

Methods in Enzymology

Volume XLII

CARBOHYDRATE METABOLISM

Part C

Methods in Enzymology
Volume XLII
Carbohydrate Metabolism

Part C

EDITED BY

W. A. Wood

DEPARTMENT OF BIOCHEMISTRY
MICHIGAN STATE UNIVERSITY
EAST LANSING, MICHIGAN

1975



ACADEMIC PRESS New York & San Francisco London

A Subsidiary of Harcourt Brace Jovanovich, Publishers

COPYRIGHT © 1975, 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.

111 Fifth Avenue, New York, New York 10003

United Kingdom Edition published by

ACADEMIC PRESS, INC. (LONDON) LTD.

24/28 Oval Road, London NW1

Library of Congress Cataloging in Publication Data

Main entry under title:

Carbohydrate metabolism.

(Methods in enzymology, v. 9)

Includes bibliographical references.

1. Carbohydrate metabolism. 2. Enzymes. I. Wood,
Willis A., Date ed. II. Series: Methods in
enzymology, v. 9 [etc.] [DNLM: 1. Carbohydrates—
Metabolism. W1ME9615K v. 9]
QP601.C733 vol. 9 574.1'925'08s [574.1'33] 72-26891
ISBN 0-12-181942-6

PRINTED IN THE UNITED STATES OF AMERICA

Contributors to Volume XLII

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

- HUSSEIN ABOU-ISSA (61), *Department of Biochemistry, Emory University, Atlanta, Georgia*
- J. B. ALPERS (20), *Department of Biological Chemistry, Harvard Medical School, Boston, Massachusetts*
- LOUISE E. ANDERSON (68), *Department of Biological Sciences, University of Illinois at Chicago Circle, Chicago, Illinois*
- RICHARD L. ANDERSON (1, 6, 11, 42, 49, 74), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- T. J. ANDREWS (72), *Department of Environmental Biology, Research School of Biological Sciences, Australian National University, Canberra City, Australia*
- ANN AUST (29), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- F. J. BALLARD (7), *Division of Nutritional Biochemistry, C.S.I.R.O., Adelaide, Australia*
- SANTIMOY BANERJEE (9), *Central Drugs Laboratory, Calcutta, India*
- T. BARANOWSKI (54), *Institute of Biochemistry and Biophysics, Medical School, Wroclaw, Poland*
- ERIC A. BARNARD (2), *Department of Biochemistry, State University of New York, Buffalo, New York*
- STEPHEN J. BENKOVIC (60), *Department of Chemistry, Pennsylvania State University, State College; Pennsylvania*
- MOSHE BENZIMAN (32), *Department of Biological Chemistry, The Hebrew University of Jerusalem, Jerusalem, Israel*
- ROBERT W. BERNLOHR (27), *Department of Microbiology, Pennsylvania State University, University Park, Pennsylvania*
- ERNEST BEUTLER (8), *Division of Medicine, City of Hope Medical Center, Duarte, California, and University of Southern California School of Medicine, Los Angeles, California*
- KARL-GEORG BLUME (8), *Freiburg University School of Medicine, Freiburg, Germany*
- LAWRENCE BOGORAD (71), *Department of Biology, Harvard University, Cambridge, Massachusetts*
- LUDWIG BRAND (16), *Department of Biology, The Johns Hopkins University, Baltimore, Maryland*
- BOB B. BUCHANAN (62), *Department of Cell Physiology, University of California, Berkeley, California*
- WILLIAM L. BYRNE (59), *Department of Biochemistry, University of Tennessee Center for the Health Sciences, Memphis, Tennessee*
- J. CARRERAS (65, 66), *Facultad de Medicina, Instituto de Fisiologia, Barcelona, Spain*
- TEH-HSING CHIU (41), *Department of Microbiology, University of Pittsburgh School of Dental Medicine; Pittsburgh, Pennsylvania*
- ALBERT C. CHOU (3), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- GIUSEPPE D'ALESSIO (24), *University of Naples, Naples, Italy*
- STANLEY DAGLEY (43), *Department of Biochemistry, College of Biological Sciences, University of Minnesota, St. Paul, Minnesota*
- A. STEPHEN DAHMS (42, 49), *Department of Chemistry, California State University, San Diego, California*
- ASIS DATTA (10), *School of Life Sciences, Jawaharlal Nehru University, New Delhi, India*
- WILLIAM C. DEAL, JR. (17), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- A. GIB DEBUSK (75), *Genetics Group,*

