Methods in Enzymology

Volume 147

Peptide Growth Factors

Part B

EDITED BY

David Barnes

David A. Sirbasku

Methods in Enzymology

Volume 147

Peptide Growth Factors

Part B

EDITED BY

David Barnes

DEPARTMENT OF BIOCHEMISTRY AND BIOPHYSICS
OREGON STATE UNIVERSITY
CORVALLIS, OREGON

David A. Sirbasku

DEPARTMENT OF BIOCHEMISTRY AND MOLECULAR BIOLOGY
UNIVERSITY OF TEXAS MEDICAL SCHOOL
HOUSTON, TEXAS

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

ACADEMIC PRESS, INC.
Orlando, Florida 32887

United Kingdom Edition published by
ACADEMIC PRESS INC. (LONDON) LTD.
24-28 Oval Road, London NW1 7DX

LIBRARY OF CONGRESS CATALOG CARD NUMBER: 54-9110

ISBN 0-12-182047-5 (alk. paper)

PRINTED IN THE UNITED STATES OF AMERICA

87 88 89 90 9 8 7 6 5 4 3 2 1

Contributors to Volume 147

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

JOHN M. ALETTA (18), *Department of Pharmacology, New York University School of Medicine, New York, New York 10016*

ROBERT H. ALLEN (21), *Division of Hematology, Department of Medicine, University of Colorado Health Sciences Center, Denver, Colorado 80262*

HARRY N. ANTONIADES (3), *Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts 02115*

THOMAS J. BARIBAULT (16), *Division of Horticultural Research, CSIRO, Adelaide 5001, South Australia*

GRAEME I. BELL (17), *Howard Hughes Medical Institute, University of Chicago, Chicago, Illinois 60637*

MAURICE C. BONDURANT (30), *Department of Medicine, Division of Hematology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232*

JEREMY P. BROCKES (19), *MRC Cell Biophysics Unit, London WC2B 5RL, England*

DAN CASSEL (38), *Department of Biology, Technion-Israel Institute of Technology, Haifa 32000, Israel*

HIDEO CHIBA (29), *Department of Food Science and Technology, Faculty of Agriculture, Kyoto University, Kyoto 606, Japan*

BRENT H. COCHRAN (6), *Center for Cancer Research and Department of Biology, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*

DENNIS D. CUNNINGHAM (14), *Department of Microbiology and Molecular Genetics, College of Medicine, University of California, Irvine, California 92717*

DERRICK DOMINGO (24), *Department of Cancer Biology, The Salk Institute for Biological Studies, San Diego, California 92138*

BO EK (1), *Ludwig Institute for Cancer Research, Biomedical Center, S-751 23 Uppsala, Sweden*

MICHAEL W. FANGER (16), *Department of Immunology, Dartmouth Medical Center, Hanover, New Hampshire 03755*

BRIAN FAULDERS (1), *Ludwig Institute for Cancer Research, Biomedical Center, S-751 23 Uppsala, Sweden*

D. GOSPODAROWICZ (9), *Cancer Research Institute, University of California Medical Center, San Francisco, California 94143*

STEVEN H. GREEN (18), *Department of Pharmacology, New York University School of Medicine, New York, New York 10016*

LLOYD A. GREENE (18), *Department of Pharmacology, New York University School of Medicine, New York, New York 10016*

GARY R. GROTENDORST (12), *Departments of Medicine and Biochemistry, Medical University of South Carolina, Charleston, South Carolina 29425*

RICHARD T. HAMILTON (39), *Department of Zoology, Iowa State University, Ames, Iowa 50011*

ANNET HAMMACHER (1), *Ludwig Institute for Cancer Research, Biomedical Center, S-751 23 Uppsala, Sweden*

MAUREEN A. HARRINGTON (36), *Comprehensive Cancer Center, University of Southern California, Los Angeles, California 90033*

SHUICHI HASHIZUME (27), *Morinaga Institute of Biological Science, Yokohama 230, Japan*

CARL-HENRIK HELDIN (1), *Ludwig Institute for Cancer Research, Biomedical Center, S-751 23 Uppsala, Sweden*

HARVEY R. HERSCHMAN (31), *Department of Biological Chemistry, and Laboratory of Biomedical and Environmental Sciences, University of California, Los Angeles School of Medicine, Los Angeles, California 90024*

