

BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY

BY

ROBERT S. BREED

Late Professor Emeritus, Cornell University, Geneva, New York

E. G. D. MURRAY

Research Professor, University of Western Ontario, London, Ontario, Canada

NATHAN R. SMITH

Senior Bacteriologist, Retired, Plant Industry Station, U. S. Department of Agriculture, Beltsville, Maryland

Assisted by

*Ninety-four Contributors Whose Names Appear
on the Immediately Following Pages*

SEVENTH EDITION



LONDON

BAILLIÈRE, TINDALL & COX, LTD.

1957

PREFACE TO SEVENTH EDITION

The general format of the seventh edition of **BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY** differs but little from that of the sixth edition. However, examination will reveal many changes in the content as the result of a thoroughgoing revision. Among these the following seem to be worthy of special comment.

The most obvious change is that of the separation into two volumes of the material comparable to that which appeared in the sixth edition. The present volume is entitled the seventh edition of **BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY**. This **MANUAL** contains an outlined classification of the bacteria and the descriptions of the taxa from Class to Species and Subspecies, together with the appropriate keys. Nearly all species regarded as having been inadequately described or that could not be definitely placed have been excluded, together with many of the less important synonyms of the accepted species. These, together with the index to all the literature of both accepted and poorly described organisms have been transferred to a volume to be known as the **INDEX BERGEYANA**. The latter volume will include all descriptions and citations to species formerly found as appendices or indefinitely placed as *species incertae sedis*. The host and habitat index will also be found in the **INDEX BERGEYANA**. The net result is that the **MANUAL** itself contains descriptions of many more species with more adequate descriptions than have former editions; the transfer of much material to the **INDEX BERGEYANA** has meant a reduction in the number of pages and a book of more convenient size and greater usefulness. The **INDEX BERGEYANA** should prove to be an invaluable tool for the research microbiologist, containing, as it will, references to the whole field of systematic bacteriology and an index to the names of described species, both valid and invalid.

Much material of historical value and interest in the sixth and earlier editions of the **MANUAL** has been excluded, not because it is lacking in real value to the student, but because repetition of its publication is now unnecessary.

This edition of the **MANUAL** represents the coordinated results of the work of one hundred contributors, about thirty-five more than assisted in preparing the sixth edition. The contributors to the **MANUAL** are to be regarded in all nomenclatural matters as strictly the authors of their sections. All new names of taxa and the names of all new combinations are to be ascribed to these authors, and not to the editors of the **MANUAL**. Contributors from countries other than the United States are more numerous than in the earlier editions. In other words, the **MANUAL** is rapidly assuming the character of an international publication. To all of these contributors the sincere thanks of the Board of Editors, and particularly of the Editor-in-Chief, are due. The seventh edition is a tribute to the patience, care and scientific acumen of these individuals. Special note should be taken of the assistance rendered in the office of the Editor-in-Chief by Mr. Erwin Lessel, Miss Maude Hogan, Mrs. Eleanore Heist Clise and Mrs. Margaret Edson Breed.

The keys to the several categories of taxa (orders, families, tribes, genera and species) have been revised with a view to making them more reliable and useful. There is included also an artificial key to the species prepared by Professor V. B. D. Skerman, which key should prove helpful.

The Section on Nomenclature, including a synopsis of the Botanical Code of Nomenclature, has been eliminated. At the time of preparation of the sixth edition, the International Code of Bacteriological Nomenclature had not been finally approved, and emphasis was properly laid upon the rules used in Botany. This is no longer pertinent. The Bacteriological Code appeared in 1948 too late for use in making appropriate revisions in the 6th Edition of the MANUAL. The revised International Code of Nomenclature of the Bacteria and Viruses is about to be published. This contains annotations that should prove of value to the student, and should be regarded as a helpful aid in the understanding of the nomenclature used in the 7th Edition of the MANUAL.

The naming and classification of the viruses, as published in the sixth edition of the MANUAL, was regarded by some eminent virologists as perhaps inadvisable because it was premature. They felt strongly that the problems of morphology, physiology, pathogenesis and inter-relationships of the viruses were not as yet sufficiently resolved to make satisfactory taxonomy and classification practicable. After consultation with the International Subcommittee on Viruses it was decided that the Virus Section should not be included in the seventh edition. This deletion has been made with the full expectation that sufficient international agreement will be reached to make possible adequate treatment in the eighth edition. The Editorial Committee recognizes that a satisfactory system of nomenclature and taxonomy for the viruses is imperative.

The Editors wish to repeat and emphasize a statement made in the Preface of the first edition of the MANUAL:

"The assistance of all bacteriologists is earnestly solicited in the correction of possible errors in the text."

