Methods in Enzymology

Volume 192

BIOMEMBRANES

Part W

Cellular and Subcellular Transport:

Epithelial Cells

Methods in Enzymology

Volume 192

Biomembranes

Part W
Cellular and Subcellular Transport: Epithelial Cells

EDITED BY

Sidney Fleischer
Becca Fleischer

DEPARTMENT OF MOLECULAR BIOLOGY
VANDERBILT UNIVERSITY
NASHVILLE, TENNESSEE

ACADEMIC PRESS, INC.
Harcourt Brace Jovanovich, Publishers
San Diego New York Boston
London Sydney Tokyo Toronto

This book is printed on acid-free paper. ∞

Academic Press, Inc.
San Diego, California 92101

United Kingdom Edition published by
Academic Press Limited
24-28 Oval Road, London NW1 7DX

Library of Congress Catalog Card Number: 54-9110

ISBN 0-12-182093-9 (alk. paper)

Printed in the United States of America
90 91 92 93 9 8 7 6 5 4 3 2 1

Contributors to Volume 192

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

ZAHUR AHMED (21), *Department of Physiology, School of Medicine, State University of New York at Buffalo, Buffalo, New York 14214*

G. ALTENBERG (43), *Department of Physiology and Biophysics, The University of Texas Medical Branch, Galveston, Texas 77550*

INDU S. AMBUDKAR (3), *Clinical Investigations and Patient Care Branch, National Institute of Dental Research, National Institutes of Health, Bethesda, Maryland 20892*

B. E. ARGENT (17), *Department of Physiological Sciences, University of Newcastle upon Tyne, Newcastle upon Tyne NE2 4HH, England*

BRUCE J. BAUM (3), *Clinical Investigations and Patient Care Branch, National Institute of Dental Research, National Institutes of Health, Bethesda, Maryland 20892*

THOMAS BERGLINDH (6), *Department of Biomedical Research, Pharmaia AB, S-751 82 Uppsala, Sweden*

A. BERTELOOT (26), *Department of Physiology, Faculty of Medicine, University of Montreal, Montreal, Quebec H3C 3T8, Canada*

RICHARD C. BOUCHER (36), *Department of Medicine, The University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599*

J. L. BOYER (32, 33, 34), *Department of Medicine and Liver Center, Yale University School of Medicine, New Haven, Connecticut 06510*

R. M. CASE (17), *Department of Physiological Sciences, University of Manchester, Manchester M13 9PT, England*

DEAN CHANG (47), *Department of Physiology and the Cellular and Molecular Biology Program, University of Michigan Medical School, Ann Arbor, Michigan 48109*

MOIRA CIOFFI (40), *Department of Biology, Temple University, Philadelphia, Pennsylvania 19122*

MORTIMER M. CIVAN (44), *Departments of Physiology and Medicine, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania 19104*

MICHEL CLARET (31), *INSERM U 274, Université Paris-Sud, Orsay, 91405 Cedex, France*

LAURENT COMBETTES (31), *INSERM U 274, Université Paris-Sud, Orsay, 91405 Cedex, France*

J. COPELLO (43), *Department of Physiology and Biophysics, The University of Texas Medical Branch, Galveston, Texas 77550*

C. COTTON (43), *Department of Pediatrics, Case Western Reserve University, Cleveland, Ohio 44106*

DWIGHT N. CRAWFORD (39), *Department of Biology, Temple University, Philadelphia, Pennsylvania 19122*

S. CURCI (5), *Istituto di Fisiologia Generale, Università di Bari, 70126 Bari, Italy*

CATHERINE DARGEMONT (31), *Ecole Normale Supérieure, Paris 75006, France*

DAVID C. DAWSON (47), *Department of Physiology and the Cellular and Molecular Biology Program, University of Michigan Medical School, Ann Arbor, Michigan 48109*

K. DAWSON (43), *Department of Physiology and the Cellular and Molecular Biology Program, University of Michigan Medical School, Ann Arbor, Michigan 48109.*

DANIEL C. DEVOR (21), *Department of Physiology, School of Medicine, State University of New York at Buffalo, Buffalo, New York 14214*

KIERTISIN DHARMSATHAPHORN (24), *Department of Medicine, University of California, San Diego, San Diego, California 92103*

P. DIETL (46), *Department of Physiology, Dartmouth Medical School, Hanover, New Hampshire 03756*

MICHAEL E. DUFFEY (21), *Department of Physiology, School of Medicine, State University of New York at Buffalo, Buffalo, New York 14214*

FRANKLIN H. EPSTEIN (49), *The Mount Desert Island Biological Laboratory, Salsbury Cove, Maine 04672*

