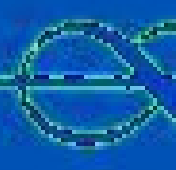


Bergey's
System
of Bacteriology



SECOND EDITION

BERGEY'S MANUAL® OF
**Systematic
Bacteriology**
Second Edition

Volume Two
The *Proteobacteria*

Part C
**The *Alpha-, Beta-, Delta-, and
Epsilonproteobacteria***

BERGEY'S MANUAL® OF
**Systematic
Bacteriology**

Second Edition

Volume Two
The Proteobacteria

Part C
*The Alpha-, Beta-, Delta-, and
Epsilonproteobacteria*

Don J. Brenner
Noel R. Krieg
James T. Staley
EDITORS, VOLUME TWO

George M. Garrity
EDITOR-IN-CHIEF

EDITORIAL BOARD

James T. Staley, Chairman, **David R. Boone**, Vice Chairman,
Don J. Brenner, **Paul De Vos**, **George M. Garrity**, **Michael Goodfellow**,
Noel R. Krieg, **Fred A. Rainey**, **Karl-Heinz Schleifer**

WITH CONTRIBUTIONS FROM 222 COLLEAGUES

 Springer

George M. Garrity, Sc.D.
Bergey's Manual Trust
Department of Microbiology and Molecular Genetics
Michigan State University
East Lansing, MI 48824-4320
USA

ISBN-10: 0-387-24145-0
ISBN-13: 978-0-387-24145-6

Library of Congress Control Number: 2005926296

© 2005, 1984–1989 Bergey's Manual Trust

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Printed in the United States of America. (APEX/MVY)

Springer is part of Springer Science+Business Media (www.springer.com)

*This volume is dedicated to our colleagues,
David R. Boone, Don J. Brenner,
Richard W. Castenholz, and Noel R. Krieg, who
retired from the Board of Trustees of Bergey's Manual
Trust as this edition was in preparation. We deeply
appreciate their efforts as editors and authors; they
have devoted their time and many years in helping
the Trust meet its objectives.*

EDITORIAL BOARD AND TRUSTEES
OF BERGEY'S MANUAL TRUST

James T. Staley, *Chairman*
David R. Boone, *Vice Chairman*
George M. Garrity
Paul De Vos
Michael Goodfellow
Fred A. Rainey
Karl-Heinz Schleifer
Don J. Brenner, *Emeritus*
Richard W. Castenholz, *Emeritus*
John G. Holt, *Emeritus*
Noel R. Krieg, *Emeritus*
John Liston, *Emeritus*
James W. Moulder, *Emeritus*
R.G.E. Murray, *Emeritus*
Charles F. Niven, Jr., *Emeritus*
Norbert Pfennig, *Emeritus*
Peter H.A. Sneath, *Emeritus*
Joseph G. Tully, *Emeritus*
Stanley T. Williams, *Emeritus*

Preface to Volume Two of the Second Edition of *Bergey's Manual*[®] of Systematic Bacteriology

There is a long-standing tradition for the Editors of *Bergey's Manual* to open their respective editions with the observation that the new edition is a departure from the earlier ones. As this volume goes to press, however, we recognize a need to deviate from this practice, by offering a separate preface to each volume within this edition. In part, this departure is necessary because the size and complexity of this edition far exceeded our expectations, as has the amount of time that has elapsed between publication of the first volume of this edition and this volume.

Earlier, we noted that systematic procaryotic biology is a dynamic field, driven by constant theoretical and methodological advances that will ultimately lead to a more perfect and useful classification scheme. Clearly, the pace has been accelerating as evidenced in the super-linear rate at which new taxa are being described. Much of the increase can be attributed to rapid advances in sequencing technology, which has brought about a major shift in how we view the relationships among *Bacteria* and *Archaea*. While the possibility of a universally applicable natural classification was evident as the First Edition was in preparation, it is only recently that the sequence databases became large enough, and the taxonomic coverage broad enough to make such an arrangement feasible. We have relied heavily upon these data in organizing the contents of this edition of *Bergey's Manual of Systematic Bacteriology*, which will follow a phylogenetic framework based on analysis of the nucleotide sequence of the small ribosomal subunit RNA, rather than a phenotypic structure. This departs from the First Edition, as well as the Eighth and Ninth Editions of the *Determinative Manual*. While the rationale for presenting the content of this edition in such a manner should be evident to most readers, they should bear in mind that this edition, as in all preceding ones represents a progress report, rather than a final classification of procaryotes.

The Editors remind the readers that the *Systematics Manual* is a peer-reviewed collection of chapters, contributed by authors who were invited by the Trust to share their knowledge and expertise of specific taxa. Citation should refer to the author, the chapter title, and inclusive pages rather than to the Editors. The Trust is indebted to all of the contributors and reviewers, without whom this work would not be possible. The Editors are grateful for the time and effort that each expended on behalf of the entire scientific community. We also thank the authors for their good grace in accepting comments, criticisms, and editing of

their manuscripts. We would also like to thank Drs. Hans Trüper, Brian Tindall, and Jean Euzéby for their assistance on matters of nomenclature and etymology.

We would like to express our thanks to the Department of Microbiology and Molecular Genetics at Michigan State University for housing our headquarters and editorial office and for providing a congenial and supportive environment for microbial systematics. We would also like to thank Connie Williams not only for her expert secretarial assistance, but also for unflagging dedication to the mission of *Bergey's Manual* Trust and Drs. Julia Bell and Denise Searles for their expert editorial assistance and diligence in verifying countless pieces of critical information and to Dr. Timothy G. Lilburn for constructing many of the phylogenetic trees used in this volume. We also extend our thanks to Alissa Wesche, Matt Chval and Kristen Johnson for their assistance in compilation of the bibliography.

A project such as the *Systematics Manual* also requires the strong and continued support of a dedicated publisher, and we have been most fortunate in this regard. We would also like to express our gratitude to Springer-Verlag for supporting our efforts and for the development of the *Bergey's* Document Type Definition (DTD). We would especially like to thank our Executive Editor, Dr. William Curtis for his courage, patience, understanding, and support; Catherine Lyons for her expertise in designing and developing our DTD, and Jeri Lambert and Leslie Grossberg of Impressions Book and Journal Services for their efforts during the pre-production and production phases. We would also like to acknowledge the support of ArborText, Inc., for providing us with state-of-the-art SGML development and editing tools at reduced cost. Lastly, I would like to express my personal thanks to my fellow trustees for providing me with the opportunity to participate in this effort, to Drs. Don Brenner, Noel Krieg, and James Staley for their enormous efforts as volume editors and to my wife, Nancy, and daughter, Jane, for their continued patience, tolerance and support.

Comments on this edition are welcomed and should be directed to *Bergey's Manual* Trust, Department of Microbiology and Molecular Genetics, 6162 Biomedical and Physical Sciences Building, Michigan State University, East Lansing, MI, USA 48824-4320. Email: garrity@msu.edu

George M. Garrity

Preface to the First Edition of *Bergey's Manual*[®] of *Systematic Bacteriology*

Many microbiologists advised the Trust that a new edition of the *Manual* was urgently needed. Of great concern to us was the steadily increasing time interval between editions; this interval reached a maximum of 17 years between the seventh and eighth editions. To be useful the *Manual* must reflect relatively recent information; a new edition is soon dated or obsolete in parts because of the nearly exponential rate at which new information accumulates. A new approach to publication was needed, and from this conviction came our plan to publish the *Manual* as a sequence of four subvolumes concerned with systematic bacteriology as it applies to taxonomy. The four subvolumes are divided roughly as follows: (a) the Gram-negatives of general, medical or industrial importance; (b) the Gram-positives other than actinomycetes; (c) the archaeobacteria, cyanobacteria and remaining Gram-negatives; and (d) the actinomycetes. The Trust believed that more attention and care could be given to preparation of the various descriptions within each subvolume, and also that each subvolume could be prepared, published, and revised as the area demanded, more rapidly than could be the case if the *Manual* were to remain as a single, comprehensive volume as in the past. Moreover, microbiologists would have the option of purchasing only that particular subvolume containing the organisms in which they were interested.

The Trust also believed that the scope of the *Manual* needed to be expanded to include more information of importance for systematic bacteriology and bring together information dealing with ecology, enrichment and isolation, descriptions of species and their determinative characters, maintenance and preservation, all focused on the illumination of bacterial taxonomy. To reflect this change in scope, the title of the *Manual* was changed and the primary publication becomes *Bergey's Manual of Systematic Bacteriology*. This contains not only determinative material such as diagnostic keys and tables useful for identification, but also all of the detailed descriptive information and taxonomic comments. Upon completion of each subvolume, the purely determinative information will be assembled for eventual incorporation into a much smaller publication which will continue the original name of the *Manual*, *Bergey's Manual of Determinative Bacteriology*, which will be a similar but improved version of the present *Shorter Bergey's Manual*. So, in the end there will be two publications, one systematic and one determinative in character.