Among the tasks of the several editions of the MANUAL has been the codification of an increasingly satisfactory classification of the bacteria and the correction of the nomenclature of the past. The present volume undoubtedly has many errors that were not caught notwithstanding a most earnest effort. There are also many unresolved questions. Inasmuch as this volume appears at almost the same time as the Revised International Bacteriological Code, there are doubtless still some inconsistencies.

E. G. D. MURRAY
N. R. SMITH
R. S. BREED, *Chairman*
Editorial Committee

NOTE

The Board of Trustees of *BERGEY'S MANUAL* wish to record their profound sorrow at the death on February 10, 1956, of Dr. Robert S. Breed, Chairman of the Board of Trustees and Editor-in-Chief of the *MANUAL*. Most regrettable is the fact that he did not live to see in printed form the results of his untiring and devoted labor. At the time of his death, most of the manuscript for the seventh edition had been placed in the hands of the publisher; the remainder was in such shape that it could be promptly submitted. The Board of Trustees of the Bergey Trust, including the Board of Editors, wish to pay tribute to the devotion, energy and skill of Dr. Breed over a period of many years, as shown in the organization of better bacterial nomenclature and classification. The science of microbiology is his debtor.

Reconciliation of the nomenclature used in the seventh edition of the *MANUAL* with the provisions of the revised International Code of Nomenclature of the Bacteria and Viruses had not been entirely completed by Dr. Breed. As far as possible, these discrepancies have been corrected before publication.

The death of Dr. Breed leaves the Editorial Committee without a chairman and editor-in-chief. The Board of Trustees is unanimous in the belief that a successor to Dr. Breed should be found outside its present membership. Dr. Breed was also Chairman of the Board of Trustees. Following his death, reorganization of the Board was undertaken by Dr. Conn, as Treasurer, and Dr. Buchanan was designated as Chairman. The latter has agreed to serve until publication of the seventh edition of *BERGEY'S MANUAL* and of the first edition of the companion volume, planned by Dr. Breed and christened by him the *INDEX BERGEYANA*. It is recognized to be a matter of urgency and difficulty to replace Dr. Breed with an editor-in-chief for the eighth edition and to find a means of making this onerous responsibility something more than the labor of love it always was to him.

E. G. D. MURRAY

N. R. SMITH

H. J. CONN

R. E. BUCHANAN, *Chairman*
Board of Trustees

PREFACE OF FIRST EDITION

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 (1917, 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

Introduction.....	1
Considerations Influencing the Classification Used in This Edition of the Manual....	4
How Bacteria are Named and Identified.....	15
Division I. <i>Protophyta</i> Sachs, 1874, <i>emend.</i> Krassilnikov, 1949.....	29
Class I. <i>Schizophyceae</i> Cohn, 1879.....	30
Class II. <i>Schizomycetes</i> von Naegeli, 1857.....	33
Order I. <i>Pseudomonadales</i> Orla-Jensen, 1921.....	35
Suborder I. <i>Rhodobacteriineae</i> Breed, Murray and Hitchens, 1944.....	35
Family I. <i>Thiorhodaceae</i> Molisch, 1907.....	38
Genus I. <i>Thiosarcina</i> Winogradsky, 1888.....	39
Genus II. <i>Thiopedia</i> Winogradsky, 1888.....	40
Genus III. <i>Thiocapsa</i> Winogradsky, 1888.....	41
Genus IV. <i>Thiodictyon</i> Winogradsky, 1888.....	41
Genus V. <i>Thiothece</i> Winogradsky, 1888.....	42
Genus VI. <i>Thiocystis</i> Winogradsky, 1888.....	42
Genus VII. <i>Lamprocystis</i> Schroeter, 1886.....	43
Genus VIII. <i>Amoebobacter</i> Winogradsky, 1888.....	44
Genus IX. <i>Thiopolycoccus</i> Winogradsky, 1888.....	45
Genus X. <i>Thiospirillum</i> Winogradsky, 1888.....	46
Genus XI. <i>Rhodobacter</i> Cohn, 1875.....	48
Genus XII. <i>Rhodotherce</i> Molisch, 1907.....	50
Genus XIII. <i>Chromatium</i> Perty, 1852.....	50
Family II. <i>Athiorhodaceae</i> Molisch, 1907.....	53
Genus I. <i>Rhodopseudomonas</i> Kluyver and van Niel, 1937, <i>emend.</i> van Niel, 1944.....	53
Genus II. <i>Rhodospirillum</i> Molisch, 1907, <i>emend.</i> van Niel, 1944.....	58
Family III. <i>Chlorobacteriaceae</i> Lauterborn, 1913.....	61
Genus I. <i>Chlorobium</i> Nadson, 1912.....	62
Genus II. <i>Pelodictyon</i> Lauterborn, 1913.....	63
Genus III. <i>Clathrochloris</i> Geitler, 1925.....	64
Genus IV. <i>Chlorobacterium</i> Lauterborn, 1915.....	65
Genus V. <i>Chlorochromatium</i> Lauterborn, 1906.....	65
Genus VI. <i>Cylindrogloea</i> Perfiliev, 1914.....	66
Suborder II. <i>Pseudomonadineae</i> Breed, Murray and Smith, <i>sub-orde nov.</i>	67
Family I. <i>Nitrobacteraceae</i> Buchanan, 1917.....	68
Genus I. <i>Nitrosomonas</i> Winogradsky, 1890.....	68
Genus II. <i>Nitrosococcus</i> Winogradsky, 1892.....	69
Genus III. <i>Nitrospirilla</i> Winogradsky, 1931.....	70
Genus IV. <i>Nitrosocystis</i> Winogradsky, 1931.....	70
Genus V. <i>Nitrosogloea</i> H. Winogradsky, 1935.....	71
Genus VI. <i>Nitrobacter</i> Winogradsky, 1892.....	72
Genus VII. <i>Nitrocystis</i> H. Winogradsky, 1935.....	73
Family II. <i>Methanomonadaceae</i> Breed, <i>fam. nov.</i>	74
Genus I. <i>Methanomonas</i> Orla-Jensen, 1909.....	74
Genus II. <i>Hydrogenomonas</i> Orla-Jensen, 1909.....	75
Genus III. <i>Carboxydomonas</i> Orla-Jensen, 1909.....	77
Family III. <i>Thiobacteriaceae</i> Janke, 1924.....	78
Genus I. <i>Thiobacterium</i> Janke, 1924.....	79
Genus II. <i>Macromonas</i> Utermöhl and Koppe, 1923.....	80
Genus III. <i>Thiovulum</i> Hinze, 1913.....	81

