The Immune Response to Infection
Contents

Contributors / ix
Preface / xv

The Immune Response to Infection:
Introduction / 1
STEFAN H. E. KAUFMANN, BARRY ROUSE, AND
DAVID SACKS

SECTION I ______________________________________
HOST DEFENSE: GENERAL / 5

1 Invertebrate Innate Immune Defenses / 7
LAURE EL CHAMY, CHARLES HETRU, AND
JULES HOFFMANN

2 The Ontogeny of the Cells of the Innate and
the Adaptive Immune System / 21
FRITZ MELCHERS

3 The Evolutionary Origins of the Adaptive
Immune System of Jawed Vertebrates / 41
JIM KAUFMAN

4 Host Defense (Antimicrobial) Peptides and
Proteins / 57
LAURENCE MADERA, SHUHUA MA, AND
ROBERT E. W. HANCOCK

5 Reactive Oxygen and Reactive Nitrogen
Intermediates in the Immune System / 69
CHRISTIAN BOGDAN

6 Complement in Infections / 85
WILHELM J. SCHWAEBLE, YO USSIF MOHAMMED ALI,
NICHOLAS J. LYNCH, AND RUSSELL WALLIS

7 Immune Defense at Mucosal Surfaces / 97
MARIAN R. NEUTRA AND JEAN-PIERRE
KRAEHENBUHL

8 Regulation of Antimicrobial
Immunity / 109
YASMIN E BELKAID, SHARVAN SEHRAWAT, AND
BARRY T. ROUSE

9 Memory and Infection / 121
DAVID MASOPUST AND MARK K. SLIFKA

SECTION II ______________________________________
THE PATHOGENS / 131

10 Overview of Viral Pathogens / 133
JONATHAN W. YEWDELL AND JACK R. BEN NINK

11 Overview of Parasitic Pathogens / 143
RICK L. TARLETON AND EDWARD J. PEARCE

12 Overview of Bacterial Pathogens / 155
PHILIPPE J. SANSONETTI AND ANDREA PUHAR

13 Overview of Fungal Pathogens / 165
AXEL A. BRAKHAGE AND PETER F. ZIPFEL

14 Prionoses and the Immune System / 173
JÜRGEN A. RICHT AND ALAN YOUNG

SECTION III ______________________________________
INNATE IMMUNITY TO MICROBIAL
INFECTIONS / 183

15 Innate Immunity to Viruses / 185
AKIKO IWASAKI

16 Natural Killer Cell Response against
Viruses / 197
JOSEPH C. SUN AND LEWIS L. LANIER
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Innate Immunity against Bacteria</td>
<td>Thomas Areschou, Annette Pluddemann, and Siamon Gordon</td>
</tr>
<tr>
<td>18</td>
<td>Innate Immunity to Parasitic Infections</td>
<td>Christopher A. Hunter and Alan Sher</td>
</tr>
<tr>
<td>19</td>
<td>Acquired Immunity against Viral Infections</td>
<td>Eva Szomolyani-Tsuda, Michael A. Brehm, and Raymond M. Welsh</td>
</tr>
<tr>
<td>20</td>
<td>Immune Responses to Persistent Viruses</td>
<td>E. John Wherry and Paul Kleenerman</td>
</tr>
<tr>
<td>21</td>
<td>Acquired Immunity: Acute Bacterial Infections</td>
<td>Dennis W. Metzger</td>
</tr>
<tr>
<td>22</td>
<td>Acquired Immunity: Chronic Bacterial Infections</td>
<td>Andrea M. Cooper and Richard Robinson</td>
</tr>
<tr>
<td>23</td>
<td>Acquired Immunity: Fungal Infections</td>
<td>Luigina Romani</td>
</tr>
<tr>
<td>24</td>
<td>Acquired Immunity to Intracellular Protozoa</td>
<td>Phillip Scott and Eleanor M. Riley</td>
</tr>
<tr>
<td>25</td>
<td>Acquired Immunity to Helminths</td>
<td>David Artis and Rick M. Maizeis</td>
</tr>
<tr>
<td>26</td>
<td>Pathology and Pathogenesis of Bacterial Infections</td>
<td>Warwick J. Britton and Bernadette M. Saunders</td>
</tr>
<tr>
<td>27</td>
<td>Helicobacter pylori: the Role of the Immune Response in Pathogenesis</td>
<td>Karen Robinson and John C. Atherton</td>
</tr>
<tr>
<td>28</td>
<td>Pathogenesis of Helminth Infections</td>
<td>Thomas A. Wynn and Judith E. Allen</td>
</tr>
<tr>
<td>29</td>
<td>Pathology and Pathogenesis of Malaria</td>
<td>Chanaki Amaratunga, Tatiana M. Lopera-Mesa, Jeanette G. Tse, Neida K. Mita-Mendoza, and Rick M. Fairhurst</td>
</tr>
<tr>
<td>30</td>
<td>Pathology and Pathogenesis of Viral Infections</td>
<td>Carmen Baca Jones and Matthias von Herrath</td>
</tr>
<tr>
<td>31</td>
<td>Viral Immune Evasion</td>
<td>Lila Farrington, Gabriela O'Neill, and Ann B. Hill</td>
</tr>
<tr>
<td>32</td>
<td>Growing Old and Immunity to Viruses</td>
<td>Janko Nikolic-Zugich and Marcia A. Blackman</td>
</tr>
<tr>
<td>33</td>
<td>Growing Old and Immunity to Bacteria</td>
<td>Joanne Turner</td>
</tr>
<tr>
<td>34</td>
<td>Bacterial Strategies for Survival in the Host</td>
<td>Anna D. Tischler and John D. McKinney</td>
</tr>
<tr>
<td>35</td>
<td>Suppression of Immune Responses to Protozoan Parasites</td>
<td>David L. Sacks</td>
</tr>
<tr>
<td>36</td>
<td>Immune Evasion by Parasites</td>
<td>John M. Mansfield and Martin Olivier</td>
</tr>
<tr>
<td>37</td>
<td>Genetics of Antibacterial Host Defenses</td>
<td>Steven M. Holland</td>
</tr>
<tr>
<td>38</td>
<td>Immunogenetics of Host Response to Parasites in Humans</td>
<td>Jenefer M. Blackwell</td>
</tr>
<tr>
<td>39</td>
<td>Immunogenetics of Virus Pathogenesis</td>
<td>Sean Wiltshire, David I. Watkins, Emil Skamene, and Silvia M. Vidal</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>VIII</td>
<td>Autoimmunity and Cancer</td>
<td>509</td>
</tr>
<tr>
<td>40</td>
<td>Viruses, Autoimmunity, and Cancer</td>
<td>511</td>
</tr>
<tr>
<td></td>
<td>MEGHANN TEAGUE GETTS, LIES BOGAERT, W. MARTIN KAST, AND STEPHEN D. MILLER</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>The Role of Bacterial and Parasitic Infections in Chronic Inflammatory Disorders and Autoimmunity</td>
<td>521</td>
</tr>
<tr>
<td></td>
<td>STEFAN EHLERS AND GRAHAM A. W. ROOK</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Theileria-Induced Leukocyte Transformation: an Example of Oncogene Addiction?</td>
<td>537</td>
</tr>
<tr>
<td></td>
<td>MARIE CHAUSSEPIED AND GORDON LANGSLEY</td>
<td></td>
</tr>
<tr>
<td>IX</td>
<td>Immune Intervention</td>
<td>547</td>
</tr>
<tr>
<td>43</td>
<td>Systems Vaccinology: Using Functional Signatures To Design Successful Vaccines</td>
<td>549</td>
</tr>
<tr>
<td></td>
<td>TROY D. QUERECA AND BALI PULENDRAN</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Meeting the Challenge of Vaccine Design To Control HIV and Other Difficult Viruses</td>
<td>559</td>
</tr>
<tr>
<td></td>
<td>BARNEY S. GRAHAM AND CHRISTOPHER WALKER</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Immune Intervention Strategies against Tuberculosis</td>
<td>571</td>
</tr>
<tr>
<td></td>
<td>PETER ANDERSEN AND STEFAN H. E. KAUFMANN</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Immune Intervention in Malaria</td>
<td>587</td>
</tr>
<tr>
<td></td>
<td>CAROLE A. LONG AND FIDEL P. ZAVALA</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Targeting Components in Vector Saliva</td>
<td>599</td>
</tr>
<tr>
<td></td>
<td>MARY ANN McDOWELL AND SHADEN KAMHAWI</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>The Major Killers (Clinics, Epidemiology, and Immune Parameters)</td>
<td>609</td>
</tr>
<tr>
<td>48</td>
<td>AIDS Vaccines: the Unfolding Story</td>
<td>611</td>
</tr>
<tr>
<td></td>
<td>STEPHEN NORLEY</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Tuberculosis</td>
<td>623</td>
</tr>
<tr>
<td></td>
<td>GERHARD WALZL, PAUL VAN HELDEN, AND PHILIP R. BOTHA</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Malaria: Clinical and Epidemiological Aspects</td>
<td>633</td>
</tr>
<tr>
<td></td>
<td>ANDREA A. BERRY, MYAING M. NYUNT, AND CHRISTOPHER V. PLOWE</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>The Epidemiology and Immunology of Influenza Viruses</td>
<td>643</td>
</tr>
<tr>
<td></td>
<td>RAFAEL A. MEDINA, IRENE RAMOS, AND ANA FERNANDEZ-SESMA</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td></td>
<td>653</td>
</tr>
</tbody>
</table>
Contributors