An important task of the Trust was to decide which genera should be covered in the first and subsequent subvolumes. We were assisted in this decision by the recommendations of our

Advisory Committees, composed of prominent taxonomic authorities to whom we are most grateful. Authors were chosen on the basis of constant surveillance of the literature of bacterial systematics and by recommendations from our Advisory Committees.

The activation of the 1976 Code had introduced some novel problems. We decided to include not only those genera that had been published in the Approved Lists of Bacterial Names in January 1980 or that had been subsequently validly published, but also certain genera whose names had no current standing in nomenclature. We also decided to include descriptions of certain organisms which had no formal taxonomic nomenclature, such as the endosymbionts of insects. Our goal was to omit no important group of cultivated bacteria and also to stimulate taxonomic research on "neglected" groups and on some groups of undoubted bacteria that have not yet been cultivated and subjected to conventional studies.

The invited authors were provided with instructions and exemplary chapters in June 1980 and, although the intended deadline for receipt of manuscripts was March 1981, all contributions were assembled in January 1982 for the final preparations. The *Manual* was forwarded to the publisher in June 1982.

Some readers will note the consistent use of the stem -var instead of -type in words such as biovar, serovar and pathovar. This is in keeping with the recommendations of the Bacteriological Code and was done against the wishes of some of the authors.

We have deleted much of the synonymy of scientific names which was contained in past editions. The adoption of the new starting date of January 1, 1980 and publication of the Approved Lists of Bacterial Names has made mention of past synonymy obsolete. We have included synonyms of a name only if they have been published since the new starting date, or if they were also on the Approved Lists and, in rare cases with certain pathogens, if the mention of an old name would help readers associate the organism with a clinical problem. If the reader is interested in tracing the history of a name we suggest he or she consult past editions of the *Manual* or the *Index Bergeyana* and its *Supplement*. In citations of names we have used the abbreviation AL to denote the inclusion of the name on the Approved Lists of Bacterial Names and VP to show the name has been validly published.

In the matter of citation of the *Manual* in the scientific literature we again stress the fact that the *Manual* is a collection

of authored chapters and the citation should refer to the author, the chapter title and its inclusive pages, not the Editor.

To all contributors, the sincere thanks of the Trust is due; the Editor is especially grateful for the good grace with which the authors accepted comments, criticisms and editing of their manuscripts. It is only because of the voluntary and dedicated efforts of these authors that the *Manual* can continue to serve the science of bacteriology on an international basis.

A number of institutions and individuals deserve special acknowledgment from the Trust for their help in bringing about the publication of this volume. We are grateful to the Department of Biology of the Virginia Polytechnic Institute and State University for providing space, facilities and, above all, tolerance for the diverted time taken by the Editor during the preparation of the book. The Department of Microbiology at Iowa State University of Science and Technology continues to provide a welcome home for the main editorial offices and archives of the Trust and we acknowledge their continued support. A grant

(LM-03707) from the National Library of Medicine, National Institutes of Health to assist in the preparation of this and the next volume of the *Manual* is gratefully acknowledged.

A number of individuals deserve special mention and thanks for their help. Professor Thomas O. McAdoo of the Department of Foreign Languages and Literatures at the Virginia Polytechnic Institute and State University has given invaluable advice on the etymology and correctness of scientific names. Those assisting the Editor in the Blacksburg office were R. Martin Roop II, Don D. Lee, Eileen C. Falk and Michael W. Friedman and their help is sincerely appreciated. In the Ames office we were ably assisted by Gretchen Colletti and Diane Triggs during the early period of preparation and by Cynthia Pease during the major portion of the editing process. Mrs. Pease has been responsible for the construction of the List of References and her willingness to handle the cumbersome details of text editing on a big computer is gratefully acknowledged.

John G. Holt

Preface to the First Edition of *Bergey's Manual*[®] of *Determinative Bacteriology*

The elaborate system of classification of the bacteria into families, tribes and genera by a Committee on Characterization and Classification of the Society of American Bacteriologists (1911, 1920) has made it very desirable to be able to place in the hands of students a more detailed key for the identification of species than any that is available at present. The valuable book on "Determinative Bacteriology" by Professor F. D. Chester, published in 1901, is now of very little assistance to the student, and all previous classifications are of still less value, especially as earlier systems of classification were based entirely on morphologic characters.

It is hoped that this manual will serve to stimulate efforts to perfect the classification of bacteria, especially by emphasizing the valuable features as well as the weaker points in the new system which the Committee of the Society of American Bacteriologists has promulgated. The Committee does not regard the classification of species offered here as in any sense final, but merely a progress report leading to more satisfactory classification in the future.

The Committee desires to express its appreciation and thanks to those members of the society who gave valuable aid in the compilation of material and the classification of certain species. . . .

The assistance of all bacteriologists is earnestly solicited in the correction of possible errors in the text; in the collection of descriptions of all bacteria that may have been omitted from the text; in supplying more detailed descriptions of such organisms as are described incompletely; and in furnishing complete descriptions of new organisms that may be discovered, or in directing the attention of the Committee to publications of such newly described bacteria.

David H. Bergey, *Chairman*

Francis C. Harrison

Robert S. Breed

Bernard W. Hammer

Frank M. Huntoon

Committee on Manual.

August, 1923.

Contents

Preface to Volume Two of the Second Edition of <i>Bergey's Manual</i>[®] of <i>Systematic Bacteriology</i>	ix
Preface to the First Edition of <i>Bergey's Manual</i>[®] of <i>Systematic Bacteriology</i>	xi
Preface to the First Edition of <i>Bergey's Manual</i>[®] of <i>Determinative Bacteriology</i>	xiii
Contributors	xxiii
Class I. <i>Alphaproteobacteria</i>	1
Order I. <i>Rhodospirillales</i>	1
Family I. <i>Rhodospirillaceae</i>	1
Genus I. <i>Rhodospirillum</i>	1
Genus II. <i>Azospirillum</i>	7
Genus III. <i>Levispirillum</i>	27
Genus IV. <i>Magnetospirillum</i>	28
Genus V. <i>Phaeospirillum</i>	32
Genus VI. <i>Rhodocista</i>	33
Genus VII. <i>Rhodospira</i>	35
Genus VIII. <i>Rhodovibrio</i>	36
Genus IX. <i>Roseospira</i>	37
Genus X. <i>Roseospirillum</i>	39
Genus XI. <i>Skermanella</i>	39
Genus Incertae Sedis XII. " <i>Sporospirillum</i> "	40
Family II. <i>Acetobacteraceae</i>	41
Genus I. <i>Acetobacter</i>	51
Genus II. <i>Acidiphilium</i>	54
Genus III. <i>Acidisphaera</i>	62
Genus IV. <i>Acidocella</i>	65
Genus V. <i>Acidomonas</i>	68
Genus VI. <i>Asaia</i>	69
Genus VII. <i>Craurococcus</i>	70
Genus VIII. <i>Gluconacetobacter</i>	72
Genus IX. <i>Gluconobacter</i>	77
Genus X. <i>Paracraurococcus</i>	81
Genus XI. <i>Rhodopila</i>	83
Genus XII. <i>Roseococcus</i>	85
Genus XIII. <i>Roseomonas</i>	88
Genus XIV. <i>Stella</i>	93
Genus XV. <i>Zavarzinia</i>	95
Order II. <i>Rickettsiales</i>	96
Family I. <i>Rickettsiaceae</i>	96
Genus I. <i>Rickettsia</i>	96
Genus II. <i>Orientia</i>	114
Family II. <i>Anaplasmataceae</i>	117
Genus I. <i>Anaplasma</i>	117
Genus II. <i>Ehrlichia</i>	125