Genus IV. <i>Thiospira</i> Vislouch, 1914.....	82
Genus V. <i>Thiobacillus</i> Beijerinck, 1904.....	83
Family IV. <i>Pseudomonadaceae</i> Winslow et al., 1917.....	88
Genus I. <i>Pseudomonas</i> Migula, 1894.....	89
Genus II. <i>Xanthomonas</i> Dowson, 1939.....	152
Genus III. <i>Acetobacter</i> Beijerinck, 1898.....	183
Genus IV. <i>Aeromonas</i> Kluyver and van Niel, 1936.....	189
Genus V. <i>Photobacterium</i> Beijerinck, 1889, <i>emend.</i> Breed and Lessel, 1954.....	193
Genus VI. <i>Azotomonas</i> Stapp, 1940.....	198
Genus VII. <i>Zymomonas</i> Kluyver and van Niel, 1936.....	199
Genus VIII. <i>Protaminobacter</i> den Dooren de Jong, 1926.....	200
Genus IX. <i>Alginomonas</i> Thjøtta and Kåss, 1945.....	202
Genus X. <i>Mycoplasma</i> Gray and Thornton, 1928.....	204
Genus XI. <i>Zoogloea</i> Cohn, 1854.....	206
Genus XII. <i>Halobacterium</i> Elazari-Volcani, 1940.....	207
Family V. <i>Caulobacteraceae</i> Henrici and Johnson, 1935, <i>emend.</i> Breed.....	212
Genus I. <i>Caulobacter</i> Henrici and Johnson, 1935.....	213
Genus II. <i>Gallionella</i> Ehrenberg, 1838.....	214
Genus III. <i>Siderophacus</i> Beger, 1944.....	216
Genus IV. <i>Nevskia</i> Famintzin, 1892.....	216
Family VI. <i>Siderocapsaceae</i> Pribram, 1929.....	217
Genus I. <i>Siderocapsa</i> Molisch, 1909.....	218
Genus II. <i>Siderosphaera</i> Beger, 1944.....	220
Genus III. <i>Sideronema</i> Beger, 1941.....	220
Genus IV. <i>Ferribacterium</i> Brusoff, 1916.....	221
Genus V. <i>Sideromonas</i> Cholodny, 1922.....	222
Genus VI. <i>Naumanniella</i> Dorff, 1934.....	223
Genus VII. <i>Ochrobium</i> Perfiliev, 1921.....	225
Genus VIII. <i>Siderococcus</i> Dorff, 1934.....	225
Genus IX. <i>Siderobacter</i> Naumann, 1922.....	226
Genus X. <i>Ferrobacillus</i> Leathen and Braley, 1954.....	227
Family VII. <i>Spirillaceae</i> Migula, 1894.....	228
Genus I. <i>Vibrio</i> Müller, 1773.....	229
Genus II. <i>Desulfovibrio</i> Kluyver and van Niel, 1936.....	248
Genus III. <i>Methanobacterium</i> Kluyver and van Niel, 1936.....	250
Genus IV. <i>Cellvibrio</i> Winogradsky, 1929.....	250
Genus V. <i>Cellfalcicula</i> Winogradsky, 1929.....	252
Genus VI. <i>Microcyclops</i> Ørskov, 1928.....	253
Genus VII. <i>Spirillum</i> Ehrenberg, 1832.....	253
Genus VIII. <i>Paraspirillum</i> Dobell, 1912.....	257
Genus IX. <i>Selenomonas</i> von Prowazek, 1913.....	258
Genus X. <i>Myxosporium</i> Cohn, 1875.....	260
Order II. <i>Chlamydobacteriales</i> Buchanan, 1917.....	262
Family I. <i>Chlamydobacteriaceae</i> Migula, 1894.....	262
Genus I. <i>Sphaerotilus</i> Kützinger, 1833.....	263
Genus II. <i>Leptothrix</i> Kützinger, 1843.....	264
Genus III. <i>Toxothrix</i> Molisch, 1925.....	269
Family II. <i>Peloplocaceae</i> Beger, <i>fam. nov.</i>	270
Genus I. <i>Peloploca</i> Lauterborn, 1913.....	270
Genus II. <i>Pelonema</i> Lauterborn, 1915.....	271
Family III. <i>Crenotrichaceae</i> Hansgirk, 1888.....	272
Genus I. <i>Crenothrix</i> Cohn, 1870.....	272

