Immunohematology

PRINCIPLES & PRACTICE

THIRD EDITION

Eva D. Quinley

Wolters Kluwer Health | Lippincott Williams & Wilkins

thePoint

Immunohematology

PRINCIPLES AND PRACTICE

THIRD EDITION

Eva D. Quinley

MS, MT(ASCP)SBB, CQA(ASQ)

Senior Vice President, Quality and Regulatory Affairs

American Red Cross

Washington, DC

Wolters Kluwer Health | Lippincott Williams & Wilkins

Philadelphia • Baltimore • New York • London

Buenos Aires • Hong Kong • Sydney • Tokyo

Acquisitions Editor: John Goucher
Product Manager: Meredith L. Brittain
Vendor Manager: Kevin Johnson
Design Coordinator: Stephen Druding
Compositor: MPS Limited, A Macmillan Company

Third Edition

351 West Camden Street
Baltimore, MD 21201

530 Walnut Street
Philadelphia, PA 19106

Printed in China

9 8 7 6 5 4 3 2

Library of Congress Cataloging-in-Publication Data
Immunohematology : principles and practice / [edited by] Eva D. Quinley.—3rd ed.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-0-7817-8204-3 (alk. paper)
1. Immunohematology. 2. Blood banks. I. Quinley, Eva D.
[DNLM: 1. Blood Transfusion—methods. 2. Blood Banks. 3. Blood Group Antigens. 4. Blood Grouping and Crossmatching. 5. Hematologic Diseases—immunology. WB 356 I323 2011]

RM171.I43 2011
615'.39—dc22

2009036981

DISCLAIMER

Care has been taken to confirm the accuracy of the information present and to describe generally accepted practices. However, the authors, editors, and publisher are not responsible for errors or omissions or for any consequences from application of the information in this book and make no warranty, expressed or implied, with respect to the currency, completeness, or accuracy of the contents of the publication. Application of this information in a particular situation remains the professional responsibility of the practitioner; the clinical treatments described and recommended may not be considered absolute and universal recommendations.

The authors, editors, and publisher have exerted every effort to ensure that drug selection and dosage set forth in this text are in accordance with the current recommendations and practice at the time of publication. However, in view of ongoing research, changes in government regulations, and the constant flow of information relating to drug therapy and drug reactions, the reader is urged to check the package insert for each drug for any change in indications and dosage and for added warnings and precautions. This is particularly important when the recommended agent is a new or infrequently employed drug.

Some drugs and medical devices presented in this publication have Food and Drug Administration (FDA) clearance for limited use in restricted research settings. It is the responsibility of the health care provider to ascertain the FDA status of each drug or device planned for use in their clinical practice.

To purchase additional copies of this book, call our customer service department at (800) 638-3030 or fax orders to (301) 223-2320. International customers should call (301) 223-2300.

Visit Lippincott Williams & Wilkins on the Internet: http://www.lww.com. Lippincott Williams & Wilkins customer service representatives are available from 8:30 am to 6:00 pm, EST.

CCS1210

This edition of **Immunohematology: Principles and Practice**
is dedicated to my family for their support and encouragement, to all the wonderful individuals who work in this great profession, and with special thoughts of Dr. Breanndan Moore, one of the finest blood bankers and most wonderful human beings I have ever known.

PREFACE

Immunohematology has always been one of the most fascinating and challenging fields in clinical laboratory medicine. *Immunohematology: Principles and Practice* provides clinical laboratory scientists and other health care professionals with a working knowledge of immunohematology. Because the information is presented in a clear and concise manner and is comprehensive and thorough, the text is a useful reference for any individual who desires knowledge of current immunohematology theory.

The third edition of *Immunohematology: Principles and Practice* incorporates the successful elements of the first two editions while expanding on them. Each chapter includes learning objectives, key words, boxes highlighting important concepts, and review questions. A comprehensive glossary and a section of color plates are included for reference as well. These elements serve as aids to increase understanding of the material presented, benefiting both the learner and the instructor.

