CRC

HANDBOOK of MICROBIOLOGY

Volume IV
Microbial Metabolism, Genetics and Immunology

EDITORS

Allen I. Laskin, Ph.D.
Esso Research and Engineering Company
Linden, New Jersey

Hubert A. Lechevalier, Ph.D.
Institute of Microbiology
Rutgers University
New Brunswick, New Jersey

CRC PRESS

18901 Cranwood Parkway, Cleveland, Ohio 44128

HANDBOOK OF MICROBIOLOGY

Volume IV: Microbial Metabolism, Genetics and Immunology

This book presents data obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Every reasonable effort has been made to give reliable data and information, but the editors and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

International Standard Book Number (ISBN)

Complete Set 0-8719-583-1
Volume IV 0-87819-584-X

Library of Congress Catalog Card Number 72-88766

PREFACE

The fourth volume of the *CRC Handbook of Microbiology* contains data in the fields of microbial physiology, immunology and genetics. It includes information on metabolic pathways and contains extensive tables on microbial transformations of steroids, alkaloids, hydrocarbons and pesticides. Genetic data, including numerous linkage maps, are presented for bacteria, bacteriophages, filamentous fungi and yeasts. The immunology section treats immunological classification of microorganisms and autoimmune diseases as well as other subjects in this area. This volume completes a series that furnishes data on microorganisms themselves (Vol. I), on their composition (Vol. II), and on their products (Vol. III). Periodic future editions should keep the *Handbook* up-to-date.

As we have done in the past, we urge all users of this *Handbook* to draw its shortcomings to our attention. Only with the cooperation of the interested public will we eventually be able to produce a handbook that will fully satisfy the needs of all microbiologists.

We wish to express our gratitude to all the authors, who have so generously contributed to these pages, and to the members of our Advisory Board, who have helped with the planning of the *Handbook*. In the case of this volume, we are especially indebted to Dr. Claude Vezina and Dr. Otto J. Plescia. With deep sorrow we regret that this volume was not published before the untimely death of Dr. Werner J. Braun, who contributed so heavily to the planning of the section on microbial genetics.

The task of putting this volume together was made light, thanks to the editorial effort of Mrs. Lisbeth Hammer and the skill of the CRC production staff, and the clerical assistance of Mrs. Verna Lepping.

A. I. Laskin
H. A. Lechevalier
New Jersey 1974

ADVISORY BOARD

Herman J. Phaff, Ph.D.
Department of Food Technology
University of California
Davis, California

Thomas B. Platt, Ph.D.
Bioanalytical Section
The Squibb Institute of Medical Research
New Brunswick, New Jersey

Otto J. Plescia, Ph.D.
Institute of Microbiology
Rutgers University
New Brunswick, New Jersey

G. Pontecorvo, Ph.D.
Department of Cell Genetics
Imperial Cancer Research Fund
London, England

Chase Van Baalen, Ph.D.
Marine Science Institute
University of Texas
Port Aransas, Texas

Claude Vezina, Ph.D.
Microbiology Department
Ayerst Laboratories
St. Laurent, P. Q., Canada

L. C. Vining, Ph.D.
National Research Council
Atlantic Regional Laboratory
Halifax, N. S., Canada

E. D. Weinberg, Ph.D.
Department of Microbiology
Indiana University
Bloomington, Indiana

Burton I. Wilner, Ph.D.
Orinda, California

CONTRIBUTORS

Bernard J. Abbott, Ph.D.
Eli Lilly & Company
Indianapolis, Indiana

James N. Adams, Ph.D.
Department of Microbiology
School of Medicine
University of South Dakota
Vermillion, South Dakota

Robert M. Benbow, Ph.D.
Laboratory of Molecular Biology
Medical Research Council
Cambridge, England

Pierluigi E. Bigazzi, M.D.
Center for Immunology
School of Medicine
State University of New York
Buffalo, New York

Vernon Bryson, Ph.D.
Institute of Microbiology
Rutgers University
New Brunswick, New Jersey