Genus II. <i>Phragmidiothrix</i> Engler, 1883.....	273
Genus III. <i>Clonothrix</i> Rose, 1896.....	274
Order III. <i>Hyphomicrobiales</i> Douglas, <i>ordo nov.</i>	276
Family I. <i>Hyphomicrobiaceae</i> Babudieri, 1950.....	276
Genus I. <i>Hyphomicrobium</i> Stutzer and Hartleb, 1898.....	277
Genus II. <i>Rhodomicrobium</i> Duchow and Douglas, 1949.....	277
Family II. <i>Pasteuriaceae</i> Laurent, 1890, <i>emend.</i> Henriei and Johnson, 1935..	278
Genus I. <i>Pasteuria</i> Metchnikoff, 1888.....	279
Genus II. <i>Blastocaulis</i> Henriei and Johnson, 1935.....	279
Order IV. <i>Eubacteriales</i> Buchanan, 1917.....	281
Family I. <i>Azotobacteraceae</i> Bergey, Breed and Murray, 1938.....	283
Genus I. <i>Azotobacter</i> Beijerinck, 1901.....	283
Family II. <i>Rhizobiaceae</i> Conn, 1938.....	285
Genus I. <i>Rhizobium</i> Frank, 1889.....	285
Genus II. <i>Agrobacterium</i> Conn, 1942.....	288
Genus III. <i>Chromobacterium</i> Bergonzini, 1881.....	292
Family III. <i>Achromobacteraceae</i> Breed, 1945.....	296
Genus I. <i>Alcaligenes</i> Castellani and Chalmers, 1919.....	297
Genus II. <i>Achromobacter</i> Bergey et al., 1923.....	300
Genus III. <i>Flavobacterium</i> Bergey et al., 1923.....	309
Genus IV. <i>Agarobacterium</i> Angst, 1929.....	322
Genus V. <i>Beneckeia</i> Campbell, <i>gen. nov.</i>	328
Family IV. <i>Enterobacteriaceae</i> Rahn, 1937.....	332
Tribe I. <i>Escherichieae</i> Bergey, Breed and Murray, 1938.....	334
Genus I. <i>Escherichia</i> Castellani and Chalmers, 1919.....	335
Genus II. <i>Aerobacter</i> Beijerinck, 1900.....	341
Genus III. <i>Klebsiella</i> Trevisan, 1885.....	344
Genus IV. <i>Paracoloclostridium</i> Borman, Stuart and Wheeler, 1944.....	346
Genus V. <i>Alginobacter</i> Thjøtta and Kåss, 1944.....	348
Tribe II. <i>Erwinieae</i> Winslow et al., 1920.....	349
Genus VI. <i>Erwinia</i> Winslow et al., 1917.....	349
Tribe III. <i>Serratiaeae</i> Bergey, Breed and Murray, 1938.....	359
Genus VII. <i>Serratia</i> Bizio, 1823, <i>emend.</i> Breed and Breed, 1927.....	359
Tribe IV. <i>Proteeae</i> Castellani and Chalmers, 1919.....	364
Genus VIII. <i>Proteus</i> Hauser, 1885.....	364
Tribe V. <i>Salmonelleae</i> Bergey, Breed and Murray, 1938.....	368
Genus IX. <i>Salmonella</i> Lignières, 1900.....	368
Genus X. <i>Shigella</i> Castellani and Chalmers, 1919.....	384
Family V. <i>Brucellaceae</i> , <i>nom. nov.</i>	394
Genus I. <i>Pasteurella</i> Trevisan, 1887.....	395
Genus II. <i>Bordetella</i> Moreno-López, 1952.....	402
Genus III. <i>Brucella</i> Meyer and Shaw, 1920.....	404
Genus IV. <i>Haemophilus</i> Winslow et al., 1917.....	406
Genus V. <i>Actinobacillus</i> Brumpt, 1910.....	414
Genus VI. <i>Calymmatobacterium</i> Aragão and Vianna, 1913.....	418
Genus VII. <i>Moraxella</i> Lwoff, 1939.....	419
Genus VIII. <i>Noguchia</i> Olitsky, Syverton and Tyler, 1934.....	421
Family VI. <i>Bacteroidaceae</i> Breed, Murray and Smith, <i>fam. nov.</i>	423
Genus I. <i>Bacteroides</i> Castellani and Chalmers, 1919.....	424
Genus II. <i>Fusobacterium</i> Knorr, 1922.....	436
Genus III. <i>Dialister</i> Bergey et al., 1923.....	440
Genus IV. <i>Sphaerophorus</i> Prévot, 1938.....	441
Genus V. <i>Streptobacillus</i> Levaditi, Nicolau and Poincloux, 1925.....	451