YOUSSIF MOHAMMED ALI
Department of Infection, Immunity and Inflammation,
University of Leicester, MSB, University Road,
Leicester LE1 9HN, United Kingdom

JUDITH E. ALLEN
Institutes of Evolution, Immunology and Infection Research,
University of Edinburgh, Edinburgh EH9 3JT, UK

CHANAKI AMARATUNGA
Laboratory of Malaria and Vector Research, National Institute of
Allergy and Infectious Diseases, Rockville, MD 20852

PETER ANDERSEN
Department of Infectious Disease Immunology, Statens Serum
Institut, Copenhagen, Denmark

THOMAS ARESCHOUG
Department of Laboratory Medicine, Division of Medical
Microbiology, Lund University, Sölvegatan 23,
22362 Lund, Sweden

DAVID ARTIS
Department of Pathobiology, School of Veterinary
Medicine, University of Pennsylvania, Philadelphia,
PA 19104-4539

JOHN C. ATHERTON
Nottingham Digestive Diseases Centre Biomedical
Research Unit, University Hospital, Nottingham,
NG7 2UH, United Kingdom

CARMEN BACA JONES
Center for Type 1 Diabetes Research, La Jolla Institute
for Allergy and Immunology, 9420 Athena Circle,
La Jolla, CA 92037

YASMIN BELKAI
Mucosal Immunology Unit, Laboratory of Parasitic Diseases,
Division of Intramural Research, National Institute of Health,
4 Center Drive B1-28, Bethesda, MD 20892

ANDREA A. BERRY
Center for Vaccine Development, University of Maryland
School of Medicine, Baltimore, MD 21201

MARCIA A. BLACKMAN
The Trudeau Institute, Saranac Lake, NY 12983

JENEFER M. BLACKWELL
Telethon Institute for Child Health Research, Centre for
Child Health Research, University of Western Australia,
Subiaco, Western Australia, Australia

LIES BOGAERT
Departments of Molecular Microbiology & Immunology and
Obstetrics & Gynecology, Norris Comprehensive Cancer
Center, University of Southern California, Los Angeles,
CA 90033, Department of Surgery and Anesthesiology of
Domestic Animals, Faculty of Veterinary Medicine,
University of Ghent, Merelbeke, B-9820, Belgium

CHRISTIAN BOGDAN
Microbiology Institute Clinical Microbiology,
Immunology and Hygiene, Friedrich Alexander University
Erlangen, Nuremberg, and University Clinic of Erlangen,
Wasserturmstraße 3/5, D-91054 Erlangen, Germany

PHILIP R. BOTHA
Division of Infectious Diseases, Department of Medicine
Tygerberg Academic Hospital, Faculty of Health Sciences,
University of Stellenbosch, P.O. Box 19063, Tygerberg,
7505, South Africa

AXEL A. BRAKHAGE
Leibniz Institute for Natural Product Research and
Infection Biology, Hans Knoell Institute (HKI),
Friedrich Schiller University Jena, Department Molecular and
Applied Microbiology and Department of Infection Biology,
Beutenbergstrasse 11a, 07745 Jena, Germany

MICHAEL A. BREHM
Department of Pathology, University of Massachusetts
Medical School, Worcester, MA 01655

WARWICK J. BRITTON
Centenary Institute, Locked Bag No 6, Newtown, 2042;
and Discipline of Medicine, Sydney Medical School,
University of Sydney (D06), Sydney, 2006, NSW, Australia
x ■ CONTRIBUTORS

MARIE CHAUSSEPIED
Institut Cochin, Université Paris Descartes, CNRS
(UMR 8104), Paris, France. Inserm, 1016, Paris, France.
Laboratory of Comparative Cell Biology of Apicomplexa,
27 rue du Faubourg Saint-Jacques, 75014 Paris, France

