

*Methods in Enzymology*

*Volume 142*

*Metabolism of Aromatic  
Amino Acids and Amines*

EDITED BY

*Seymour Kaufman*

58 0307  
M592  
142

*Methods in Enzymology*

*Volume 142*

*Metabolism of Aromatic  
Amino Acids and Amines*

EDITED BY

*Seymour Kaufman*

LABORATORY OF NEUROCHEMISTRY  
NATIONAL INSTITUTE OF MENTAL HEALTH  
BETHESDA, MARYLAND



ACADEMIC PRESS, INC.

Harcourt Brace Jovanovich, Publishers

Orlando San Diego New York Austin  
Boston London Sydney Tokyo Toronto

**COPYRIGHT © 1987 BY ACADEMIC PRESS, INC.**  
**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**

**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 0-12-182042-4 (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 142

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

- CREED W. ABELL (31, 74), *Division of Medicinal Chemistry, College of Pharmacy, University of Texas, Austin, Texas 78712*
- JEAN-PIERRE ABITA (3), *INSERM Unité 204, Hôpital Saint Louis, 75475 Paris Cedex 10, France*
- SYED ASHRAFUDDIN AHMED (49), *Laboratory of Biochemical Pharmacology, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Building 8, Room 2A07, Bethesda, Maryland 20892*
- SHERRY S. ANSHER (77), *Laboratory of Biochemistry and Metabolism, National Institute of Arthritis, Diabetes, and Digestive and Kidney Diseases, National Institutes of Health, Building 10, Room 9N119, Bethesda, Maryland 20892*
- IAN A. ANTON (40), *Imperial Cancer Research Fund, Clare Hall Laboratories, South Mimms, Hertfordshire EW6 3LD, England*
- RONALD BAUERLE (47, 49), *Department of Biology, University of Virginia, Charlottesville, Virginia 22901*
- IRAJ BEHBAHANI-NEJAD (50), *Department of Chemistry, University of Michigan-Flint, Flint, Michigan 48503*
- STEPHEN J. BENKOVIC (6), *Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania 16802*
- FÉLICIEENNE BLANDIN-SAVOJA (3), *INSERM Unité 12, Hôpital des Enfants Malades, 75015 Paris, France*
- C. BONNER (57, 58), *Department of Microbiology and Cell Science, University of Florida, Gainesville, Florida 32611*
- MARTIN R. BOOCOCK (42), *Department of Genetics, University of Glasgow, Glasgow G11 5JS, Scotland*
- DALE BROWN (29), *Department of Zoology and Physiology, Biological Sciences Building, University of Wyoming, Laramie, Wyoming 82070*
- DAVID J. BUCKTHAL (18), *Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania 16802*
- VALENTIN CENA (68), *Section on Neuroendocrinology, Laboratory of Developmental Neurobiology, National Institute of Child Health and Human Development, National Institutes of Health, Building 10, Room 8D42C, Bethesda, Maryland 20892*
- SUBHENDU CHAUDHURI (40, 41, 42), *Department of Biochemistry, University of Glasgow, Glasgow G12 8QQ, Scotland*
- S. CHEEMA-DHADLI (17), *St. Michael's Hospital, Toronto, Ontario, Canada M5B 1A6*
- JOHN R. COGGINS (40, 41, 42, 43, 44), *Department of Biochemistry, University of Glasgow, Glasgow G12 8QQ, Scotland*
- JAMES A. CONNELLY (51, 54), *United States Department of Agriculture, Agriculture Research Station-Northern States Area, Plant Science Research Unit, Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minnesota 55108*
- R. G. H. COTTON (16), *Murdoch Institute, Royal Children's Hospital, Parkville, Victoria 3052, Australia*
- IRVING P. CRAWFORD (37, 38), *Department of Microbiology, University of Iowa, Iowa City, Iowa 52242*
- D. M. DANKS (16), *Murdoch Institute, Royal Children's Hospital, Parkville, Victoria 3052, Australia*
- BARRIE E. DAVIDSON (52, 53), *Russell*

