

# ADVANCES IN PROTEIN CHEMISTRY

EDITED BY

FREDERIC M. RICHARDS

*Department of Molecular Biophysics  
and Biochemistry  
Yale University  
New Haven, Connecticut*

DAVID S. EISENBERG

*Department of Chemistry and Biochemistry  
University of California, Los Angeles  
Los Angeles, California*

PETER S. KIM

*Department of Biology  
Massachusetts Institute of Technology  
Whitehead Institute for Biomedical Research  
Howard Hughes Medical Institute Research Laboratories  
Cambridge, Massachusetts*

VOLUME 48

## Enzymes and Proteins from Hyperthermophilic Microorganisms

EDITED BY

MICHAEL W. W. ADAMS

*University of Georgia  
Athens, Georgia*



ACADEMIC PRESS

San Diego London Boston New York  
Sydney Tokyo Toronto

## CONTENTS

CONTRIBUTORS . . . . .	ix
PREFACE . . . . .	xi

### Overview of Hyperthermophiles and Their Heat-Shock Proteins

JOHN A. BAROSS AND JAMES F. HOLDEN

I. Introduction . . . . .	1
II. Definition of Hyperthermophilic Microorganisms . . . . .	2
III. Ecology of Hyperthermophiles . . . . .	3
IV. Phylogeny and Evolution . . . . .	7
V. Physiological Characteristics of Hyperthermophiles . . . . .	16
VI. Heat-Shock Proteins in Hyperthermophiles . . . . .	17
VII. Summary and Conclusions . . . . .	26
References . . . . .	27

### Respiratory Metabolism in Hyperthermophilic Organisms: Hydrogenases, Sulfur Reductases, and Electron Transport Factors That Function at Temperatures Exceeding 100°C

ROBERT J. MAIER

I. Sulfur-Dependent Respiratory Metabolism and Energy Conservation . . . . .	36
II. Nonsulfur Respiratory Metabolism at High Temperatures . . . . .	39
III. Organisms Capable of Respiratory Metabolism . . . . .	40
IV. Respiratory Enzymes . . . . .	46
V. Redox Potentials and Electron Flow . . . . .	68
VI. Quinones and Hyperthermophily . . . . .	75
VII. Generating a Proton and Electrochemical Gradient at High Temperatures . . . . .	78
VIII. Thermal Stability of Membrane-Bound Enzymes . . . . .	83
References . . . . .	93

## Oxidoreductase-Type Enzymes and Redox Proteins Involved in Fermentative Metabolisms of Hyperthermophilic Archaea

MICHAEL W. W. ADAMS AND ARNULF KLETZIN

I.	Introduction . . . . .	101
II.	Physiological Roles of Oxidoreductase-Type Enzymes in Pathways of Fermentation . . . . .	103
III.	2-Keto Acid Oxidoreductases . . . . .	110
IV.	Tungsten-Containing Aldehyde-Oxidizing Oxidoreductases . . . . .	130
V.	Dehydrogenases . . . . .	147
VI.	Hydrogenases . . . . .	153
VII.	Redox Proteins . . . . .	156
VIII.	Summary and Conclusions . . . . .	171
	References . . . . .	173

## Structure and Stability of Hyperstable Proteins: Glycolytic Enzymes from Hyperthermophilic Bacterium *Thermotoga maritima*

R. JAENICKE, H. SCHURIG, N. BEAUCAMP, AND R. OSTENDORP

I.	Introduction . . . . .	181
II.	Fundamentals of Protein Stability . . . . .	184
III.	Limits of Growth . . . . .	200
IV.	Hyperthermophilic Bacterium <i>Thermotoga maritima</i> . . . . .	207
V.	Glycolytic Enzymes . . . . .	211
VI.	Conclusions . . . . .	258
	References . . . . .	260

## Proteases and Glycosyl Hydrolases from Hyperthermophilic Microorganisms

MICHAEL W. BAUER, SHERYL B. HALIO, AND ROBERT M. KELLY

I.	Introduction . . . . .	271
II.	Hyperthermophilic Microorganisms as Sources of Proteolytic and Glycosidic Enzymes . . . . .	272
III.	Proteases . . . . .	273
IV.	Glycosyl Hydrolases . . . . .	287
V.	Summary . . . . .	305
	References . . . . .	305

## Enzymes of Central Nitrogen Metabolism from Hyperthermophiles: Characterization, Thermostability, and Genetics

JOCELYNE DiRUGGIERO AND FRANK T. ROBB

Overview . . . . .	311
I. Introduction . . . . .	312
II. Glutamate Dehydrogenase . . . . .	313
III. Glutamine Synthetase . . . . .	331
IV. Aminotransferases . . . . .	334
V. Conclusions . . . . .	335
References . . . . .	336

## Pressure Effects on Enzyme Activity and Stability at High Temperatures

PETER C. MICHELS, DEREK HEI, AND DOUGLAS S. CLARK

I. Introduction . . . . .	341
II. Theoretical Treatment of Enzyme Inactivation . . . . .	343
III. Effect of Pressure on Enzymes. . . . .	345
IV. Pressure and Protein Stability: Case Studies . . . . .	361
V. Conclusion . . . . .	371
References . . . . .	373

## Thermostable DNA Polymerases

FRANCINE B. PERLER, SANJAY KUMAR, AND HUIMIN KONG

I. DNA Polymerases from Mesophiles: Clues for Understanding Thermostable DNA Polymerases . . . . .	377
II. DNA Polymerases of Thermophilic Eubacteria . . . . .	393
III. DNA Polymerases of Archaea . . . . .	403
IV. Properties of Thermostable DNA Polymerases . . . . .	415
V. Summary . . . . .	428
References . . . . .	430

## DNA Stability and DNA Binding Proteins

ROWAN A. GRAYLING, KATHLEEN SANDMAN, AND JOHN N. REEVE

I. Chemical Degradation of DNA at High Temperatures . . . . .	437
II. Thermal Denaturation of DNA . . . . .	439

III.	DNA Binding Proteins	442
IV.	Topoisomerases	459
V.	Conclusions	462
	References	463
AUTHOR INDEX		469
SUBJECT INDEX		501