Second Edition

Academic Cell

Primer to The Immune Response

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Mary E. Saunders
Bradley D. Jett

AP Cell PRESS

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AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
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APCell PRESS

AP Cell is an imprint of Elsevier
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
525 B Street, Suite 1900, San Diego, California 92101-4495, USA
84 Theobald's Road, London WC1X 8RR, UK

This book is printed on acid-free paper.

Library of Congress Cataloging-in-Publication Data
Mak, Tak W., 1945-
Primer to the immune response / Tak W. Mak, Mary E. Saunders, Bradley D. Jett; contributors, Wendy L. Tamminen, Maya R. Chaddah.
Includes index.
ISBN-13: 978-0-12-374163-9 (alk. paper) 1. Immune response. 2. Immunology. I. Mak, Tak W., II. Saunders, Mary E., Ph.D. III. Jett, Bradley D., Immune response. IV. Title.
[DNLM: 1. Immune System. 2. Immune System Diseases. 3. Immunity. QW 504 M235p 2008]
QR186.M35 2008
616.07'9–dc22
2008001748

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

ISBN: 978-0-12-385245-8

For information on all AP Cell publications, visit our Web site at www.books.elsevier.com

Printed in China
14 15 16 9 8 7 6 5 4 3 2 1

Abbreviations

ACR	acute cellular graft rejection
ADCC	antibody-dependent cell-mediated cytotoxicity
AHR	acute humoral graft rejection
AICD	activation-induced cell death
AID	activation-induced cytidine deaminase
AIDS	acquired immunodeficiency syndrome
ALL	acute lymphocytic leukemia
AML	acute myeloid leukemia
APC	antigen-presenting cell
β2m	beta2-microglobulin
BALT	bronchi-associated lymphoid tissue
BCR	B cell receptor
BMT	bone marrow transplant
C	constant; or complement component
CD	cluster of differentiation
CDR	complementarity-determining region
CGR	chronic graft rejection
CHS	contact hypersensitivity
CLL	chronic lymphocytic leukemia
CLP	common lymphoid progenitor
CLR	C-type lectin receptor
CML	chronic myelogenous leukemia
CMP	common myeloid progenitor
CMV	cytomegalovirus
CNS	central nervous system
CR	complement receptor
CSF	colony-stimulating factor
cTEC	cortical thymic epithelial cell
CTL	cytotoxic T lymphocyte (effector)
D	diversity
DAMP	damage-associated molecular pattern
DC	dendritic cell
DN	double negative ($CD4^-CD8^-$)
DP	double positive ($CD4^+CD8^+$)
DTH	delayed type hypersensitivity
EBV	Epstein–Barr virus
ER	endoplasmic reticulum
FAE	follicle-associated epithelium
FcR	Fc receptor
FDC	follicular dendritic cell
fTh	follicular Th cells
GALT	gut-associated lymphoid tissue
GC	germinal center
GM-CSF	granulocyte–monocyte colony-stimulating factor
GvHD	graft-versus-host disease
GvL	graft-versus-leukemia effect
H	heavy chain of Ig molecule; or hemagglutinin protein of influenza virus
HAR	hyperacute rejection
HC	hematopoietic cancer
HAV	hepatitis A virus
HBV	hepatitis B virus
HCV	hepatitis C virus
HEV	high endothelial venule
HIV	human immunodeficiency virus
HL	Hodgkin's lymphoma
HLA	human leukocyte antigen
HP	hypersensitivity pneumonitis
HPV	human papilloma virus
HS	hypersensitivity
HSC	hematopoietic stem cell
HSCT	hematopoietic stem cell transplant
HSP	heat shock protein
HSV	herpes simplex virus
IBD	inflammatory bowel disease
IC	immune complex
ICAM	intercellular adhesion molecule
IFN	interferon
Ig	immunoglobulin
Ii	invariant chain
IL	interleukin
iNOS	inducible nitric oxide synthase
ITAM	immunoreceptor tyrosine-based activation motif
ITIM	immunoreceptor tyrosine-based inhibition motif
iTreg	induced regulatory T cell
IV-IG	intravenous immunoglobulin replacement therapy
J	joining
KIR	killer Ig-like receptor
L	ligand; or light chain of Ig molecule
LC	Langerhans cell
LPS	lipopolysaccharide
LT	lymphotoxin
mAb	monoclonal antibody
MAC	membrane attack complex