MICHAEL FIELD (48), *Department of Medicine and Physiology, College of Physicians and Surgeons, Columbia University, New York, New York 10032*

GUNNAR FLEMSTRÖM (9), *Department of Physiology and Medical Biophysics, Uppsala University Biomedical Center, S-751 23 Uppsala, Sweden*

HENRIK FORSSELL (9), *Department of Surgery, Sahlgren's Hospital, University of Gothenburg, S-143 45 Gothenburg, Sweden*

J. G. FORTE (10), *Department of Molecular and Cell Biology, University of California, Berkeley, Berkeley, California 94720*

MICHAEL FROMM (29), *Institut für Klinische Physiologie, Universitätsklinikum Steglitz, Freie Universitat Berlin, D-1000 Berlin 45, Federal Republic of Germany*

E. FRÖMTER (5, 45), *Zentrum der Physiologie, Johann Wolfgang Goethe-Universität, D-6000 Frankfurt am Main, Federal Republic of Germany*

D. V. GALLACHER (20), *Department of Physiology, University of Liverpool, Liverpool L69 3BX, England*

JERRY D. GARDNER (16, 18), *The Digestive Diseases Branch, National Institute of Diabetes, Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland 20892*

HAIM GARTY (44), *Department of Membrane Research, The Weizmann Institute of Science, Rehovot, Israel*

B. GASSNER (46), *Department of Physiology, University of Würzburg, D-8700 Würzburg, Federal Republic of Germany*

L. G. M. GORDON (45), *Department of Physiology, University of Otago Medical School, Dunedin, New Zealand*

J. GRAF (32), *Department of General and Experimental Pathology, University of Vienna, Vienna, Austria*

K. HAGG (2), *Medizinische Universitätsklinik, D-7800 Freiburg, Federal Republic of Germany*

PHILIPPE A. HALBAN (13, 14), *Jeantet Research Laboratories, University of Geneva School of Medicine, CH-1211 Geneva 4, Switzerland*

JOHN W. HANRAHAN (42), *Department of Physiology, McGill University, Montreal, Quebec H3G 1Y6, Canada*

WILLIAM R. HARVEY (39, 40), *Department of Biology, Temple University, Philadelphia, Pennsylvania 19122*

ULRICH HEGEL (29), *Institut für Klinische Physiologie, Universitätsklinikum Steglitz, Freie Universitat Berlin, D-1000 Berlin 45, Federal Republic of Germany*

JOSEPH HELMAN (3), *Department of Oral and Maxillofacial Surgery, Rambam Medical Center, Haifa, Israel 31096*

STEPHEN HERSEY (8), *Department of Physiology, Emory University, Atlanta, Georgia 30322*

ULRICH HOPFER (25), *Department of Physiology and Biophysics, Case Western Reserve University, Cleveland, Ohio 44106*

VALERIE J. HORN (3), *Clinical Investigations and Patient Care Branch, National Institute of Dental Research, National Institutes of Health, Bethesda, Maryland 20892*

ROBERT T. JENSEN (16, 18), *The Digestive Diseases Branch, National Institute of Diabetes, Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland 20892*

THOMAS J. JENTSCH (37), *Zentrum für Molekulare Neurobiologie, Universität Hamburg, D-2000 Hamburg 20, Federal Republic of Germany*

NEIL KAPLOWITZ (30), *Department of Medicine, USC School of Medicine, Los Angeles, California 90033*

GEORGE A. KIMMICH (22), *Department of Biochemistry, School of Medicine and Dentistry, University of Rochester, Rochester, New York 14642*

ULLA KLEIN (40), *Zoologisches Institut der Universität, D-8000 Munchen 2, Federal Republic of Germany*

H. KNAUF (2), *Medizinische Universitätsklinik, D-7800 Freiburg, Federal Republic of Germany*

G. KOTTRA (45), *Zentrum der Physiologie, Klinikum der J. W. Goethe-Universität, 6000 Frankfurt 70, Federal Republic of Germany*

SIMON A. LEWIS (42), *Department of Physiology and Biophysics, University of Texas Medical Branch, Galveston, Texas 77550*

CAROLE M. LIEDTKE (35), *Department of Pediatrics, Case Western Reserve University, Cleveland, Ohio 44106*

TERRY E. MACHEN (4), *Department of Molecular and Cell Biology, University of California, Berkeley, Berkeley, California 94720*

JAMES L. MADARA (24), *Department of Pathology, Harvard Medical School, Boston, Massachusetts 02115*

S. H. P. MADDRELL (41), *Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, England*

PARAMESWARA MALATHI (27), *Department of Physiology and Biophysics, University of Medicine and Dentistry of New Jersey–Robert Wood Johnson Medical School, Piscataway, New Jersey 08854*