As with the previous editions, it is the desire of the editor and contributors of this book to provide an excellent resource for those who seek knowledge in immunohematology—one that is written in a manner that is readable, interesting, and easily understood. It is also our hope that the pages of this text will become well worn, having been used time and time again by students, practicing blood bankers, and others who want to know more about this fascinating subject.

ORGANIZATIONAL PHILOSOPHY

This edition of *Immunohematology: Principles and Practice* begins with an overview of blood collection and component practices in Unit 1, "Blood and Blood Components." This unit includes a chapter devoted to apheresis (Chapter 2), one of the fastest growing and most promising methods of blood collection and component harvesting. In Unit 2, "Genetic and Immunologic Principles," chapters on basic concepts of genetics (Chapter 4) and immunology (Chapter 5) provide a foundation for understanding antibody detection and identification (Chapter 6) and the blood group systems (discussed in Unit 4, Chapters 9 through 12).

A thorough discussion of current transfusion practices in Unit 5 (Chapter 13) allows the reader to understand the indications and contraindications for transfusion of various blood components. In Unit 6, "Clinical Conditions Associated with Immunohematology," the importance of transfusion-transmitted diseases is presented (Chapter 15), including etiologic agents, prevalence, pathology, testing, and prevention. This section also includes specific pathologic conditions in which blood banking practices play an important role, such as hemolytic disease of the newborn (Chapter 16) and autoimmune hemolytic anemias (Chapter 17), so that the reader can understand the pathology involved and the interventional role the blood bank plays.

Because regulatory issues have become one of the most important topics in the field of blood banking, Unit 7, "Quality Assurance and Regulatory Issues," includes a chapter devoted to quality assurance and safety issues (Chapter 18) and a chapter on issues related to regulation and accreditation of blood banks (Chapter 19). Unit 8, "Additional Topics of Interest," includes two chapters that are new to this edition: Information Technology (Chapter 20) and Principles of Project Management (Chapter 22). The chapter on process management (Chapter 21) has been expanded to discuss Six Sigma and Lean Principles.

ADDITIONAL RESOURCES

Immunohematology: Principles and Practice, Third Edition, includes additional resources that are available on the book's companion website at thePoint.lww.com/Quinley3e. Students who have purchased the book have access to an online study guide, which includes basic to advanced case studies and questions that are organized to be used as supplements to each chapter. Written with a practical working knowledge of immunohematology, the case studies provide the opportunity to put learned information into practice.

In addition, purchasers of the text can access the searchable Full Text On-line by going to the *Immunohematology: Principles and Practice,* Third Edition website at thePoint.lww.com/Quinley3e. See the inside front cover of this text for more details, including the passcode you will need to gain access to the website.

CONTRIBUTORS

Patricia Arndt, MSMT, MT(ASCP)SBB
Senior Research Associate
American Red Cross Blood Services
Immunohematology Research Laboratory
Pomona, CA

Suzanne Butch, MA, MT(ASCP)SBB
Administrative Manager
University of Michigan Hospitals & Health Centers
Blood Bank—Pathology
Ann Arbor, MI

Tony Casina, BS, MT(ASCP)SBB
Marketing Manager
Worldwide Marketing
Ortho-Clinical Diagnostics
Raritan, NJ

Ann Church, MS
Director of Change Integration
American Red Cross
Biomedical Services
Washington, DC

Susan Connor, MT(ASCP)SBB, MBGM
Clinical & Therapeutic Apheresis Manager
Gambro BCT
Sales & Marketing
Lakewood, CO

Kay Crull, MS, MT(ASCP)SBB
Vice President, Manufacturing
American Red Cross
Biomedical Services
Washington, DC

Julie Cruz, MD
Associate Medical Director
Indiana Blood Center
Indianapolis, IN

Helene De Palma, MT(ASCP)SBB, CQA(ASQ)
Director of Operations
New York Blood Center
Laboratory of Immunohematology
New York, NY

