

Methods in Enzymology
Volume 288

0054887

Methods in Enzymology

Volume 288

Chemokine Receptors

EDITED BY

Richard Horuk

DEPARTMENT OF IMMUNOLOGY

BERLEX BIOSCIENCES

RICHMOND, CALIFORNIA



ACADEMIC PRESS

San Diego London Boston New York Sydney Tokyo Toronto

This book is printed on acid-free paper. (C)

Copyright © 1997 by ACADEMIC PRESS

All Rights Reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the Publisher.

The appearance of the code at the bottom of the first page of a chapter in this book indicates the Publisher's consent that copies of the chapter may be made for personal or internal use, or for the personal or internal use of specific clients. This consent is given on the condition, however, that the copier pay the stated per copy fee through the Copyright Clearance Center, Inc. (222 Rosewood Drive, Danvers, Massachusetts 01923) for copying beyond that permitted by Sections 107 or 108 of the U.S. Copyright Law. This consent does not extend to other kinds of copying, such as copying for general distribution, for advertising or promotional purposes, for creating new collective works, or for resale. Copy fees for pre-1997 chapters are as shown on the chapter title pages. If no fee code appears on the chapter title page, the copy fee is the same as for current chapters.

0076-6879/97 \$25.00

Academic Press

15 East 26th Street, 15th Floor, New York, New York 10010, USA

<http://www.apnet.com>

Academic Press Limited

24-28 Oval Road, London NW1 7DX, UK

<http://www.hbuk.co.uk/ap/>

International Standard Book Number: 0-12-182189-7

PRINTED IN THE UNITED STATES OF AMERICA

97 98 99 00 01 02 MM 9 8 7 6 5 4 3 2 1

0054487

Methods in Enzymology

Volume 288

Chemokine Receptors

METHODS IN ENZYMOLOGY
Richard D. Smith

Methods in Enzymology

Volume 288

CHEMOKINE RECEPTORS

EDITED BY
RICHARD D. SMITH

AND
NATHAN O. KAPLAN



ACADEMIC PRESS

SAN DIEGO, CALIFORNIA 92101 NEW YORK, NEW YORK 10017 LONDON, ENGLAND W2 6AE

METHODS IN ENZYMOLOGY

EDITORS-IN-CHIEF

John N. Abelson Melvin I. Simon

DIVISION OF BIOLOGY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

FOUNDING EDITORS

Sidney P. Colowick and Nathan O. Kaplan

Contributors to Volume 288

Article numbers are in parentheses following the names of contributors.
Affiliations listed are current.

- HIDENORI ARAI (6), *Gladstone Institute of Cardiovascular Disease, University of California, San Francisco, California 94141*
- DOUGLAS A. ARENBERG (14), *University of Michigan, Ann Arbor, Michigan 48109*
- KEVIN B. BACON (21, 22), *Department of Immunobiology, DNAX Research Institute, Palo Alto, California 94304-1104*
- SUZANNE K. BECKNER (19), *Westat, Rockville, Maryland 20850*
- GREGORY L. BENNETT (10), *Department of Bioanalytical Technology, Genentech, Inc., South San Francisco, California 94080*
- JOANNE F. BERSON (9), *Department of Pathology and Laboratory Medicine, University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- V. COURTNEY BROADDUS (12), *Lung Biology Center, Department of Medicine, University of California, San Francisco, San Francisco, California 94143-0854*
- SAMUEL D. H. CHAN (7), *Molecular Devices Corporation, Sunnyvale, California 94089*
- ISRAEL F. CHARO (6), *Gladstone Institute of Cardiovascular Disease, University of California, San Francisco, California 94141*
- YING-HUA CHEN (4), *Departments of Biochemistry and Molecular Biology, Pathology and Laboratory Medicine, Internal Medicine, and Surgery, Henry Vogt Cancer Research Institute of James Graham Brown Cancer Center, University of Louisville, Louisville, Kentucky 40292*
- ANAN CHUNTHARAPAI (2), *Department of Antibody Techniques, Genentech, Inc., South San Francisco, California 94080*
- PAUL D. COLLINS (16), *Division of Applied Pharmacology, Imperial College School of Medicine at the National Heart and Lung Institute, London SW3 6LY, United Kingdom*
- ROBERT W. DOMS (9), *Department of Pathology and Laboratory Medicine, University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- BENJAMIN J. DORANZ (9), *Department of Pathology and Laboratory Medicine, University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- JIAN-GUO DU (4), *Departments of Biochemistry and Molecular Biology, Pathology and Laboratory Medicine, Internal Medicine, and Surgery, Henry Vogt Cancer Research Institute of James Graham Brown Cancer Center, University of Louisville, Louisville, Kentucky 40292*
- AIMEE L. EDINGER (9), *Department of Pathology and Laboratory Medicine, University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- VICTOR H. FINGAR (11), *Department of Surgery, University of Louisville, Louisville, Kentucky 40292*
- ANDRZEJ R. GLABINSKI (13), *Department of Neurology, Medical University of Lodz, Lodz, Poland*
- DAVID A. GRIFFITHS-JOHNSON (16), *Division of Applied Pharmacology, Imperial College School of Medicine at the National Heart and Lung Institute, London SW3 6LY, United Kingdom*
- HAI-HONG GUO (4, 11), *Department of Biochemistry and Molecular Biology, University of Louisville, Louisville, Kentucky 40292*
- MEREDITH HALKS-MILLER (3), *Department of Experimental Pathology, Berlex Biosciences, Richmond, California 94804*