DANUTA H. MALINOWSKA (7), *Department of Physiology and Biophysics, University of Cincinnati College of Medicine, Cincinnati, Ohio 45267*

JEAN-PIERRE MAUGER (31), *INSERM U 274, Université Paris-Sud, Orsay, 91405 Cedex, France*

PAOLO MEDA (13, 14), *Department of Morphology, University of Geneva School of Medicine, CH-1211 Geneva 4, Switzerland*

PETER J. MEIER (33, 34), *Division of Clinical Pharmacology, Department of Medicine, University Hospital, CH-8091 Zurich, Switzerland*

HANS PETER MEISSNER (15), *Free University of Berlin, D-1000 Berlin 21, Federal Republic of Germany*

JAMES E. MELVIN (3), *Department of Dental Research, University of Rochester Medical Center, Rochester, New York 14642*

DELIA MENOZZI (18), *The Digestive Diseases Branch, National Institute of Diabetes, Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland 20892*

LAWRENCE M. MERTZ (3), *Endocrinology and Reproduction Research Branch, National Institute of Child Health and Human Development, National Institutes of Health, Bethesda, Maryland 20892*

MELISSA MILLER (8), *Department of Physiology, Emory University, Atlanta, Georgia 30322*

AUSTIN K. MIRCHEFF (23), *Department of Physiology and Biophysics, University of Southern California, School of Medicine, Los Angeles, California 90033*

MARK W. MUSCH (48), *Department of Medicine, The University of Chicago, Chicago, Illinois 60637*

PAUL A. NEGULESCU (4), *Department of Molecular and Cell Biology, University of California, Berkeley, Berkeley, California 94720*

I. NOVAK (1), *Physiologisches Institut, Albert-Ludwigs-Universität, D-7800 Freiburg, Federal Republic of Germany*

SCOTT M. O'GRADY (48), *Department of Veterinary Biology, University of Minnesota, St. Paul, Minnesota 55108*

H. OBERLEITHNER (46), *Department of Physiology, University of Würzburg, D-8700 Würzburg, Federal Republic of Germany*

MURAD OOKHTENS (30), *Department of Medicine, USC School of Medicine, Los Angeles, California 90033*

Y. OSIPCHUK (20), *Bogomoletz Institute of Physiology, Ukranian Academy of Sciences, 252601 Kiev 24, U.S.S.R.*

J. A. OVERTON (41), *Department of Zoology, University of Cambridge, Cambridge CB2 3EJ, England*

BRIAN E. PEERCE (11), *Department of Physiology and Biophysics, University of Texas Medical Branch, Galveston, Texas 77550*

O. H. PETERSEN (20), *Department of Physiology, University of Liverpool, Liverpool L69 3BX, England*

J. M. PHILLIPS (32), *Research Institute and Department of Pathology, Hospital for Sick Children and University of Toronto, Toronto, Ontario, Canada*

JAN POHL (8), *Microchemical Facility, Emory University, Atlanta, Georgia 30322*

W. W. REENSTRA (10), *Research Institute, Children's Hospital of Oakland, Oakland, California 94609*

L. REUSS (43), *Department of Physiology and Biophysics, The University of Texas Medical Branch, Galveston, Texas 77550*

FUSAKO SATO (38), *Department of Dermatology, University of Iowa College of Medicine, Iowa City, Iowa 52242*

KENZO SATO (38), *Department of Dermatology, University of Iowa College of Medicine, Iowa City, Iowa 52242*

IRENE SCHULZ (19), *Max-Planck-Institut für Biophysik, D-6000 Frankfurt am Main 70, Federal Republic of Germany*

HELMUT SCHWEIKL (40), *Zoologisches Institut der Universität, D-8000 Munchen 2, Federal Republic of Germany*

Y. SEGAL (43), *Department of Physiology and Biophysics, The University of Texas Medical Branch, Galveston, Texas 77550*

G. SEMENZA (26), *Department of Biochemistry, Swiss Institute of Technology, ETH-Zentrum, CH-8092 Zurich, Switzerland*

PATRICIO SILVA (49), *Department of Medicine, Beth Israel Hospital, Boston, Massachusetts 02215*

STEVEN M. SIMASKO (21), *Department of Physiology, School of Medicine, State University of New York at Buffalo, Buffalo, New York 14214*

RICHARD J. SOLOMON (49), *Renal Unit, Westchester County Medical Center and New York Medical College, Valhalla, New York 10595*

DANIEL D. SPAETH (39), *Department of Biology, Temple University, Philadelphia, Pennsylvaia 19122*

MARK TAKAHASHI (27), *Department of Physiology and Biophysics, University of Medicine and Dentistry of New Jersey–Robert Wood Johnson Medical School, Piscataway, New Jersey 08854*