Genus III. <i>Neorickettsia</i>	132
Genus IV. <i>Wolbachia</i>	138
Genus Incertae Sedis V. <i>Aegyptianella</i>	143
Family III. <i>Holosporaceae</i>	146
Genus I. <i>Holospira</i>	149
Genus Incertae Sedis II. <i>Caedibacter</i>	152
Genus Incertae Sedis III. <i>Lyticum</i>	156
Genus Incertae Sedis IV. <i>Candidatus Odysella</i>	157
Genus Incertae Sedis V. <i>Candidatus Paracaedibacter</i>	157
Genus Incertae Sedis VI. <i>Pseudocaedibacter</i>	158
Genus Incertae Sedis VII. " <i>Pseudolyticum</i> "	160
Genus Incertae Sedis VIII. <i>Tectibacter</i>	160
Order III. <i>Rhodobacterales</i>	161
Family I. <i>Rhodobacteraceae</i>	161
Genus I. <i>Rhodobacter</i>	161
Genus II. <i>Ahrensia</i>	167
Genus III. <i>Amaricoccus</i>	168
Genus IV. <i>Antarctobacter</i>	172
Genus V. <i>Gemmobacter</i>	174
Genus VI. <i>Hirschia</i>	176
Genus VII. <i>Hyphomonas</i>	179
Genus VIII. <i>Ketogulonicigenium</i>	187
Genus IX. <i>Maricaulis</i>	188
Genus X. <i>Methylarcula</i>	192
Genus XI. <i>Octadecabacter</i>	194
Genus XII. <i>Paracoccus</i>	197
Genus XIII. <i>Rhodobaca</i>	204
Genus XIV. <i>Rhodovulum</i>	205
Genus XV. <i>Roseibium</i>	209
Genus XVI. <i>Roseinatronobacter</i>	209
Genus XVII. <i>Roseivivax</i>	210
Genus XVIII. <i>Roseobacter</i>	212
Genus XIX. <i>Roseovarius</i>	215
Genus XX. <i>Rubrimonas</i>	217
Genus XXI. <i>Ruegeria</i>	218
Genus XXII. <i>Sagittula</i>	219
Genus XXIII. <i>Staleyia</i>	221
Genus XXIV. <i>Stappia</i>	223
Genus XXV. <i>Sulfitobacter</i>	224
Genus Incertae Sedis XXVI. <i>Rhodothalassium</i>	228
Order IV. <i>Sphingomonadales</i>	230
Family I. <i>Sphingomonadaceae</i>	233
Genus I. <i>Sphingomonas</i>	234
Genus II. <i>Blastomonas</i>	258
Genus III. " <i>Citromicrobium</i> "	263
Genus IV. <i>Erythrobacter</i>	267
Genus V. <i>Erythromicrobium</i>	268
Genus VI. <i>Erythromonas</i>	274
Genus VII. <i>Porphyrobacter</i>	275
Genus VIII. <i>Sandaracinobacter</i>	279
Genus IX. <i>Zymomonas</i>	282
Order V. <i>Caulobacterales</i>	287
Family I. <i>Caulobacteraceae</i>	287
Genus I. <i>Caulobacter</i>	287
Genus II. <i>Asticcacaulis</i>	303
Genus III. <i>Brevundimonas</i>	308
Genus IV. <i>Phenylobacterium</i>	316

Order VI. <i>Rhizobiales</i>	324
Family I. <i>Rhizobiaceae</i>	324
Genus I. <i>Rhizobium</i>	325
Genus II. <i>Agrobacterium</i>	340
Genus III. <i>Allorhizobium</i>	345
Genus IV. <i>Carbophilus</i>	346
Genus V. <i>Chelatobacter</i>	347
Genus VI. <i>Ensifer</i>	354
Genus VII. <i>Sinorhizobium</i>	358
Family II. <i>Bartonellaceae</i>	362
Genus I. <i>Bartonella</i>	362
Family III. <i>Brucellaceae</i>	370
Genus I. <i>Brucella</i>	370
Genus II. <i>Mycoplana</i>	386
Genus III. <i>Ochrobactrum</i>	389
Family IV. <i>Phyllobacteriaceae</i>	393
Genus I. <i>Phyllobacterium</i>	394
Genus II. <i>Aminobacter</i>	397
Genus III. <i>Aquamicrobium</i>	399
Genus IV. <i>Defluviobacter</i>	400
Genus V. <i>Candidatus Liberibacter</i>	400
Genus VI. <i>Mesorhizobium</i>	403
Genus VII. <i>Pseudaminobacter</i>	409
Family V. <i>Methylocystaceae</i>	411
Genus I. <i>Methylocystis</i>	413
Genus II. <i>Albibacter</i>	416
Genus III. <i>Methylosinus</i>	417
Genus Incertae Sedis IV. <i>Methylopila</i>	420
Family VI. <i>Beijerinckiaceae</i>	422
Genus I. <i>Beijerinckia</i>	423
Genus II. <i>Chelatococcus</i>	433
Genus III. <i>Methylocella</i>	437
Family VII. <i>Bradyrhizobiaceae</i>	438
Genus I. <i>Bradyrhizobium</i>	438
Genus II. <i>Afipia</i>	443
Genus III. <i>Agromonas</i>	448
Genus IV. <i>Blastobacter</i>	452
Genus V. <i>Bosea</i>	459
Genus VI. <i>Nitrobacter</i>	461
Genus VII. <i>Oligotropha</i>	468
Genus VIII. <i>Rhodoblastus</i>	471
Genus IX. <i>Rhodopseudomonas</i>	473
Family VIII. <i>Hyphomicrobiaceae</i>	476
Genus I. <i>Hyphomicrobium</i>	476
Genus II. <i>Ancalomicrobium</i>	494
Genus III. <i>Ancylobacter</i>	497
Genus IV. <i>Angulomicrobium</i>	501
Genus V. <i>Aquabacter</i>	504
Genus VI. <i>Azorhizobium</i>	505
Genus VII. <i>Blastochloris</i>	506
Genus VIII. <i>Devosia</i>	509
Genus IX. <i>Dichotomicrobium</i>	513
Genus X. <i>Filomicrobium</i>	518
Genus XI. <i>Gemmiger</i>	520
Genus XII. <i>Labrys</i>	523
Genus XIII. <i>Methylorhabdus</i>	525
Genus XIV. <i>Pedomicrobium</i>	527

Genus XV. <i>Prosthecomicrobium</i>	538
Genus XVI. <i>Rhodomicrobium</i>	543
Genus XVII. <i>Rhodoplanes</i>	545
Genus XVIII. <i>Seliberia</i>	549
Genus XIX. <i>Starkeya</i>	554
Genus XX. <i>Xanthobacter</i>	555
Family IX. <i>Methylobacteriaceae</i>	567
Genus I. <i>Methylobacterium</i>	567
Family X. <i>Rhodobiaceae</i>	571
Genus I. <i>Rhodobium</i>	571
Class II. <i>Betaproteobacteria</i>	575
Order I. <i>Burkholderiales</i>	575
Family I. <i>Burkholderiaceae</i>	575
Genus I. <i>Burkholderia</i>	575
Genus II. <i>Cupriavidus</i>	600
Genus III. <i>Lautropia</i>	604
Genus IV. <i>Pandoraea</i>	605
Genus V. <i>Paucimonas</i>	607
Genus VI. <i>Polynucleobacter</i>	607
Genus VII. <i>Ralstonia</i>	609
Genus VIII. <i>Thermothrix</i>	620
Family II. <i>Oxalobacteraceae</i>	623
Genus I. <i>Oxalobacter</i>	624
Genus II. <i>Duganella</i>	628
Genus III. <i>Herbaspirillum</i>	629
Genus IV. <i>Janthinobacterium</i>	636
Genus V. <i>Massilia</i>	643
Genus VI. <i>Telluria</i>	643
Family III. <i>Alcaligenaceae</i>	647
Genus I. <i>Alcaligenes</i>	653
Genus II. <i>Achromobacter</i>	658
Genus III. <i>Bordetella</i>	662
Genus IV. <i>Derxia</i>	671
Genus V. <i>Oligella</i>	674
Genus VI. <i>Pelistega</i>	678
Genus VII. <i>Pigmentiphaga</i>	681
Genus VIII. <i>Sutterella</i>	682
Genus IX. <i>Taylorella</i>	684
Family IV. <i>Comamonadaceae</i>	686
Genus I. <i>Comamonas</i>	689
Genus II. <i>Acidovorax</i>	696
Genus III. <i>Brachymonas</i>	704
Genus IV. <i>Delftia</i>	706
Genus V. <i>Hydrogenophaga</i>	710
Genus VI. <i>Lampropedia</i>	716
Genus VII. <i>Macromonas</i>	721
Genus VIII. <i>Polaromonas</i>	724
Genus IX. <i>Rhodoferax</i>	727
Genus X. <i>Variovorax</i>	732
Genus Incertae Sedis XI. <i>Aquabacterium</i>	735
Genus Incertae Sedis XII. <i>Ideonella</i>	738
Genus Incertae Sedis XIII. <i>Leptothrix</i>	740
Genus Incertae Sedis XIV. <i>Roseateles</i>	746
Genus Incertae Sedis XV. <i>Rubrivivax</i>	749
Genus Incertae Sedis XVI. <i>Sphaerotilus</i>	750
Genus Incertae Sedis XVII. <i>Tepidimonas</i>	755
Genus Incertae Sedis XVIII. <i>Thiomonas</i>	757