- CAROLINE A. HÉBERT (12), *Genentech, Inc., South San Francisco, California 94080-4990*
- JOSEPH HESSELGESSER (3), *Department of Immunology, Berlex Biosciences, Richmond, California 94804*
- MARGARET HIRST (7), *Molecular Devices Corporation, Sunnyvale, California 94089*
- RICHARD HORUK (3, 10, 20), *Department of Immunology, Berlex Biosciences, Richmond, California 94804*
- GILLIAN M. K. HUMPHRIES (7), *Molecular Devices Corporation, Sunnyvale, California 94089*
- PETER J. JOSE (16), *Division of Applied Pharmacology, Imperial College School of Medicine at the National Heart and Lung Institute, London SW3 6LY, United Kingdom*
- K. JIN KIM (2), *Department of Antibody Techniques, Genentech, Inc., South San Francisco, California 94080*
- STEVEN L. KUNKEL (14, 15), *Department of Pathology, University of Michigan Medical Center, Ann Arbor, Michigan 48109*
- DEBORAH LONG (9), *Department of Pathology and Laboratory Medicine, University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- ZHAO-HAI LU (5, 11), *Department of Biochemistry and Molecular Biology, University of Louisville, Louisville, Kentucky 40292*
- SHAUN R. MCCOLL (18), *Department of Microbiology and Immunology, The University of Adelaide, Adelaide, South Australia 5005*
- ILONA J. MIKO (3), *Department of Experimental Pathology, Berlex Biosciences, Richmond, California 94804*
- FELIPE S. MONTECLARO (6), *Gladstone Institute of Cardiovascular Disease, University of California, San Francisco, California 94141*
- SUSAN MUELLER (1), *Department of Cell Biology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232-2175*
- PHILIP M. MURPHY (8), *Laboratory of Host Defenses, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, Maryland 20892*
- PAUL H. NACCACHE (18), *Centre de Recherche en Rhumatologie et Inflammation, Centre de Recherche du CHUL and Faculty of Medicine, Université Laval, Québec, Canada G1V 4G2*
- STEPHEN C. PEIPER (4, 5, 11), *Departments of Biochemistry and Molecular Biology, Pathology and Laboratory Medicine, University of Louisville, Louisville, Kentucky 40292*
- SIMON PITCHFORD (7), *Molecular Devices Corporation, Sunnyvale, California 94089*
- PETER J. POLVERINI (14), *University of Michigan, Ann Arbor, Michigan 48109*
- RICHARD M. RANSOHOFF (13), *The Research Institute and Mellen Center for Multiple Sclerosis Treatment and Research, Cleveland Clinic Foundation, Cleveland, Ohio 44195*
- ANN RICHMOND (1), *Department of Cell Biology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232-2175, and Department of Veterans Affairs Medical Center, Nashville, Tennessee 37232-2175*
- JOSEPH RUCKER (9), *Department of Pathology and Laboratory Medicine, University of Pennsylvania, Philadelphia, Pennsylvania 19104*
- WAYNE SCHRAW (1), *Department of Cell Biology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232-2175*
- JENS-MICHAEL SCHRÖDER (17), *Department of Dermatology, University of Kiel, D-24105 Kiel, Germany*
- ARMEN SHANAFELT (14), *Institute of Molecular Biologicals and Institute of Research Technologies, Bayer Corporation, West Haven, Connecticut 06516*
- THEODORE J. STANDIFORD (15), *Division of Pulmonary and Critical Care Medicine, University of Michigan Medical Center, Ann Arbor, Michigan 48109*
- ROBERT M. STRIETER (14, 15), *Division of Pulmonary and Critical Care Medicine, University of Michigan Medical Center, Ann Arbor, Michigan 48109*