MAdCAM	mucosal addressin cellular adhesion molecule
MALT	mucosa-associated lymphoid tissue
MAMP	microbiota-associated molecular pattern
MBL	mannose-binding lectin
MBP	myelin basic protein
MCP	mast cell progenitor
MHC	major histocompatibility complex
mIg	membrane-bound Ig
MiHA	minor histocompatibility antigen
MIIC	MHC class II compartment
miRNA	microRNA
MPP	multipotent progenitor
MS	multiple sclerosis
mTEC	medullary thymic epithelial cell
N	neuraminidase protein of influenza virus
NALT	nasopharynx-associated lymphoid tissue
NCR	natural cytotoxicity receptor
NET	neutrophil extracellular trap
NHC	non-hematopoietic cancer
NHEJ	non-homologous end joining pathway of DNA repair
NHL	non-Hodgkin's lymphoma
NK	natural killer cell
NKT	natural killer T cell
NLR	NOD-like receptor
nTreg	natural regulatory T cell
PALS	periarteriolar lymphoid sheath
PAMP	pathogen-associated molecular pattern
PCR	polymerase chain reaction
PD-1	programmed death-1
pDC	plasmacytoid dendritic cell
pIgR	poly-Ig receptor
pMHC	peptide–MHC complex
PMN	polymorphonuclear leukocytes
PRM	pattern recognition molecule
PRR	pattern recognition receptor
pTα	pre-T alpha chain
PTK	protein tyrosine kinase
RA	rheumatoid arthritis
RAG	recombination activation gene
RBC	red blood cell
RCA	regulator of complement activation
RLR	retinoic acid inducible gene-1-like receptor
RNI	reactive nitrogen intermediate
ROI	reactive oxygen intermediate
RSS	recombination signal sequence
S	switch region
SALT	skin-associated lymphoid tissue
SCF	stem cell factor
SCID	severe combined immunodeficiency
sIg	secreted Ig
SIg	secretory Ig
SLC	surrogate light chain
SLE	systemic lupus erythematosus
SMAC	supermolecular activation cluster
SNP	single nucleotide polymorphism
SP	single positive ($CD4^+$ or $CD8^+$)
T1DM	type 1 diabetes mellitus
TAA	tumor-associated antigen
TAP	transporter associated with antigen processing
TB	tuberculosis
Tc	cytotoxic T cell (naïve)
Tcm	central memory T cell
TCR	T cell receptor
Td	T-dependent
TdT	terminal dideoxy transferase
T_{DTH}	T cell mediating delayed type hypersensitivity
TEC	thymic epithelial cell
Tem	effector memory T cell
TGFβ	transforming growth factor beta
Th	helper T cell
Ti	T-independent
TIL	tumor-infiltrating lymphocyte
TLR	Toll-like receptor
TNFR	tumor necrosis factor receptor
TSA	tumor-specific antigen
TSG	tumor suppressor gene
TSLP	thymic stromal lymphopoietin
V	variable
VAERS	Vaccine Adverse Events Reporting System
VCAM	vascular cellular adhesion molecule
VEGF	vascular endothelial growth factor
VZV	varicella zoster virus
WHO	World Health Organization
WT	wild type
XP	xeroderma pigmentosum

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2nd Edition

Cover Image

The cover image portrays a myeloid-derived suppressor cell (MDSC; light-blue cell with short protrusions) as it differentiates into tumor-associated macrophages. Depending on the microenvironment surrounding the tumor (clumps of reddish-brown cells), MDSCs are thought to give rise to either M1 macrophages (dark-brown spherical cells with long protrusions) or M2 macrophages (light-blue spherical cells with long protrusions in the background). M1 macrophages have tumoricidal activities, whereas M2 macrophages promote tumor growth. This image, rendered by Cheng-Jung Lai, was taken from a 2011 article titled "Paired Immunoglobulin-like Receptor-B Regulates the Suppressive Function and Fate of Myeloid-Derived Suppressor Cells," by Ma, G., Pan, P., Eisenstein, S., Divino, C., Lowell, C., Takai, T., and Chen, S. (*Immunity* 34: 385–395). This article is featured in the "Focus on Relevant Research" box in Chapter 16 of the textbook as well as in the corresponding chapter in the associated online study guide (see *Primer to The Immune Response, 2nd Edition* website: http://booksite. academicpress.com/Mak/primerAC/).