Genus Incertae Sedis XIX. <i>Xylophilus</i>	759
Order II. <i>Hydrogenophilales</i>	763
Family I. <i>Hydrogenophilaceae</i>	763
Genus I. <i>Hydrogenophilus</i>	763
Genus II. <i>Thiobacillus</i>	764
Order III. <i>Methylophilales</i>	770
Family I. <i>Methylophilaceae</i>	770
Genus I. <i>Methylophilus</i>	770
Genus II. <i>Methylobacillus</i>	771
Genus III. <i>Methylovorus</i>	773
Order IV. <i>Neisseriales</i>	774
Family I. <i>Neisseriaceae</i>	775
Genus I. <i>Neisseria</i>	777
Genus II. <i>Alysiella</i>	798
Genus III. <i>Aquaspirillum</i>	801
Genus IV. <i>Chromobacterium</i>	824
Genus V. <i>Eikenella</i>	828
Genus VI. <i>Formivibrio</i>	832
Genus VII. <i>Iodobacter</i>	833
Genus VIII. <i>Kingella</i>	836
Genus IX. <i>Microvirgula</i>	840
Genus X. <i>Prolinoborus</i>	841
Genus XI. <i>Simonsiella</i>	844
Genus XII. <i>Vitreoscilla</i>	851
Genus XIII. <i>Vogesella</i>	858
Genus Incertae Sedis XIV. <i>Catenococcus</i>	859
Genus Incertae Sedis XV. <i>Morococcus</i>	861
Order V. <i>Nitrosomonadales</i>	863
Family I. <i>Nitrosomonadaceae</i>	864
Genus I. <i>Nitrosomonas</i>	864
Genus II. <i>Nitrosolobus</i>	868
Genus III. <i>Nitrospira</i>	868
Genus IV. " <i>Nitrosovibrio</i> "	869
Family II. <i>Spirillaceae</i>	870
Genus I. <i>Spirillum</i>	870
Family III. <i>Gallionellaceae</i>	880
Genus I. <i>Gallionella</i>	880
Order VI. <i>Rhodocyclales</i>	887
Family I. <i>Rhodocyclaceae</i>	887
Genus I. <i>Rhodocyclus</i>	887
Genus II. <i>Azoarcus</i>	890
Genus III. <i>Azonexus</i>	901
Genus IV. <i>Azospira</i>	902
Genus V. <i>Azovibrio</i>	902
Genus VI. <i>Dechloromonas</i>	903
Genus VII. <i>Dechlorosoma</i>	904
Genus VIII. <i>Ferribacterium</i>	904
Genus IX. <i>Propionibacter</i>	905
Genus X. <i>Propionivibrio</i>	906
Genus XI. <i>Thauera</i>	907
Genus XII. <i>Zoogloea</i>	913
Class IV. <i>Deltaproteobacteria</i>	922
Order I. <i>Desulfurellales</i>	922
Family I. <i>Desulfurellaceae</i>	923
Genus I. <i>Desulfurella</i>	923
Genus II. <i>Hippea</i>	925
Order II. <i>Desulfovibrionales</i>	925

Family I. <i>Desulfovibrionaceae</i>	926
Genus I. <i>Desulfovibrio</i>	926
Genus II. <i>Bilophila</i>	938
Genus III. <i>Lawsonia</i>	940
Family II. <i>Desulfomicrobiaceae</i>	944
Genus I. <i>Desulfomicrobium</i>	944
Family III. <i>Desulfohalobiaceae</i>	948
Genus I. <i>Desulfohalobium</i>	949
Genus II. <i>Desulfonatronovibrio</i>	953
Genus III. <i>Desulfothermus</i>	955
Family IV. <i>Desulfonatronumaceae</i>	956
Genus I. <i>Desulfonatronum</i>	956
Order III. <i>Desulfobacterales</i>	959
Family I. <i>Desulfobacteraceae</i>	959
Genus I. <i>Desulfobacter</i>	961
Genus II. <i>Desulfobacterium</i>	965
Genus III. <i>Desulfobacula</i>	968
Genus IV. <i>Desulfobotulus</i>	970
Genus V. <i>Desulfocella</i>	971
Genus VI. <i>Desulfococcus</i>	972
Genus VII. <i>Desulfofaba</i>	975
Genus VIII. <i>Desulfofrigus</i>	976
Genus IX. <i>Desulfonema</i>	977
Genus X. <i>Desulfosarcina</i>	981
Genus XI. <i>Desulfospira</i>	984
Genus XII. <i>Desulfotignum</i>	987
Family II. <i>Desulfobulbaceae</i>	988
Genus I. <i>Desulfobulbus</i>	988
Genus II. <i>Desulfocapsa</i>	992
Genus III. <i>Desulfofustis</i>	994
Genus IV. <i>Desulforhopalus</i>	995
Genus V. <i>Desulfotalea</i>	997
Family III. <i>Nitrospinaceae</i>	999
Genus I. <i>Nitrospina</i>	999
Order IV. <i>Desulfarcales</i>	1003
Family I. <i>Desulfarculaceae</i>	1003
Genus I. <i>Desulfarculus</i>	1004
Order V. <i>Desulfuromonales</i>	1005
Family I. <i>Desulfuromonaceae</i>	1006
Genus I. <i>Desulfuromonas</i>	1007
Genus II. <i>Desulfuromusa</i>	1010
Genus III. <i>Malonomonas</i>	1012
Genus IV. <i>Pelobacter</i>	1013
Family II. <i>Geobacteraceae</i>	1017
Genus I. <i>Geobacter</i>	1017
Genus II. <i>Trichlorobacter</i>	1020
Order VI. <i>Syntrophobacterales</i>	1021
Family I. <i>Syntrophobacteraceae</i>	1021
Genus I. <i>Syntrophobacter</i>	1021
Genus II. <i>Desulfacinum</i>	1027
Genus III. <i>Desulforhabdus</i>	1029
Genus IV. <i>Desulfovirga</i>	1030
Genus V. <i>Thermodesulforhabdus</i>	1031
Family II. <i>Syntrophaceae</i>	1033
Genus I. <i>Syntrophus</i>	1033
Genus II. <i>Desulfobacca</i>	1035
Genus III. <i>Desulfomonile</i>	1036

Genus IV. <i>Smithella</i>	1039
Order VII. <i>Bdellovibrionales</i>	1040
Family I. <i>Bdellovibrionaceae</i>	1040
Genus I. <i>Bdellovibrio</i>	1041
Genus II. <i>Bacteriovorax</i>	1053
Genus III. <i>Micavibrio</i>	1057
Genus IV. <i>Vampirovibrio</i>	1058
Order VIII. <i>Myxococcales</i>	1059
Family I. <i>Myxococcaceae</i>	1073
Genus I. <i>Myxococcus</i>	1074
Genus II. <i>Corallococcus</i>	1079
Genus III. <i>Pyxicoccus</i>	1083
Family II. <i>Cystobacteraceae</i>	1085
Genus I. <i>Cystobacter</i>	1086
Genus II. <i>Archangium</i>	1097
Genus III. <i>Hyalangium</i>	1099
Genus IV. <i>Melittangium</i>	1101
Genus V. <i>Stigmatella</i>	1104
Family III. <i>Polyangiaceae</i>	1109
Genus I. <i>Polyangium</i>	1110
Genus II. <i>Byssophaga</i>	1118
Genus III. <i>Chondromyces</i>	1121
Genus IV. <i>Haploangium</i>	1129
Genus V. <i>Jahnia</i>	1130
Genus VI. <i>Sorangium</i>	1132
Family IV. <i>Nannocystaceae</i>	1136
Genus I. <i>Nannocystis</i>	1137
Family V. <i>Kofleriaceae</i>	1143
Genus I. <i>Kofleria</i>	1143
Class V. <i>Epsilonproteobacteria</i>	1145
Order I. <i>Campylobacterales</i>	1145
Family I. <i>Campylobacteraceae</i>	1145
Genus I. <i>Campylobacter</i>	1147
Genus II. <i>Arcobacter</i>	1161
Genus III. <i>Sulfurospirillum</i>	1165
Family II. <i>Helicobacteraceae</i>	1168
Genus I. <i>Helicobacter</i>	1169
Genus II. <i>Thiovulum</i>	1189
Genus III. <i>Wolinella</i>	1191
Bibliography	1195
Index	1363

Contributors

Wolf-Rainer Abraham

Chemical Microbiology Group, GBF-National Research Centre for Biotechnology, Mascheroder Weg 1, D-38124 Braunschweig, Germany

Paula Aguiar

Portland State University, Portland, OR 97207-0751, USA

Milton J. Allison

Department of Microbiology, Iowa State University, Ames, IA 50011-3211, USA

Rudolf Amann

Nachwuchsgruppe Molekulare Ökologie, Max Planck-Institute für Marine Mikrobiologie, Celsiusstrasse 1, D-28359 Bremen, Germany

Georg Auling

Institute für Mikrobiologie, Universität Hannover, Schneiderberg 50, D-30167 Hannover, Germany

Marcie L. Baer

Biology Department, Shippensburg University, Shippensburg, PA 17257, USA

Simon C. Baker

Birkbeck College, Malet Street, Bloomsbury, London WC1E 7HX, United Kingdom

José Ivo Baldani

Centro Nacional de Pesquisa de Agrobiologia, Empresa Brasileira de Pesquisa Agropecuária, Room 247-23851-970 Seropédica, Caixa Postal 74.505, Rio de Janeiro 465, Brazil

Vera Lúcia Divan Baldani

Centro Nacional de Pesquisa de Agrobiologia, Empresa Brasileira de Pesquisa Agropecuária, Room 247-23851-970 Seropédica, Caixa Postal 74.505, Rio de Janeiro 465, Brazil

David L. Balkwill

Department of Biological Science, Florida State University, Tallahassee, FL 32306-4470, USA

Menachem Banai

Ministry of Agriculture, Veterinary Services & Animal Health, Kimron Veterinary Institute, P.O. Box 12, Bet Dagan 50 250, Israel

Claudio Bandi

Dipartimento di Patologia Animale, Igiene e Sanità Pubblica Veterinaria, Sezione di Patologia Generale e Parassitologia, Università degli Studi di Milano, Via Celoria 10 20133 Milano, Italy