Theresa Downs, BS, MT(ASCP)SBB
Laboratory Supervisor
University of Michigan Health System
Pathology—Blood Bank & Transfusion Service
Ann Arbor, MI

Steve Gregurek, MD
Assistant Professor
Department of Pathology and Laboratory Medicine
Indiana University School of Medicine

Sandra Hedberg, BS, MT(ASCP)
Partner
SoftwareCPR
Clinton, TN

Susan Hsu, PhD
Director, Histocompatibility / Molecular Genetics
American Red Cross
Histocompatibility/Molecular Genetics
Philadelphia, PA

Regina Leger, MSQA, MT(ASCP)SBB, CMQ/OE(ASQ)
Research Associate
American Red Cross Blood Services
Immunohematology Research Laboratory
Pomona, CA

Mary Lieb, BS, MT(ASCP)SBB, CQA(ASQ)
Quality Consultant
Quality Source by Blood Systems Inc.
Scottsdale, AZ

Sandra Taddie Nance, MS, MT(ASCP)SBB
Adjunct Assistant Professor
University of Pennsylvania, Philadelphia, PA
Senior Director
American Red Cross Biomedical Services
Operations and Heritage Division
Philadelphia, PA

Eva D. Quinley, MS, MT(ASCP)SBB, CQA(ASQ)
Senior Vice President, Quality and Regulatory Affairs
American Red Cross
Washington, DC

Marion Reid, PhD, FIMLS
Director of Immunohematology
New York Blood Center
Laboratory of Immunohematology
New York, NY

Scott Schifter, RPh, BS, MBA
Senior Director
American Red Cross
Client Services and Account Management—Biomedical Information Management
Washington, DC

Daniel Smith, MD
Professor
Director of Transfusion Medicine
Pathology and Laboratory Medicine
Indiana University
Indianapolis, IN

Jean Stanley, MT(ASCP)SBB, CQA(ASQ)
Consultant
Quality Focus
Moraga, CA

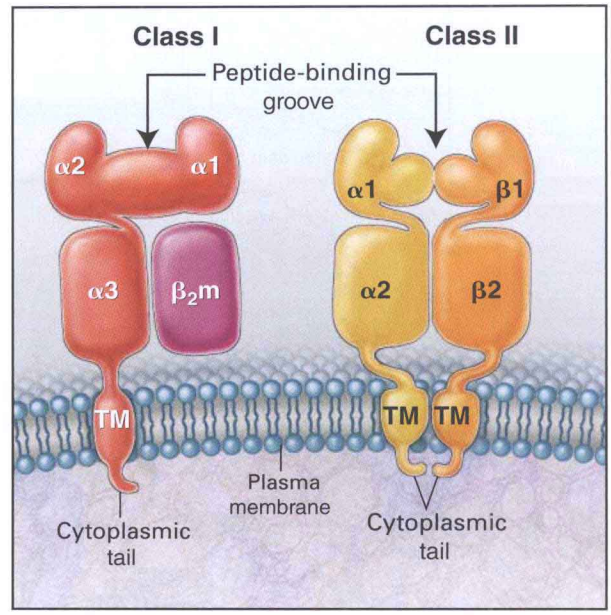
Margaret Stoe, BSMT(ASCP)SBB
Senior Administrative Specialist Healthcare Quality
Corporate Quality Improvement
University of Michigan Hospital and Health System
Ann Arbor, MI

Susan Stramer, PhD
Executive Scientific Officer
American Red Cross
Scientific Support Office
Gaithersburg, MD