A. M. Chakrabarty, Ph.D.
Physical Chemistry Laboratory
General Electric Corporate Research & Development Center
Schenectady, New York

Sewell P. Champe, Ph.D.
Institute of Microbiology
Rutgers University
New Brunswick, New Jersey

Alex Ciegler, Ph.D.
Northern Regional Research Laboratory
Agricultural Research Service, U.S.D.A.
Peoria, Illinois

A. John Clutterbuck, Ph.D.
Department of Genetics
Glasgow University
Glasgow, Scotland

D. J. Cove, Ph.D.
Department of Genetics
Cambridge University
Cambridge, England

John E. Evans, Ph.D.
Department of Biology
University of Houston
Houston, Texas

William E. Gledhill, Ph.D.
Industrial Chemicals Division
Monsanto Company
St. Louis, Missouri

A. Arthur Gottlieb, M.D.
Institute of Microbiology
Rutgers University
New Brunswick, New Jersey

B. W. Holloway, Ph.D.
Department of Genetics
Monash University
Clayton, Victoria, Australia

David A. Hopwood, Ph.D.
Department of Genetics
John Innes Institute
Norwich, England

O. Hutzinger, Ph.D.
Atlantic Regional Laboratory
National Research Council
Halifax, Nova Scotia, Canada

J. B. G. Kwapinski, D.M., D.Sc.
Department of Medical Microbiology
University of Manitoba
Winnipeg, Manitoba, Canada

Hubert A. Lechevalier, Ph.D.
Institute of Microbiology
Rutgers University
New Brunswick, New Jersey

R. P. Levine, Ph.D.
Department of Biology
Harvard University
Cambridge, Massachusetts

Dan Lewis, Ph.D., D.Sc.
Departments of Botany and Microbiology
University College
London, England

Brooks Low, Ph.D.
Departments of Radiobiology and Microbiology
School of Medicine
Yale University
New Haven, Connecticut

Susumu Mitsuhashi, M.D., Ph.D.
Department of Microbiology
School of Medicine
Gunma University
Maebashi City, Japan

Jane North, Ph.D.
Biological Laboratory
University of Kent
Canterbury, Kent, England

Richard P. Novick, M.D.
Department of Microbiology
The Public Health Research Institute
New York, New York

David Perlman, Ph.D.
School of Pharmacy
University of Wisconsin
Madison, Wisconsin

Suman Rakhit, Ph.D.
Department of Chemistry
Ayerst Research Laboratories
Montreal, Quebec, Canada

Arnold W. Ravin, Ph.D.
Departments of Biology and Microbiology
University of Chicago
Chicago, Illinois

Peter Reeves, Ph.D.
Department of Molecular Biology
University of Edinburgh
Edinburgh, Scotland

Noel R. Rose, M.D., Ph.D.
Departments of Immunology and Microbiology
School of Medicine
Wayne State University
Detroit, Michigan

Charles Rosenblum, Ph.D.
Department of Biochemical Sciences
Moffett Laboratories
Princeton University
Princeton, New Jersey

Ruth Sager, Ph.D.
Department of Biological Sciences
Hunter College
City University
New York, New York

Kenneth E. Sanderson, Ph.D.
Department of Biology
University of Calgary
Calgary, Alberta, Canada

Robert L. Sinsheimer, Ph.D.
Division of Biology
California Institute of Technology
Pasadena, California

Waclaw Szybalski, D.Sc.
McArdle Laboratory
University of Wisconsin
Madison, Wisconsin

Austin L. Taylor, Ph.D.
Medical Center
University of Colorado
Denver, Colorado

Curtis B. Thorne, Ph.D.
Department of Microbiology
University of Massachusetts
Amherst, Massachusetts

Thomas A. Trautner, Dr. rer. nat.
Max Planck Institute for Molecular Genetics
Berlin, Germany