Ellen Jo Baron

Clinical Microbiology/Virology Laboratory, Stanford University Medical Center, Stanford, CA 94305-5250, USA

Janiche Beeder

Section for Biotechnology, Novsk Hydro ASA Research Centre, P. O. Box 2560, N-3901 Porsgruun, Norway

Julia A. Bell

Department of Microbiology and Molecular Genetics, Michigan State University, East Lansing, MI 48824-4320, USA

Nancy M.C. Bleumink-Pluym

Dept. of Bacteriology, Inst. of Infectious Diseases & Immunology, Vet. Medicine, Universit t Utrecht, Yalelaan 1, 3584 CL Utrecht, The Netherlands

Eberhard Bock

Inst. f r Allgemeine Botanik und Botanischer Garten, Universit t Hamburg, Ohnhorststrasse 18, D-22609 Hamburg, Germany

David R. Boone

Department of Environmental Biology, Portland State University, Portland, OR 97207-0751, USA

Edward J. Bottone

Department of Infectious Diseases, The Mount Sinai Hospital, New York, NY 10029-6574, USA

John P. Bowman

School of Agricultural Science, University of Tasmania, Antartic CRC, Private Bag 54, Hobart 7001, Tasmania, Australia

Kristian K. Brandt

Section of Genetics and Microbiology, Department of Ecology, Royal Veterinary and Agricultural University, DK-1871 Frederiksberg, Denmark

Don J. Brenner

Meningitis & Special Pathogens Branch Laboratory Section, Centers for Disease Control & Prevention, Atlanta, GA 30333, USA

Hans-J rgen Busse

Institut f r Bakteriologie, Mykologie und Hygiene, Veterin rmedizinische Universit t Wien, Veterin rplatz 1, A-1210 Wien, Austria

Douglas E. Caldwell

Dept. of Applied Microbiology and Food Science, University of Saskatchewan, Saskatoon, 51 Campus Drive, Saskatchewan S7N 5A8 SK, Canada

Wen Xin Chen

Department of Microbiology, Biology College, Beijing Agricultural University, Beijing, P.R. China

John D. Coates

Plant and Microbial Biology, University of California, Berkeley, Berkeley, CA 94720-3102, USA

John D. Coates

Plant and Microbial Biology, University of California, Berkeley, Berkeley, CA 94720-3102, USA

Michael J. Corbel

National Institute for Biol. Standards & Control, Blanche Lane, South Mimms, Potters Bar, Hertfordshire EN6 3QG, United Kingdom

Milton S. da Costa

Departamento de Zoologia, Centro de Neuroci ncias, Universidade de Coimbra, Apartado 3126, P-3004-517 Coimbra, Portugal

Subrata K. Das

Institute of Life Sciences, Nalco square, Bhubaneswar 751 023, India

Gregory A. Dasch

Division of Viral and Rickettsial Diseases, Viral and Rickettsial Zoonoses Branch, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Atlanta, GA 30333, USA

Frank B. Dazzo

Department of Microbiology and Molecular Genetics, Michigan State University, East Lansing, MI 48824-4320, USA

Kim A. DeWeerd

Department of Chemistry, State University of New York, University at Albany, Albany, NY 12222, USA

Ewald B.M. Denner

Abteilung Mikrobiologie und Biotechnologie, Institut für Mikrobiologie und Genetik, Dr. Bohr-Gasse 9, A-1030 Wien, Austria

Richard Devereux

NHEERL, Gulf Ecology Division, U.S.E.P.A., Gulf Breeze, FL 32561, USA

Floyd E. Dewhirst

Department of Molecular Genetics, The Forsyth Institute, 140 The Fenway, Boston, MA 02115-3799, USA

Johanna Döbereiner (Deceased)

Centro Nacional de Pesquisa de Agrobiologia, Empresa Brasileira de Pesquisa Agropecuária, Room 247, 23851-970 Seropédica, Caixa Postal 74.505, Rio de Janeiro 465, Brazil

Nina V. Doronina

Inst. of Biochemistry & Physiology of Micro-organisms RAS, Laboratory of Methylo-trophy, Russian Academy of Sciences, Pushchino-on-the-Oka, Moscow Region 142290, Russia

Galina A. Dubinina

Institute of Microbiology, Russian Academy of Sciences, Prospect 6—let. Oktyabrya 7/2, Moscow, Russia

J. Stephen Dumler

Division of Microbiology, Department of Pathology, The Johns Hopkins Hospital, Univ. School of Medicine, Baltimore, MD 21287-7093, USA

Jürgen Eberspächer

Institut für Mikrobiologie (250), Universität Hohenheim, Gartenstrasse 30, D-70599 Stuttgart, Germany

Thomas W. Egli

Department of Microbiology, EAWAG, Überlandstrasse 133, CH 8600 Dübendorf, Switzerland

Stefanie J.W.H. Oude Elferink

ID TNO Animal Nutrition, P.O. Box 65, 8200 AB Lelystad, The Netherlands

Takayuki T. Ezaki

Department of Microbiology and Bioinformatics, Regeneration and Advanced Medical Science, Gifu University School of Medicine, 40 Tsukasa-machi, Gifu 500 8705, Japan

Mark Fegan

Coop. Research Centre for Tropical Plant Protection, Dept. of Micro. & Parasitology, The University of Queensland, St. Lucia, Brisbane, Queensland 4072, Australia

Andreas Fesefeldt

Geibelallee 12a, 24116 Kiel, Germany

Kai W. Finster

Department of Microbial Ecology, Institute of Biological Sciences, University of Aarhus, Building 540, Ny, Munkegade, DK-8000 Aarhus C, Denmark

James G. Fox

Department of Comparative Medicine, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

Michael Friedrich

Abteilung Biogeochemie, Max Planck-Institut für Terrestrische Mikrobiologie, Karl-von-Frisch-Strasse, D-35043 Marburg, Germany

Georg Fuchs

Mikrobiologie, Institut für Biologie II, Albert-Ludwigs-Universität Freiburg, D-79104 Freiburg, Germany

John A. Fuerst

Center for Bacterial Diversity and Identification, Department of Microbiology, University of Queensland, Brisbane, Queensland 4072, Australia

Jean-Louis Garcia

Laboratoire de Microbiologie, ORSTOM-ESIL-Case 925, Université de Provence, 163, Avenue de Luminy, 13288 Marseille, Cédex 9, France

Monique Garnier (Deceased)

Institut National de la Recherche Agronomique et Université Victor Ségalen, Laboratoire de Biologie Cellulaire et Moléculaire, Bordeaux 2, 33883, BP 81, Villenave d'Ormon Cedex, France

George M. Garrity

Dept. of Microbiology and Molecular Genetics, Michigan State University, East Lansing, MI 48824, USA

Rainer Gebers

Depenweg 12, D-24217 Schönberg/Holstein, Germany

Connie J. Gebhart

Division of Comparative Medicine, University of Minnesota Health Center, Minneapolis, MN 55455, USA

Barbara R. Sharak Genthner

Center for Environmental Diagnostics and Bioremediation, University of West Florida, Pensacola, FL 32514, USA

Peter Gerner-Smith

Department of Gastrointestinal Infections, Statens Serum Institut, Artillerivej 5, DK-2300 Copenhagen S, Denmark

Monique Gillis

Laboratorium voor Microbiologie Vakgroep WE 10V, Universiteit Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Christian Gliesche

Institut für Ökologie, Ernst-Moritz-Arndt-Universität, Greifswald Schwedenhagen 6, D-18565 Kloster/Hiddensee, Germany

José M. González

Departamento de Microbiología y Biología Celular, Facultad de Farmacia, Universidad de La Laguna, 38071 La Laguna. Tenerife, Spain

Yvonne E. Goodman

Department of Medical Bacteriology, University of Alberta, Medical Services Building, Edmonton, Alberta, Canada

Vladimir M. Gorlenko

Institute of Microbiology, Russian Academy of Sciences, Prospect 60-letiya, Oktyabrya 7, korpus 2, Moscow 117312, Russia

Hans-Dieter Görtz

Department of Zoology, Biologisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany

John J. Gosink

Amgen, Inc., Seattle, WA 98101, USA

Jennifer Gossling

8401 University Drive, St. Louis, MO 63105-3641, USA

Peter N. Green

National Collection of Industrial & Marine Bacteria, 23 St. Machar Drive, Aberdeen AB24 3RY, United Kingdom

Lotta E-L. Hallbeck

Department of Cell and Molecular Biology, Göteborg University, Medicinaregatan 9 C, Box 462, S-405 30 Göteborg, Sweden

Theo A. Hansen

Department of Microbial Physiology, Groningen Biomolecular Sci. & Biotech. Inst., University of Groningen, P. O. Box 14, 9750 AA Haren, The Netherlands

Anton Hartmann

Institute of Soil Ecology, Rhizosphere Biology Division, GSF Research Center, PO Box 1129, D-85764 Neuherberg, München, Germany

Fawzy M. Hashem

Sustainable Agriculture Laboratory, Animal and Natural Resources Institute, Beltsville Agricultural Research Institute, USDA-ARS, Beltsville, MD 20705, USA