ANDREA M. COOPER
Trudeau Institute, Inc., 154 Algonquin Ave.,
Saranac Lake, NY

STEFAN EHLERS
Microbial Inflammation Research, Research Center Borstel,
Parkallee 1, D-23845 Borstel, Germany, and Molecular
Inflammation Medicine, Institute of Experimental Medicine,
Christian-Albrechts-University, Arnold-Heller-Str. 3,
D-24105 Kiel, Germany

LAURE EL CHAMY
Institut de Biologie Moléculaire et Cellulaire, 15, Rue René
Descartes, 67084 Strasbourg, France

RICK M. FAIRHURST
Laboratory of Malaria and Vector Research, National Institute
of Allergy and Infectious Diseases, Rockville, MD 20852

LILA FARRINGTON
Dept. of Molecular Microbiology and Immunology,
Oregon Health and Science University, Portland, OR 97239

ANA FERNANDEZ-SESMA
Department of Microbiology and the Emerging
Pathogens Institute, Mount Sinai School of Medicine,
New York, NY 10029

MEGHANN TEAGUE GETTS
Department of Microbiology-Immunology and:
Interdepartmental Immunobiology Center, Feinberg School
of Medicine, Northwestern University, Chicago, IL 60611

SIAMON GORDON
Sir William Dunn School of Pathology, University of Oxford,
South Parks Road, Oxford, OX1 3RE, United Kingdom

BARNEY S. GRAHAM
Vaccine Research Center, National Institute of Allergy and
Infectious Diseases, Bethesda, MD 20892

ROBERT E. W. HANCOCK
Department of Microbiology and Immunology, Centre for
Microbial Diseases & Immunity Research, University of
British Columbia, Vancouver, BC, V6T 1Z4, Canada

CHARLES HETRU
Institut de Biologie Moléculaire et Cellulaire, 15, Rue René
Descartes, 67084 Strasbourg, France

ANN B. HILL
Dept. of Molecular Microbiology and Immunology,
Oregon Health and Science University, Portland, OR 97239

JULES HOFFMANN
Institut de Biologie Moléculaire et Cellulaire, 15, Rue René
Descartes, 67084 Strasbourg, France

STEVEN M. HOLLAND
Laboratory of Clinical Infectious Diseases, National Institute
of Allergy and Infectious Diseases, National Institutes of
Health, Bethesda, MD 20892-1684

CHRISTOPHER A. HUNTER
Department of Pathobiology School of Veterinary Medicine,
University of Pennsylvania, Rm 313, Hill Pavilion,
380 South University Avenue, Philadelphia, PA 19104-4539

AKIKO IWASAKI
Department of Immunobiology, Yale University School of
Medicine, New Haven, CT 06520

SHADEN KAMHAWI
Laboratory of Malaria and Vector Research, National Institute
of Allergy and Infectious Disease, National Institutes of
Health, 12735 Twinbrook Parkway, Rockville, MD 20852

W. MARTIN KAST
Departments of Molecular Microbiology & Immunology and
Obstetrics & Gynecology, Norris Comprehensive Cancer
Center, University of Southern California, Los Angeles,
CA 90033. Cancer Research Center of Hawaii, University of
Hawaii, Honolulu, HI 96822

JIM KAUFMAN
University of Cambridge Department of Pathology,
Tennis Court Road, Cambridge, CB2 1QP, Department
of Veterinary Medicine, Madingley Road, Cambridge,
CB3 0ES, United Kingdom

STEFAN H. E. KAUFMANN
Department of Immunology, Max Planck Institute for
Infection Biology, Charitéplatz 1, D 10117 Berlin, Germany

PAUL KLENERMAN
Nuffield Dept of Medicine and NIHR Biomedical Research
Centre Programme, Peter Medawar Building, University of
Oxford, Oxford OX1 3SY, UK

JEAN-PIERRE KRAEHENBUHL
Health Sciences eTraining (HSeT) Foundation, CH 1066
Epalinges, Switzerland

GORDON LANGSLEY
Institut Cochin, Université Paris Descartes, CNRS
(UMR 8104), Paris, France. Inserm, 1016, Paris, France.
Laboratory of Comparative Cell Biology of Apicomplexa,
27 rue du Faubourg Saint-Jacques, 75014 Paris, France

LEWIS L. LANIER
Department of Microbiology and Immunology and
the Cancer Research Institute, University of California,
San Francisco, CA 94143

CAROLE A. LONG
Malaria Immunology Section, Laboratory of Malaria and
Vector Research, National Institute of Allergy and
Infectious Diseases, National Institutes of Health,
Rockville, MD 20852

TATIANA M. LOPERA-MESA
Laboratory of Malaria and Vector Research,
National Institute of Allergy and Infectious Diseases,
Rockville, MD 20852

NICHOLAS J. LYNCH
Department of Infection, Immunity and Inflammation,
University of Leicester, MSB, University Road,
Leicester LE1 9HN, United Kingdom

SHUHUA MA
Department of Microbiology and Immunology, Centre for
Microbial Diseases & Immunity Research, University of
British Columbia, Vancouver, BC, V6T 1Z4, Canada
LAURENCE MADERA  
Department of Microbiology and Immunology, Centre for Microbial Diseases & Immunity Research, University of British Columbia, Vancouver, BC, V6T 1Z4, Canada

RICK M. MAIZELS  
Centre for Immunity, Infection and Evolution, and Institute of Immunology and Infection Research, University of Edinburgh, Edinburgh EH9 3JT, United Kingdom

JOHN M. MANSFIELD  
Department of Bacteriology, Microbial Sciences Building, 1550 Linden Drive, University of Wisconsin-Madison, Madison, WI 53716

DAVID MASOPUST  
Department of Microbiology, Center for Immunology, University of Minnesota, 2-182 Medical Biosciences Building, 2101 6th St. SE, Minneapolis, MN 55455

MARY ANN McDOWELL  
The Eck Institute for Global Health and Infectious Diseases, Department of Biological Sciences, University of Notre Dame, Notre Dame, IN 46556

JOHN D. McKinney  
Global Health Institute, Swiss Federal Institute of Technology (EPFL), CH-1015 Lausanne, Switzerland

RAFAEL A. MEDINA  
Department of Microbiology and the Emerging Pathogens Institute, Mount Sinai School of Medicine, New York, NY 10029

FRITZ MELCHERS  
Max Planck Institute for Infection Biology, Senior Research Group on Lymphocyte Development, Charitéplatz 1, D 10117, Berlin, Germany

DENNIS W. METZGER  
Center for Immunology and Microbial Disease, Albany Medical College, Albany, New York 12208

STEPHEN D. MILLER  
Department of Microbiology-Immunology and Interdepartmental Immunobiology Center, Feinberg School of Medicine, Northwestern University, Chicago, IL 60611

NEIDA K. MITA-MENDEZ  
Laboratory of Malaria and Vector Research, National Institute of Allergy and Infectious Diseases, Rockville, MD 20852

MARIAN R. NEUTRA  
Department of Pediatrics, Harvard Medical School, and GI Cell Biology Laboratory, Children's Hospital, Boston, MA 02115

JANKO NIKOLICH-ZUGIC  
Department of Immunobiology and the Arizona Center on Aging, University of Arizona College of Medicine, Tucson, AZ 85718

STEPHEN NORLEY  
Robert Koch Institute, 13353 Berlin, Germany

MYAING M. NYUNT  
Department of International Health, Global Disease Epidemiology and Control Program, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD 21205

MARTIN OLIVIER  
Department of Microbiology and Immunology, Duff Medical Building, 3775 University, McGill University, Montréal, Québec, Canada.