MARIE TANI (13), *Department of Neurosciences, The Research Institute, Cleveland Clinic Foundation, Cleveland, Ohio 44195*

VÉRONIQUE E. TIMMERMANS (7), *Molecular Devices Corporation, Sunnyvale, California 94089*

VINCENT K. TUOHY (13), *Department of Immunology, The Research Institute, Cleveland Clinic Foundation, Cleveland, Ohio 44195*

H. GARRETT WADA (7), *Molecular Devices Corporation, Sunnyvale, California 94089*

ZI-XUAN WANG (4, 5), *Departments of Biochemistry and Molecular Biology, Pathology and Laboratory Medicine, Internal Medicine, and Surgery, Henry Vogt Cancer Research Institute of James Graham Brown*

Cancer Center University of Louisville, Louisville, Kentucky 40292

JOHN R. WHITE (1), *Department of Immunology, SmithKline Beecham Pharmaceuticals, King of Prussia, Pennsylvania 19406-0939*

TIMOTHY J. WILLIAMS (16), *Division of Applied Pharmacology, Imperial College School of Medicine at the National Heart and Lung Institute, London SW3 6LY, United Kingdom*

TIAN-YUAN ZHANG (5), *Departments of Biochemistry and Molecular Biology, Pathology and Laboratory Medicine, Internal Medicine, and Surgery, Henry Vogt Cancer Research Institute of James Graham Brown Cancer Center, University of Louisville, Louisville, Kentucky 40292*

METHODS IN ENZYMOLOGY

Preface

Chemokines play an important role in inducing the directed migration of blood leukocytes in the body. When this process goes awry and immune cells turn on and attack their own tissues, autoimmune diseases such as rheumatoid arthritis and multiple sclerosis result. In light of these proinflammatory properties, chemokines and their cellular receptors have become therapeutic targets for drug intervention by major pharmaceutical companies. In addition, chemokine receptors have been in the scientific spotlight recently because of the finding that they are coreceptors, along with CD4, for pathogenic organisms such as HIV-1, which use them to gain entry into, and infect, mammalian cells. These and other related findings have placed chemokines in the limelight and exposed them to intense scrutiny by an increasingly broad population of the scientific community.

Given this increased interest in chemokines there was a real need for a practical bench guide that gives detailed protocols and methods that can be used by researchers and advanced students as a step-by-step guide for studying these molecules. With this in mind I assembled a series of comprehensive articles from acknowledged experts in the chemokine field. They are presented in Volumes 287 and 288 of *Methods in Enzymology*. Volume 287 deals with methods in chemokine research; Volume 288 covers chemokine receptor protocols. These volumes provide a detailed compendium of laboratory methods that will appeal both to the novice and to the more experienced researcher wanting to enter this field.

I would like to express my sincere thanks to all the contributing authors for their outstanding efforts and patience during the production of this work. Also, I would like to thank Shirley Light of Academic Press for providing guidance, encouragement, and advice in the preparation of these volumes.

RICHARD HORUK

METHODS IN ENZYMOLOGY

VOLUME I. Preparation and Assay of Enzymes

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME II. Preparation and Assay of Enzymes

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME III. Preparation and Assay of Substrates

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME IV. Special Techniques for the Enzymologist

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME V. Preparation and Assay of Enzymes

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME VI. Preparation and Assay of Enzymes (*Continued*)

Preparation and Assay of Substrates

Special Techniques

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME VII. Cumulative Subject Index