FUMIAKI ITO (34), *Department of Biochemistry, Faculty of Pharmaceutical Sciences, Setsunan University, 45-1 Nagaotoge-cho, Hirakata-shi, Osaka 573-01, Japan*

ANN JOHNSSON (1), *EMBL, Postfach 1022.40, 6900 Heidelberg 1, Federal Republic of Germany*

MICHAEL E. KAMARCK (25), *Molecular Therapeutics Inc., West Haven, Connecticut 06516*

JERRY KAPLAN (22), *Department of Pathology, University of Utah School of Medicine, Salt Lake City, Utah 84132*

WILLIAM R. KIDWELL (37), *Growth Regulation Center, Laboratory of Tumor Immunology and Biology, National Cancer Institute, Bethesda, Maryland 20892*

MICHAEL KLAGSBRUN (8), *Departments of Biological Chemistry and Surgery, Children's Hospital and Harvard Medical School, Boston, Massachusetts 02115*

SIGRUN KORSCHING (15), *Division of Biology, California Institute of Technology, Pasadena, California 91125*

MARK J. KOURY (30), *Department of Medicine, Division of Hematology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232*

KAZUHIKO KURODA (27), *Morinaga Institute of Biological Science, Yokohama 230, Japan*

JAYNE F. LESLEY (24), *Department of Cancer Biology, The Salk Institute for Biological Studies, San Diego, California 92138*

RAMON LIM (20), *Division of Neurochemistry and Neurobiology, Department of Neurology, University of Iowa, Iowa City, Iowa 52242*

STEVE LOVEJOY (28), *SRI International, Menlo Park, California 94025*

GEORGE J. MARKELONIS (26), *Department of Anatomy, University of Maryland School of Medicine, Baltimore, Maryland 21201*

ALAN MCCLELLAND (25), *Molecular Therapeutics Inc., West Haven, Connecticut 06516*

K. A. MCKEEHAN (13, 35), *W. Alton Jones Cell Science Center, Inc., Lake Placid, New York 12946*

W. L. MCKEEHAN (13, 35), *W. Alton Jones Cell Science Center, Inc., Lake Placid, New York 12946*

MARK MERCOLA (6), *Department of Microbiology and Molecular Genetics, Harvard Medical School and the Dana-Farber Cancer Institute, Boston, Massachusetts 02115*

JOYCE F. MILLER (20), *Division of Neurochemistry and Neurobiology, Department of Neurology, University of Iowa Hospital, Iowa City, Iowa 52242*

HIROKI MURAKAMI (27), *Department of Food Science and Technology, Kyushu University, Fukuoka 812, Japan*

KENNETH E. NEET (16), *Department of Biochemistry, Case Western Reserve University, Cleveland, Ohio 44106*

MARIT NILSEN-HAMILTON (39), *Department of Biochemistry and Biophysics, Iowa State University, Ames, Iowa 50011*

TAE H. OH (26), *Department of Anatomy, University of Maryland School of Medicine, Baltimore, Maryland 21201*

PANAYOTIS PANTAZIS (3), *Department of Nutrition, Harvard School of Public Health, Boston, Massachusetts 02115*

LOREN PICKART (28), *Procyte, Redmond, Washington 98052*

W. JACKSON PLEDGER (7, 36), *Department of Cell Biology, Vanderbilt University Medical School, Nashville, Tennessee 37232*

ELAINE W. RAINES (5), *Department of Pathology, University of Washington, Seattle, Washington 98195*

HANS-GEORG RAMMENSEE (24), *Basel Institute for Immunology, 4005 Basel, Switzerland*

BARRETT ROLLINS (6), *Department of Microbiology and Molecular Genetics, Harvard Medical School and the Dana-Farber Cancer Institute, Boston, Massachusetts 02115*

LARS RÖNNSTRAND (1), *Ludwig Institute for Cancer Research, Biomedical Center, S-751 23 Uppsala, Sweden*

RUSSELL ROSS (5), *Department of Pathology, University of Washington, Seattle, Washington 98195*

PAUL ROTHENBERG (38), *Department of Pathology, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts 02115*

E. ROZENGURT (4), *Laboratory of Growth Regulation, Imperial Cancer Research Fund, London WC2A 3PX, England*

FRANK H. RUDDLE (25), *Department of Biology, Yale University, New Haven, Connecticut 06511*