- Grimwade School of Biochemistry, University of Melbourne, Parkville, Victoria 3052, Australia*
- ROBERT DE FEYTER (45), *Department of Cell Biology, University of Auckland, Auckland, New Zealand*
- ANNE P. DØSKELAND (4), *Department of Biochemistry, University of Bergen, N-5000 Bergen, Norway*
- STEIN OVE DØSKELAND (4), *Department of Anatomy, University of Bergen, N-5000 Bergen, Norway*
- R. DUBBELS (67), *Center of Human Genetics, University of Bremen, 2800 Bremen 33, Federal Republic of Germany*
- KENNETH DUNCAN (41), *Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139*
- J. L. DYE (50), *Department of Chemistry, Michigan State University, East Lansing, Michigan 48824*
- J. H. FELLMAN (21), *Department of Biochemistry, Oregon Health Sciences University, Portland, Oregon 97201*
- FRANK A. FIRGAIRA (16), *Department of Haematology, Flinders University Medical Centre, Bedford Park, Adelaide, South Australia 5042, Australia*
- R. FISCHER (56, 59, 60, 61), *Department of Microbiology and Cell Science, University of Florida, Gainesville, Florida 32611*
- TORGEIR FLATMARK (4), *Department of Biochemistry, University of Bergen, N-5000 Bergen, Norway*
- BRIAN J. R. FORBES (18), *Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania 16802*
- SARAH FRENCH (47), *Department of Biology, University of Virginia, Charlottesville, Virginia 22901*
- RONALD P. FRIGON (70), *Department of Medicine, Veterans Administration Medical Center, and University of California, San Diego, California 92161*
- JOHN W. FROST (39), *Department of Chemistry, Stanford University, Stanford, California 94305*
- HITOSHI FUJISAWA (5, 8, 10, 12), *Department of Biochemistry, Asahikawa Medical College, Nishikagura, Asahikawa, Hokkaido 078-11, Japan*
- RAY W. FULLER (76), *Lilly Research Laboratories, Eli Lilly and Company, Lilly Corporate Center, Indianapolis, Indiana 46285*
- FRANK H. GAERTNER (46), *Department of Molecular Genetics, Mycogen Corporation, San Diego, California 92121*
- ANNA GIARTOSIO (25), *Department of Biochemical Sciences, University of Rome "La Sapienza," Rome 00185, Italy*
- DAVID G. GILCHRIST (54), *Department of Plant Pathology, University of California-Davis, Davis, California 95616*
- DAMODAR D. GODSE (66), *Section of Biochemical Psychiatry, Clarke Institute of Psychiatry, and Department of Clinical Biochemistry, University of Toronto, Toronto, Ontario, Canada M5S 1R8*
- EIICHI GOHDA (36), *Department of Biochemistry, Kagoshima University Dental School, Usuki-cho, Kagoshima 890, Japan*
- HELMUT GÖRISCH (55), *Institut für Mikrobiologie, Universität Hohenheim, D-7000 Stuttgart 70, Federal Republic of Germany*
- VRENI HAGER (48), *Abteilung Biophysikalische Chemie, Biozentrum der Universität Basel, CH 4056 Basel, Switzerland*
- GORDON A. HAMILTON (18), *Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania 16802*
- HIROYUKI HASEGAWA (11, 14, 15), *Department of Biochemistry, Hamamatsu University School of Medicine, 3600 Handa-cho, Hamamatsu 431-31, Japan*
- EVELYN A. HAVIR (32), *Department of Biochemistry and Genetics, The Connecticut Agricultural Experiment Station, New Haven, Connecticut 06504*