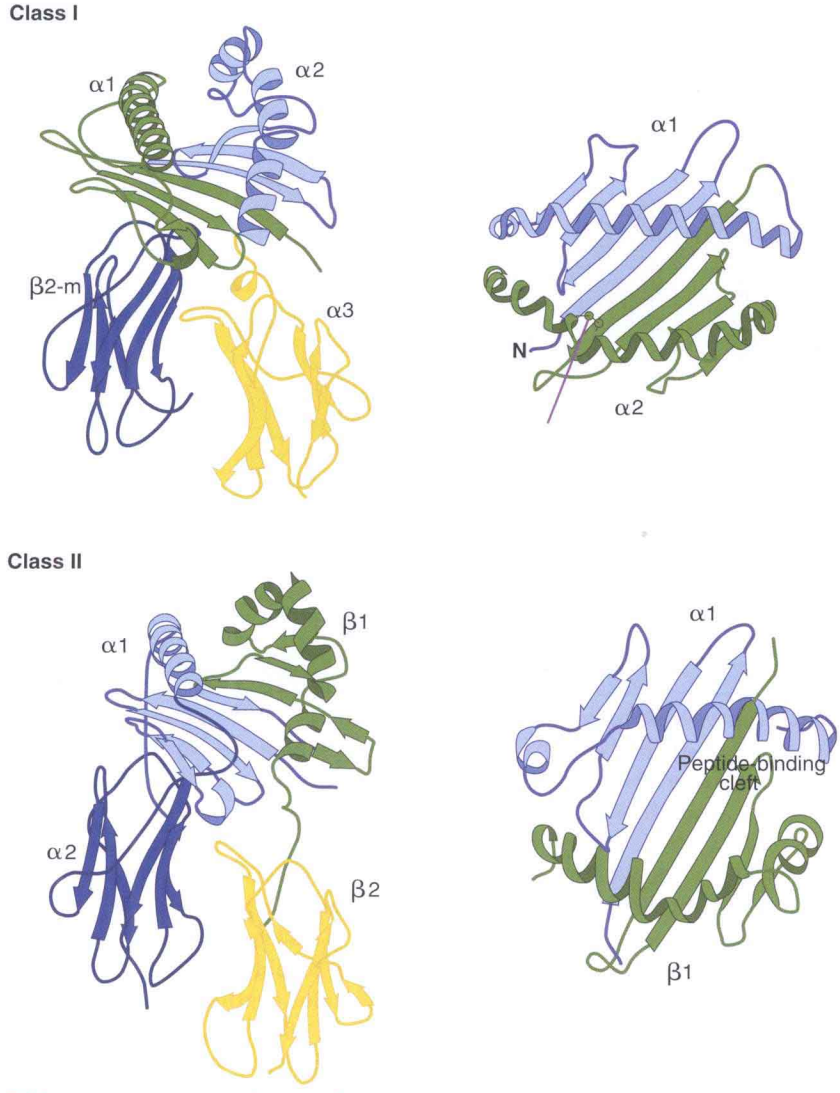
Marla Troughton, MD
Associate Medical Director
BioLife Plasma Services
Birmingham, AL

Dan Waxman, MD
Executive Vice President/Chief Medical Officer
Indiana Blood Center
Indianapolis, IN