ADRIANA RUKENSTEIN (18), *Department of Pharmacology, New York University School of Medicine, New York, New York 10016*

RUSSELL RYBKA (8), *Department of Surgery, Children's Hospital, Boston, Massachusetts 02115*

RYUZO SASAKI (29), *Department of Food Science and Technology, Faculty of Agriculture, Kyoto University, Kyoto 606, Japan*

CAROL SAUVAGE (24), *Department of Cancer Biology, The Salk Institute for Biological Studies, San Diego, California 92138*

STEPHEN T. SAWYER (30), *Department of Medicine, Division of Hematology, Vanderbilt University School of Medicine, Nashville, Tennessee 37232*

CHARLES D. SCHER (7), *Division of Oncology, Department of Pediatrics, The Children's Hospital of Philadelphia, University of Pennsylvania, Philadelphia, Pennsylvania 19104*

ROBERTA SCHULTE (24), *Department of Cancer Biology, The Salk Institute for Biological Studies, San Diego, California 92138*

JAMES SCOTT (17), *Molecular Medicine Group, MRC Clinical Research Centre, Harrow, Middlesex HA1, 3UJ, England*

MARK J. SELBY (17), *Hormone Research Institute, University of California, San Francisco, California 94143*

PAUL A. SELIGMAN (21), *Division of Hematology, Department of Medicine, University of Colorado Health Sciences Center, Denver, Colorado 80262*

NOBUYOSHI SHIMIZU (33, 34), *Department of Molecular Biology, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo 160, Japan, and Department of Molecular and Cellular Biology, University of Arizona, Tucson, Arizona 85721*

YUEN SHING (8), *Department of Surgery, Children's Hospital, Boston, Massachusetts 02115*

JAI PAL SINGH (2), *Department of Atherosclerosis and Thrombosis, The Upjohn Company, Kalamazoo, Michigan 49001*

SANDRA SMITH (8), *Department of Surgery, Children's Hospital, Boston, Massachusetts 02115*

CHARLES D. STILES (6), *Department of Microbiology and Molecular Genetics, Harvard Medical School and the Dana-Farber Cancer Institute, Boston, Massachusetts 02115*

DANIEL S. STRAUS (32), *Biomedical Sciences Division and Department of Biology, University of California, Riverside, California 92521*

P. STROOBANT (4), *Medical and Molecular Biology Unit, Department of Biochemistry, University College and Middlesex School of Medicine, London W1P 6DB, England*

ROBERT SULLIVAN (8), *Department of Surgery, Children's Hospital, Boston, Massachusetts 02115*

HOWARD H. SUSSMAN (23), *Department of Pathology, Stanford University School of Medicine, Stanford, California 94305*

HANS THOENEN (15), *Department of Neurochemistry, Max-Planck-Institute for Psychiatry, D-8033 Martinsried, Federal Republic of Germany*

KENNETH A. THOMAS (10), *Department of Biochemistry and Molecular Biology, Merck Institute for Therapeutic Research, Merck Sharp and Dohme Research Laboratories, Rahway, New Jersey 07065*

JAMES A. THOMPSON (14), *Department of Microbiology and Molecular Genetics, College of Medicine, University of California, Irvine, California 92717*

SUSAN E. TONIK (23), *Department of Pathology, Stanford University School of Medicine, Stanford, California 94305*

IAN S. TROWBRIDGE (24), *Department of Cancer Biology, The Salk Institute for Biological Studies, San Diego, California 92138*

JOHN H. WARD (22), *Department of Medicine, University of Utah School of Medicine, Salt Lake City, Utah 84132*

ÅKE WASTESON (1), *Department of Cell Biology, University of Linköping, S-581 85 Linköping, Sweden*

M. D. WATERFIELD (4), *Medical and Molecular Biology Unit, Department of Biochemistry, University College and Middlesex School of Medicine, London W1P 6DB, England*

SUZANNE WENNERGREN (1), *Ludwig Institute for Cancer Research, Biomedical Center, S-751 23 Uppsala, Sweden*

BENGT WESTERMARK (1), *Department of Pathology, University Hospital, S-751 85 Uppsala, Sweden*

SHIN-ICHI YANAGAWA (29), *Department of Biophysics, Institute for Virus Research, Kyoto University, Kyoto 606, Japan*

