASCP)SH
Program Director and Lecturer
Medical Technology Program
Department of Laboratory Medicine
University of Washington
Seattle, Washington

Linda Collins, MS, MT(ASCP)
Instructor
Delaware Technical and Community College
Georgetown, Delaware

Terry Kotrla, MS, MT(ASCP)BB
Department Chair and Professor
Medical Laboratory Technology Program
Austin Community College
Austin, Texas

Max P. Marschner, MBA, MT(ASCP)SBB, CHS
Manager, Tissue Typing Lab
Florida Hospital Medical Center
Orlando, Florida

Nicole S. Pekarek, MAT, MT(ASCP)
Instructor
Clinical Laboratory Science Instructor
Winston-Salem State University
Winston-Salem, North Carolina

Ellen F. Romani, MHSA, MT(ASCP)DLM, BB
Department Chair
Medical Laboratory Technology Program
Spartanburg Community College
Spartanburg, South Carolina

Judith A Seidel, MT(ASCP)SBB
Clinical Instructor, Immunohematology
Clinical Laboratory Science Program
Indiana University Health
Indianapolis, Indiana

Melissa Volny, MT(ASCP)SBB, MBA
Coordinator of Transfusion Services
Centegra Health System
McHenry, Illinois;
Elgin Community College
Elgin, Illinois

Preface

Basic & Applied Concepts of Blood Banking and Transfusion Practices was developed for students in 2- or 4-year medical laboratory science programs, laboratory professionals undergoing retraining, and other health care professionals who desire knowledge in routine blood banking practices. Basic didactic concepts are introduced, and the practical application of these theories to modern transfusion and blood bank settings is emphasized.

The third edition includes updates to the ever-changing field of blood banking. Donor criteria and testing have been updated to include the current donor restrictions, infectious disease testing methods, and current requirements for viral marker testing. A new chapter was added to address automation for the transfusion service. The section on molecular techniques applying to blood banking was expanded, accompanied by an expanded section on HLA. The chapter on blood components and therapy includes a description of new products such as leukoreduced components and red cell apheresis.

This textbook provides important features to assist both the student and the instructor. Each chapter features:

- Chapter outlines listing the important elements in the chapter
- Learning objectives for use by both the student and the instructor
- Study questions for self-assessment
- Key words with definitions on the same page
- Chapter summaries, in varying formats, to provide a succinct overview of the chapter's important points
- Critical thinking exercises to illustrate the practical applications to the clinical environment
- Illustrations and tables designed to reinforce and summarize the most important information found in the chapter

The third edition's presentation of topics was reorganized to improve the overall flow of the information. We also included additional details on some topics more appropriate for the 4-year medical laboratory science programs.

The third edition also has an accompanying Evolve website where the ancillaries are highlighted. For students, the ancillaries include additional case studies and access to the laboratory manual. The instructor ancillaries include an image collection that features figures found in the text, an extensive collection of test bank questions as well as answers to the critical thinking exercises, and PowerPoint presentations for each chapter that include illustrations appearing in this text.

We are very appreciative of the editors at Elsevier for their patience and professionalism in the manuscript review and publication process for this third edition. We are proud of the final product, which is user friendly to students and instructors.

Kathy D. Blaney
Paula R. Howard

Contents

1 IMMUNOLOGY: Basic Principles and Applications in the Blood Bank

CHAPTER OUTLINE

LEARNING OBJECTIVES

On completion of this chapter, the reader should be able to:

1. Define the following terms in relation to red cells and transfusion: antigen, immunogen, epitopes, and antigenic determinants.
2. Describe the characteristics of antigens that are located on red cells, white cells, and platelets.
3. Diagram the basic structure of an IgG molecule and label the following components: heavy and light chains, Fab, and Fc regions, variable region, hinge region, antigen-binding site, and macrophage-binding site.
4. Compare and contrast IgM and IgG antibodies with regard to structure, function, and detection by agglutination reactions.
5. Distinguish the primary and secondary immune response with regard to immunoglobulin class, immune cells involved, level of response, response time, and antibody affinity.
6. Apply the properties that influence the binding of an antigen and antibody to agglutination tests to achieve optimal results.
7. List the variables in the agglutination test that affect sensitization and lattice formation.
8. Accurately grade and interpret observed agglutination reactions using the agglutination grading scale for antigen-antibody reactions performed in test tubes.
9. Compare the classical and alternative pathways of complement activation.
10. Outline the biological effects mediated by complement proteins in the clearance of red cells.
11. Recognize hemolysis in an agglutination reaction and explain the significance.
12. Outline how the immune system responds to antigen stimulation through transfusion and pregnancy. Explain the factors that cause variations in these in vivo responses.
13. Using the principles of tissue matching, select the best potential graft given the HLA typing and antibody specificities.
14. Predict the probable HLA typing results in a family study performed for graft selection.