GABRIELA ONEILL  
Dept. of Molecular Microbiology and Immunology, Oregon Health and Science University, Portland, OR 97239

EDWARD J. PEARCE  
Trudeau Institute Inc., 154 Algonquin Avenue, Saranac Lake, NY 12983

CHRISTOPHER V. PLOWE  
Center for Vaccine Development, Howard Hughes Medical Institute and University of Maryland School of Medicine, Baltimore, MD 21201

ANNETTE PLÜDDE  
Department of Primary Health Care, University of Oxford Old Road Campus, Oxford, OX3 7LF, UK

ANDREA PUHAR  
Unité de Pathogénie Microbienn Moléculaire, INSERM U786, Institut Pasteur, 75724 Paris Cedex 15, France

BALI PULENDRAN  
Emory Vaccine Center, Emory University, 954 Gatewood Road, Atlanta, GA 30329

TROY D. QUEREC  
Emory Vaccine Center, Emory University, 954 Gatewood Road, Atlanta, GA 30329

IRENE RAMOS  
Department of Microbiology and the Emerging Pathogens Institute, Mount Sinai School of Medicine, New York, NY 10029

JÜRGEN A. RICHT  
Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, K224B Mosier Hall, Manhattan, KS 66506-5601

ELEANOR M. RILEY  
Department of Infectious and Tropical Diseases, London School of Tropical Medicine and Hygiene, London, UK

RICARD ROBINSON  
Trudeau Institute, Inc., 154 Algonquin Ave., Saranac Lake, NY

KAREN ROBINSON  
Department of International Health, Global Disease Epidemiology and Control Program, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD 21205
BARRY T. ROUSE
Department of Pathobiology, College of Veterinary Medicine,
University of Tennessee, 1414 Cumberland Ave.,
Knoxville, TN 37996

DAVID L. SACKS
Laboratory of Parasitic Diseases, National Institutes of
Allergy and Infectious Diseases, National Institutes of
Health, Building 4, Room 126, 4 Center Dr., MSC 0425,
Bethesda, MD 20892-0425.

PHILIPPE J. SANSONETTI
Unité de Pathogénie Microbienne Moléculaire, INSERM
U786, Institut Pasteur, 75724 Paris Cedex 15, France

BERNADETTE M. SAUNDERS
Centenary Institute, Locked Bag No 6, Newtown, 2042;
and Discipline of Medicine, Sydney Medical School,
University of Sydney (D06), Sydney, 2006, NSW, Australia

WILHELM J. SCHWAEBLE
Department of Infection, Immunity and Inflammation,
University of Leicester, MSB, University Road,
Leicester LE1 9HN, United Kingdom

PHILLIP SCOTT
Department of Pathobiology, School of Veterinary Medicine,
University of Pennsylvania, Philadelphia, PA 19104

SHARVAN SEHRAWAT
Department of Pathobiology, College of Veterinary Medicine,
University of Tennessee, 1414 Cumberland Ave.,
Knoxville, TN 37996

ALAN SHER
Laboratory of Parasitic Diseases NIAID, NIH Building 50,
Room 6140, 50 South Drive, MSC-8003, Bethesda,
MD 20892-8003

EMIL SKAMENE
Department of Human Genetics, The McGill Life Sciences
Complex, Bellini Pavilion, Room 356, 3649 Promenade Sir
William Osler, Montreal, QC H3G 0B1, Canada

MARK K. SLIFKA
Vaccine and Gene Therapy Institute, Oregon Health &
Science University, 505 NW 185th Ave., Beaverton, OR 97006

JOSEPH C. SUN
Department of Microbiology and Immunology and
the Cancer Research Institute, University of California,
San Francisco, CA 94143

EVA SZOMOLANYI-TSUDA
Department of Pathology, University of Massachusetts
Medical School, Worcester, MA 01655

RICK L. TARLETON
Center for Tropical & Emerging Global Diseases,
Coverdell Center for Biomedical Research (Rm 310B),
500 D.W. Brooks Drive, University of Georgia,
Athens, GA 30602

ANNA D. TISCHLER
Global Heath Institute, Swiss Federal Institute of Technology
(EPFL), CH-1015 Lausanne, Switzerland

JEANETTE G. TSE
Laboratory of Malaria and Vector Research,
National Institute of Allergy and Infectious Diseases,
Rockville, MD 20892

JOANNE TURNER
Center for Microbial Interface Biology, and Department
of Internal Medicine, Division of Infectious Diseases,
The Ohio State University, 460 West 12th Ave.,
Columbus, OH 43210

PAUL VAN HELDEN
DST/NRF Centre of Excellence for Biomedical TB Research,
Division of Molecular Biology and Human Genetics,
Department of Biomedical Sciences, Faculty of Health
Sciences, University of Stellenbosch, P.O. Box 19063,
Tygerberg, 7505, South Africa

SILVIA VIDAL
Department of Human Genetics, The McGill
Life Sciences Complex, Bellini Pavilion, Room 356,
3649 Promenade Sir William Osler, Montreal,
QC H3G 0B1, Canada

MATTHIAS VON HERRATH
Center for Type 1 Diabetes Research, La Jolla Institute
for Allergy and Immunology, 9420 Athena Circle,
La Jolla, CA 92037

CHRISTOPHER WALKER
Nationwide Children’s Hospital and the Departments of
Pediatrics, Pathology, and Molecular Virology, Immunology
and Medical Genetics, The Ohio State University, Columbus,
OH 43205

RUSSELL WALLIS
Department of Infection, Immunity and Inflammation,
University of Leicester, MSB, University Road,
Leicester LE1 9HN, United Kingdom