Edited by SIDNEY P. COLOWICK AND NATHAN O. KAPLAN

VOLUME VIII. Complex Carbohydrates

Edited by ELIZABETH F. NEUFELD AND VICTOR GINSBURG

VOLUME IX. Carbohydrate Metabolism

Edited by WILLIS A. WOOD

VOLUME X. Oxidation and Phosphorylation

Edited by RONALD W. ESTABROOK AND MAYNARD E. PULLMAN

VOLUME XI. Enzyme Structure

Edited by C. H. W. HIRS

VOLUME XII. Nucleic Acids (Parts A and B)

Edited by LAWRENCE GROSSMAN AND KIVIE MOLDAVE

VOLUME XIII. Citric Acid Cycle

Edited by J. M. LOWENSTEIN

VOLUME XIV. Lipids

Edited by J. M. LOWENSTEIN

VOLUME XV. Steroids and Terpenoids

Edited by RAYMOND B. CLAYTON

VOLUME XVI. Fast Reactions

Edited by KENNETH KUSTIN

VOLUME XVII. Metabolism of Amino Acids and Amines (Parts A and B)

Edited by HERBERT TABOR AND CELIA WHITE TABOR

VOLUME XVIII. Vitamins and Coenzymes (Parts A, B, and C)

Edited by DONALD B. McCORMICK AND LEMUEL D. WRIGHT

VOLUME XIX. Proteolytic Enzymes

Edited by GERTRUDE E. PERLMANN AND LASZLO LORAND

VOLUME XX. Nucleic Acids and Protein Synthesis (Part C)

Edited by KIVIE MOLDAVE AND LAWRENCE GROSSMAN

VOLUME XXI. Nucleic Acids (Part D)

Edited by LAWRENCE GROSSMAN AND KIVIE MOLDAVE

VOLUME XXII. Enzyme Purification and Related Techniques

Edited by WILLIAM B. JAKOBY

VOLUME XXIII. Photosynthesis (Part A)

Edited by ANTHONY SAN PIETRO

VOLUME XXIV. Photosynthesis and Nitrogen Fixation (Part B)

Edited by ANTHONY SAN PIETRO

VOLUME XXV. Enzyme Structure (Part B)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME XXVI. Enzyme Structure (Part C)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME XXVII. Enzyme Structure (Part D)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME XXVIII. Complex Carbohydrates (Part B)

Edited by VICTOR GINSBURG

VOLUME XXIX. Nucleic Acids and Protein Synthesis (Part E)

Edited by LAWRENCE GROSSMAN AND KIVIE MOLDAVE

VOLUME XXX. Nucleic Acids and Protein Synthesis (Part F)

Edited by KIVIE MOLDAVE AND LAWRENCE GROSSMAN

VOLUME XXXI. Biomembranes (Part A)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME XXXII. Biomembranes (Part B)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME XXXIII. Cumulative Subject Index Volumes I-XXX

Edited by MARTHA G. DENNIS AND EDWARD A. DENNIS

VOLUME XXXIV. Affinity Techniques (Enzyme Purification: Part B)

Edited by WILLIAM B. JAKOBY AND MEIR WILCHEK

VOLUME XXXV. Lipids (Part B)

Edited by JOHN M. LOWENSTEIN

VOLUME XXXVI. Hormone Action (Part A: Steroid Hormones)

Edited by BERT W. O'MALLEY AND JOEL G. HARDMAN

VOLUME XXXVII. Hormone Action (Part B: Peptide Hormones)

Edited by BERT W. O'MALLEY AND JOEL G. HARDMAN

VOLUME XXXVIII. Hormone Action (Part C: Cyclic Nucleotides)

Edited by JOEL G. HARDMAN AND BERT W. O'MALLEY

VOLUME XXXIX. Hormone Action (Part D: Isolated Cells, Tissues, and Organ Systems)

Edited by JOEL G. HARDMAN AND BERT W. O'MALLEY

VOLUME XL. Hormone Action (Part E: Nuclear Structure and Function)

Edited by BERT W. O'MALLEY AND JOEL G. HARDMAN

VOLUME XLI. Carbohydrate Metabolism (Part B)

Edited by W. A. WOOD

VOLUME XLII. Carbohydrate Metabolism (Part C)

Edited by W. A. WOOD

VOLUME XLIII. Antibiotics

Edited by JOHN H. HASH

VOLUME XLIV. Immobilized Enzymes

Edited by KLAUS MOSBACH

VOLUME XLV. Proteolytic Enzymes (Part B)