- Department of Biological Science, Florida State University, Tallahassee, Florida*
- K. A. DECKER (40), *Biochemisches Institut der Universität, Freiburg im Breisgau, Germany*
- EUGENE E. DEKKER (45, 46), *Department of Biological Chemistry, The University of Michigan, Ann Arbor, Michigan*
- J. DE LEY (48), *Laboratory of Microbiology and Microbial Genetics, Faculty of Sciences, State University, Ghent, Belgium*
- MARGARET M. DEMAINE (60), *Department of Chemistry, Pennsylvania State University, State College, Pennsylvania*
- C. C. DOUGHTY (21), *Department of Biological Chemistry, University of Illinois at the Medical Center, Chicago, Illinois*
- DIANA ERSFELD (40), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- KAREN L. EVANS (41), *Department of Microbiology, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania*
- DAVID S. FEINGOLD (41), *Department of Microbiology, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania*
- L. E. FLANDERS (28), *Searle Laboratories, Chicago, Illinois*
- ARTHUR M. GELLER (59), *Department of Biochemistry, The University of Tennessee Center for the Health Sciences, Memphis, Tennessee*
- SUDHAMOY GHOSH (9), *Institut de Biologie Moléculaire, Université de Paris, Paris, France*
- MARTIN GIBBS (36), *Department of Biology, Brandeis University, Waltham, Massachusetts*
- JANE GIBSON (19), *Section of Biochemistry, Molecular and Cell Biology, Cornell University, Ithaca, New York*
- AIDA GOLDSTEIN (76), *Johnson & Johnson Baby Products Company, New Brunswick, New Jersey*
- JONATHAN GOLDTHWAITE (71), *Department of Biology, Boston College, Chestnut Hill, Massachusetts*
- SHARON R. GRADY (45, 46), *Department of Biological Chemistry, The University of Michigan, Ann Arbor, Michigan*
- CHARLES C. GRIFFIN (16), *Department of Chemistry, Miami University, Oxford, Ohio*
- S. GRISOLIA (65, 66), *Department of Biochemistry and Molecular Biology, University of Kansas Medical Center, Kansas City, Kansas*
- ARABINDA GUHA (35), *The Rockefeller University, New York, New York*
- R. H. HAMMERSTEDT (40), *Department of Biochemistry, Pennsylvania State University, University Park, Pennsylvania*
- THOMAS E. HANSON (11), *Department of Biology, Temple University, Philadelphia, Pennsylvania*
- BETH A. HART (19), *Department of Biochemistry, University of Vermont College of Medicine, Burlington, Vermont*
- M. D. HATCH (34, 55), *Division of Plant Industry, C.S.I.R.O., Canberra City, Australia*
- J. S. HAWKER (55), *Division of Horticultural Research, C.S.I.R.O., Glen Osmond, South Australia*
- JAMES A. HAYASHI (21), *Department of Biochemistry, Rush Medical School, Chicago, Illinois*
- WOLFGANG HENGSTENBERG (73), *Max-Planck Institut für Medizinische Forschung, Heidelberg, West Germany*
- PATRICIA HOFFEE (44), *Department of Microbiology, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania*
- B. L. HORECKER (37), *Roche Institute of Molecular Biology, Nutley, New Jersey*
- ROGER JEFFCOAT (43), *Unilever Research Laboratory, Colworth House, Sharnbrook, Bedford, England*
- B. CONNOR JOHNSON (51), *Department of Biochemistry and Molecular Biology, University of Oklahoma Medical*