GERHARD WALZL
DST/NRF Centre of Excellence for Biomedical TB Research,
Division of Molecular Biology and Human Genetics,
Department of Biomedical Sciences, Faculty of Health
Sciences, University of Stellenbosch, P.O. Box 19063,
Tygerberg, 7505, South Africa

PHILLIP SCOTT
Department of Pathobiology, School of Veterinary Medicine,
University of Pennsylvania, Philadelphia, PA 19104

SHARVAN SEHRAWAT
Department of Pathobiology, College of Veterinary Medicine,
University of Tennessee, 1414 Cumberland Ave.,
Knoxville, TN 37996

ALAN SHER
Laboratory of Parasitic Diseases NIAID, NIH Building 50,
Room 6140, 50 South Drive, MSC-8003, Bethesda,
MD 20892-8003

EMIL SKAMENE
Department of Human Genetics, The McGill Life Sciences
Complex, Bellini Pavilion, Room 356, 3649 Promenade Sir
William Osler, Montreal, QC H3G 0B1, Canada

MARK K. SLIFKA
Vaccine and Gene Therapy Institute, Oregon Health &
Science University, 505 NW 185th Ave., Beaverton, OR 97006

JOSEPH C. SUN
Department of Microbiology and Immunology and
the Cancer Research Institute, University of California,
San Francisco, CA 94143

EVA SZOMOLANYI-TSUDA
Department of Pathology, University of Massachusetts
Medical School, Worcester, MA 01655

RICK L. TARLETON
Center for Tropical & Emerging Global Diseases,
Coverdell Center for Biomedical Research (Rm 310B),
500 D.W. Brooks Drive, University of Georgia,
Athens, GA 30602

ANNA D. TISCHLER
Global Heath Institute, Swiss Federal Institute of Technology
(EPFL), CH-1015 Lausanne, Switzerland

JEANETTE G. TSE
Laboratory of Malaria and Vector Research,
National Institute of Allergy and Infectious Diseases,
Rockville, MD 20892

JOANNE TURNER
Center for Microbial Interface Biology, and Department
of Internal Medicine, Division of Infectious Diseases,
The Ohio State University, 460 West 12th Ave.,
Columbus, OH 43210

PAUL VAN HELDEN
DST/NRF Centre of Excellence for Biomedical TB Research,
Division of Molecular Biology and Human Genetics,
Department of Biomedical Sciences, Faculty of Health
Sciences, University of Stellenbosch, P.O. Box 19063,
Tygerberg, 7505, South Africa

SILVIA VIDAL
Department of Human Genetics, The McGill
Life Sciences Complex, Bellini Pavilion, Room 356,
3649 Promenade Sir William Osler, Montreal,
QC H3G 0B1, Canada

MATTHIAS VON HERRATH
Center for Type 1 Diabetes Research, La Jolla Institute
for Allergy and Immunology, 9420 Athena Circle,
La Jolla, CA 92037

CHRISTOPHER WALKER
Nationwide Children’s Hospital and the Departments of
Pediatrics, Pathology, and Molecular Virology, Immunology
and Medical Genetics, The Ohio State University, Columbus,
OH 43205

RUSSELL WALLIS
Department of Infection, Immunity and Inflammation,
University of Leicester, MSB, University Road,
Leicester LE1 9HN, United Kingdom

GERHARD WALZL
DST/NRF Centre of Excellence for Biomedical TB Research,
Division of Molecular Biology and Human Genetics,
Department of Biomedical Sciences, Faculty of Health
Sciences, University of Stellenbosch, P.O. Box 19063,
Tygerberg, 7505, South Africa

PHILLIP SCOTT
Department of Pathobiology, School of Veterinary Medicine,
University of Pennsylvania, Philadelphia, PA 19104

SHARVAN SEHRAWAT
Department of Pathobiology, College of Veterinary Medicine,
University of Tennessee, 1414 Cumberland Ave.,
Knoxville, TN 37996

ALAN SHER
Laboratory of Parasitic Diseases NIAID, NIH Building 50,
Room 6140, 50 South Drive, MSC-8003, Bethesda,
MD 20892-8003

EMIL SKAMENE
Department of Human Genetics, The McGill Life Sciences
Complex, Bellini Pavilion, Room 356, 3649 Promenade Sir
William Osler, Montreal, QC H3G 0B1, Canada

MARK K. SLIFKA
Vaccine and Gene Therapy Institute, Oregon Health &
Science University, 505 NW 185th Ave., Beaverton, OR 97006

JOSEPH C. SUN
Department of Microbiology and Immunology and
the Cancer Research Institute, University of California,
San Francisco, CA 94143

EVA SZOMOLANYI-TSUDA
Department of Pathology, University of Massachusetts
Medical School, Worcester, MA 01655

RICK L. TARLETON
Center for Tropical & Emerging Global Diseases,
Coverdell Center for Biomedical Research (Rm 310B),
500 D.W. Brooks Drive, University of Georgia,
Athens, GA 30602

ANNA D. TISCHLER
Global Heath Institute, Swiss Federal Institute of Technology
(EPFL), CH-1015 Lausanne, Switzerland
THOMAS A. WYNN
Immunopathogenesis Section, National Institute of Allergy and Infectious Disease, National Institutes of Health, Bethesda, MD 20892-8003

FIDEL P. ZAVALA
Department of Molecular Microbiology and Immunity, Bloomberg School of Public Health, Malaria Research Institute, Johns Hopkins University, 615 N. Wolfe St., Baltimore, MD 21205

JONATHAN W. YEWDELL
Laboratory of Viral Diseases, National Institute of Allergy and Infectious Diseases, Bethesda, MD 20892-3209

PETER F. ZIPFEL
Leibniz Institute for Natural Product Research and Infection Biology, Hans Knoell Institute (HKI), Friedrich Schiller University Jena, Department Molecular and Applied Microbiology and Department of Infection Biology, Beutenbergstrasse 11a, 07745 Jena, Germany

ALAN YOUNG
Department of Veterinary Science, South Dakota State University, Box 2175, ARW168F, Brookings, SD 57007

JONATHAN W. YEWDELL
Laboratory of Viral Diseases, National Institute of Allergy and Infectious Diseases, Bethesda, MD 20892-3209
Preface

“Excellent textbooks and review volumes on immunology, virology, parasitology, medical microbiology, and infectious diseases abound. So what gap is this book aimed to fill?”

This question was posed in the preface of the ASM Press book *Immunology of Infectious Diseases* (edited by Stefan H. E. Kaufmann, Alan Sher, and Raft Ahmed), published in 2002. The explanation provided then still holds true today. Microbiology and immunology, despite their common roots, have matured as distinct disciplines, and infectious diseases are too often viewed from the perspective of either the microbe or the host. A more holistic approach was provided by that book and a second one published by ASM Press in 2004, *The Innate Immune Response to Infection* (edited by Stefan H. E. Kaufmann, Ruslan Medzhitov, and Siamon Gordon).

