

Methods in Enzymology

Volume 167

Cyanobacteria

EDITED BY

Lester Packer

DEPARTMENT OF PHYSIOLOGY AND ANATOMY
UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELEY, CALIFORNIA

Alexander N. Glazer

DEPARTMENT OF MICROBIOLOGY AND IMMUNOLOGY
UNIVERSITY OF CALIFORNIA, BERKELEY
BERKELEY, CALIFORNIA

Editorial Advisory Board

Robert Haselkorn

Germaine Stanier



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

E4103b 601167



COPYRIGHT © 1988 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.

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 0-12-182068-8 (alk. paper)

PRINTED IN THE UNITED STATES OF AMERICA
88 89 90 91 9 8 7 6 5 4 3 2 1

Table of Contents

CONTRIBUTORS TO VOLUME 167	xii
PREFACE	xvii
VOLUMES IN SERIES	xix

Section I. Isolation, Identification, and Culturing of Cyanobacteria

1. Isolation and Purification of Cyanobacteria	ROSMARIE RIPPKA	3
2. Recognition and Identification of Cyanobacteria	ROSMARIE RIPPKA	28
3. Culturing Methods for Cyanobacteria	RICHARD W. CASTENHOLZ	68
4. Purification and Storage of Nitrogen-Fixing Filamentous Cyanobacteria	C. PETER WOLK	93
5. Thermophilic Cyanobacteria: Special Problems	RICHARD W. CASTENHOLZ	96
6. Isolation and Growth of Marine Planktonic Cyanobacteria	JOHN B. WATERBURY AND JOANNE M. WILLEY	100
7. Isolation and Culture of Marine Nitrogen-Fixing Unicellular Cyanobacteria <i>Synechococcus</i>	AKIRA MITSUI AND SHULI CAO	105
8. Symbiotic Associations	J. C. MEEKS	113
9. Cell Stability and Storage	S. EDWARD STEVENS, JR.	122
10. New Taxonomic Methods: DNA/DNA Hybridization	W. T. STAM AND B. K. STULP	125
11. 16 S Ribosomal RNA Cataloging	ERKO STACKEBRANDT AND WOLFGANG LUDWIG	132
12. Reverse Transcriptase Sequencing of Ribosomal RNA for Phylogenetic Analysis	DAVID J. LANE, KATHARINE G. FIELD, GARY J. OLSEN, AND NORMAN R. PACE	138
13. Protein Sequences as Taxonomic Probes of Cyanobacteria	ALASTAIR AITKEN	145

Section II. Ultrastructure, Inclusions, and Differentiation

14. Fine Structure of Cyanobacteria	G. STANIER (COHEN-BAZIRE)	157
15. Cell Walls and External Layers	JÜRGEN WECKESSER AND UWE-JOHANNES JÜRGENS	173

16. Cyanobacterial Fimbriae	TIMO VAARA AND MARTTI VAARA	189
17. Inclusions: Granules of Polyglucose, Polyphosphate, and Poly- β -hydroxybutyrate	J. M. SHIVELY	195
18. Inclusions: Carboxysomes	J. M. SHIVELY	204
19. Inclusions: Cyanophycin	MARY MENNES ALLEN	207
20. Gas Vesicles: Chemical and Physical Properties	P. K. HAYES	213
21. Cellular Differentiation: Akinetes	MICHAEL HERDMAN	222
22. Cellular Differentiation: Hormogonia and Baeocytes	MICHAEL HERDMAN AND ROSMARIE RIPPKA	232

Section III. Membranes, Pigments, Redox Reactions, and Nitrogen Fixation

23. Isolation of Cyanobacterial Plasma Membranes	NORIO MURATA AND TATSUO OMATA	245
24. Membrane Lipids	NAOKI SATO AND NORIO MURATA	251
25. Rapid Permeabilization of <i>Anacystis nidulans</i> to Electrolytes	GEORGE C. PAPAGEORGIOU	259
26. Photosystem I and Photosystem II Preparations from Thermophilic <i>Synechococcus</i>	SAKAE KATOH	263
27. Prenylquinones	SAKAE KATOH AND KAZUHIKO SATOH	269
28. Oxygen-Evolving Photosystem II Particles from <i>Phormidium laminosum</i>	DEREK S. BENDALL, JANE M. BOWES, ALISON C. STEWART, AND MARY E. TAYLOR	272
29. <i>In Vivo</i> Effect of Calcium on Photosystem II	JERRY J. BRAND AND DAVID W. BECKER	280
30. Photosystem II-Phycobilisome Complex Preparations	E. GANTT, J. D. CLEMENT-METRAL, AND B. M. CHERESKIN	286
31. Phycobiliproteins	ALEXANDER N. GLAZER	291
32. Phycobilisomes	ALEXANDER N. GLAZER	304
33. Phycobilisome Stability	TETZUYA KATOH	313
34. Complementary Chromatic Adaptation: Physiological Conditions and Action Spectra	N. TANDEAU DE MARSAC AND J. HOUARD	318