- Center, Oklahoma City, Oklahoma
- L. JORIS (47), *College of Medicine and Dentistry of New Jersey, Newark, New Jersey*
- JOHN JOSSE (24), *Institute of Molecular Biology, Syntex Research, Palo Alto, California*
- VERNE F. KEMERER (16), *National Institute of Arthritis, Metabolic, and Digestive Diseases, National Institutes of Health, Bethesda, Maryland*
- ROBERT G. KEMP (12, 13), *Department of Biochemistry, Medical College of Wisconsin, Milwaukee, Wisconsin*
- K. KERSTERS (48), *Laboratory for Microbiology and Microbial Genetics, Faculty of Sciences, State University, Ghent, Belgium*
- RODGER D. KOBES (45), *The University of Miami School of Medicine, Miami, Florida*
- J. F. KOSTER (30), *Department of Biochemistry, Faculty of Medicine, Erasmus University, Rotterdam, The Netherlands*
- NANCY KRATOWICH (61), *Department of Biochemistry, University of Georgia, Athens, Georgia*
- GLENN D. KUEHN (69), *Department of Chemistry, New Mexico State University, Las Cruces, New Mexico*
- SHIGERU KUROOKA (15), *Dainippon Pharmaceutical Company, Ltd., Osaka, Japan*
- J. OLIVER LAMPEN (76), *Institute of Microbiology, Rutgers University, New Brunswick, New Jersey*
- M. DANIEL LANE (70), *Department of Physiological Chemistry, The Johns Hopkins University School of Medicine, Baltimore, Maryland*
- ROBERT B. LAYZER (18), *Department of Neurology, University of California School of Medicine, San Francisco, California*
- HERBERT G. LEBHERZ (39), *Laboratory for Developmental Biology, Swiss Federal Institute of Technology, Zurich, Switzerland*
- CAROL B. LIBBY (60), *Department of Chemistry, Pennsylvania State University, State College, Pennsylvania*
- G. H. LORIMER (72), *Department of Environmental Biology, Research School of Biological Sciences, Australian National University, Canberra, Australia*
- BRUCE A. MCFADDEN (69), *Department of Chemistry, Washington State University, Pullman, Washington*
- P. K. MAITRA (4), *Tata Institute of Fundamental Research, Bombay, India*
- THOMAS H. MASSEY (17), *Norwich Pharmaceutical Research and Development Laboratories, Norwich, New York*
- RUDOLPH MEDICUS (61), *Department of Biochemistry, University of Georgia, Athens, Georgia*
- EDON MELLONI (57), *Institute of Biochemistry, University of Genoa, Genoa, Italy*
- JOSEPH MENDICINO (61), *Department of Biochemistry, University of Georgia, Athens, Georgia*
- GEORGE MICHAELS (33), *Department of Biochemistry, Case Western Reserve University School of Medicine, Cleveland, Ohio*
- YORAM MILNER (33), *Department of Biological Chemistry, The Hebrew University, Jerusalem, Israel*
- H. MÖHLER (40), *Medical Research Department, Hoffman-LaRoche and Company, A. G., Basel, Switzerland*
- M. L. MORSE (73), *Webb-Waring Lung Institute, and Department of Biophysics and Genetics, University of Colorado Medical Center, Denver, Colorado*
- HIROMU NISHIHARA (46), *The Center for Adult Diseases, Higashinari-ku, Osaka, Japan*
- RICHARD E. PALMER (1, 74), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- EDWARD E. PENHOET (38), *Department of Biochemistry, University of California, Berkeley, California*
- S. J. PILKIS (5), *Department of Physiology,*

- ogy, *Vanderbilt University School of Medicine, Nashville, Tennessee*
- BURTON M. POGELL (60), *Department of Microbiology, St. Louis University School of Medicine, St. Louis, Missouri*
- SANDRO PONTREMOLI (56, 57), *Institute of Biochemistry, University of Genoa, Genoa, Italy*
- GIAMPIETRO RAMPONI (64), *Department of Biochemistry, University of Florence Medical School, Florence, Italy*
- D. D. RANDALL (63), *Department of Agricultural Chemistry, University of Missouri, Columbia, Missouri*
- RICHARD E. REEVES (31), *Department of Biochemistry, Louisiana State University Medical Center, New Orleans, Louisiana*
- ZELDA B. ROSE (67), *The Institute for Cancer Research, Fox Chase Cancer Center, Philadelphia, Pennsylvania*
- ORA M. ROSEN (58), *Department of Medicine, Albert Einstein College of Medicine, New York, New York*
- WILLIAM J. RUTTER (38, 39), *Department of Biochemistry and Biophysics, University of California, San Francisco, California*
- H. J. SALLACH (28), *Department of Physiological Chemistry, University of Wisconsin Medical School, Madison, Wisconsin*
- VIRGINIA L. SAPICO (6, 11), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- L. H. SCHLOEN (28), *Sloan-Kettering Institute for Cancer Research, New York, New York*
- Z. SCHNEIDER (51), *Institute of Biochemistry, Academy of Agriculture, Wolynska, Poland*
- R. K. SCOPES (22, 23), *Department of Biochemistry, La Trobe University, Bundoora, Victoria, Melbourne, Australia*
- MARVIN I. SIEGEL (70), *Department of Pharmacology and Experimental Therapeutics, The Johns Hopkins University School of Medicine, Baltimore, Maryland*
- C. R. SLACK (34), *Plant Physiology Division, Department of Scientific and Industrial Research, Palmerston North, New Zealand*
- DOROTHY J. SOUTH (31), *Department of Biochemistry, Louisiana State University Medical Center, New Orleans, Louisiana*
- THOMAS G. SPRING (52), *Department of Biophysical Sciences, University of Houston, Houston, Texas*
- G. E. J. STAAL (30), *Haematological Department, State University Hospital, Utrecht, The Netherlands*
- EARLE STELLWAGEN (14), *Department of Biochemistry, University of Iowa, Iowa City, Iowa*
- RICHARD STEPHENS (75), *Genetics Group, Department of Biological Science, The Florida State University, Tallahassee, Florida*
- ALLEN C. STOOLMILLER (50), *Departments of Pediatrics and Biochemistry, The University of Chicago, Chicago, Illinois*
- A. STROINSKI (51), *Department of Plant Physiology, Academy of Agriculture, Wolynska, Poland*
- C. H. SUELTER (29), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- F. ROBERT TABITA (69), *Department of Microbiology, University of Texas, Austin, Texas*
- JEREMY W. THORNER (26), *Department of Bacteriology and Immunology, University of California, Berkeley, California*
- N. E. TOLBERT (63, 72), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- SERENA TRANIELLO (56), *Istituto di Chimica Biologica dell'Universita di Ferrara, Ferrara, Italy*
- O. TSOLAS (47), *Roche Institute of Molecular Biology, Nutley, New Jersey*
- F. WILLIAM TUOMINEN (27), *Biochemicals Division, General Mills Chemicals, Inc., Minneapolis, Minnesota*