- OSAMU HAYAISHI (26, 27), *Osaka Medical College, 2-7 Diagakumachi, Takatsuki, Osaka 569, Japan*
- VINCENT J. HEARING, JR. (22), *Laboratory of Cell Biology, National Cancer Institute, National Institutes of Health, Building 37, Room 1B27, Bethesda, Maryland 20892*
- JOHN HESS (47), *Division of Biology, California Institute of Technology, Pasadena, California 91125*
- M. J. M. HITCHCOCK (29), *Bristol Myers Company, Pharmaceutical Research & Development Division, Wallingford, Connecticut 06492*
- PAUL HJEMDAHL (63), *Department of Pharmacology, Karolinska Institute, S-104 01 Stockholm, Sweden*
- GRAHAM S. HUDSON (53), *Commonwealth Scientific and Industrial Research Organization, Division of Plant Industry, Canberra City, Australian Capital Territory 2601, Australia*
- ARATA ICHIYAMA (11), *Department of Biochemistry, Hamamatsu University School of Medicine, 3600 Handa-cho, Hamamatsu 431-31, Japan*
- WILLIAM B. JAKOBY (77), *Laboratory of Biochemistry and Metabolism, National Institute of Arthritis, Diabetes, and Digestive and Kidney Diseases, National Institutes of Health, Building 10, Room 9N119, Bethesda, Maryland 20892*
- THEODORE S. JARDETZKY (48), *Department of Biochemistry and Molecular Biology, Harvard University, Cambridge, Massachusetts 02138*
- I. JENNINGS (16), *Murdoch Institute, Royal Children's Hospital, Parkville, Victoria 3052, Australia*
- R. JENSEN (56, 57, 58, 59, 60, 61), *Department of Microbiology and Cell Science, University of Florida, Gainesville, Florida 32611*
- EDWARD KATZ (29), *Department of Microbiology, Georgetown University Schools of Medicine and Dentistry, Washington, D.C. 20007*
- SEYMOUR KAUFMAN (1, 13), *Laboratory of Neurochemistry, National Institute of Mental Health, Building 36, Room 3D30, Bethesda, Maryland 20892*
- BRIGITTE KELLER (62), *Institut für Mikrobiologie, Universität Hohenheim, D-7000 Stuttgart 70, Federal Republic of Germany*
- EBERHARD KELLER (62), *Limburgerhof der BASF, D-6703 Limburgerhof, Federal Republic of Germany*
- KASPER KIRSCHNER (48), *Abteilung Biophysikalische Chemie, Biozentrum der Universität Basel, CH 4056 Basel, Switzerland*
- D. C. KLEIN (67, 68), *Section on Neuroendocrinology, Laboratory of Developmental Neurobiology, National Institute of Child Health and Human Development, National Institutes of Health, Building 10, Room 8D42C, Bethesda, Maryland 20892*
- JEREMY R. KNOWLES (39), *Department of Chemistry, Harvard University, Cambridge, Massachusetts 02138*
- JOHN M. LAMBERT (42), *Division of Tumor Immunology, Dana-Farber Cancer Institute, Boston, Massachusetts 02115*
- KONRAD LERCH (23), *Institute of Biochemistry, University of Zurich, CH-8057 Zurich, Switzerland*
- ANN LEWENDON (43), *Department of Biochemistry, University of Leicester, Leicester LE1 7RH, England*
- PETER P. LI (66), *Section of Biochemical Psychiatry, Clarke Institute of Psychiatry, University of Toronto, Toronto, Ontario, Canada M5T 1R8*
- SVEN LINDSTEDT (19, 20), *Department of Clinical Chemistry, Gothenburg University, Sahlgren's Hospital, S-413 45 Gothenburg, Sweden*
- FRANZ LINGENS (62), *Institut für Mikrobiologie, Universität Hohenheim, D-7000 Stuttgart 70, Federal Republic of Germany*
- TORBJÖRN LIONES (69), *Department of*