An Online Study Guide is now available with your textbook, containing case studies, and all of the journal articles.

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1. To access the Online Study Guide, as well as other online resources for the book, please visit: http://booksite.academicpress.com/Mak/primerAC/

2. For instructor-only materials, please visit: http://textbooks.elsevier.com/web/product_details.aspx?isbn=9780123847430

Preface

In 2008, we published the first edition of *Primer to The Immune Response* (by Drs. Tak W. Mak and Mary E. Saunders). Our goal was to create a compact textbook that would serve as a useful resource for undergraduates in the life sciences or health science professions, or for anyone else who wished to gain a solid grounding in the basic concepts of immunology and its clinical connections. The *Primer* was designed to be a clear and succinct distillation of the immunological essentials that were provided at a more advanced level in our 2005 reference book entitled *The Immune Response*. In 2010, we partnered with Academic Cell to issue the Update Edition of the *Primer to The Immune Response*, which comprised the first edition of the textbook enhanced by an accompanying online study guide. This study guide, authored by Dr. Bradley Jett, featured cases studies in immunology and links to relevant research articles published by Cell Press. Now we are pleased to present a second edition of the *Primer to The Immune Response* textbook and its accompanying online study guide, both of which have been fully updated to include the many exciting advances in immunology over the past few years. Specifically, all chapters now take into account the growing appreciation of the fundamental function of innate immunity as the foundation of all immune responses. As a result, the vital role of chronic inflammation in initiating and perpetuating autoimmune and inflammatory disorders as well as transplant rejection, hypersensitivity and cancer is highlighted. In addition, the critical importance of the body's commensal organism populations to immune protection and maintenance of homeostasis is emphasized, as is the role of local tissue microenvironments in directing immune responses. Lastly, a new chapter is included that draws together current information on immunodeficiencies that are caused by either a genetic abnormality (primary immunodeficiencies) or HIV infection (acquired immunodeficiency syndrome; AIDS).

Our Contributors, educational consultant Wendy Tamminen and illustrator Maya Chaddah, have once again turned their outstanding talents and backgrounds in immunology toward making the *Primer* as useful as possible to readers needing a rapid, accurate and painless introduction to the immune system. We are truly grateful for the sound, logical pedagogy and crystal clear illustrations resulting from their efforts. During its evolution, the *Primer* has also benefitted greatly from the input of numerous experts on a vast array of immunological topics. These experts, many of whom consented to be listed on the Acknowledgements page, gave freely of their valuable time and perceptive insights to improve the quality and accuracy of both the text and the illustrations. Any remaining errors are solely the responsibility of the authors.

As in previous editions, the *Primer to The Immune Response, 2nd Edition* is divided into two major sections: Part I, "Basic Immunology," and Part II, "Clinical Immunology." In both sections, we have attempted to cover the relevant topics in an engaging way that is concise and clear but comprehensive. Part I (Chapters 1–12) describes the cellular and molecular elements of the immune system and immune responses, while Part II (Chapters 13–20) examines how these elements either combine to preserve good health or malfunction to cause disease. Parts I and II are followed by Appendices A–F, which present current information on topics ranging from historical milestones in immunology to comparative immunology to key techniques used in immunology labs. The textbook is completed by the inclusion of an updated and extensive Glossary that defines the key immunological terms shown in bold throughout the text.

With respect to specific textbook features, the most successful of the approaches used in the first edition have been maintained in the second edition, including the use of special topic *Boxes* that provide an extended discussion of a particular point of interest, and the *Take-Home Message* and *Did You Get It? A Self-Test Quiz* at the end of each chapter. Users of our first edition subsequently gave us feedback on additional

features that would increase the utility of our book, and we have listened. New features include tips in the page margins that provide small but important pieces of information for the reader, such as a link to a useful website on the topic under discussion or a cross-reference to another relevant part of the textbook or a salient statistic. *Notes* are small boxes that are embedded in the main text between paragraphs and allow a short, crisp expansion of an associated point. As part of the Academic Cell series, our second edition also contains *Focus on Relevant Research* boxes that give the reader a taste of front-line experimental work and introduce the Cell Press journal article used to build the case study in the corresponding chapter of the online study guide. In addition to these text enhancements, the second edition of the *Primer* contains *Full Color Illustrations* that are not only fully updated with respect to content but also use color as a means of identifying cell lineages and their products. Complete *Figure Legends* are now provided for each figure and plate. Our *Tables*, which are helpful in summarizing important points on a topic, have also been updated. Instructors will appreciate our inclusion at the end of each chapter of a new feature entitled *Can You Extrapolate? Some Conceptual Questions*, the answers for which are supplied online only. Also as requested by our audience, we have provided a supplemental reading list for each chapter entitled *Would You Like to Read More?* As always, we welcome any input that will help to make future editions of this book even more useful for its intended audience.