15. Compare and contrast the class I and II MHC complexes with regard to antigens, their associated immune cells, and their role in immunity.
16. Explain the role of HLA testing in platelet transfusion support, organ transplants, and hematopoietic progenitor cell transplants.
17. Define graft-versus-host disease (GVHD) and select methods of prevention in transfusion and transplantation.
18. Outline the serologic test methods used in HLA typing and antibody identification.

Immunohematology: study of blood group antigens and antibodies.

The science of **immunohematology** embodies the study of blood group antigens and antibodies. Immunohematology is closely related to the field of immunology because it involves the immune response to the transfusion of cellular elements. Red cells (erythrocytes), white cells (leukocytes), and platelets are cellular components that can potentially initiate immune responses after transfusion. To enhance the reader's understanding of the physiology involved in this immune response, this text begins with an overview of the immune system with an emphasis on the clinical and serologic nature of antibodies and antigens.

SECTION 1
CHARACTERISTICS ASSOCIATED WITH ANTIGEN-ANTIBODY REACTIONS

GENERAL PROPERTIES OF ANTIGENS

Antigen: foreign molecules that bind specifically to an antibody or a T-cell receptor.

Allogeneic: cells or tissue from a genetically different individual.

Autologous: cells or tissue from self.

Hapten: small-molecular-weight particle that requires a carrier molecule to be recognized by the immune system.

B lymphocytes (B cells): lymphocytes that mature in the bone marrow, differentiate into plasma cells when stimulated by an antigen, and produce antibodies.

T lymphocytes (T cells): lymphocytes that mature in the thymus and produce cytokines to activate the immune cells including the B cell.

Cytokines: secreted proteins that regulate the activity of other cells by binding to specific receptors. They can increase or decrease cell proliferation, antibody production, and inflammation reactions.

Memory B cells: B cells produced after the first exposure that remain in the circulation and can recognize and respond to an antigen faster.

Plasma cells: antibody-producing B cells that have reached the end of their differentiating pathway.

An **antigen** is a molecule that binds to an antibody or T-cell receptor. This binding can occur within the body (in vivo) or in a laboratory test (in vitro). In chemical terms, antigens are large-molecular-weight proteins (including conjugated proteins such as glycoproteins, lipoproteins, and nucleoproteins) and polysaccharides (including lipopolysaccharides). These protein and polysaccharide antigens may be located on the surfaces of cell membranes or may be an integral portion of the cell membrane. Antigens are located on viruses, bacteria, fungi, protozoa, blood cells, organs, and tissues.

Transfused red cells contain antigens that may be recognized as foreign to the individual receiving the blood. These antigens are called **allogeneic** because they are unfamiliar to the individual being transfused but are derived from the same species. These foreign antigens may elicit an immune response in the recipient. The body's immune system normally recognizes and tolerates self-antigens. These antigens are termed **autologous** because they originate from the individual. However, the failure to tolerate self-antigens may cause an immune response against cells or tissue from self. This immune response to self may result in various forms of autoimmune disease. In terms of transfusion, an allogeneic transfusion involves the exposure to antigens that are different from the individual receiving a transfusion, whereas an autologous transfusion involves antigens that originated in the recipient.

The concept of an antigen having sufficient size to induce an immune response contrasts with a **hapten,** which is a small-molecular-weight particle that requires a carrier molecule to initiate the immune response. Haptens may include medications such as penicillin and are sometimes referred to as partial antigens.

The immune response to foreign or potentially pathogenic antigens involves a complex interaction between several types of leukocytes. In the transfusion setting, immune response is primarily humoral, involving mainly **B lymphocytes (B cells).** Following a transfusion, the recipient's B cells may "recognize" these foreign red cell antigens through B-cell receptors (Fig. 1-1). This recognition causes the B cells to present the antigen to the **T lymphocytes (T cells).** After presentation, the T-cell **cytokines** signal the B cells to be transformed into plasma cells that produce antibodies with the same specificity as the original B-cell receptors. These antibodies are glycoprotein molecules that continue to circulate and specifically recognize and bind to the foreign antigen that originally created the response. **Memory B cells** are also made at this time. If there is a reexposure at a later date, the memory B cells can respond quickly and change into antibody-producing **plasma cells;** memory B cells do not require presentation to the T cell to be activated. Memory B cells allow a fast response to an antigen, an important principle used in vaccination.