H. E. Umbarger, Ph.D.
Department of Biological Sciences
Purdue University
West Lafayette, Indiana

Charles Van Baalen, Ph.D.
Marine Science Institute
University of Texas
Port Aransas, Texas

Claude Vezina, Ph.D.
Department of Microbiology
Ayerst Research Laboratories
St. Laurent, Quebec, Canada

Leo C. Vining, Ph.D.
Department of Biology
Dalhousie University
Halifax, Nova Scotia, Canada

P. R. Wallnöfer, Ph.D.
Bayerische Landesanstalt
Munich, Germany

Robert G. White, D.M.
Departments of Bacteriology and Immunology
University of Glasgow
Glasgow, Scotland

TABLE OF CONTENTS

IMMUNOLOGY

MISCELLANEOUS

THE AMINO ACID REQUIREMENTS OF MICROORGANISMS FOR GROWTH

DR. BEVERLY GUIRARD*

The microorganisms included in the following table are those isolated from natural sources. Artificially produced mutants are not considered here, since it is possible to produce, almost at will, auxotrophs of many species with any desired amino acid requirement. Of protozoan species, only those capable of being cultured axenically are included.

Strain identification numbers refer either to the American Type Culture Collection (ATCC), the National Culture Type Collection of England (NCTC), or to the laboratory collection of the respective investigators.

The amino acid requirements of the microorganisms were determined in most cases by omitting individually each of the amino acids from a complete synthetic medium that supported growth and observing the effect of the deletion. If growth was markedly depressed, the amino acid was labeled "essential" (E); if growth was partially reduced, the amino acid was labeled "stimulatory" (S); if the deletion had little or no effect on growth, the amino acid was labeled "non-essential" (N). Sometimes a minimal medium was supplemented individually with the amino acids, in which case the growth response is an individual one and is indicated in the table by a fine line under the symbols, e.g., $\underline{E}$, $\underline{S}$, $\underline{N}$. To indicate better than average stimulation, the symbol is primed (S′). When the deletion of an amino acid improved growth or its addition to the medium reduced growth, it was labeled "inhibitory" (I). The responses recorded are to the natural, or L-isomers, or to racemic mixtures where D-isomers are known to have no effect on growth. The effects of D-isomers, when known, are recorded in the notes. It was frequently observed that an otherwise complete medium containing only essential or essential and stimulatory amino acids (as determined by the deletion technique) failed to support good growth of the microorganism under investigation. This phenomenon has been ascribed to certain interrelationships among amino acids, or to quantitative imbalances, or both.

Responses to amino acids by the respective microorgansims for which microbiological assays have been developed for their quantitative determination are given in bold type.

Microorganisms	Strain identification and no. tested	Alanine	Arginine	Aspartic acid	Cystine or cysteine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Asparagine	Glutamine	References
ALGAE																						
Chlorella *vulgaris*[a]		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	—	S	*1*
Digenea *simplex*[a]		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	—		*2*
Euglena																						
anabaena var. *minor*[a]	Ehrenberg	S	N	S		N		N		S	N		S	S	N	—	N	N	S	S		*3*
deses		E		E		E				E	E		N	E	E	—		N	N	E		*3*
gracilis[a]		S	N	S	—	S		S		S	N		S	S	S	—	N	N	S	S		*3*
klebsii[a]		S	N	N	—	S		S		S	S		N	S	S	—	N	N	S	S		*3*
stellata[a]		S	S	S		S		S		S	S		S	S	S	—	N	N	S	S		*3*
Porphyra *tenera*[a]		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S			*2*
BACTERIA																						
Acetobacter *oxydans*		E	N	N	E	N	N	E	E	N	N	N	N	E	N	N	N	N	E			*4*
rancens var. *africans*		E	N	E[b]	E		N	E	E	N	N	N	N	E	N	N	N	N	E			*4*
suboxydans	ATCC 621	E	N	S	S	S	N	S	E	N	N	N	N	S	N	N	N	N	E			*5*
xylinum[c]	X1, NIH	S	N	N	N	S	N	N	S	N	N	S	N	N	N	N	N	N	S			*6*
Acidaminococcus *fermentans* sp. n.[d]	Strain VR4, ATCC 25085 and 14 others	N	E	N	S	E	S	S	N	N	N	N	S	N	S	N	E	S	E	N		*7*
Actinomyces		S	S								S				S							*7a*
aureofaciens		N	N	N	E	E	N	N	E	E	E	N	N	N	E	N	E	N	N	S		*8*
israelii	Wills' and 11 others																					
Aerobacter *aerogenes*		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		*9*
Agrobacterium																						
rhizogenes	4 strains	N	N	N	N	E	N	N	N	N	N	N	N	N	N	N	N	N	N			*10*
rubi	2 strains	N	N	N	N	E	N	N	N	N	N	N	N	N	N	N	N	N	N			*10*
Bacillus *alvei*	ATCC 6344 and 4 others	S	S	S	S	S	S	S	N	S	N	S	S	N	S	N	S	S	S			*11, 12*