BRUCE R. ZETTER (11), *Departments of Physiology and Surgery, Harvard Medical School, Children's Hospital, Boston, Massachusetts 02115*

JOHN ZULLO (6), *Department of Microbiology and Molecular Genetics, Harvard Medical School and the Dana-Farber Cancer Institute, Boston, Massachusetts 02115*

PETER ZUMSTEIN (6), *W. Alton Jones Cell Science Center, Lake Placid, New York, 12946*

Dedication

Sidney Colowick and Nate Kaplan were personally involved to a great degree in the development of Peptide Growth Factors, Parts A and B, Volumes 146 and 147 of *Methods in Enzymology*. Although their scientific interests and research directions were varied, they directed their interests toward hormone-related research from time to time throughout their careers. (See, for instance, the chapter on Growth Factor Stimulation of Sugar Uptake by Inman and Colowick in Volume 146.) From the early discussions regarding these volumes, Sidney's and Nate's comments, advice, and suggestions made our task easier, and their wisdom contributed greatly to the quality of the final product. Sadly, neither lived to see the completion of the work.

Other tributes to these extraordinary men have appeared in *Methods in Enzymology*, and we could add little that has not been expressed. The series itself may be the best demonstration of their remarkable scientific insight and comprehension. However, those who knew them realize that in spite of their enormous intellectual contributions it is the personal impact they had on colleagues, students, and friends that is their greatest legacy. These men and their families touched our lives profoundly. We dedicate these volumes to Sidney and Maryda, Nate and Goldie, and their families.

DAVID BARNES
DAVID A. SIRBASKU

Preface

Applications of new techniques and proliferation of investigators in the area of peptide growth factors have led to enormous expansion in understanding the mechanisms of action of these molecules in the past few years and have, in turn, raised new and intriguing questions concerning the relationship of peptide growth factors, receptors, and related molecules to normal and abnormal regulation of cell division and differentiation *in vivo*. Volumes 146 and 147 of *Methods in Enzymology* are a reflection of the recent advances. In these volumes we have attempted to cover methods specific for each growth factor in the areas of purification, immunoassay, radioreceptor assay, biological activity assay, and receptor identification and quantitation. Also included in both volumes are general methods for the study of mechanisms of action that are applicable to many of the factors.

Volume 146 includes techniques concerning epidermal growth factor, transforming growth factors alpha and beta, somatomedin C/insulin-like growth factors, and bone and cartilage growth factors. It also contains methods for quantitative cell growth assays and techniques for the study of growth factor-modulated protein phosphorylation and cell surface membrane effects. Volume 147 covers techniques concerning platelet-derived growth factor, angiogenesis, endothelial and fibroblast growth factors (heparin-binding growth factors), nerve and glial growth factors, transferrin, erythropoietin, and related factors. Also included are genetic approaches to growth factor action and additional methods for the study of biological effects of these molecules.

Procedures related to the basic aspects of research concerning epidermal, nerve, platelet-derived, and insulin-like growth factors have appeared in the Hormone Action series of *Methods in Enzymology*, and methods concerning most aspects of growth factors for lymphoid cells have appeared in the Immunochemical Techniques series. We have attempted to avoid major duplication of material appearing elsewhere in this series in the belief that volumes of moderate size providing recent and complimentary methodology are of more practical value to the researcher. For example, we have not attempted to cover growth factors for lymphoid cells, with the exception of transferrin, which appears to be a requirement for optimal growth of many cell types. Similarly, some approaches that are finding current intensive use in the field, such as recombinant DNA, hybridoma, nucleic acid, or peptide synthesis techniques, are covered per se in other volumes of *Methods in Enzymology*. Detailed

techniques in these areas are included only in situations in which the authors or editors felt that they were sufficiently novel or specific to the area of growth factor research.

We thank the many contributors to this project, and hope these volumes will be useful to investigators in the field.

DAVID BARNES
DAVID A. SIRBASKU

METHODS IN ENZYMOLOGY

EDITED BY

Sidney P. Colowick and Nathan O. Kaplan

VANDERBILT UNIVERSITY
SCHOOL OF MEDICINE
NASHVILLE, TENNESSEE

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF CALIFORNIA
AT SAN DIEGO
LA JOLLA, CALIFORNIA

METHODS IN ENZYMOLOGY

EDITORS-IN-CHIEF

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