Edited by LASZLO LORAND

VOLUME XLVI. Affinity Labeling

Edited by WILLIAM B. JAKOBY AND MEIR WILCHEK

VOLUME XLVII. Enzyme Structure (Part E)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME XLVIII. Enzyme Structure (Part F)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME XLIX. Enzyme Structure (Part G)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME L. Complex Carbohydrates (Part C)

Edited by VICTOR GINSBURG

VOLUME LI. Purine and Pyrimidine Nucleotide Metabolism

Edited by PATRICIA A. HOFFEE AND MARY ELLEN JONES

VOLUME LII. Biomembranes (Part C: Biological Oxidations)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME LIII. Biomembranes (Part D: Biological Oxidations)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME LIV. Biomembranes (Part E: Biological Oxidations)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME LV. Biomembranes (Part F: Bioenergetics)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME LVI. Biomembranes (Part G: Bioenergetics)

Edited by SIDNEY FLEISCHER AND LESTER PACKER

VOLUME LVII. Bioluminescence and Chemiluminescence

Edited by MARLENE A. DeLUCA

VOLUME LVIII. Cell Culture

Edited by WILLIAM B. JAKOBY AND IRA PASTAN

VOLUME LIX. Nucleic Acids and Protein Synthesis (Part G)

Edited by KIVIE MOLDAVE AND LAWRENCE GROSSMAN

VOLUME LX. Nucleic Acids and Protein Synthesis (Part H)

Edited by KIVIE MOLDAVE AND LAWRENCE GROSSMAN

VOLUME 61. Enzyme Structure (Part H)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME 62. Vitamins and Coenzymes (Part D)

Edited by DONALD B. McCORMICK AND LEMUEL D. WRIGHT

VOLUME 63. Enzyme Kinetics and Mechanism (Part A: Initial Rate and Inhibitor Methods)

Edited by DANIEL L. PURICH

VOLUME 64. Enzyme Kinetics and Mechanism (Part B: Isotopic Probes and Complex Enzyme Systems)

Edited by DANIEL L. PURICH

VOLUME 65. Nucleic Acids (Part I)

Edited by LAWRENCE GROSSMAN AND KIVIE MOLDAVE

VOLUME 66. Vitamins and Coenzymes (Part E)

Edited by DONALD B. McCORMICK AND LEMUEL D. WRIGHT

VOLUME 67. Vitamins and Coenzymes (Part F)

Edited by DONALD B. McCORMICK AND LEMUEL D. WRIGHT

VOLUME 68. Recombinant DNA

Edited by RAY WU

VOLUME 69. Photosynthesis and Nitrogen Fixation (Part C)

Edited by ANTHONY SAN PIETRO

VOLUME 70. Immunochemical Techniques (Part A)

Edited by HELEN VAN VUNAKIS AND JOHN J. LANGONE

VOLUME 71. Lipids (Part C)

Edited by JOHN M. LOWENSTEIN

VOLUME 72. Lipids (Part D)

Edited by JOHN M. LOWENSTEIN

VOLUME 73. Immunochemical Techniques (Part B)

Edited by JOHN J. LANGONE AND HELEN VAN VUNAKIS

VOLUME 74. Immunochemical Techniques (Part C)

Edited by JOHN J. LANGONE AND HELEN VAN VUNAKIS

VOLUME 75. Cumulative Subject Index Volumes XXXI, XXXII, XXXIV-LX

Edited by EDWARD A. DENNIS AND MARTHA G. DENNIS

VOLUME 76. Hemoglobins

Edited by ERALDO ANTONINI, LUIGI ROSSI-BERNARDI, AND EMILIA CHIANCONE

VOLUME 77. Detoxication and Drug Metabolism

Edited by WILLIAM B. JAKOBY

VOLUME 78. Interferons (Part A)

Edited by SIDNEY PESTKA

VOLUME 79. Interferons (Part B)

Edited by SIDNEY PESTKA

VOLUME 80. Proteolytic Enzymes (Part C)

Edited by LASZLO LORAND

VOLUME 81. Biomembranes (Part H: Visual Pigments and Purple Membranes, I)

Edited by LESTER PACKER

VOLUME 82. Structural and Contractile Proteins (Part A: Extracellular Matrix)