Family VII. <i>Micrococcaceae</i> Pribram, 1929.....	454
Genus I. <i>Micrococcus</i> Cohn, 1872.....	455
Genus II. <i>Staphylococcus</i> Rosenbach, 1894.....	464
Genus III. <i>Gaffkyia</i> Trevisan, 1885.....	466
Genus IV. <i>Sarcina</i> Goodsir, 1842.....	467
Subgenus I. <i>Zymosarcina</i> Smit, 1930.....	468
Subgenus II. <i>Methanosarcina</i> Kluyver and van Niel, 1936.....	468
Subgenus III. <i>Sarcinococcus</i> Breed, 1948.....	468
Subgenus IV. <i>Urosarcina</i> Miquel, 1888.....	468
Genus V. <i>Methanococcus</i> Kluyver and van Niel, 1936, <i>emend.</i> Barker, 1936.....	473
Genus VI. <i>Peptococcus</i> Kluyver and van Niel, 1936.....	474
Family VIII. <i>Neisseriaceae</i> Prévot, 1933.....	486
Genus I. <i>Neisseria</i> Trevisan, 1885.....	480
Genus II. <i>Veillonella</i> Prévot, 1933.....	485
Family IX. <i>Brevibacteriaceae</i> Breed, 1953.....	490
Genus I. <i>Brevibacterium</i> Breed, 1953.....	490
Genus II. <i>Kurthia</i> Trevisan, 1885.....	503
Family X. <i>Lactobacillaceae</i> Winslow et al., 1917.....	505
Tribe I. <i>Streptococceae</i> Trevisan, 1889.....	506
Genus I. <i>Diplococcus</i> Weichselbaum, 1886.....	507
Genus II. <i>Streptococcus</i> Rosenbach, 1884.....	508
Genus III. <i>Pediococcus</i> Balcke, 1884, <i>emend.</i> Mees, 1934.....	529
Genus IV. <i>Leuconostoc</i> van Tieghem, 1878, <i>emend.</i> Hucker and Pederson, 1930.....	531
Genus V. <i>Peptostreptococcus</i> Kluyver and van Niel, 1936.....	533
Tribe II. <i>Lactobacillae</i> Winslow et al., 1920.....	541
Genus I. <i>Lactobacillus</i> Beijerinck, 1901.....	542
Subgenus I. <i>Lactobacillus</i> Beijerinck, 1901.....	543
Subgenus II. <i>Saccharobacillus</i> van Laer, 1892.....	543
Genus II. <i>Eubacterium</i> Prévot, 1938.....	552
Genus III. <i>Catenabacterium</i> Prévot, 1938.....	560
Genus IV. <i>Ramibacterium</i> Prévot, 1938.....	563
Genus V. <i>Cillobacterium</i> Prévot, 1938.....	566
Family XI. <i>Propionibacteriaceae</i> Delwiche, <i>fam. nov.</i>	569
Genus I. <i>Propionibacterium</i> Orla-Jensen, 1909.....	569
Genus II. <i>Butyribacterium</i> Barker and Haas, 1944.....	577
Genus III. <i>Zymobacterium</i> Wachsmann and Barker, 1954.....	577
Family XII. <i>Corynebacteriaceae</i> Lehmann and Neumann, 1907.....	578
Genus I. <i>Corynebacterium</i> Lehmann and Neumann, 1896.....	579
Genus II. <i>Listeria</i> Pirie, 1940.....	597
Genus III. <i>Erysipelothrix</i> Rosenbach, 1909.....	599
Genus IV. <i>Microbacterium</i> Orla-Jensen, 1919.....	600
Genus V. <i>Cellulomonas</i> Bergey et al., 1923, <i>emend.</i> Clark, 1952.....	601
Genus VI. <i>Arthrobacter</i> Fischer, 1895, <i>emend.</i> Conn and Dimmick, 1947.....	605
Family XIII. <i>Bacillaceae</i> Fischer, 1895.....	613
Genus I. <i>Bacillus</i> Cohn, 1872.....	613
Genus II. <i>Clostridium</i> Prazmowski, 1880.....	634
*Order V. <i>Actinomycetales</i> Buchanan, 1917.....	694