- Chemistry, University of Trondheim, N-7055 Dragvoll, Norway*
- JAMES LUMSDEN (42), *Department of Biochemistry, University of Glasgow, Glasgow G12 8QQ, Scotland*
- CHARALAMPOS MAVRIDES (33), *Department of Biochemistry, University of Ottawa, Ottawa, Ontario, Canada K1N 9B4*
- SHUJAATH MEHDI (39), *Merrell Dow Research Institute, Cincinnati, Ohio 45215*
- EDITH WILSON MILES (49), *Laboratory of Biochemical Pharmacology, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Building 8, Room 2A09, Bethesda, Maryland 20892*
- THOMAS J. MOOREHEAD (18), *Norwich Eaton Pharmaceuticals, Inc., Norwich, New York 13815*
- ELISABETH MORIER-TEISSIER (64), *Unité de Pharmacologie Chimique, Institut National de la Santé et de la Recherche Médicale, 75005 Paris, France*
- DAVID M. MOUSDALE (44), *Department of Biochemistry, University of Glasgow, Glasgow G12 8QQ, Scotland*
- TOSHIHARU NAGATSU (7), *Department of Biochemistry, Nagoya University School of Medicine, Nagoya 466, Japan*
- NOBUO NAKANISHI (14, 15), *Department of Biochemistry, Josai Dental University, Sakado 350-02, Saitama, Japan*
- HIROYASU NAKATA (5, 10, 12), *Section of Histopharmacology, Laboratory of Clinical Science, National Institute of Mental Health, Building 10, Room 3D48, Bethesda, Maryland 20892*
- M. A. A. NAMBOODIRI (67), *Department of Biology, Georgetown University, Washington, D.C. 20057*
- GILLIAN A. NIMMO (42), *Department of Biochemistry, University of Glasgow, Glasgow G12 8QQ, Scotland*
- TOMOO NOGUCHI (34, 35), *Department of Biochemistry, Kyushu Dental College, Manazuru 2-6-1, Kokura-ku, Kitakyushu 803, Japan*
- MITSUHIRO NOZAKI (75), *Department of Biochemistry, Shiga University of Medical Science, Seta, Ohtsu, Shiga 520-21, Japan*
- BIRGIT ODELHÖG (19, 20), *Department of Clinical Chemistry, Gothenburg University, Sahlgren's Hospital, S-413 45 Gothenburg, Sweden*
- KAZUHIRO OKA (7), *Department of Medicine, Mount Sinai School of Medicine, New York, New York 10029*
- SACHIKO OKUNO (8), *Department of Biochemistry, Asahikawa Medical College, Nishikagura, Asahikawa, Hokkaido 078-11, Japan*
- STEPHEN O. PEMBER (6), *Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania 16802*
- HENRY C. PITOT (36), *McArdle Laboratory for Cancer Research, University of Wisconsin-Madison, Madison, Wisconsin 53706*
- RAFFAELE PORTA (78), *Institute of Chemistry and Biological Chemistry, First Medical School, University of Naples, 80138 Naples, Italy*
- WILLIAM J. RAUM (65), *Department of Medicine, Harbor-LA Medical Center, University of California at Los Angeles School of Medicine, Torrance, California 90509*
- FRANÇOISE REY (3), *INSERM Unité 12, Hôpital des Enfants Malades, 75015 Paris, France*
- RICHARD RIPS (64), *Unité de Pharmacologie Chimique, Institut National de la Santé et de la Recherche Médicale, 75005 Paris, France*
- PATRICK A. ROCHE (18), *E. I. DuPont de Nemours & Co., Wilmington, Delaware 19898*
- JAMES I. SALACH (73), *Molecular Biology Division, Veterans Administration Medical Center, San Francisco, California 94121*