These books now urgently need updating because the knowledge base in immunology, as well as with all types of infectious agents, has expanded dramatically. The present volume, *The Immune Response to Infection*, covers all aspects of innate and adaptive immune mechanisms and describes how they interact with pathogens of different types, resulting in either success or failure to control infection and clinical disease. This volume also emphasizes how our understanding of mechanistic events is leading the design and production of more effective prophylactic and therapeutic control measures for infectious agents.

Most of the chapters here consider host-pathogen interactions in the context of the broad divisions of the microbial world—either viruses, bacteria, or parasites—and do not confine their discussion to any individual pathogen. The exceptions are for the agents of the “big three” infectious diseases—HIV/AIDS, tuberculosis, and malaria—which account for almost one-third of human deaths from infections, as well as influenza, which is the focus of much media and public attention. We have also included chapters that consider the detrimental sequelae of infection that are an indirect result of the infectious process, such as chronic inflammation, cancer, and autoimmunity. Finally, all of the chapters emphasize the special attributes that make pathogens difficult to control, and they appraise the prospects of current and future prophylactic and therapeutic vaccines.

We hope that this book, which comprises the rich variety of aspects of infection and immunity, helps to further promote the important relationship between immunology and medical microbiology. We express our deep appreciation to the editorial staff of ASM Press, in particular, Greg Payne and Ellie Tupper. We also want to thank our associates Mary Louise Grossman and Lisa Washington for their secretarial help and for their wonderful dedication. Most of all, we thank our colleagues for sacrificing so much of their valuable time to generously share their outstanding expertise with us and with the readers of this book.

STEFAN H. E. KAUFMANN, BARRY T. ROUSE, AND DAVID L. SACKS
Acute rheumatic fever (ARF), 524
Acute phase reactants, 403
Acute infection, 274–276
Active tuberculosis disease, 627
Activation-induced cytidine deaminase (AID), 30, 124
Acrocephalus arundinaceus, 50
Acetobacter lwoffi, chronic inflammatory infections and, 527
Acquired cellular responses, 283–284
Acquired immunity
acute bacterial infections, 269–276
acute infection and, 274–276
antibacterial, 274–276
in gastrointestinal tract, 314–317
Helicobacter pylori, 342–344
to helminths, 313–321
immunogenetics, 486t
induction of, 274
innate immunity and, 239–240, 272, 571–572
to intracellular protozoa, 301–308
Mycobacterium leprae, 285–286
Mycobacterium tuberculosis, 284–285
Mycobacterium ulcerans, 285
TB and, 572–573
against viral infection, 239–251
Acquired immunodeficiency syndrome (AIDS), 1, 134, 580
animal models for, 611
clinical trials, 616
DNA vaccines, 614
genetic vaccines, 613–614
reasons for optimism, 617–618
recombinant viral vectors, 614
replicating vectors, 617
subunit vaccines, 613
therapeutic vaccines, 616–617
vaccines, 611–618
Acrorhynchus annulatus, 50
Activation-induced cytokine deaminase (AID), 30, 124
Active tuberculosis disease, 627
diagnostic markers for, 628
ACTs. See Artemisinin-based combination therapies
Acute infection
acquired immunity, 274–276
immune responses following, 256–258
Acute phase reactants, 403
Acute rheumatic fever (ARF), 524
Acute viruses, immunity to, 404–409
Adaptive immune system, 257–262
ontogeny of cells of, 41–52
innate immune system linking with, 32
in jawed invertebrates, 42–45
in jawed vertebrates, 42–45
lymphocytes in, 21
MHC and, 51–52
ontogeny of cells of, 21–33
parasitic infections and, 231–232
viral immunity and, 404
ADCC. See Antibody-dependent cellular cytotoxicity
ADCl. See Antibody-dependent cellular inhibition
Adeno-associated virus (AAV), 239
Adeno-associated virus vectors (AA V V), 615
Adenovirus, 577–578
Adhesion defects, 477–479
Adjuvants
pathogens as, 515
for protein subunit vaccines, 576–577
synthetic, 552
Treg, 529
Aedes aegypti, 15
Ag85, 576
Aging
animal models of, 419
bacterial immunity and, 413–419
CD8 T-cell memory and, 405–406
CMV and, 408–409
De Novo infections and, 406
EBV and, 407–408
HCV and, 409
HIV and, 409, 421
HSV and, 409, 413
human studies of, 420
immune function and, 413
peripheral memory T-cells and, 406
respiratory infections and, 405
viral immunity and, 403–410
VZV and, 407
Agnathans, 17
AHR. See Allergic airway hypersensitivity response
AID. See Activation-induced cytidine deaminase
AIDS. See Acquired immunodeficiency syndrome
AIDS-associated retrovirus (ARV), 493
AIM2, 190
AIM2-ASC inflammasome, 191
AKT, Fleurieria and, 541t
Alkyl hydroperoxide reductase (AphC), 431
Allergic airway hypersensitivity response (AIRH), 385
Allergic response, 384t
Alternative activated macrophages, 317–318
Alternative complement pathway, 88
deficiencies, 90
Alum, 552–553
ALVAC, 565, 566
AMA1, 592
Amblyomma americanum, 604
Amoebastoma mexicanum, 50
Amphimedon queenslandica, 16
Amphioxus, 44
AMPs. See Antimicrobial peptides
Ancient antiviral defense mechanisms, 191
Ancestry, 15
Ancestral, 638
Anopheles gambiae, 15
Anaplasma phagocytophilum, 15, 638
ANT3, 644
Anthrax, 3
Antibacterial-acquired immunity, 274–276
Antibacterial host defenses, 473–474
barrier defects, 473
cutaneous defenses, 473–474
immune defects, 474–477
pulmonary defenses, 474–477
Antibiotics, 529
Antibodies
mucosal, 629
usefulness of, 250–251
viral infection control by, 249–250
Antibody-dependent cellular cytotoxicity (ADCC), 104, 250, 272
Antibody-dependent cellular inhibition (ADCl), 592
Antibody-dependent enhancement of infection, 384t, 385
Antibody-mediated immune effector mechanisms, 307–308
Antibody-mediated immunity, fungal infections, 292–295
Antibody-mediated protection, 269–270
Antibody responses
importance of, 247
kinetics, 247–248
Antibodies-secreting cells (ASC), 125–126, 247
INDEX