Microorganisms	Strain identification and no. tested	Alanine	Arginine	Aspartic acid	Cystine or cysteine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Asparagine	Glutamine	References
***Bacillus*—(*Continued*)**																						
paraalvei[e]	3 strains	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	—	—	*11, 13*
anthracis[f]	NCTC 110	—	—	—	S	—	S	—	S	E	—	—	—	—	—	—	—	—	E	—	S	*14, 15*
anthracis	1607	—	—	—	S	—	S	—	S	S	—	—	—	—	—	—	S	—	S	—	S	*14, 15*
anthracis	631	—	—	—	S	—	S	—	S	E	—	—	—	—	—	—	S	—	S	—	S	*14, 15*
anthracis	4991	—	—	—	S	—	S	—	S	E	—	—	—	—	—	—	—	—	E	—	S	*14, 15*
anthracis	most strains	I	—	E	E	N	E	E	—	N	—	—	—	E	—	—	N	—	—	—	—	*16*
anthracis	1 strain	I	—	E	E	E	E	E	—	E	—	—	E	E	—	—	N	—	—	—	—	*16*
brevis[g]	ATCC 8185 and 9 others	E	E	E	E	E	E	E	N	E	N	E	E	N	E	N	E	E	E	—	—	*12*
cereus[g]	ATCC 6630 and 2 others	E	N	N	N	E	N	N	N	E	N	E	N	E	E	N	N	N	N	E	—	*12*
cereus[g]	ATCC 6463 and 7 others	E	E	E	E	E	E	E	N	E	N	E	E	N	E	N	E	E	E	—	—	*12*
cereus	ATCC 4342	S	—	S	—	E	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*17*
cereus var. *mycoides*	no. 5259	E	—	—	—	E	—	—	E	E	—	—	—	—	—	—	—	—	E	—	—	*18*
circulans[h]	ATCC 7046	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*12, 19*
circulans	no. 7-2	—	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*19*
coagulans[i]	no. 2	—	N	—	N	N	—	E	N	N	N	N	—	—	—	—	N	—	N	—	—	*20, 21*
coagulans	no. 12	—	N	—	N	N	—	E	N	E	N	N	—	—	—	—	N	—	E	—	—	*20*
coagulans	no. 32	—	N	—	N	N	—	N	N	N	N	E	—	—	—	—	E	—	N	—	—	*20*
coagulans	no. 1039	—	N	—	N	N	—	N	N	N	N	N	—	—	—	—	N	—	N	—	—	*20*
coagulans	no. 132	—	—	—	—	E	—	—	E	E	—	—	—	—	—	E	—	—	E	—	—	*22*
coagulans	4 strains	—	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*22*
firmus[g]	18 strains	E	—	—	—	E	—	—	—	E	—	E	—	E	E	—	—	—	—	E	—	*12*
lentus[g]	6 strains	E	—	—	—	E	—	—	—	E	—	E	—	E	E	—	—	—	—	E	—	*12*
licheniformis	mesophilic no. S8	E	E	E	—	E	E	E	—	—	E	—	—	—	—	—	—	—	—	—	—	*19*
licheniformis	thermophilic no. S8	—	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*19*