Brian P. Hedlund

Department of Biological Sciences, University of Nevada, Las Vegas, Las Vegas, NV 89154-4004, USA

Johann Heider

Mikrobiologie, Institut für Biologie II, Universität Freiburg, Schänzlestrasse 1, D-79104 Freiburg, Germany

Karl-Heinz Hinz

Klinik für Geflügel der Tierärztlichen Hochschule, Bünteweg 17, D-30559 Hannover, Germany

Akira Hiraishi

Department of Ecological Engineering, Toyohashi University of Technology, Tempaku-cho, Toyohashi 441-8580, Japan

Peter Hirsch

Institut für Allgemeine Mikrobiologie der Biozentrum, Universität Kiel, Am Botanischen Garten 1-9, D-24118 Kiel, Germany

Becky Hollen

Department of Biological Sciences, Louisiana State University, Baton Rouge, LA 70803, USA

Barry Holmes

Public Health Laboratory Service, Central Public Health Laboratory, National Collection of Type Cultures, 61 Colindale Avenue, London NW9 5HT, United Kingdom

John Holt

Department of Microbiology and Molecular Genetics, Michigan State University, East Lansing, MI 48824-1101, USA

Philip Hugenholtz

Ecosystem Sciences Division, Department of Environmental Science, Policy, and Management, University of California, Berkeley, Berkeley, CA 94720-3110, USA

Thomas Hurek

Arbeitsgruppe Symbiosforschung, Planck-Institut für Terrestrische Mikrobiologie, Karl-von-Frisch-Strasse, D-35043 Marburg, Germany

Johannes F. Imhoff

Institut für Meereskunde, Abt. Marine Mikrobiologie, Universität Kiel, Düsternbrooker Weg 20, D-24105 Kiel, Germany

Kjeld Ingvorsen

Department of Microbial Ecology, Institute of Biological Sciences, University of Aarhus, Building 540, Ny Munkegade, DK-8000 Aarhus C, Denmark

Francis L. Jackson

Medical Microbiology and Immunology, University of Alberta, 1-41-Medical Sciences Building, Edmonton, Alberta AB T6G 2H7, Canada

Cheryl Jenkins

Department of Microbiology, University of Washington, Seattle, WA 98195-0001, USA

Sibylle Kalmbach

Studienstiftung des Deutschen Volkes, Mirbachstrasse 7, D-53173 Bonn, Germany

Peter Kämpfer

Institut für Angewandte Mikrobiologie, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 26-32, IFZ, D-35392 Giessen, Germany

Yoshiaki Kawamura

Department of Microbiology, Gifu University School of Medicine, 40 Tsukasa-machi, Gifu 500 8705, Japan

Donovan P. Kelly

Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, United Kingdom

Suzanne V. Kelly

Professor of Biology, Scottsdale Community College, Scottsdale, AZ 85250, USA

Christina Kennedy

Department of Plant Pathology, College of Agriculture, The University of Arizona, Tucson, AZ 85721-0036, USA

Christina Kennedy

Division of Plant Pathology and Microbiology, Department of Plant Pathology, The University of Arizona, Tucson, AZ 85721-0036, USA

Allen Kerr

Waite Agricultural Research Institute, The University of Adelaide, Glen Osmond 5064, South Australia

Karel Kersters

Lab. voor Mikrobiologie, Vakgroep Biochemie, Fysiologie en Microbiologie, Rijksuniversiteit Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Hans-Peter Klenk

VP Genomics, Epidauros Biotechnology Inc., Am Neuland 1, D-82347 Bernried, Germany

Oliver Klimmek

Biozentrum Niederursel, Institut für Mikrobiologie der Johann Wolfgang Goethe-Universität, Marie-Curie-Strasse 9, D-60439 Frankfurt am Main, Germany

Allan E. Konopka

Department of Biological Science, Purdue University, West Lafayette, IN 47907-2054, USA

Hans-Peter Koops

Abteilung Mikrobiologie, Inst. für Allgemeine Botanik und Botanischer Garten, Universität Hamburg, Ohnhorststrasse 18, D-22609 Hamburg, Germany

Yoshimasa Kosako

The Institute of Physical and Chemical Research, Japan Collection of Microorganisms, RIKEN, Wako-shi, Saitama 351-0198, Japan

Julius P. Kreier

Department of Microbiology, The Ohio State University, Columbus, OH 43201, USA

Noel R. Krieg

Department of Biology, Virginia Polytechnic Institute & State University, Blacksburg, VA 24061-0406, USA

Achim Kröger (Deceased)

Biozentrum Niederursel, Institut für Mikrobiologie der Johann Wolfgang Goethe-Universität, Marie-Curie-Strasse 9, D-60439 Frankfurt am Main, Germany

J. Gijs Kuenen

Faculty of Chemical Tech. & Materials Science, Kluyver Laboratory for Biotechnology, Delft University of Technology, 2628 BC Delft, The Netherlands

Jan Kuever

Department of Microbiology, Institute for Material Testing, Foundation Institute for Materials Science, D-28199 Bremen, Germany

L. David Kuykendall

Molecular Plant Pathology Laboratory, Plant Sciences Institute, United States Department of Agriculture, Beltsville, MD 20705-2350, USA

David P. Labeda

Natl. Ctr. for Agricultural Utilization Research, Microbial Properties Research, U.S. Department of Agriculture, Peoria, IL 61604-3999, USA

Matthias Labrenz

Institut für Allgemeine Mikrobiologie, Biologiezentrum, University of Kiel, Am Botanischen Garten 1-9, 24118 Kiel, Germany

Adrian Lee

School of Microbiology and Immunology, University of New South Wales, Kensington, Sydney, Australia

Werner Liesack

Max Planck-Institut für Terrestrische Mikrobiologie, Karl-von-Frisch-Strasse, D-35043 Marburg, Germany

Timothy Lilburn

ATCC Bioinformatics, Manassas, VA 20110-2209, USA

Niall A. Logan

School of Biological and Biomedical Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, United Kingdom

Derek R. Lovley

Department of Microbiology, University of Massachusetts, Physiology & Ecology of Anaerobic Micro., Amherst, MA 01003, USA

Wolfgang Ludwig

Lehrstuhl für Mikrobiologie, Technische Universität München, Am Hochanger 4, D-85350 Freising, Germany

Barbara J. MacGregor

Max Planck-Institute for Marine Microbiology, Celsiusstrasse 1, D-28359 Bremen, Germany

Michael T. Madigan

Department of Microbiology, Life Science II, Southern Illinois University, Carbondale, IL 62901-6508, USA

Åsa Malmqvist

ANOX AB, Klosterangsvagen 11A, S-226 47 Lund, Sweden

Werner Manz

Section G3, Ecotoxicology and Biochemistry, German Federal Institute of Hydrology, Kaiserin-Augusta-Anlagen 15-17, P. O. Box 20 02 53, D-56002 Koblenz, Germany

Esperanza Martínez-Romero

Centro de Investigación sobre Fijación de Nitrógeno, UNAM, Ap Postal 565-A, Cuernavaca, Morelos, México

Abdul M. Maszenan

Environmental Engineering Research Centre, School of Civil and Structural Engineering, Nanyang Technological University, Block N1, #1a-29, 50 Nanyang Avenue, Singapore 639798

Michael J. McInerney

Department of Botany and Microbiology, The University of Oklahoma, Norman, OK 73019-6131, USA

Steven McOrist

Department of Biomedical Sciences, Tufts University College of Veterinary Medicine, North Grafton, MA 01536, USA

Roy D. Meredith (Deceased)**Joris Mergaert**

Laboratorium voor Mikrobiologie Vakgroep Biochemie, Fysiologie en Microbiol., Universiteit Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Ortwin D. Meyer

Lehrstuhl für Mikrobiologie, Universität Bayreuth, Universitätsstrasse 30, D-95440 Bayreuth, Germany

Edward R.B. Moore

Programme of Soil Quality and Protection, The Macaulay Research Institute, Macaulay Dr., Craigiebuckler, AB15 8QH Aberdeen, United Kingdom

R.G.E. Murray

Department of Microbiology and Immunology, The University of Western Ontario, London, Ontario N6A 5C1, Canada

Yasuyoshi Nakagawa

Biological Resource Center (NBRC), Department of Biotechnology, National Institute of Technology and Evaluation, 2-5-8, Kazusakamatari, Kisarazu, Chiba 292-0818, Japan

M. Fernanda Nobre

Departamento de Zoologia, Universidade de Coimbra, Apartado 3126, P-3000 Coimbra, Portugal

Jani L. O'Rourke

School of Microbiology and Immunology, University of New South Wales, Kensington, Sydney, Australia

Bernard Ollivier

Laboratoire de Microbiologie—LMI, ORSTOM, Case 925, Université de Provence, ESIL, 163 Avenue de Luminy, Marseille 13288 Cedex 09, France