35. <i>In Vitro</i> Carotenoid Biosynthesis in <i>Aphanocapsa</i>	GERHARD SANDMANN	329
36. Carotene Oxygenase in <i>Microcystis</i>	FRIEDRICH JÜTTNER	336
37. Cytochrome <i>b₆/f</i> Complex in Cyanobacteria: Common Components of Respiratory and Photosynthetic Electron Transport Systems	RICHARD MALKIN	341
38. Preparation of Coupling Factor F ₁ -ATPase from Cyanobacteria	DAVID B. HICKS	350
39. Respiratory Proton Extrusion and Plasma Membrane Energization	G. A. PESCHEK, W. H. NITSCHMANN, AND T. CZERNY	361
40. Anoxygenic Photosynthetic Electron Transport	SHIMSHON BELKIN, YOSEPHA SHAHAK, AND ETANA PADAN	380
41. Soluble Cytochromes and Ferredoxins	HIROSHI MATSUBARA AND KEISHIRO WADA	387
42. Thioredoxin System	PETER ROWELL, ALLAN J. DARLING, AND WILLIAM D. P. STEWART	410
43. Ferredoxin/Thioredoxin System	NANCY A. CRAWFORD, BOIHON C. YEE, MICHEL DROUX, DONALD E. CARLSON, AND BOB B. BUCHANAN	415
44. Electron Paramagnetic Resonance Characterization of Iron-Sulfur Proteins	R. CAMMACK	427
45. Characterization of Cytochrome- <i>c</i> Oxidase in Isolated and Purified Plasma and Thylakoid Membranes from Cyanobacteria	GÜNTER A. PESCHEK, VÉRONIQUE MOLITOR, MARIA TRNKA, MARNIK WASTYN, AND WALTER ERBER	437
46. Electron Paramagnetic Resonance-Detectable Cu ²⁺ in <i>Synechococcus</i> 6301 and 6311: <i>aa₃</i> -Type Cytochrome- <i>c</i> Oxidase of Cytoplasmic Membrane	IAN V. FRY AND GÜNTER A. PESCHEK	450
47. Nitrogen and Hydrogen Metabolism: Induction and Measurement	HELMAR ALMON AND PETER BÖGER	459
48. Measurement of Hydrogen Exchange and Nitrogen Uptake by Mass Spectrometry	BENT B. JENSEN AND RAYMOND P. COX	467
49. Nitrogen Fixation in Cyanobacterial Mats	LUCAS J. STAL	474
50. Nitrogen Fixation by Synchronously Growing Unicellular Aerobic Nitrogen-Fixing Cyanobacteria	AKIRA MITSUI AND SHUZO KUMAZAWA	484

51. Isolation of Metabolically Active Heterocysts from Cyanobacteria	RUSSELL L. SMITH, CHASE VAN BAALEN, AND F. ROBERT TABITA	490
52. Electron Donation to Nitrogenase in Heterocysts	HERMANN BOTHE AND GABRIELE NEUER	496
53. Hydrogenases: Isolation and Assay	K. K. RAO AND D. O. HALL	501
54. Measurement of Bioenergetics Phenomena in Cyanobacteria with Magnetic Resonance Techniques	ROLF J. MEHLHORN AND RICHARD SULLIVAN	509