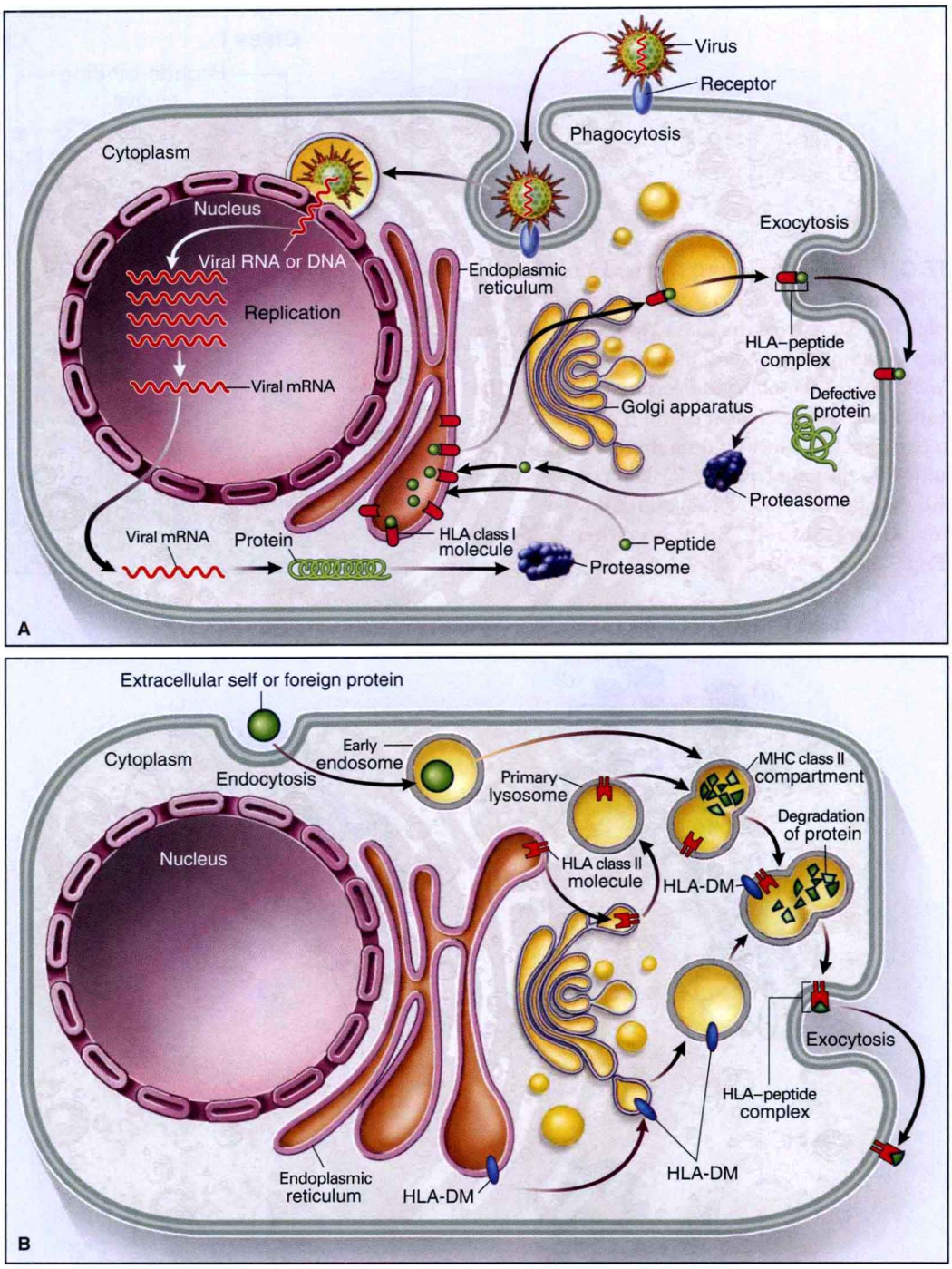
Connie M. Westhoff, MT(ASCP)SBB, PhD
Adjunct Assistant Professor
Pathology and Laboratory Medicine
University of Pennsylvania, Philadelphia, PA
Scientific Director
American Red Cross
Molecular Blood Group and Platelet Antigen Testing
Philadelphia, PA