Our hope is that the *Primer to The Immune Response, 2nd Edition* will propel students on a journey of immunological learning that is rewarding and exhilarating. We are confident that students who embark on this journey will be left in no doubt that the immune system is among the most vital and intriguing elements of the human body.

Tak W. Mak, Mary E. Saunders and Bradley D. Jett

The Academic Cell Approach

In attending conferences and speaking with professors across the biological sciences, the editors at Academic Press and Cell Press learned that journal articles were increasingly being incorporated into the undergraduate classroom experience. They were told of the concrete benefits students received from an early introduction to journal content: the ability to view lecture material in a broader context, the acquisition of improved analytical skills, and exposure to the most current and cutting-edge scientific developments in a given field. Instructors also shared their concerns with the editors about how much additional preparation time was required to find relevant articles, obtain images for classroom presentations, and distill the content of the articles into a form suitable for their students. The desire to provide a solution to these difficulties led to a collaborative effort resulting in the birth of the Academic Cell line of textbooks.

The objective of the Academic Cell initiative is to offer instructors and their students the benefits of a traditional textbook combined with access to an online study guide that highlights the use of primary research articles. The textbook serves as a reference for students and a lecture framework for instructors, and the online study guide is divided into chapters that align with those of the textbook. Each study guide chapter contains a brief summary of the textbook chapter material plus a case study based on a relevant research article chosen from a Cell Press journal. Questions are posed that challenge the student to use the textbook information to understand the research article and work through the case study. The textbook and study guide articles are further integrated by Focus on Relevant Research boxes that appear in the textbook. These passages introduce the Cell Press article used for the accompanying case study and provide context that encourages students to delve further into the article. Instructors will be pleased to note that images from the Cell Press articles have been made available in a PowerPoint format that instructors can use freely. Additional materials contained in the online study guide are the answers to the Conceptual Questions posed in the textbook as well as optional test bank questions and flash cards.

Introduction to the Online Study Guide

Immunology is a complex subject. Over my many years as a research scientist, I have enjoyed the challenge of sharing the mysteries of immunology with students of all ages and educational levels. For younger students, I have tried to explain difficult concepts using simple analogies, such as "The Adventures of Tommy the T Cell," who stands fast against marauders of disease.

For the reader of an immunology textbook—that is, for a true student of immunology—explanations necessarily have to become more sophisticated. In writing the first edition of the *Primer to the Immune Response*, Dr. Mary Saunders and I were extremely happy to have created a textbook that presented complex immunological concepts to the novice student in a clear, interesting and effective way. Reading of the first edition of our book firmly grounded a student in the basics of the subject, but there remained a desire to connect this information with immunology in the "real world." This meant going beyond the facts and figures to give the student a taste of how this body of knowledge was created in the first place, and how it continues to expand on a daily basis in research labs around the world. It also meant giving the student a look at how today's new ideas and observations can translate into medical treatments that improve the health and lives of people everywhere. To make this connection, we partnered with Dr. Bradley Jett to create the Academic Cell *Primer to The Immune Response*, an updated first edition of our book that included an online study guide. Now, in the Academic Cell *Primer to The Immune Response, 2nd Edition*, updated content and new pedagogical features in our textbook have been combined with access to an updated online study guide containing new research articles and case studies.

In each chapter of the online study guide, Dr. Jett has selected a journal article from the current scientific literature that complements the corresponding chapter of the *Primer to The Immune Response, 2nd Edition*. In each case, after offering a concise, easy-to-read summary of the chapter contents, he has provided thought-provoking questions and scenarios that relate to the journal article and challenge the student to think like a scientist or clinician. In this way, the study guide provides a bridge that encourages the reader to cross over from the realm of the "immunology student" into the realm of the "immunologist."

By using the online study guide as part of their immunology course work, students will grasp immunological concepts more fully. They will also face head-on the sometimes frustrating, sometimes invigorating fact that the field of immunology is never static. The science constantly moves forward, driven by the novel, exciting and sometimes controversial work of front-line researchers. It is into this fascinating world that the study guide immerses the budding immunologist.