Stephen L.W. On

Danish Veterinary Institute, Bülowsvej 27, DK-1790, Copenhagen V, Denmark

Ronald S. Oremland

Water Research Division, U.S. Geological Survey, Menlo Park, CA 94025-3591, USA

Norberto J. Palleroni

Rutgers, North Caldwell, NJ 07006-4146, USA

Bruce J. Paster

Department of Molecular Genetics, The Forsyth Institute, 140 The Fenway, Boston, MA 02115-3799, USA

Bharat K.C. Patel

Microbial Discovery Research Unit, School of Biomolecular Sciences, Griffith University, Nathan Campus, Kessels Road, Brisbane, Queensland 4111, Australia

Dominique Patureau

Laboratoire de Biotechnologie de l'Environnement, INRA Narbonne, avenue des étangs, 11 100 Narbonne, France

Karsten Pedersen

Department of Cell and Molecular Biology, Göteborg University, Medicinaregatan 9 C, Box 462, S-405 30 Göteborg, Sweden

Jeanne S. Poindexter

Department of Biological Sciences, Barnard College, Columbia University, New York, NY 10027-6598, USA

Andreas Pommerening-Röser

Abteilung Mikrobiologie, Inst. für Allgemeine, Botanik und Botanischer Garten, Universität Hamburg, Ohnhorststrasse 18, D-22609 Hamburg, Germany

Bruno Pot

Science Department, Yakult Belgium, Joseph Wybranlaan 40, B-1070 Brussels, Belgium

Fred A. Rainey

Department of Biological Sciences, Louisiana State University, Baton Rouge, LA 70803, USA

Didier Raoult

Faculté de Médecine, CNRS, Unité des Rickettsies, 27 Boulevard Jean Moulin, 13385 Marseille Cedex 05, France

Christopher Rathgeber

Department of Microbiology, The University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

Gavin N. Rees

Murray-Darling Freshwater Research Centre, CRC Freshwater Ecology, Ellis Street, Thurgoona, PO Box 921, Albury NSW 2640, Australia

Hans Reichenbach

Arbeitsgruppe Mikrobielle Sekundärstoffe, Gesellschaft für Biotechnologische Forschung mbH, Mascheroder Weg 1, D-38124 Braunschweig, Germany

Barbara Reinhold-Hurek

Universität Bremen, Fachbereich 2, Allgemeine Mikrobiologie, P. O. Box 330440, D-28334 Bremen, Germany

Anna-Louise Reysenbach

Department of Environmental Biology, Portland State University, Portland, OR 97207, USA

Yasuko Rikihisa

Department of Veterinary Biosciences, The Ohio State University, 1925 Coffey Road, Columbus, OH 43210-1093, USA

Lesley A. Robertson

Kluyver Laboratory for Biotechnology, Delft University of Technology, Julianalaan 67, P. O. Box 5057, 2628BC Delft, The Netherlands

Takeshi Sakane

Institute for Fermentation, Osaka, Yodogawa-ku, Osaka 532-8686, Japan

Abigail A. Salyers

Department of Microbiology, University of Illinois-Urbana, Champaign, Urbana, IL 61801-3704, USA

Gary N. Sanden

Epidemic Investigations Laboratory, Meningitis and Special Pathogens Branch, Division of Bacterial and Mycotic Diseases, Centers for Disease Control and Prevention, Atlanta, GA 30333, USA

Hiroyuki Sawada

National Institute of Agro-Environmental Sciences, 3-1-1 Kannondai, Tsukuba, Ibaraki 305-8604, Japan

Bernhard H. Schink

Fakultät für Biologie, Lehrstuhl für Mikrobielle Ökologie, Universität Konstanz, Postfach 55 60, D-78457 Konstanz, Germany

Karl-Heinz Schleifer

Lehrstuhl für Mikrobiologie, Technische Universität München, Am Hochanger 4, Freising D-85350, Germany

Karl-Heinz Schleifer

Lehrstuhl für Mikrobiologie, Technische, Universität München, Am Hochanger 4, Freising D-85350, Germany

Heinz Schlesner

Institut für Allgemeine Mikrobiologie, Universität Kiel, Am Botanischen Garten 1-9, Biologiezentrum, D-24118 Kiel, Germany

Helmut J. Schmidt

Biological Faculty, University of Kaiserslautern, Building 14, Pf 3049, D-67653 Kaiserslautern, Germany

Jean M. Schmidt

Department of Microbiology, Arizona State University, Tempe, AZ 85287-2701, USA

Dirk Schüler

Max Planck-Institute for Marine Microbiology, Celsiusstrasse 1, D-28359 Bremen, Germany

Bernard La Scola

CNRS UMR6020, Unité des Rickettsies, 27 Boulevard Jean Moulin, 13385 Marseille Cedex 05, France

Paul Segers

Lab. voor Mikrobiologie Vakgroep WE 10V, Universiteit Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Robert J. Seviour

Biotechnology Research Centre, La Trobe University, P.O. Box 199, Bendigo VIC 3550, Australia

Richard Sharp

School of Applied Sciences, South Bank University, 103 Borough Road, London SE1 0AA, United Kingdom

Tsuneo Shiba

Shimonoseki University of Fisheries, Dept. of Food Science and Technology, Yoshimi-Nagatahonocho Shimonose, Yamaguchi 759-65, Japan

Martin Sievers

University of Applied Sciences, Department of Biotechnology, Molecular Biology, P. O. Box 335, CH 8820 Wädenswil, Switzerland

Lindsay I. Sly

Centre for Bacterial Diversity and Identification, Department of Microbiology and Parasitology, University of Queensland, St. Lucia, Brisbane, Queensland 4072, Australia

Peter H.A. Sneath

Department of Microbiology and Immunology, School of Medicine, University of Leicester, P.O. Box 138, Leicester LE1 9HN, United Kingdom

Martin Sobieraj

Department of Environmental Biology, Portland State University, P. O. Box 751, Portland, OR 97207-0751, USA

Dimitry Y. Sorokin

Institute of Microbiology, Russian Academy of Sciences, Prospect 60-let. Oktyabrya 7/2, Moscow 117811, Russia

Rob J.M. van Spanning

Department of Molecular Cell Physiology/Molecular Microbial Ecology, Vrije Universiteit, De Boelelaan 1087, NL-1081 HV Amsterdam, The Netherlands

Eva Spieck

Inst. für Allgemeine Botanik und Botanischer Garten, Universität Hamburg, Ohnhorststrasse 18, D-22609 Hamburg, Germany

Georg A. Sprenger

Forschungszentrum Jülich GmbH, Institut für Biotechnologie 1, P. O. Box 1913, D-52425 Jülich, Germany

Stefan Spring

DSMZ-Deutsche Sammlung von Mikroorganismen und Zellkulturen, GmbH, D-38124 Braunschweig, Germany

David A. Stahl

Civil and Environmental Engineering, University of Washington, Seattle, WA 98195-2700, USA

James T. Staley

Department of Microbiology, University of Washington, Seattle, WA 98195-0001, USA

Alfons J.M. Stams

Department of Microbiology, Wageningen Agricultural University, Hesselink Van Suchtelenweg 4, NL-6703 CT Wageningen, The Netherlands

Patricia M. Stanley

Minntech Corporation, North, Minneapolis, MN 55447-4822, USA

John F. Stolz

Department of Biological Sciences, Duquesne University, Pittsburgh, PA 15282-2504, USA

Adriaan H. Stouthamer

Dept. of Molecular Cell Physiology/Molecular Microbial Ecology, Vrije Universiteit, De Boelelaan 1087, NL-1081 HV Amsterdam, The Netherlands

William R. Strohl

Merck & Company, Rahway, NJ 07065-0900, USA

Joseph M. Suflita

Environmental and General Applied Microbiology, Department of Botany & Micro., The University of Oklahoma, Norman, OK 73019-0245, USA

Jörg Süling

Institut für Meereskunde, Abt Marine Mikro-biologie, Universität Kiel, Düsterbrookweg 20, D-24105 Kiel, Germany

Jean Swings

Laboratorium voor Microbiologie, Vakgroep WE10V, Fysiologie en Microbiologie, Universiteit of Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Ulrich Szewzyk

Department of Microbial Ecology, Technical University Berlin, Franklinstrasse 29, Secr. OE 5, D-10587 Berlin, Germany

Zhiyuan Tan

Department of Microbiology and Molecular Genetics, College of Agronomy, South China Agricultural University, 510642, China

Anders Ternström

ANOX AB, Klosterangsvagen 11A, S-226 47 Lund, Sweden

Tone Tønjum

Institute of Microbiology, Section of Molecular Microbiology A3, Rikshospitalet (National Hospital), Pilestredet 32, N-0027 Oslo, Norway

G. Todd Townsend

University of Oklahoma, Norman, OK 73072, USA

Yuri A. Trotsenko

Institute of Biochemistry and Physiology of Microorganisms RAS, Laboratory of Methylo-trophy, Prospekt Nauki, 5, Moscow Region 142290, Russia

Hans G. Trüper

Institut für Mikrobiologie und Biotechnologie, Universität Bonn, Mechenheimer Allee 168, W-53115 Bonn, Germany

Richard F. Unz

Department of Civil Engineering, The Pennsylvania State University, University Park, PA 16802-1408, USA