Antigenic drift, 647
Antigenic variation, 427–429
Neisseria gonorrhoeae, 427, 428
trypanosome, 454–455
Antigen presentation, 75
viral immunity and, 242–243
Antigen-presenting cells (APCs), 111, 212, 282, 348, 515, 571
alterations in, 457–459
costimulatory molecules and, 243–244
cytokine secretion, 199–201
signal 3 cytokines and, 244
virus detection by, 199–201
Antigen receptor-expressing lymphocyte repertoires, 26–28
Antigens
barriers to, 98–99
delivery, 114–175
maintenance, 176–177
at mucosal surfaces, 98–101
mycobacterial, 629
Antigen sampling, 99
exploitation of, 100
at mucosal effector sites, 100
at mucosal inductive sites, 100
Antigen-specific B-cells, 126–127
Antigen-specific receptor, 45–46
Antigen-specific serum antibody responses, 125–126
Anti-influenza mediators
dysplastic diseases and, 297t
helminths and, 353
Antimicrobial activity
BPI, 64
cathelicidins, 60
defensins, 58
iNOS, 77–78
lysozyme, 65
mechanisms of, 62
Antimicrobial immunity, 109–117
Antimicrobial peptides (AMPs), 7, 213, 245, 297, 329, 342
Antimicrobial antibodies, 526
Antineutrophil cytoplasmic antibodies, 526
Antiprion therapy, 179
Anti RNase B, 629
Anti-TNF therapy, 331
Antiviral B-cell responses, 249
Antiviral cytokines, 191–194, 245
Antiviral response, Drosophila, 13
Antiviral vaccination strategies, 387–388
APCs. See Antigen-presenting cells
AphC. See Alkyl hydroperoxide reductase
Apicomplexans, 143–145
Apl mellin, 15
APKCs. See Atypical protein kinase C
APOBECG, 281
APOBEC family, 194, 498
Apopotax, 384t, 393–396
viral immune evasion of, 399–400
APRIL, 31, 99, 247, 271
ARF, See Acute reticulocyte fever
l-Arginine, 78, 353, 354f
Arg1, 304
schistosomiasis and, 349–350
Arginase-1, 318
helminths and, 350–351
Artemisinin-based combination therapies (ACTs), 635
Arthrodema benhamiae, 169
ARV, See AIDS-associated retrovirus
ASC. See Antibody-secreting cells
Ascorbic acid, 146
GLWS, 487t
ASO1, 577
ASO2, 577
Aspartic acid, 50
Aspergillus fumigatus, 166, 289, 291
Aspergillus nidulans, 166
Asthma, 524
Asymptomatic parasitemia, 363
Atherosclerosis, 523–524
ATP-binding cascade (ABC), 474
Attaecins, 8
Attenuated parasite vaccines, 589–590
Atypical protein kinase C (aPKC), 10
Auramine-Rhodamine, 627
Autoantigen-presenting cells, in primary lymphoid organs, 29
Autoantigen reactivities, 28–29
Autoimmune disorders, infections as promoters of, 521–526
Autoimmune inflammation
bacteria as inhibitors of, 526–531
helminths as inhibitors of, 526–531
molecular mimicry during, 525t
Autoimmune vasculitis syndromes, 526
Autoimmunity
infectious etiologies for, 511–512
murine models of, 512
to viruses and cancer and, 511–519
virus-induced, 387–388
babA2. See Blood group antigen-binding gene A2
Bacillus anthracis, 58, 65, 155
Bacillus Calmette-Guerin (BCG), 476, 575–576
Bacillus subtilis, 514
Bacteria-induced shock syndromes, 329–330
Bacterial immunity, aging and, 413–419
Bacterial infection
acquired immunity to, 269–276
acute, 269–276
adhesion, 159
autoimmune inflammatory damage induced by, 334
chronic, 279–286
complement system in, 90–93
course of, 158
in elderly, 413
extracellular, 327–330
growth, 160
innate recognition receptors in, 214–219
invasion, 159–160
pathogenesis of, 327–334
pathology of, 327–334
transmission, 158–159
Bacterial pathogens, 155–162. See also specific pathogens
construction of, 161–162
of elderly, 413
general aspects of, 211–212
host interactions, 156
as inflammation inhibitors, 526–531
innate immunity and, 209–222
survival of, 161
transmission of, 156–157
virulence factors, 159–161
Bacterial survival, 425–427
stress resistance and, 430–433
Bacterial vectors, 615–616
Bactericidal permeability-increasing protein (BPI), 63
antimicrobial activity, 64
immunomodulation, 64–65
therapeutic potential, 65
Bacteroides fragilis, chronic inflammatory infections and, 527t
Bacteroides thetaiotaomicron, 161
Bacteroidetes, 156, 157
Baculoviral IAP repeat (BIR), 395
BAFF, 99
BAFF-receptor, 31
BALB/c mice, 303, 304
BALT. See Bronchus-associated lymphoid tissue
Barrier defects, 473
Baronella henselae, 157
Basophils, 210, 316f
Bax-Bak, 395
B-cell(s), 29–30, 260
antigen-specific, 126–127
central tolerance failure, 33
development, 27
differentiation, 103
GALT-associated compartments, 32
ingnorne of, 31
immature, 29–30
memory, 125–127
peripheral, without IG, 31–32
positive selection of, 30–31
responses, 247–250, 261–262, 264
subsets, 249
viral antigen recognition by, 247
B-cell differentiations, 26
B-cell inhibitory protein (BIP), from xides ricinus, 604
B-cell receptors (BCR), 21, 26, 247
in immature compartments, 28
B-cells, regulatory, 530
BCG. See Bacillus Calmette-Guerin
BCMA, 31
BeR. See B-cell receptors
BeR complex, 32
BCV. See Brucella-containing vacuole
Beauveria bassiana, 15
Bifidobacterium infantis, 529
Big Bang, 44
Biofilm development
bacterial survival and, 433–434
extracellular bacterial infection, 329
Biomarkers
breath, 629
candidate, 629
cytokines and, 629–630
for extent of disease, 629
identifying, 630
mycobacterial, 629
nonspecific, 630
for protective immunity, 628
TB, 628–630
of treatment effect, 629
Biopharmalalia glabrata, 16, 43
BIP. See B-cell inhibitory protein
BIR. See Baculoviral IAP repeat
BL, 539
BL3, 539
BL20, 539
B-lineage commitment, 25
Blood and marrow transplantation (BMT), 165
Blood group antigen-binding gene A2 (babA2), 340
INDEX