It is my hope that students and instructors will take advantage of this excellent online study guide and use it as an enriching companion to *Primer to The Immune Response, 2nd Edition*. They will benefit, and I will feel I have taken another step in my evolution as an educator. And to think it all started with "Tommy the T cell."

Tak W. Mak
Toronto, Canada
January 2014

Tak Wah Mak

Tak W. Mak is the Director of the Campbell Family Institute for Breast Cancer Research in the Princess Margaret Hospital, Toronto, Canada, and a University Professor in the Departments of Medical Biophysics and Immunology, University of Toronto. He was trained at the University of Wisconsin in Madison, the University of Alberta, and the Ontario Cancer Institute. He gained worldwide prominence in 1984 as the leader of the team that first cloned the genes of the human T cell antigen receptor. His group went on to create a series of genetically altered mice that have proved critical to understanding intracellular programs governing the development and function of the immune system, and to dissecting signal transduction cascades in various cell survival and apoptotic pathways. His current research remains centered on mechanisms of immune recognition/regulation, malignant cell survival/death, inflammation in autoimmunity and cancer, and metabolic adaptation in tumor cells. Dr. Mak has published over 700 papers and holds many patents. He has been granted honorary doctoral degrees from universities in North America and Europe, is an Officer of the Orders of Canada and Ontario, and has been elected a Foreign Associate of the National Academy of Sciences (U.S.), a Fellow of the Royal Society of London (U.K.), and a Fellow of the AACR Academy. Dr. Mak has won international recognition as the recipient of the Emil von Behring Prize, the King Faisal International Prize for Medicine, the Gairdner Foundation International Award, the Sloan Prize of the General Motors Cancer Foundation, the Novartis Prize in Immunology, the Robert Noble Prize, the Killam Prize, the Stacie Prize, the McLaughlin Medal, and the Paul Ehrlich and Ludwig Darmstaedter Prize.

Mary Evelyn Saunders

Mary E. Saunders holds the position of Scientific Editor for the Campbell Family Institute for Breast Cancer Research, Toronto, Canada. She completed her B.Sc. degree in Genetics at the University of Guelph, Ontario, and received her Ph.D. in Medical Biophysics at the University of Toronto. Dr. Saunders works with Dr. Mak and members of his laboratory on the writing and editing of scientific papers for peer-reviewed journals as well as on various grant applications and book projects. She takes pride and pleasure in producing concise, clear, highly readable text and making complex scientific processes readily understandable.

Bradley Dale Jett

Bradley D. Jett is the James Hurley Professor of Biology at Oklahoma Baptist University (OBU) in Shawnee, Oklahoma, USA. He completed his B.S. degree in Biology from OBU, followed by his Ph.D. in Microbiology and Immunology from the University of Oklahoma College of Medicine. After a postdoctoral fellowship at Washington University in St. Louis, Missouri, he joined the faculty at the University of Oklahoma College of Medicine. His research interests are primarily focused on host–parasite relationships. Much of his published work relates to the virulence factors of Gram-positive bacteria such as *Enterococcus, Staphylococcus* and *Bacillus,* as well as the host immunological responses to these infections. In his current full-time, undergraduate teaching position at his alma mater, he has been awarded Oklahoma Baptist University's Promising Teacher Award and the Distinguished Teaching Award.

Contributors

Maya Rani Chaddah

Maya R. Chaddah graduated with a B.Sc. in Human Biology and a B.A. in Spanish, followed by an M.Sc. in Immunology at the University of Toronto. In 1996, she started a business focused on the writing and editing of scientific and medical publications. Her expertise has grown to include scientific and medical illustration, and she continues to produce a variety of communications for diverse audiences in the public and private sectors. (www.mayachaddah.com)

Wendy Lynn Tamminen

Wendy L. Tamminen completed her B.Sc. degree in Chemistry and Biochemistry at McMaster University, Hamilton, and received her Ph.D. in Immunology from the University of Toronto. She has taught immunology at the undergraduate level to students in both the biomedical sciences and medicine at the University of Toronto, where her teaching skills have been recognized with an Arts and Science Undergraduate Teaching Award. In her role as writer, editor and lecturer, Dr. Tamminen's main interest is the communication of scientific concepts to both science specialists and non-specialists.