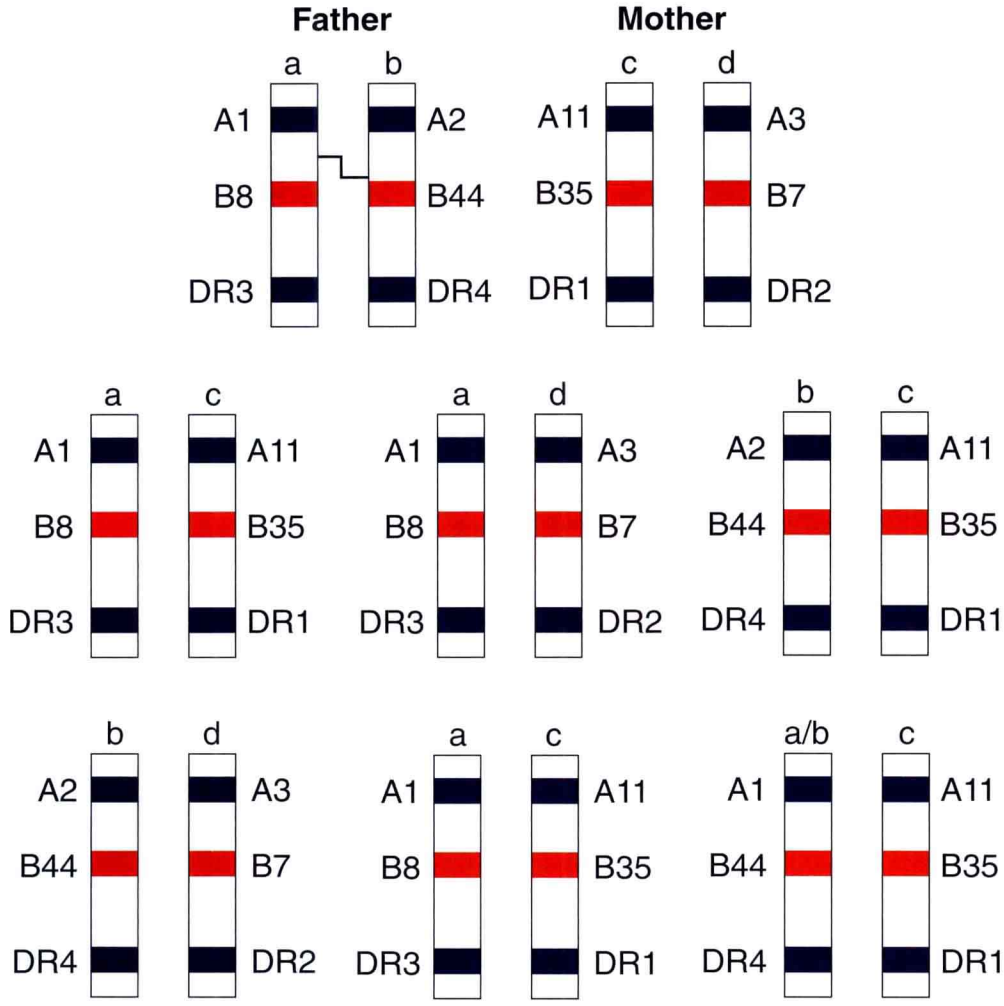
COLOR PLATE C-1 Structures of HLA class I and class II molecules. β_2-Microglobulin (β_2 m) is the light chain of the class I molecule. The α chain of the class I molecule has two peptide-binding domains (α1 and α2), an immunoglobulin-like domain (α3), the transmembrane region (TM), and the cytoplasmic tail. Each of the class II α and β chains has four domains: the peptide-binding domain (α1 or β1), the immunoglobulin-like domain (α2 or β2), the transmembrane region, and the cytoplasmic tail. (Reproduced with permission from Klein J, Sato A. The HLA system: first of two parts. *N Engl J Med*. 2000;343:704.)