LAURA TANG (8), *Department of Physiology, Emory University, Atlanta, Georgia 30322*

R. JAMES TURNER (3), *Clinical Investigations and Patient Care Branch, National Institute of Dental Research, Bethesda, Maryland 20892*

EMILE J. J. M. VAN CORVEN (23), *Department of Physiology and Biophysics, University of Southern California, School of Medicine, Los Angeles, California 90033*

M. WAKUI (20), *Department of Physiology, Tohoku University, School of Medicine, Sendai 980, Japan*

JULIAN R. F. WALTERS (28), *Department of Medicine, Royal Postgraduate Medical School, Hammersmith Hospital, London W12 OHS, England*

W. WANG (46), *Department of Cellular and Molecular Physiology, Yale Medical School, New Haven, Connecticut 06510*

STEPHEN A. WANK (16), *The Digestive Diseases Branch, National Institute of Diabetes, Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland 20892*

F. WEHNER (43), *Max-Plank-Institut für Sytemphysiologie, D-4600 Dortmund 1, Federal Republic of Germany*

MILTON M. WEISER (28), *Department of Medicine, State University of New York at Buffalo, Buffalo General Hospital, Buffalo, New York 14203*

HELMUT WIECZOREK (40), *Zoologisches Institut der Universität, D-8000 Munchen 2, Federal Republic of Germany*

MICHAEL WIEDERHOLT (37), *Institut für Klinische Physiologie, Klinikum Steglitz, Freie Universität Berlin, D-1000 Berlin 45, Federal Republic of Germany*

MICHAEL G. WOLFERSBERGER (40), *Department of Biology, Temple University, Philadelphia, Pennsylvania 19122*

CLAES B. WOLLHEIM (13, 14), *Department of Medicine, Division of Clinical Biochemistry, University of Geneva School of Medicine, CH-1211 Geneva 4, Switzerland*

TADATAKA YAMADA (12), *Department of Internal Medicine, University of Michigan Hospitals, Ann Arbor, Michigan 48109*

JAMES R. YANKASKAS (36), *Department of Medicine, The University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599*

D. YULE (20), *Department of Physiology, University of Liverpool, Liverpool L69 3BX, England*

Preface

Biological transport is part of the Biomembranes series of *Methods in Enzymology*. It is a continuation of methodology concerned with membrane function. This is a particularly good time to cover the topic of biological membrane transport because there is now a strong conceptual basis for its understanding. The field of transport has been subdivided into five topics.

1. Transport in Bacteria, Mitochondria, and Chloroplasts
2. ATP-Driven Pumps and Related Transport
3. General Methodology of Cellular and Subcellular Transport
4. Cellular and Subcellular Transport: Eukaryotic (Nonepithelial) Cells
5. Cellular and Subcellular Transport: Epithelial Cells

Topic 1 covered in Volumes 125 and 126 initiated the series. Topic 2 is covered in Volumes 156 and 157, Topic 3 in Volumes 171 and 172, and Topic 4 in Volumes 173 and 174. The remaining Topic 5 is now covered in 191 and 192.

Topic 5 is divided into two parts: this volume (Part W) which deals with gastrointestinal and a diversity of other epithelial cells, and Volume 191 (Part V) which covers transport in kidney, hormonal modulation, stimulus secretion coupling, pharmacological agents and targeting, and intracellular trafficking in epithelial cells.

We are fortunate to have the good counsel of our Advisory Board. Their input insures the quality of these volumes. The same Advisory Board has served for the complete transport series. Valuable input on the outlines of the five topics was also provided by Qais Al-Awqati, Ernesto Carafoli, Halvor Christensen, Isadore Edelman, Joseph Hoffman, Phil Knauf, and Hermann Passow. Additional valuable input for Volumes 191 and 192 was obtained from Michael Berridge, Eberhard Fromter, Ari Helenius, and Heine Murer.

The names of our advisory board members were inadvertently omitted in Volumes 125 and 126. When we noted the omission, it was too late to rectify the problem. For volumes 125 and 126, we are also pleased to acknowledge the advice of Angelo Azzi, Youssef Hatefi, Dieter Oesterhelt, and Peter Pedersen.

The enthusiasm and cooperation of the participants have enriched and made these volumes possible. The friendly cooperation of the staff of Academic Press is gratefully acknowledged. We are pleased to acknowledge Ms. Laura Taylor for her tireless efforts and secretarial skills.

These volumes are dedicated to Professor Sidney Colowick, a dear friend and colleague, who died in 1985. We shall miss his wise counsel, encouragement, and friendship.

SIDNEY FLEISCHER
BECCA FLEISCHER

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, and 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