Microorganisms	Strain identification and no. tested	Alanine	Arginine	Aspartic acid	Cystine or cysteine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Asparagine	Glutamine	References
Bacillus **(Continued)**																						
pasteurii	ATCC 6452 and 9 others	Amino acids required, but specific ones were not determined.																				*12*
pulvifaciens[g]	3 strains	E		—		E	—	—	—	E	—	E	—	E	E	—	—	—	—	E	—	*12*
sphaericus[g]	6 of 9	E				E	—		—	E	—	E	—	E	E	—	—	—	—	E	—	*12*
stearothermophilus	no. 1356	N	—	—	N	N	—	N	N	E	N	N	—	—	—	—	N	—	N	—	—	*20*
stearothermophilus	no. 1373b	N	—	—	N	E	—	E	N	E	N	E	—	—	—	—	N	—	N	—	—	*20*
stearothermophilus	no. 1503	N	—	—	N	N	—	N	N	N	N	N	—	—	—	—	N	—	E	—	—	*20, 21*
stearothermophilus	no. 3656	N	—	—	N	N	—	E	N	N	N	N	—	—	—	—	N	—	N	—	—	*20*
stearothermophilus	no. 131102		S	—	—	—	—	S	S	—	—	—	—	—	—	—	—	—	—	—	—	*19*
terminalis		S	—	E	—	S	—	—	—	—	—	—	E	E	—	S	E	—	—	—	—	*22a*
Bacterium *linens*	no. 456	N	S	N	S′	N	I	S	N	S′	S	S′	N	N	I	N	N	I	I	—	I	*23*
tularense	B-38 and 4 others		—		E	N	—	N	—	N	N	N	N	—	—	—	N	N	—	—	—	*24*
Bacteroides	23 strains	N	N	N	E	N	N	N	N	N	N	S′	N	N	N	N	N	N	N	—	—	*25*
ruminicola	GA 33	N	N	N	E	N	N	N	N	N	N	E	N	N	N	N	N	N	N	—	—	*25*
fragilis	7 strains	N	E	E	N	N	E	E	E	E	E	N	N	E	E	E	E	E	E	—	—	*25a*
Bordetella *pertussis*	Strains 3803, 3843, 1855, 7231, 251K		—	—	E	E	—	—	—	—	—	—	E	E	—	—	—	—	—	—	—	*25b*
Brucella *abortus melitensis* and *suis*			E	—	E′	E	—	E	—	—	—	—	E	—	E	—	—	—	—	—	—	*26*
Butyric acid *bacteria*	—	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	—	—	*27*
Butyrivibrio sp.[k]		—	—	I	S′	—	—	S′	S′	S	S′	S′	—	—	—	—	—	S	S	—	—	*27a*
Cellulomonas sp.		Amino acids stimulated growth.																				*27b*
Clostridium *acetobutylicum*	Todai 314		N	—		E		N	E	N	N	N	N	N	—	—	N	—	E	—	—	*27c*
botulinum	Types A and B	S	—	—	E	—	S	—	—	E	S	—	—	E	—	—	E	—	—	—	—	*28-30*
botulinum	Type A	—	E	—	—	—	—	—	E	E	—	E	E	—	—	E	E	E	E	—	—	*31*
botulinum	Type B		E	—	—	—	—	E	E	E	—	E	E	—	—	—	E	E	E	—	—	*31*
histolyticum	H-3		E	E	E	E	—	E	E	E	E	E	E	E	—	E	E	E	E	—	—	*32*
histolyticum	H-13, H-37	E	E	E	E	E	—	E	E	E	E	E	E	E	—	E	—	E	E	—	—	*32*
perfringens		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	—	—	*33*