- K. G. SCRIMGEOUR (17), *Department of Biochemistry, University of Toronto, Toronto, Ontario, Canada M5S 1A8*
- RONG-SEN SHEN (31), *Division of Biochemistry, Department of Human Biological Chemistry and Genetics, University of Texas Medical Branch, Galveston, Texas 77550*
- ROSS SHIMAN (2), *Department of Biological Chemistry, The Milton S. Hershey Medical Center, The Pennsylvania State University, Hershey, Pennsylvania 17033*
- DANIEL L. SIEHL (51), *Department of Biochemistry and Biophysics, University of California-Davis, California 95616*
- D. DRUMMOND S. SMITH (42), *Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, England*
- THEODORE L. SOURKES (24), *Departments of Psychiatry and Biochemistry, McGill University, Montreal, Quebec, Canada H3A 1A1*
- MARILYN K. SPEEDIE (30), *Department of Medicinal Chemistry/Pharmacognosy, University of Maryland at Baltimore, Baltimore, Maryland 21201*
- CLARENCE H. SUELTER (50), *Department of Biochemistry, Michigan State University, East Lansing, Michigan 48824*
- DAVID SUGDEN (68), *Department of Physiology, Kings College London (KQC), University of London, London W8 7AH, England*
- HALINA SZADKOWSKI (48), *Abteilung Biophysikalische Chemie, Blozentrum der Universität Basel, CH 4056 Basel, Switzerland*
- YOSHIKAZU TAKADA (35), *Department of Biochemistry, Kyushu Dental College, Manazuru 2-6-1, Kokura-kita, Kitakyushu 803, Japan*
- KATSUJI TAKAI (27), *Department of Nutrition, School of Health Sciences, Faculty of Medicine, The University of Tokyo, Tokyo 113, Japan*
- A. WILLIAM TANK (9), *Department of Pharmacology, University of Rochester Medical Center, Rochester, New York 14642*
- MEIR TENNE (72), *Rappaport Family Research Institute, Faculty of Medicine-Technion, Bat Galim, Haifa 31906, Israel*
- MICHAEL C. TOBES (28), *Medical Diagnostic Systems, AT&T Bell Laboratories, Middletown, New Jersey 07748*
- CARLO TURANO (25), *Department of Biochemical Sciences, University of Rome "La Sapienza," Rome 00185, Italy*
- JOSEPH J. VILLAFRANCA (6), *Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania 16802*
- CARLA BORRI VOLTATTORNI (25), *Institute of Biological Chemistry, University of Perugia, Perugia 06100, Italy*
- JERRY J. WARSH (66), *Section of Biochemical Psychiatry, Clarke Institute of Psychiatry, and Departments of Pharmacology and Institute of Medical Sciences, University of Toronto, Toronto, Ontario, Canada M5T 1R8*
- NORMAN WEINER (9), *Pharmaceutical Discovery, Abbott Laboratories, Abbott Park, Illinois 60064*
- ROGER M. WEPPELMAN (71), *Merck Sharp & Dohme Research Laboratories, Rahway, New Jersey 07065*
- WALTER WEYLER (73), *Molecular Biology Division, Veterans Administration Medical Center, San Francisco, California 94121*
- RYOTARO YOSHIDA (26), *Department of Medical Chemistry, Kyoto University Faculty of Medicine, Kyoto 606, Japan*
- MOUSSA B. H. YOUDIM (72), *Rappaport Family Research Institute, Faculty of Medicine-Technion, Bat Galim, Haifa 31906, Israel*



## Preface

The enzymes involved in the metabolism of the aromatic amino acids and amines were last reviewed in this series in 1970 and 1971 in Volumes XVII A and XVII B, which cover all of the amino acids. It is a testimony to the progress in this area since then that a separate volume is now needed to adequately cover this group of enzymes.

It is worth noting that in many cases several purification procedures for the same enzyme from the same source have been published. For the vast majority of enzymes for which this type of duplication was evident, I selected the procedure that in my opinion was the most useful. However, for a few enzymes I thought the inclusion of two procedures for the same enzyme would give the investigator a valuable choice; in those cases, I opted to include both of them.

During the process of compiling the final list of topics and contributors, I received invaluable advice from a number of investigators working in this area, including Drs. Crawford, Coggins, Görish, Jensen, and Knowles. I gratefully acknowledge their help. I was pleasantly surprised by the high percentage of enthusiastic acceptances that I received from those I contacted.

I want to thank all of the contributors for their articles and many of them for their words of encouragement. I am also pleased to acknowledge the cooperation of the staff of Academic Press. Finally, I want to mention that Sidney Colowick and Nathan Kaplan served as essential catalysts for this endeavor. Without their efforts, including some gentle prodding at times, the book would not have been written. I respectfully dedicate this volume to their memory.

SEYMOUR KAUFMAN

# 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

- I. Preparation and Assay of Enzymes
- II. Preparation and Assay of Enzymes
- III. Preparation and Assay of Substrates
- IV. Special Techniques for the Enzymologist
- V. Preparation and Assay of Enzymes
- VI. Preparation and Assay of Enzymes (*Continued*)
  - Preparation and Assay of Substrates
  - Special Techniques
- VII. Cumulative Subject Index

# 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*



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

*Edited by* DIXIE W. FREDRIKSEN 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