Teizi Urakami

Biochemicals Development Div., Mitsubishi Building, Mitsubishi Gas Chemical Company, 5-2, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8324, Japan

Marc Vancanneyt

Laboratorium voor Microbiologie, Universiteit Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Peter Vandamme

Lab. voor Microbiologie en Microbiele Genetica, Univeriteit of Gent, Faculteit Wetenschappen, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Leana V. Vasilyeva

Institute of Microbiology RAN, 117811, Russian Academy of Sciences, 60-let. Oktyabrya 7 build. 2, Moscow, Russia

Henk W. van Verseveld

Dept. of Molecular Cell Physiology, Molecular and Microbial Ecology, Vrije Universiteit, De Boelelaan 1087, NL-1081 HV Amsterdam, The Netherlands

Paul De Vos

Dept. of Biochem., Physiology and Microbiology (WE 10V), University of Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

David H. Walker

Department of Pathology, University of Texas Medical Branch, 301 University Boulevard, Galveston, TX 77555-0609, USA

En Tao Wang

Departamento de Microbiología, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, Carpio y Plan de Ayala S/N, México D.F. 11340, México

Naomi L. Ward

The Institute for Genomic Research, Rockville, MD 20850, USA

Richard I. Webb

Department of Microbiology, University of Queensland, Brisbane, Queensland 4072, Australia

Ronald M. Weiner

Cell Biology Cluster, Division of Molecular and Cellular Biosciences, National Science Foundation, Arlington, VA 22230, USA

David F. Welch

Laboratory Corporation of America, Dallas, Texas 75230, USA

Aimin Wen

Food Science and Technology Program, Pacific Agri-Food Research Centre, Summerland BC V0H 1Z0, Canada

Hannah M. Wexler

Department of Veterans Affairs, West Los Angeles Medical Ctr., UCLA School of Medicine, 11301 Wilshire Boulevard, Los Angeles, CA 90073, USA

Robbin S. Weyant

Meningitis & Special Pathogens Branch, Centers for Disease Control and Prevention, Atlanta, GA 30333, USA

Anne M. Whitney

Meningitis & Special Pathogens Branch Lab. Section, MS D-11, Centers for Disease Control & Prevention, Atlanta, GA 30303, USA

Friedrich W. Widdel

Abteilung Mikrobiologie, Max Planck-Institut für Marine Mikrobiologie, Celsiusstrasse 1, D-28359 Bremen, Germany

Jürgen K.W. Wiegell

Department of Microbiology, University of Georgia, Athens, GA 30602-2605, USA

Anne Willems

Laboratorium voor Microbiologie, Universiteit Gent, K.L. Ledeganckstraat 35, B-9000 Gent, Belgium

Henry N. Williams

Department of OCBS, Dental School, University of Maryland at Baltimore, Baltimore, MD 21201-1510, USA

Ann P. Wood

Microbiology Research Group, King's College, London, Div. of Life Sciences, Franklin-Wilkins Building, 150 Stamford Street, London SE1 8WA, United Kingdom

Eiko Yabuuchi

Aichi Medical University, Omiya 4-19-18, Asahi-ku, Osaka 535-0002, Japan

Akira Yokota

Institute of Molecular and Cellular Biosciences, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113-0032, Japan

John M. Young

Mt. Albert Research Centre, Landcare Research New Zealand Ltd., Private Bage 92 170, Auckland, New Zealand

Xue-jie Yu

Department of Pathology, University of Texas Medical Branch, 301 University Boulevard, Galveston, TX 77555-0609

Vladimir V. Yurkov

Department of Microbiology, The University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada

George A. Zavarzin

Institute of Microbiology, Russian Academy of Sciences, Building 2, Prospect 60-letja Oktyabrya 7a, Moscow 117312, Russia

Bernard A.M. van der Zeijst

National Institute of Public Health and Environ., Antonie van Leeuwenhoeklaan 9, P. O. Box 1, P. O. Box 80.165, 3720 BA Bilthoven, The Netherlands

Tatjana N. Zhilina

Institute of Microbiology, Russian Academy of Sciences, Prospect 60-letja Oktyabrya 7a, Moscow 117312, Russia

Stephen H. Zinder

Department of Microbiology, Cornell University, Ithaca, NY 14853-0001, USA

Class I. **Alphaproteobacteria** *class. nov.*

GEORGE M. GARRITY, JULIA A. BELL AND TIMOTHY LILBURN

Al.pha.pro.te.o.bac.te'ri.a. Gr. n. *alpha* name of first letter of Greek alphabet; Gr. n. *Proteus* ocean god able to change shape; Gr. n. *bakterion* a small rod; M.L. fem. pl. n. *Alphaproteobacteria* class of bacteria having 16S rRNA gene sequences related to those of the members of the order *Caulobacterales*.

The class *Alphaproteobacteria* was circumscribed for this volume on the basis of phylogenetic analysis of 16S rRNA sequences; the class contains the orders *Caulobacterales*, "*Parvularculales*", *Rhizo-*

biales, *Rhodobacterales*, *Rhodospirillales*, *Rickettsiales*, and *Sphingomonadales*.

Type order: Caulobacterales Henrici and Johnson 1935a, 4.

Order I. **Rhodospirillales** Pfennig and Truper 1971, 17^{AL}

GEORGE M. GARRITY, JULIA A. BELL AND TIMOTHY LILBURN

Rho.do.spi.ril.la'les. M.L. neut. n. *Rhodospirillum* type genus of the order; *-ales* suffix to denote order; M.L. fem. n. *Rhodospirillales* the *Rhodospirillum* order.

The order *Rhodospirillales* was circumscribed for this volume on the basis of phylogenetic analysis of 16S rRNA sequences; the order contains the families *Rhodospirillaceae* and *Acetobacteraceae*.

Order is morphologically, metabolically, and ecologically diverse. Includes chemoorganotrophs, chemolithotrophs, and fac-

ultative photoheterotrophs; some of the latter are also able to grow photoautotrophically. Other species can grow methylo-

trophically.
Type genus: Rhodospirillum Molisch 1907, 24 emend. Imhoff, Petri and Süling 1998, 796.

Family I. **Rhodospirillaceae** Pfennig and Trüper 1971, 17^{AL}

GEORGE M. GARRITY, JULIA A. BELL AND TIMOTHY LILBURN

Rho.do.spi.ril.la'ce.ae. M.L. neut. n. *Rhodospirillum* type genus of the family; *-aceae* ending to denote family; M.L. fem. pl. n. *Rhodospirillaceae* the *Rhodospirillum* family.

The family *Rhodospirillaceae* was circumscribed for this volume on the basis of phylogenetic analysis of 16S rRNA sequences; the family contains the genera *Rhodospirillum* (type genus), *Azospirillum*, *Inquilineus*, *Levispirillum*, *Magnetospirillum*, *Phaeospirillum*, *Rhodocista*, *Rhodospira*, *Rhodovibrio*, *Roseospira*, *Skermanella*, *Thalassospira*, and *Tistrella* (type genus). *Inquilineus*, *Thalassospira*, and *Tistrella* were proposed after the cut-off date for inclusion in this volume (June 30, 2001) and are not described here (see Coenye et al., 2002; López-López et al., 2002; and Shi et al., 2002, respectively).

Preferred mode of growth for most genera is photoheterotrophic under anoxic conditions in light. Grow chemotrophically in the dark. *Azospirillum*, *Magnetospirillum*, and *Skermanella* are chemoorganotrophic. Motile by means of polar flagella; may have lateral flagella.

Type genus: Rhodospirillum Molisch 1907, 24 emend. Imhoff, Petri and Süling 1998, 796.

Genus I. Rhodospirillum Molisch 1907, 24^{AL} emend. Imhoff, Petri and Süling 1998, 796

JOHANNES F. IMHOFF

Rho.do.spi.ril.lum. Gr. n. *rhodon* the rose; M.L. neut. n. *Spirillum* a bacterial genus; M.L. neut. n. *Rhodospirillum* the rose *Spirillum*.

Cells are vibrioid to spiral shaped, are motile by means of bipolar flagella, and multiply by binary fission. **Gram negative, belonging to the Alphaproteobacteria.** Internal photosynthetic membranes are present as vesicles or as lamellae forming a sharp angle to the cytoplasmic membrane. Photosynthetic pigments are **bacteriochlorophyll a** (esterified with phytol or geranylgeraniol) and **carotenoids of the spirilloxanthin series** with spirilloxanthin itself lacking in some species. **Ubiquinones and rhodoquinones with 8 or 10 isoprene units** are present. **Major cellular fatty acids are**

C_{18:1}, C_{16:1}, and C_{16:0}, with C_{18:1} as dominant component (51–55% of total fatty acids).

Grow preferentially photoheterotrophically under anoxic conditions in the light. **Photoautotrophic growth with molecular hydrogen and sulfide** as photosynthetic electron donors may occur. **Chemotrophic growth occurs under microoxic to oxic conditions in the dark.** Some species are very sensitive to oxygen; others grow equally well aerobically in the dark. **Fermentation and oxidant-dependent growth may occur.** Polysaccharides, poly-β-hy-