* Erratum: Due to a clerical error the orders *Caryophanales* and *Actinomycetes* of the class *Schizomycetales* appear in the wrong sequence in numerous places throughout the MANUAL: correctly, *Caryophanales* is Order V and should appear before Order VI, *Actinomycetales* (see pages 12, 33, and 34 for reasons why *Caryophanales* precedes *Actinomycetales* in the classification scheme).

Family I. <i>Mycobacteriaceae</i> Chester, 1901.....	695
Genus I. <i>Mycobacterium</i> Lehmann and Neumann, 1896.....	695
Genus II. <i>Mycococcus</i> Krassilnikov, 1938.....	707
Family II. <i>Actinomycetaceae</i> Buchanan, 1918.....	713
Genus I. <i>Nocardia</i> Trevisan, 1889.....	713
Genus II. <i>Actinomyces</i> Harz, 1877.....	742
Family III. <i>Streptomycetaceae</i> Waksman and Henrici, 1943.....	744
Genus I. <i>Streptomyces</i> Waksman and Henrici, 1943.....	744
Genus II. <i>Micromonospora</i> Ørskov, 1923.....	822
Genus III. <i>Thermoactinomyces</i> Tsiklinsky, 1899.....	824
Family IV. <i>Actinoplanaceae</i> Couch, 1955.....	825
Genus I. <i>Actinoplanes</i> Couch, 1950.....	826
Genus II. <i>Streptosporangium</i> Couch, 1955.....	828
Order VI. <i>Caryophanales</i> Peshkoff, 1940.....	830
Family I. <i>Caryophanaceae</i> Peshkoff, 1940.....	830
Genus I. <i>Caryophanon</i> Peshkoff, 1940.....	831
Genus II. <i>Lineola</i> Pringsheim, 1950.....	832
Genus III. <i>Simonsiella</i> Schmid, 1922.....	833
Family II. <i>Oscillospiraceae</i> Peshkoff, 1940.....	834
Genus I. <i>Oscillospira</i> Chatton and Pérard, 1913.....	834
Family III. <i>Arthromitaceae</i> Peshkoff, 1940.....	835
Genus I. <i>Arthromitus</i> Leidy, 1849.....	835
Genus II. <i>Coleomitus</i> Duboseq and Grassé, 1930.....	836
Order VII. <i>Beggiatoales</i> Buchanan, <i>ordo nov.</i>	837
Family I. <i>Beggiatoaceae</i> Migula, 1894.....	837
Genus I. <i>Beggiatoa</i> Trevisan, 1842.....	838
Genus II. <i>Thiospirillopsis</i> Uphof, 1927.....	840
Genus III. <i>Thioploca</i> Lauterborn, 1907.....	841
Genus IV. <i>Thiothrix</i> Winogradsky, 1888.....	842
Family II. <i>Vitreoscillaceae</i> Pringsheim, 1949.....	844
Genus I. <i>Vitreoscilla</i> Pringsheim, 1951.....	845
Genus II. <i>Bactoscilla</i> Pringsheim, 1951.....	848
Genus III. <i>Microscilla</i> Pringsheim, 1951.....	849
Family III. <i>Leucotrichaceae</i> Buchanan, <i>fam. nov.</i>	850
Genus I. <i>Leucothrix</i> Oersted, 1844, <i>emend.</i> Harold and Stanier, 1955.....	850
Family IV. <i>Achromatiaceae</i> Massart, 1902.....	851
Genus I. <i>Achromatium</i> Schewiakoff, 1893.....	852
Order VIII. <i>Myzobacterales</i> Jahn, 1915.....	854
Family I. <i>Cytophagaceae</i> Stanier, 1940.....	858
Genus I. <i>Cytophaga</i> Winogradsky, 1929.....	858
Family II. <i>Archangiaceae</i> Jahn, 1924.....	863
Genus I. <i>Archangium</i> Jahn, 1924.....	863
Genus II. <i>Stelangium</i> Jahn, 1915.....	866
Family III. <i>Sorangiaceae</i> Jahn, 1924.....	866
Genus I. <i>Sorangium</i> Jahn, 1924.....	866
Family IV. <i>Polyangiaceae</i> Jahn, 1924.....	870
Genus I. <i>Polyangium</i> Link, 1809.....	870
Genus II. <i>Synangium</i> Jahn, 1924.....	877
Genus III. <i>Podangium</i> Jahn, 1924.....	877
Genus IV. <i>Chondromyces</i> Berkeley and Curtis, 1874.....	879
Family V. <i>Myzococcaceae</i> Jahn, 1924.....	882
Genus I. <i>Myzococcus</i> Thaxter, 1892.....	883
Genus II. <i>Chondrococcus</i> Jahn, 1924.....	886