IL-1. See Interleukin 1
IL-1β. See Interleukin 1β
IL-1R. See Interleukin 1 receptor
IL-1 receptor-associated kinase (IRAK), 9, 74, 249
IL-2. See Interleukin 2
IL-4. See Interleukin 4
IL-5. See Interleukin 5
IL-6. See Interleukin 6
IL-7. See Interleukin 7
IL-8. See Interleukin 8
IL-9. See Interleukin 9
IL-10. See Interleukin 10
IL-12. See Interleukin 12
IL-13. See Interleukin 13
IL-15. See Interleukin 15
IL-17. See Interleukin 17
IL-23. See Interleukin 23
IL-27. See Interleukin 27
IL-33. See Interleukin 33
IL-IR/TLR. See Interleukin IR/Toll-like receptor
IMD pathway. 7
Drosophila. 11–12
FADD and. 9
Immune adaptation, bacterial survival and, 430–433
Immune cells. differentiation of, 75
Immune complex formation, 384–385
Immune complex-mediated pathology, 330
Immune defects, 474–477
adhesion, 477–479
neutrophil granule formation, 476
neutrophil oxidative metabolism, 476
Immune effectors, Drosophila. 8
Immune evasion, 453–465
cellular activation and, 459–460
HIV, 560–561
Leishmania, 461–465
T-cell, 398–399
Immune modulation, mechanisms of, 461
Immune reconstitution disease (IRD), 626
Immune regulation catalase (IRC), 13
Immune stromal keratitis (ISK), 384–385
Immune subversion, bacterial survival and, 434–435
Immune suppression
bacterial survival and, 435–437
Chagas disease and, 446
of dendritic cells, 441–443
IL-10 and, 443–446
Leishmania and, 445–446
protozoa and, 441–449
regulatory T-cells and, 443–446
Immunity. See specific types
Immunogenetics
acquired immunity, 486
innate immunity, 486
innate related, 486
of parasite host response, 483–488
of virus pathogenesis, 491–506
Immunoglobulin-like repeat proteins, 14
Immunoglobulin superfamily (IgSF), 16
Immunology. birth of, 3
Immunomodulation. 59–60
BPI, 64–65
cathelicidins, 61–62
defensins, 59–60
fungal infections, 297
iNOS, 79
mechanisms of, 62–63
ROI, 74
Immune receptors tyrosine-based activation motif (ITIM). 14, 32, 272, 329
Immune receptor tyrosine-based inhibitory motif (ITIM). 46, 329, 492
Immune receptor tyrosine-based inhibitory motif (ITIM). 14, 32, 272, 329
Immune recognition receptors, in bacterial infection, 214–215
iNOS, 303, 331, 351, 431
antimicrobial activity, 77–78
conceptual framework, 77
cytotoxic effects of, 77–78
enzyme activity, 77
functions of, 77
gene transcription, 77
immunomodulation and, 79
mRNA, 77
negative regulators of, 76
positive regulators of, 76
protein, 76
subcellular localization of, 76
Interferon-mediated immunity, 495–502
effectors, 497–498
signaling, 497–498
viral escape, 498
Interferon receptors. 201
Interferons (IFNs). 185, 200
amplification of, 191
antiviral effectors induced by, 193
induction, 192
NK cells, 201–202
type 1, 191–194
Interferon stimulated response element (ISRE). 193
Interleukin 1 (IL-1). 89, 306, 337
Borelia burgdorferi and. 435
Interleukin 1β (IL-1β). 58
Interleukin 1 receptor (IL-1R). 8
Interleukin 2 (IL-2). 122
Interleukin 4 (IL-4). 284, 315, 317
Interleukin 5 (IL-5). 229, 315, 320
Interleukin 6 (IL-6). 60, 61, 306
Interleukin 7 (IL-7). 33, 122
receptors, 259
Interleukin 8 (IL-8). 427
Interleukin 9 (IL-9). 315
Interleukin 10 (IL-10). 109, 149–150, 206, 241, 283, 303, 307, 415, 446, 447, 448
production of, 434
subsets of, 444
suppression of immune responses by, 443–446
Interleukin 12 (IL-12). 201, 228–229, 283, 320, 441, 447
type 1, 202
Interleukin 13 (IL-13). 314, 315, 317
Interleukin 15 (IL-15). 122, 202
receptors, 259
Interleukin 17 (IL-17). 303, 474
Interleukin 23 (IL-23). 283
Interleukin 27 (IL-27). 474
Interleukin 33 (IL-33). 316
Interleukin IR/Toll-like receptor (IL-IR/TLR). 7
Intestinal epithelial cells (IECs). 315
Intracellular bacteria
pathology of, 330–334
rapidly growing, 331
Intracellular control mechanisms, 23
Intracellular cytokines
acquired immunity to, 301–308
of phagocytic cells, 302–304
T-cell dependent control of, 302–303
Intraepithelial lymphocytes, 98
Invertebrate innate defenses, 7–17
Invertebrate immune defenses, 7–17
IRIS. 1, 200
IRAK. See IL-1 receptor-associated kinase
IRAK-1. 462
ISG. See IFN-stimulated genes
ISG15. 194
ISK. See Immune stromal keratitis
Isoniazid monotherapy (IMT). 625
ISRE. See IFN-stimulus response elements
Interferon-stimulated response element
IISMs. See Sphingomyelinase-like enzyme
ITAM. See Immune receptor tyrosine-based inhibitory motif
ITIM. See Immune receptor tyrosine-based inhibitory motif
Visceral leishmaniasis (VL), 485, 599

Vitamin D3, 61

Vitamin D receptor (VDR), 332

Vivax malaria
genetic resistance to, 375
pathogenesis of, 371
reticulocytes and, 371–372
severe, 374

VL. See Visceral leishmaniasis

VLR. See Variable lymphocytes receptor

von Behring, Emil, 3

VSG. See Variant surface glycoprotein

VSV. See Vesicular stomatitis virus

V to J rearrangements, 28

VV. See Vaccinia virus

VZV. See Vesicular stomatitis virus

Warren, Robin, 337

Warts, hypogammaglobulinemia, infections, and myelokathexis (WHIM), 475

West Nile virus (WNV), 239, 406–407, 493, 602
susceptibility loci, 504

WHIM. See Warts, hypogammaglobulinemia, infections, and myelokathexis

Whole cell vaccines, 593

Whole inactivated virus vaccines, 612

Wnt-signaling pathway, 23

Wound healing, 75

Wright, Almroth, 4

Wuchereria bancrofti, 146

Xenophagy, 191

Xenopus laevis, 50

Xenopus tropicalis, 48, 50

X-linked severe congenital neutropenia (XLN), 475

XLN. See X-linked severe congenital neutropenia

Yellow fever virus (YFV), 553
susceptibility loci, 504t
Yersinia enterocolitica, 159, 161
Yersinia pestis, 271, 273, 280, 435
Yersinia pseudotuberculosis, 330
YFV. See Yellow fever virus

YM-1, 318

ZAP-70, 32