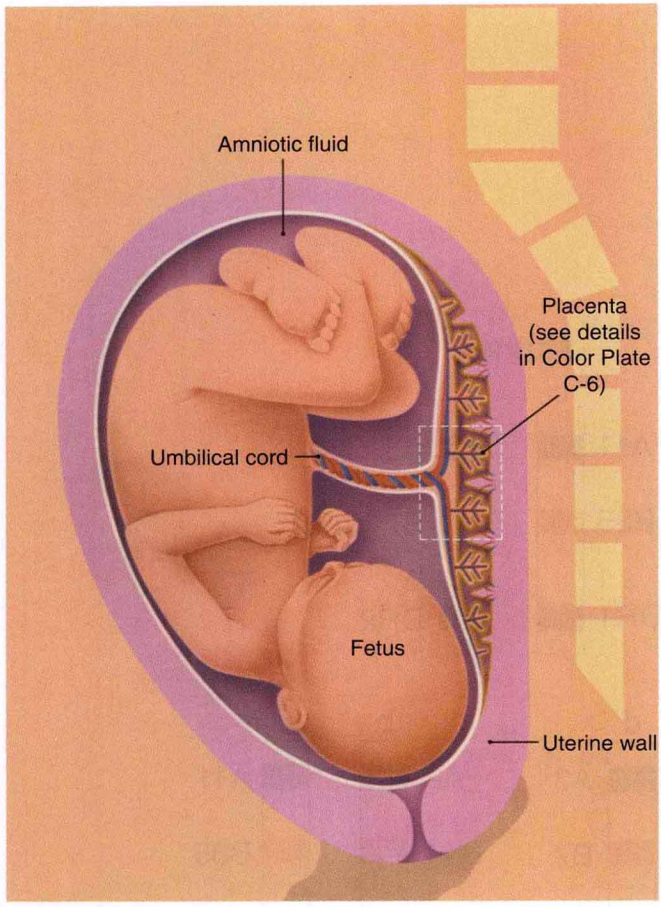
COLOR PLATE C-2 Ribbon structure simulation of the class I and class II HLA molecule and a three-dimensional view of the peptide groove of an HLA class I and class II molecule (Adapted with permission from Macmillan Publishers Ltd. Bjorkman PJ, Saper MA, Samraoui B, et al. The foreign antigen binding site and T cell recognition regions of class I histocompatibility antigens. *Nature*. 1987;329:506).



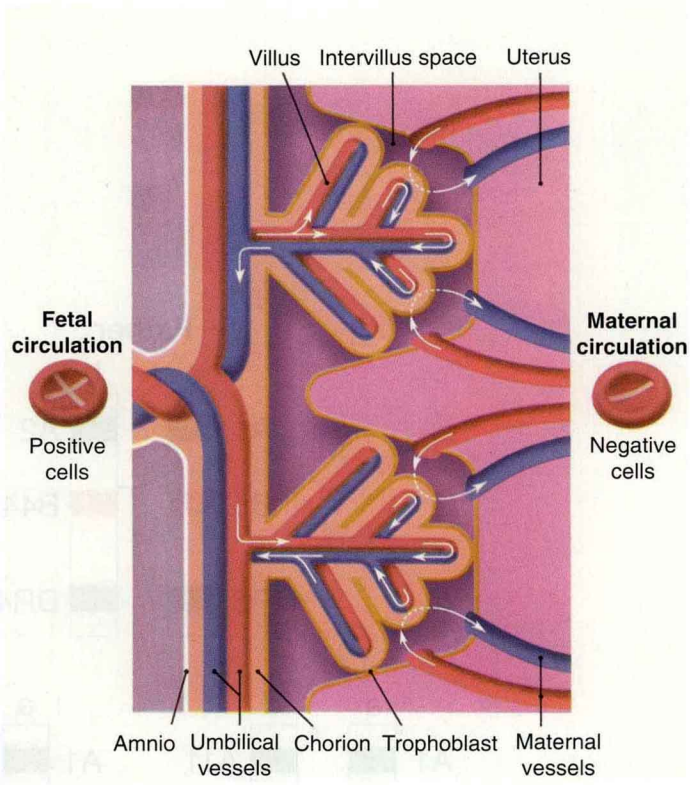
COLOR PLATE C-3 **Antigen processing. Panel A shows the principal pathways of generating peptides for loading onto HLA class I molecules. Worn-out or defective proteins in the cytosol are degraded into peptides in proteasomes. Selected peptides are then transported into the endoplasmic reticulum, where they are loaded onto newly synthesized class I molecules. The HLA–peptide complexes are exported by way of the Golgi apparatus to the surface of the cell. In tissues infected with a virus, viral particles are taken up by cells and uncoated. The viral DNA or RNA enters the nucleus and replicates within it. The viral messenger RNA (mRNA) then enters the cytosol and is transcribed into proteins. Some of the proteins are subsequently degraded in proteasomes, and the peptides are delivered into the endoplasmic reticulum, where they are loaded onto class I molecules for export to the surface of the cell. Panel B shows the processing of extracellular proteins. Self or foreign proteins are taken up by endocytosis (or phagocytosis) and sequestered into endosomes. Class II molecules synthesized in the endoplasmic reticulum are delivered by way of the Golgi apparatus into primary lysosomes, which fuse with the early endosomes to form the major histocompatibility complex (MHC) class II compartment. Enzymes brought into this compartment by the lysosomes degrade the engulfed proteins into peptides. HLA-DM molecules synthesized in the endoplasmic reticulum and delivered into the MHC class II compartment by transport vesicles help load the peptides onto the class II molecules. The HLA–peptide complexes are then exported to the surface of the cell. (Reproduced with permission from Klein, J. The HLA system: first of two parts. *N Engl J Med.* 2000;343:705.)**