Genus III. <i>Angiococcus</i> Jahn, 1924.....	889
Genus IV. <i>Sporocytophaga</i> Stanier, 1940.....	890
Order IX. <i>Spirochaetales</i> Buchanan, 1918.....	892
Family I. <i>Spirochaetaceae</i> Swellengrebel, 1907.....	892
Genus I. <i>Spirochaeta</i> Ehrenberg, 1833.....	893
Genus II. <i>Saprospira</i> Gross, 1911.....	894
Genus III. <i>Cristispira</i> Gross, 1910.....	895
Family II. <i>Treponemataceae</i> Robinson, 1948.....	896
Genus I. <i>Borrelia</i> Swellengrebel, 1907.....	897
Genus II. <i>Treponema</i> Schaudinn, 1905.....	904
Genus III. <i>Leptospira</i> Noguchi, 1917.....	907
Order X. <i>Mycoplasmatales</i> Freundt, 1955.....	914
Family I. <i>Mycoplasmataceae</i> Freundt, 1955.....	914
Genus I. <i>Mycoplasma</i> Nowak, 1929.....	914
Addendum to Class II, <i>Schizomycetes</i> von Naegeli. Bacteria symbiotic or parasitic in protozoa.....	926
Class III. <i>Microtubotiotes</i> Philip, 1956.....	931 and 933
Order I. <i>Rickettsiales</i> Buchanan and Buchanan, 1938, <i>emend.</i> Gieszczykiewicz, 1939.....	934
Family I. <i>Rickettsiaceae</i> Pinkerton, 1936.....	934
Tribe I. <i>Rickettsieae</i> Philip, <i>trib. nov.</i>	935
Genus I. <i>Rickettsia</i> da Rocha-Lima, 1916.....	935
Subgenus A. <i>Rickettsia</i> Philip, 1943.....	937
Subgenus B. <i>Zinssera</i> Macchiavello, 1947.....	939
Subgenus C. <i>Dermacentrozenus</i> (Wolbach, 1919) Philip, 1943.....	941
Subgenus D. <i>Rochalimaea</i> Macchiavello, 1947.....	945
Genus II. <i>Coxiella</i> Philip, 1948.....	947
Tribe II. <i>Ehrlichieae</i> Philip, <i>trib. nov.</i>	948
Genus III. <i>Ehrlichia</i> Moshkovskiy, 1945.....	949
Genus IV. <i>Cowdria</i> Moshkovskiy, 1945.....	950
Genus V. <i>Neorickettsia</i> Philip et al., 1953.....	951
Tribe III. <i>Wolbachieae</i> Philip, 1956.....	952
Genus VI. <i>Wolbachia</i> Hertig, 1936.....	953
Genus VII. <i>Symbiotes</i> Philip, 1956.....	956
Genus VIII. <i>Rickettsiella</i> Philip, 1956.....	957
Family II. <i>Chlamydiaceae</i> Rake, <i>fam. nov.</i>	957
Genus I. <i>Chlamydia</i> Rake, 1956.....	958
Genus II. <i>Colesiota</i> Rake, 1948.....	959
Genus III. <i>Ricolesia</i> Rake, <i>gen. nov.</i>	959
Genus IV. <i>Colettsia</i> Rake, <i>nom. nov.</i>	961
Genus V. <i>Miyagawanella</i> Brumpt, 1938.....	961
Family III. <i>Bartonellaceae</i> Gieszczykiewicz, 1939.....	968
Genus I. <i>Bartonella</i> Strong, Tyzzer and Sellards, 1915.....	969
Genus II. <i>Grahamella</i> Brumpt, 1911.....	971
Genus III. <i>Haemobartonella</i> Tyzzer and Weinman, 1939.....	972
Genus IV. <i>Eperythrozoon</i> Schilling, 1928.....	977
Family IV. <i>Anaplasmataceae</i> Yakimov, 1931.....	980
Genus I. <i>Anaplasma</i> Theiler, 1910.....	981
Order II. <i>Virales</i> Breed, Murray and Hitchens, 1944.....	985
Artificial Key.....	987
Index of Genera and Species.....	1093