- EDGAR H. ULM (60), *Department of Drug Metabolism, Merck Institute for Therapeutic Research, West Point, Pennsylvania*
- KOSAKU UYEDA (15), *Veterans Administration Hospital, and Department of Biochemistry, University of Texas Southwest Medical School, Dallas, Texas*
- C. VEEGER (30), *Department of Biochemistry, Agricultural University, Wageningen, The Netherlands*
- HARVEY WILGUS (14), *Department of Biochemistry, University of Iowa, Iowa City, Iowa*
- JAMES M. WILLARD (36), *Department of Biochemistry, University of Vermont College of Medicine, Burlington, Vermont*
- JOHN E. WILSON (3), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- FINN WOLD (52, 53), *Department of Biochemistry, University of Minnesota, St. Paul, Minnesota*
- E. WOLNA (54), *Institute of Biochemistry and Biophysics, Medical School, Wroclaw, Poland*
- HARLAND G. WOOD (33), *Department of Biochemistry, Case Western Reserve University School of Medicine, Cleveland, Ohio*
- W. A. WOOD (40), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*
- AKIRA YOSHIDA (25), *Department of Biochemical Genetics, City of Hope Medical Center, Duarte, California*
- SHYUN-LONG YUN (29), *Department of Biochemistry, Michigan State University, East Lansing, Michigan*

Preface

Volumes XLI and XLII of "Methods in Enzymology" report new procedures appearing in the literature since 1965. As with Volume IX, the procedures included are for dissimilatory reactions between disaccharides and pyruvate. A few important reactions of pyruvate leading to fermentation end products are also included. The originally planned single volume became two volumes in recognition of the greatly increased number of pages needed to adequately cover this expanding field. The distribution of material between the volumes is arbitrary.

I wish to thank all of the authors for their contributions and their cooperation. It is a pleasure to recognize Ms. Patti Prokopp for her expert secretarial assistance.

W. A. Wood

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 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