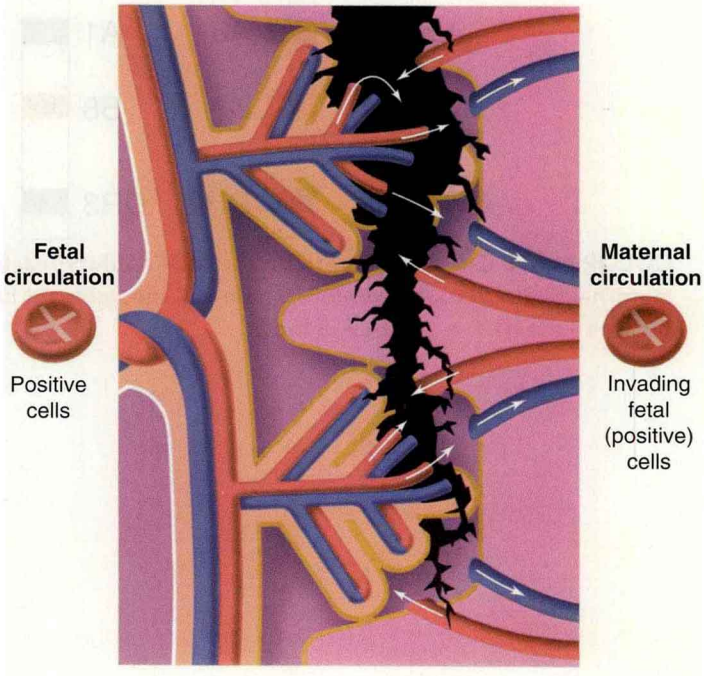
COLOR PLATE C-4 The inheritance of HLA haplotypes. a and b denote paternal haplotypes, and c and d denote maternal haplotypes. a/b denote a paternal recombinant haplotype derived from a recombination event occurring between the HLA-A and HLA-B locus.



COLOR PLATE C-5 Fetus and placenta. (From *Blood Group Antigens and Antibodies as Applied to Hemolytic Disease of the Newborn*. Raritan, NJ: Ortho Diagnostics, Inc.; 1968, with permission.)



COLOR PLATE C-6 Scheme of placental circulation. White arrows depict separate routines of fetal and maternal circulations within the placenta. Dotted lines represent oxygen nutrient and waste exchange through the placental barrier. (From *Blood Group Antigens and Antibodies as Applied to Hemolytic Disease of the Newborn*. Raritan, NJ: Ortho Diagnostics, Inc.; 1968, with permission.)



COLOR PLATE C-7 Separation of placenta following delivery. Diagram portrays the rupture of placental vessels (villi) and connective tissues allowing escape of fetal blood cells. Prior to complete constriction of the open-end maternal vessels, some fetal blood may enter maternal circulation. (From *Blood Group Antigens and Antibodies as Applied to Hemolytic Disease of the Newborn*. Raritan, NJ: Ortho Diagnostics, Inc.; 1968, with permission.)

TABLE OF CONTENTS

UNIT 4
RED BLOOD CELL GROUPS AND HLA 119

UNIT 6
CLINICAL CONDITIONS ASSOCIATED WITH IMMUNOHEMATOLOGY 233