Microorganisms	Strain identification and no. tested	Alanine	Arginine	Aspartic acid	Cystine or cysteine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Asparagine	Glutamine	References
***Clostridium*—(Continued)**																						
parabotulinum	—	—	E	—	—	—	—	N	E	S	S	S	E	—	—	E	E	S	E	—	—	*34*
sporogenes	NCTC 1533	—	E	—	E	—	E	S	—	E	S	E	E	E	—	—	E	E	S	—	—	*35, 36*
tetani[i]	4 strains	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	E	—	—	—	—	*35a*
thiaminolyticum	—	—	E	—	—	—	E	E	E	—	—	—	E	E	—	—	E	E	E	—	—	*36a*
welchii	BP6K	—	E	—	—	E	—	E	E	E	E	E	E	—	E	E	E	E	E	—	—	*37*
Corynebacterium																						
diphtheriae	H-Y	—	—	—	E	E	E	E	—	—	—	E	S	—	—	—	E	—	E	—	—	*38*
diphtheriae	P-W no. 8	—	—	—	E	E	—	—	—	E	—	E	—	—	—	—	—	—	E	—	—	*39*
diphtheriae	Allen	—	—	S	E	S	—	—	—	—	—	E	—	N	—	—	—	N	N	—	—	*40*
flaccumfaciens	9 isolates		Rate of growth stimulated by amino acids.																			*41*
insidiosum	also 2 other species		Amino acids required, but specific ones were not determined.																			*41*
sepedonicum	ATCC 9850 and 8 others	S	S	—	I	—	—	S′	—	S′	—	S′	I	S	—	—	I	I	—	S′	—	*41–42*
Corynebacterium[m]	A-11	—	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*43*
Corynebacterium[m]	B-10	E	—	E	—	E	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	*43*
***Diplococcus** glycinophilus*[m]	—	—	—	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*44*
***Erwinia** group*			Rate of growth stimulated by amino acids.																			*45*
***Escherichia** coli*	—	—	—	S	S	S	—	S	—	—	—	—	—	S	—	—	S	S	—	S	—	*46*
Flavobacterium[m]	A-18	E	E	—	E	E	—	—	—	—	—	E	—	—	—	E	—	—	—	—	—	*43*
Flavobacterium[m]	A-28	—	—	—	—	E	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*43*
Flavobacterium	B-9	—	E	E	—	E	—	E	—	—	—	—	—	E	—	—	—	—	—	—	—	*43*
Flavobacterium	B-17	E	—	—	—	—	—	—	—	—	—	E	—	—	—	—	—	—	—	—	—	*43*
Flavobacterium[n]	B-4	S	E	S	S	S	E	S	E	E	S	E	S	S	S	S	S	S	E	—	—	*47*
Flavobacterium																						
proteus	nos. 1 and 2	—	E	E	E	E	—	E	—	E	—	—	—	—	—	E	—	—	—	—	—	*48*
proteus	nos. 41 and 60	—	E	E	E	E	E	E	—	E	—	—	—	—	—	E	—	—	—	—	—	*48*
Fusobacterium																						
nucleatum[l]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	E	—	—	—	—	*48a*
polymorphum Knorr	ATCC 10953	—	—	—	—	E	—	—	—	—	E	—	—	—	E	—	E	—	—	—	—	*48b*