Table of Contents

CONTRIBUTORS TO VOLUME XLII	xi
PREFACE	xvii
VOLUMES IN SERIES.	xix

Section I. Kinases

1. β -Glucoside Kinase	RICHARD L. ANDERSON AND RICHARD E. PALMER	3
2. Hexokinases from Yeast	ERIC A. BARNARD	6
3. Hexokinase of Rat Brain	ALBERT C. CHOU AND JOHN E. WILSON	20
4. Glucokinase from Yeast	P. K. MAITRA	25
5. Glucokinase of Rat Liver	S. J. PILKIS	31
6. D-Fructose (D-Mannose) Kinase	RICHARD L. ANDERSON AND VIRGINIA L. SAPICO	39
7. Galactokinase from Pig Liver	F. J. BALLARD	43
8. Galactokinase from Human Erythrocytes	KARL-GEORG BLUME AND ERNEST BEUTLER	47
9. N-Acetylmannosamine Kinase	SANTIMOY BANERJEE AND SUDHAMOY GHOSH	53
10. N-Acetylglucosamine Kinase from Hog Spleen	ASIS DATTA	58
11. D-Fructose-1-phosphate Kinase	RICHARD L. ANDERSON, THOMAS E. HANSON, AND VIRGINIA L. SAPICO	63
12. Phosphofructokinase from Rabbit Liver	ROBERT G. KEMP	67
13. Phosphofructokinase from Rabbit Skeletal Muscle	ROBERT G. KEMP	71
14. Phosphofructokinase of Yeast	EARLE STELLWAGEN AND HARVEY WILGUS	78
15. Phosphofructokinase from <i>Clostridium pasteurianum</i>	KOSAKU UYEDA AND SHIGERU KUROOKA	86
16. Phosphofructokinase from <i>Escherichia coli</i>	VERNE F. KEMERER, CHARLES C. GRIFFIN, AND LUDWIG BRAND	91
17. Phosphofructokinases from Porcine Liver and Kidney and from Other Mammalian Tissues	THOMAS H. MASSEY AND WILLIAM C. DEAL, JR.	99

18. Phosphofructokinase from Human Erythrocytes	ROBERT B. LAYZER	110
19. Ribulose-5-phosphate Kinase from <i>Chromatium</i>	BETH A. HART AND JANE GIBSON	115
20. Phosphoribokinase from <i>Pseudomonas saccharophila</i>	J. B. ALPERS	120
21. D-Glycerate 3-Kinase from <i>Escherichia coli</i>	C. C. DOUGHTY AND JAMES A. HAYASHI	124
22. 3-Phosphoglycerate Kinase of Skeletal Muscle	R. K. SCOPES	127
23. 3-Phosphoglycerate Kinase of Baker's Yeast	R. K. SCOPES	134
24. Phosphoglycerate Kinase and Phosphoglyceromutase from <i>Escherichia coli</i>	GIUSEPPE D'ALESSIO AND JOHN JOSSE	139
25. Human Phosphoglycerate Kinase	AKIRA YOSHIDA	144
26. Glycerol Kinase	JEREMY W. THORNER	148
27. Pyruvate Kinase of <i>Bacillus licheniformis</i>	F. WILLIAM TUOMINEN AND ROBERT W. BERNLOHR	157
28. Isozymes of Pyruvate Kinase from the Grassfrog	L. E. FLANDERS, L. H. SCHLOEN, AND H. J. SALLACH	166
29. Pyruvate Kinase from Yeast (<i>Saccharomyces cerevisiae</i>)	ANN AUST, SHYUN-LONG YUN, AND C. H. SUELTER	176
30. Human Erythrocyte Pyruvate Kinase	G. E. J. STAAL, J. F. KOSTER, AND C. VEEGER	182
31. Pyruvate, Orthophosphate Dikinase from <i>Bacteroides symbiosus</i>	DOROTHY J. SOUTH AND RICHARD E. REEVES	187
32. Pyruvate, Orthophosphate Dikinase from <i>Acetobacter xylinum</i>	MOSHE BENZIMAN	192
33. Pyruvate, Orthophosphate Dikinase of <i>Bacteroides symbiosus</i> and <i>Propionibacterium shermanii</i>	YORAM MILNER, GEORGE MICHAELS, AND HARLAND G. WOOD	199
34. Pyruvate, P _i Dikinase from Leaves	M. D. HATCH AND C. R. SLACK	212

Section II. Aldolases

35. Fructose-diphosphate Aldolase from Lobster Muscle	ARABINDA GUHA	223
36. Fructose-diphosphate Aldolase from Blue-Green Algae	JAMES M. WILLARD AND MARTIN GIBBS	228