Section IV. Physiology and Metabolism

55. Buoyancy and Suspension of Planktonic Cyanobacteria	R. L. OLIVER AND A. E. WALSBY	521
56. Osmotic Adjustment: Organic Solutes	ROBERT H. REED	528
57. Inorganic Carbon Uptake by Cyanobacteria	AARON KAPLAN, YEHOUDA MARCUS, AND LEONORA REINHOLD	534
58. Carbon Metabolism: Studies with Radioactive Tracers <i>in Vivo</i>	JAMES A. BASSHAM AND SCOTT E. TAYLOR	539
59. Transport of Carbohydrates into Cyanobacteria	ARNOLD J. SMITH AND JOHN E. MORE	551
60. Ammonium Transport	JANE GIBSON	557
61. Cation Transport in Cyanobacteria	ETANA PADAN AND ALEXANDER VITTERBO	561
62. Sulfur Metabolism in Cyanobacteria	AHLERT SCHMIDT	572
63. Cyclic Nucleotides	MICHAEL HERDMAN AND KHALIL ELMORJANI	584
64. Cyanobacterial DNA-Dependent RNA Polymerase	GEORGE BORBELY AND GEORGE J. SCHNEIDER	592
65. Extracellular Proteins	D. J. SCANLAN AND N. G. CARR	599
66. Geosmin Production	HELGA NAES	605
67. Quantitative Trace Analysis of Volatile Organic Compounds	FRIEDRICH JÜTTNER	609
68. Cyanobacterial Flocculants	YESHAYA BAR-OR AND MOSHE SHILO	616
69. Cyanobacterial Heat-Shock Proteins and Stress Responses	GEORGE BORBELY AND GYULA SURANYI	622

70. Immobilization Methods for Cyanobacteria in Solid Matrices	M. BROUERS, D. J. SHI, AND D. O. HALL	629
--	--	-----

Section V. General Physical Methods

71. Microsensors	BO BARKER JØRGENSEN AND NIELS PETER REVSBÆCH	639
72. Determination of Turgor Pressure and Other Cell-Solute Relations by Using Gas Vesicles as Pressure Probes	A. E. WALSBY	660
73. Energetic Status of Cyanobacteria: ^{31}P -NMR Spectra	LESTER PACKER, SUSAN SPATH, RICHARD BLIGNY, JEAN-BAPTISTE MARTIN, AND CLAUDE ROBY	667
74. Electron Spin Resonance Oximetry	SHIMSHON BELKIN, ROLF J. MEHLHORN, AND LESTER PACKER	670
75. Determination of pH Gradients in Intact Cyanobacteria by Electron Spin Resonance Spectroscopy	SHIMSHON BELKIN AND LESTER PACKER	677
76. Mass Spectrometric Measurement of Photosynthetic and Respiratory Oxygen Exchange	BERNARD DIMON, PIERRE GANS, AND GILLES PELTIER	686
77. Laser Light Scattering Techniques for Determining Size and Surface Charges of Membrane Vesicles from Cyanobacteria	MARIE-EMMANUEL RIVIÈRE, GEORGES JOHANNIN, DIDIER GAMET, VÉRONIQUE MOLITOR, GÜNTER A. PESCHEK, AND BERNARD ARRIÖ	691

Section VI. Molecular Genetics

78. DNA Transformation	RONALD D. PORTER	703
79. Transformation in <i>Synechocystis</i> PCC 6714 and 6803: Preparation of Chromosomal DNA	FRANÇOISE JOSET	712
80. Mutagenesis of Cyanobacteria by Classical and Gene-Transfer-Based Methods	SUSAN S. GOLDEN	714
81. Selection for Mutants in Energetic Pathways: Enrichment Procedures	FRANÇOISE JOSET	728
82. Use of Reporter Genes in Cyanobacteria	DEVORAH FRIEDBERG	736

83. Conjugal Transfer of DNA to Cyanobacteria	JEFF ELHAI AND C. PETER WOLK	747
84. Isolation of Genes Encoding Components of Photosynthetic Apparatus	DONALD A. BRYANT AND NICOLE TANDEAU DE MARSAC	755
85. Construction of Specific Mutations in Photosystem II Photosynthetic Reaction Center by Genetic Engineering Methods in <i>Synechocystis</i>	JOHN G. K. WILLIAMS	766
6803		
86. Isolation and Characterization of Genes for Cytochrome <i>b₆/f</i> Complex	TOIVO KALLAS AND RICHARD MALKIN	779
87. Genes for ATP Synthase in <i>Synechococcus</i> 6301	ALISON L. COZENS AND JOHN E. WALKER	794
88. Tests on <i>nif</i> Probes and DNA Hybridizations	CLAUDETTE FRANCHE AND THIERRY DAMERVAL	803
89. Cyanobacterial Genetic Tools: Current Status	JEAN HOUARD AND NICOLE TANDEAU DE MARSAC	808

Addendum

Addendum to Article [22]	MICHAEL HERDMAN AND ROSMARIE RIPPKA	851
AUTHOR INDEX		855
SUBJECT INDEX		885