Microorganisms	Strain identification and no. tested	Alanine	Arginine	Aspartic acid	Cystine or cysteine	Glutamic acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Asparagine	Glutamine	References
Halobacterium																						
salinarium	no. 1	—	S	—	—	—	—	—	E	E	S	E	S	S	—	—	—	S	E	—	S	*49*
Hemophilus																						
parainfluenzae	ATCC 7901	—	E	S	E	E	—	—	E	S	S	—	S	—	—	—	—	E	E	—	—	*50*
pertussis	724 and others	—	S	S	E	E	—	—	—	—	—	—	S	S	—	—	—	—	—	—	—	*51*
Hiochi bacteria	T 107	—	—	—	—	S	—	—	—	—	—	—	—	—	S	—	—	—	—	—	—	*52*
Lactobacillus																						
acidophilus	—	—	—	—	E	E	—	—	—	—	—	E	E	—	E	—	—	—	E	—	—	*53*
acidophilus	4 strains	S	E	S	E	E	N, S	E	S	E	E, S	E, S	E	E	E, S	E, N	E	E	E	—	—	*54*
acidophilus[o]	R-26	S	E	E	S	—	E	E	S	E	S	S	E	E	E	E	E	E	E	—	E	*54a*
arabinosus[p] 17-5	ATCC 8041	S	S	S	E	E	N	N, S	E	E	S, E	E, S	S	N, S	N, S	S, E	E	S	E	—	—	*55–60*
arabinosus φ	—	N	N	—	N	E	N	N	N	E	N	N	N	N	N	N	E	S	E	N	—	*61*
arabinosus	10 S	S	S	E	S	E	—	—	—	E	—	—	S	—	—	—	S	—	E	—	—	*62*
bifidus	DD 5	N	E	—	N	E	E	N	N	E	E	N	N	E	E	E	E	S	E	N	—	*61*
bifidus	EE 1	S	E	—	N	E	E	N	N	E	N	N	N	E	E	E	E	E	E	N	—	*61*
bifidus	ureolytic biotype	—	—	—	N	—	S	—	S	—	—	E	—	—	S	S	—	—	S	—	—	*63*
brassicae	ATCC 8041	—	—	—	E	E	—	—	E	E	—	S	—	—	—	—	—	—	E	—	—	*64*
brevis	ATCC 8257	S	E	—	E	E	E	E	E	E	E	E	E	S	S	E	E	E	E	E	—	*64*
buchneri		—	—	—	E	E	—	—	E	E	—	E	—	—	—	—	—	—	E	E	—	*64*
buchneri	α	N	E	—	N	E	E	N	N	E	E	N	N	S	E	E	E	S	E	S	—	*61*
buchneri	—	E	E	E	E	E	—	—	—	S	E	E	E	—	E	E	E	E	E	—	—	*65*
casei[q]	ATCC 7469	S	E	E	E	E	—	S	S	E	S	S	E	—	E	S	E	E	E	S	S	*64, 66–70*
casei	9 normal + 4 lac. neg.	N	E	S	E	E	N, S	N, S	S	E	N	N	E	N	S	N	E	E	E	—	—	*54*
delbrueckii[r]	ATCC 9649	E	E	E	E	E	—	E	—	E	E	—	E	—	E	E	E	E	E	—	—	*74*
delbrueckii[s] LD 5	ATCC 9595	E	E	E	E	E	N	—	E	E	E	E	E	N	E	E	E	E	E	—	—	*64, 75, 76*
fermenti[t] 36	ATCC 9338	—	E	—	—	E	—	E	E	E	—	E	E	—	—	E	E	E	E	—	—	*77, 78*
fermenti	5 strains	S	E	S	E, S	E	N, S	N, E	S, E	E	N	N	E	N	N	E, S	E	E	E	—	—	*54*
frigidus	HH5	S	E	—	N	E	E	—	N	E	S	—	N	E	E	E	E	E	S	N	—	*61*
fructosus	Strain 353	N	E	E	S	E	N	E	E	S	S	S	N	N	S	S	S	S	E	S	—	*61a*
gayonii	ATCC 8289	—	E	—	—	E	—	E	E	E	—	E	E	—	—	S	E	E	E	—	—	*64*
leichmannii 313	ATCC 7830	E	E	E	E	E	N	E	E	S	S	E	E	N	S	S	E	S	E	—	—	*79–80a*
leichmannii 327	ATCC 4797	E	E	E	E	E	N	E	E	S	S	E	E	N	S	S	E	S	E	—	—	*79*
leichmannii	AA 3	S	S	—	S	E	E	N	N	E	E	N	E	E	E	N	S	N	E	E	—	*61*