37. Fructose-bisphosphate Aldolase from Spinach	B. L. HORECKER	234
38. Detection and Isolation of Mammalian Fructose-diphosphate Aldolases	EDWARD E. PENHOET AND WILLIAM J. RUTTER	240
39. The Class I (Schiff Base) Fructose-diphosphate Aldolase of <i>Peptococcus aerogenes</i>	HERBERT G. LEBHERZ AND WILLIAM J. RUTTER	249
40. 2-Keto-3-deoxy-6-phosphogluconic Aldolase from <i>Pseudomonas putida</i>	R. H. HAMMERSTEDT, H. MÖHLER, K. A. DECKER, DIANA ERSFELD, AND W. A. WOOD	258
41. L-Rhamnulose-1-phosphate Aldolase	TEH-HSING CHIU, KAREN L. EVANS, AND DAVID S. FEINGOLD	264
42. 2-Keto-3-deoxy-L-arabonate Aldolase	RICHARD L. ANDERSON AND A. STEPHEN DAHMS	269
43. D-4-Deoxy-5-ketoglutarate Hydro-lyase (Decarboxylating)	STANLEY DAGLEY AND ROGER JEFFCOAT	272
44. Deoxyribose-5-phosphate Aldolase from <i>Salmonella typhimurium</i>	PATRICIA HOFFEE	276
45. 2-Keto-4-hydroxyglutarate Aldolase from Bovine Liver	EUGENE E. DEKKER, RODGER D. KOBES, AND SHARON R. GRADY	280
46. 2-Keto-4-hydroxyglutarate Aldolase from <i>Escherichia coli</i>	EUGENE E. DEKKER, HIROMU NISHIHARA, AND SHARON R. GRADY	285
47. Transaldolase	O. TSOLAS AND L. JORIS	290

Section III. Dehydratases

48. D-Gluconate Dehydratase from <i>Alcaligenes</i>	K. KERSTERS AND J. DE LEY	301
49. D-Fuconate Dehydratase	RICHARD L. ANDERSON AND A. STEPHEN DAHMS	305
50. L-2-Keto-3-deoxyarabonate Dehydratase	ALLEN C. STOOLMILLER	308
51. Glycerol Dehydratase from <i>Aerobacter aerogenes</i>	B. CONNOR JOHNSON, A. STROINSKI, AND Z. SCHNEIDER	315
52. Enolase from <i>Escherichia coli</i>	THOMAS G. SPRING AND FINN WOLD	323
53. Enolase from Fish Muscle	FINN WOLD	329
54. Enolase from Human Muscle	T. BARANOWSKI AND E. WOLNA	335

Section IV. Phosphatases

55. Sucrose-phosphate Phosphohydrolase (Sucrose Phosphatase) from Plants	J. S. HAWKER AND M. D. HATCH	341
56. Fructose-1,6-diphosphatase and Sedoheptulose-1,7-diphosphatase from <i>Candida utilis</i>	SANDRO PONTREMOLI AND SERENA TRANIELLO	347
57. Fructose-1,6-diphosphatase from Rabbit Liver	SANDRO PONTREMOLI AND EDON MELLONI	354
58. Purification of Fructose-1,6-diphosphatase from <i>Polysphondylium pallidum</i>	ORA M. ROSEN	360
59. Fructose-1,6-diphosphatase from Bovine Liver	ARTHUR M. GELLER AND WILLIAM L. BYRNE	363
60. Fructose-1,6-diphosphatase from Rabbit Liver	EDGAR H. ULM, BURTON M. POGELL, MARGARET M. DEMAINE, CAROL B. LIBBY, AND STEPHEN J. BENKOVIC	369
61. Fructose-1,6-diphosphatase, Phosphofructokinase, Glycogen Synthetase, Phosphorylase, and Protein Kinase from Swine Kidney	JOSEPH MENDICINO, HUSSEIN ABOU-ISSA, RUDOLF MEDICUS, AND NANCY KRATOWICH	375
62. Ferredoxin-Activated Fructose-1,6-diphosphatase System of Spinach Chloroplasts	BOB B. BUCHANAN	397
63. 3-Phosphoglycerate Phosphatase	D. D. RANDALL AND N. E. TOLBERT	405
64. 1,3-Diphosphoglycerate Phosphatase	GIAMPIETRO RAMPONI	409

Section V. Mutases

65. Phosphoglycerate Mutase from Wheat Germ (2,3-PGA-Independent)	S. GRISOLIA AND J. CARRERAS	429
66. Phosphoglycerate Mutase from Yeast, Chicken Breast Muscle, and Kidney (2,3-PGA-Dependent)	S. GRISOLIA AND J. CARRERAS	435
67. 2,3-Diphosphoglycerate Mutase from Human Erythrocytes	ZELDA B. ROSE	450

Section VI. Carboxylases and Decarboxylases

68. Ribulose-1,5-diphosphate Carboxylase from <i>Rhodospirillum rubrum</i>	LOUISE E. ANDERSON	457
69. Ribulose-diphosphate Carboxylase from the Hydrogen Bacteria and <i>Rhodospirillum rubrum</i>	BRUCE A. MCFADDEN, F. ROBERT TABITA, AND GLENN D. KUEHN	461