Edited by LEON W. CUNNINGHAM AND DIXIE W. FREDERIKSEN

VOLUME 83. Complex Carbohydrates (Part D)

Edited by VICTOR GINSBURG

VOLUME 84. Immunochemical Techniques (Part D: Selected Immunoassays)

Edited by JOHN J. LANGONE AND HELEN VAN VUNAKIS

VOLUME 85. Structural and Contractile Proteins (Part B: The Contractile Apparatus and the Cytoskeleton)

Edited by DIXIE W. FREDERIKSEN AND LEON W. CUNNINGHAM

VOLUME 86. Prostaglandins and Arachidonate Metabolites

Edited by WILLIAM E. M. LANDS AND WILLIAM L. SMITH

VOLUME 87. Enzyme Kinetics and Mechanism (Part C: Intermediates, Stereochemistry, and Rate Studies)

Edited by DANIEL L. PURICH

VOLUME 88. Biomembranes (Part I: Visual Pigments and Purple Membranes, II)

Edited by LESTER PACKER

VOLUME 89. Carbohydrate Metabolism (Part D)

Edited by WILLIS A. WOOD

VOLUME 90. Carbohydrate Metabolism (Part E)

Edited by WILLIS A. WOOD

VOLUME 91. Enzyme Structure (Part I)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME 92. Immunochemical Techniques (Part E: Monoclonal Antibodies and General Immunoassay Methods)

Edited by JOHN J. LANGONE AND HELEN VAN VUNAKIS

VOLUME 93. Immunochemical Techniques (Part F: Conventional Antibodies, Fc Receptors, and Cytotoxicity)

Edited by JOHN J. LANGONE AND HELEN VAN VUNAKIS

VOLUME 94. Polyamines

Edited by HERBERT TABOR AND CELIA WHITE TABOR

VOLUME 95. Cumulative Subject Index Volumes 61-74, 76-80

Edited by EDWARD A. DENNIS AND MARTHA G. DENNIS

VOLUME 96. Biomembranes [Part J: Membrane Biogenesis: Assembly and Targeting (General Methods; Eukaryotes)]

Edited by SIDNEY FLEISCHER AND BECCA FLEISCHER

VOLUME 97. Biomembranes [Part K: Membrane Biogenesis: Assembly and Targeting (Prokaryotes, Mitochondria, and Chloroplasts)]

Edited by SIDNEY FLEISCHER AND BECCA FLEISCHER

VOLUME 98. Biomembranes (Part L: Membrane Biogenesis: Processing and Recycling)

Edited by SIDNEY FLEISCHER AND BECCA FLEISCHER

VOLUME 99. Hormone Action (Part F: Protein Kinases)

Edited by JACKIE D. CORBIN AND JOEL G. HARDMAN

VOLUME 100. Recombinant DNA (Part B)

Edited by RAY WU, LAWRENCE GROSSMAN, AND KIVIE MOLDAVE

VOLUME 101. Recombinant DNA (Part C)

Edited by RAY WU, LAWRENCE GROSSMAN, AND KIVIE MOLDAVE

VOLUME 102. Hormone Action (Part G: Calmodulin and Calcium-Binding Proteins)

Edited by ANTHONY R. MEANS AND BERT W. O'MALLEY

VOLUME 103. Hormone Action (Part H: Neuroendocrine Peptides)

Edited by P. MICHAEL CONN

VOLUME 104. Enzyme Purification and Related Techniques (Part C)

Edited by WILLIAM B. JAKOBY

VOLUME 105. Oxygen Radicals in Biological Systems

Edited by LESTER PACKER

VOLUME 106. Posttranslational Modifications (Part A)

Edited by FINN WOLD AND KIVIE MOLDAVE

VOLUME 107. Posttranslational Modifications (Part B)

Edited by FINN WOLD AND KIVIE MOLDAVE

VOLUME 108. Immunochemical Techniques (Part G: Separation and Characterization of Lymphoid Cells)

Edited by GIOVANNI DI SABATO, JOHN J. LANGONE, AND HELEN VAN VUNAKIS

VOLUME 109. Hormone Action (Part I: Peptide Hormones)

Edited by LUTZ BIRNBAUMER AND BERT W. O'MALLEY

VOLUME 110. Steroids and Isoprenoids (Part A)

Edited by JOHN H. LAW AND HANS C. RILLING

VOLUME 111. Steroids and Isoprenoids (Part B)

Edited by JOHN H. LAW AND HANS C. RILLING

VOLUME 112. Drug and Enzyme Targeting (Part A)

Edited by KENNETH J. WIDDER AND RALPH GREEN

VOLUME 113. Glutamate, Glutamine, Glutathione, and Related Compounds

Edited by ALTON MEISTER

VOLUME 114. Diffraction Methods for Biological Macromolecules (Part A)

Edited by HAROLD W. WYCKOFF, C. H. W. HIRS, AND SERGE N. TIMASHEFF

VOLUME 115. Diffraction Methods for Biological Macromolecules (Part B)

Edited by HAROLD W. WYCKOFF, C. H. W. HIRS, AND SERGE N. TIMASHEFF

VOLUME 116. Immunochemical Techniques (Part H: Effectors and Mediators of Lymphoid Cell Functions)

Edited by GIOVANNI DI SABATO, JOHN J. LANGONE, AND HELEN VAN VUNAKIS

VOLUME 117. Enzyme Structure (Part J)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME 118. Plant Molecular Biology

Edited by ARTHUR WEISSBACH AND HERBERT WEISSBACH

VOLUME 119. Interferons (Part C)

Edited by SIDNEY PESTKA

VOLUME 120. Cumulative Subject Index Volumes 81-94, 96-101

VOLUME 121. Immunochemical Techniques (Part I: Hybridoma Technology and Monoclonal Antibodies)

Edited by JOHN J. LANGONE AND HELEN VAN VUNAKIS

VOLUME 122. Vitamins and Coenzymes (Part G)

Edited by FRANK CHYTIL AND DONALD B. MCCORMICK

VOLUME 123. Vitamins and Coenzymes (Part H)

Edited by FRANK CHYTIL AND DONALD B. MCCORMICK

VOLUME 124. Hormone Action (Part J: Neuroendocrine Peptides)

Edited by P. MICHAEL CONN

VOLUME 125. Biomembranes (Part M: Transport in Bacteria, Mitochondria, and Chloroplasts: General Approaches and Transport Systems)

Edited by SIDNEY FLEISCHER AND BECCA FLEISCHER

VOLUME 126. Biomembranes (Part N: Transport in Bacteria, Mitochondria, and Chloroplasts: Protonmotive Force)

Edited by SIDNEY FLEISCHER AND BECCA FLEISCHER

VOLUME 127. Biomembranes (Part O: Protons and Water: Structure and Translocation)

Edited by LESTER PACKER

VOLUME 128. Plasma Lipoproteins (Part A: Preparation, Structure, and Molecular Biology)

Edited by JERE P. SEGREST AND JOHN J. ALBERS

VOLUME 129. Plasma Lipoproteins (Part B: Characterization, Cell Biology, and Metabolism)

Edited by JOHN J. ALBERS AND JERE P. SEGREST

VOLUME 130. Enzyme Structure (Part K)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME 131. Enzyme Structure (Part L)

Edited by C. H. W. HIRS AND SERGE N. TIMASHEFF

VOLUME 132. Immunochemical Techniques (Part J: Phagocytosis and Cell-Mediated Cytotoxicity)

Edited by GIOVANNI DI SABATO AND JOHANNES EVERSE

VOLUME 133. Bioluminescence and Chemiluminescence (Part B)

Edited by MARLENE DELUCA AND WILLIAM D. McELROY

VOLUME 134. Structural and Contractile Proteins (Part C: The Contractile Apparatus and the Cytoskeleton)

Edited by RICHARD B. VALLEE

VOLUME 135. Immobilized Enzymes and Cells (Part B)

Edited by KLAUS MOSBACH

VOLUME 136. Immobilized Enzymes and Cells (Part C)

Edited by KLAUS MOSBACH

VOLUME 137. Immobilized Enzymes and Cells (Part D)

Edited by KLAUS MOSBACH

VOLUME 138. Complex Carbohydrates (Part E)

Edited by VICTOR GINSBURG

VOLUME 139. Cellular Regulators (Part A: Calcium- and Calmodulin-Binding Proteins)

Edited by ANTHONY R. MEANS AND P. MICHAEL CONN

VOLUME 140. Cumulative Subject Index Volumes 102-119, 121-134