LIST OF CONTRIBUTORS

Allen, O. N., Mr. & Mrs.	<i>Rhizobium</i>	285
Andrewes, C. H.	<i>Virales</i>	985
Barker, H. Albert	<i>Methanococcus</i>	473
	<i>Butyribacterium</i>	577
	<i>Zymobacterium</i>	577
Beger, H.	<i>Caulobacteraceae</i>	212
	<i>Siderocapsaceae</i>	217
	<i>Chlamydobacteriales</i>	262
Bier, Otto	<i>Calymmatobacterium</i>	418
Borman, E. K.	<i>Paracolobactrum</i>	346
Branham, Sara E.	<i>Neisseria</i>	480
Breed, R. S.†	Introduction.....	1
	Considerations influencing the classification.....	4
	<i>Methanomonadaceae</i>	74
	<i>Thiobacteriaceae</i>	78
	<i>Photobacterium</i>	193
	<i>Protaminobacter</i>	200
	<i>Mycoplasma</i>	204
	<i>Caulobacteraceae</i>	212
	<i>Siderocapsaceae</i>	217
	<i>Vibrio</i>	229
	<i>Methanobacterium</i>	250
	<i>Cellvibrio</i>	250
	<i>Cellfalcicula</i>	252
	<i>Spirillum</i>	253
	<i>Chlamydobacteriales</i>	262
	<i>Chromobacterium</i>	292
	<i>Alcaligenes</i>	297
	<i>Achromobacter</i>	300
	<i>Flavobacterium</i>	309
	<i>Agarobacterium</i>	322
	<i>Enterobacteriaceae</i>	332
	<i>Escherichia</i>	335
	<i>Aerobacter</i>	341
	<i>Klebsiella</i>	344
	<i>Serratia</i>	359
	<i>Pasteurella</i>	395
	<i>Bacteroidaceae</i>	423
	<i>Sphaerophorus</i>	441
	<i>Micrococcaceae</i>	454
	<i>Micrococcus</i>	455
	<i>Sarcina</i>	467
	<i>Brevibacteriaceae</i>	490
	<i>Corynebacteriaceae</i>	578
	<i>Caryophanales</i>	830
	<i>Virales</i>	985
	Numerous contributions to various other taxa.....	
Broom, J. C.	<i>Leptospira</i>	907

† Deceased.

Buchanan, R. E.	How Bacteria are Named and Identified.....	15
	<i>Paraspirillum</i>	257
	<i>Beggiatoales</i>	837
	<i>Beggiatoaceae</i>	837
	<i>Leucotrichaceae</i>	850
Burkholder, Walter H.	<i>Pseudomonas</i>	89
	<i>Xanthomonas</i>	152
	<i>Agrobacterium</i>	288
	<i>Erwinia</i>	349
	<i>Corynebacterium</i>	579
Campbell, L. Leon, Jr.	<i>Beneckeia</i>	328
Clark, F. A.	<i>Cellulomonas</i>	601
Clise, Eleanor H.	<i>Pasteurella</i>	395
	<i>Eubacterium</i>	552
	<i>Catenabacterium</i>	500
	<i>Ramibacterium</i>	563
	<i>Cillobacterium</i>	566
Conn, H. J.	<i>Agrobacterium</i>	288
	<i>Alcaligenes</i>	297
Couch, John N.	<i>Actinomycetales</i>	694
	<i>Actinoplanaceae</i>	825
Davis, Gordon E.	<i>Spirochaetales</i>	892
Delwiche, Eugene A.	<i>Propionibacteriaceae</i>	569
Doetsch, R. N.	<i>Microbacterium</i>	600
Douglas, H. C.	<i>Hyphomicrobiales</i>	276
	<i>Peptococcus</i>	474
Dumas, Julien	<i>Shigella</i>	384
Elazari-Volcani, Benjamin	<i>Halobacterium</i>	207
Eltzinger, Ethel	<i>Chromobacterium</i>	292
Evans, James B.	<i>Staphylococcus</i>	464
Freundt, E. A.	<i>Streptobacillus</i>	451
	<i>Mycoplasmatales</i>	614
Gordon, Ruth	<i>Bacillus</i>	613
	<i>Mycobacterium</i>	695
Hanks, John H.	<i>Mycobacterium</i>	695
Hansen, Paul Arne	<i>Erysipelothrix</i>	599
Haupt, Herbert	<i>Actinobacillus</i>	414
Haynes, William C.	<i>Pseudomonas</i>	89
Hitchens, A. Parker†	<i>Dialister</i>	440
Hofer, A. W.	<i>Azotomonas</i>	198
	<i>Azotobacteraceae</i>	283
Hoffman, Heiner	<i>Fusobacterium</i>	436
	<i>Sphaerophorus</i>	441
Holmes, Francis O.	<i>Vireles</i>	985
Honigberg, B. M.	Parasites of protozoa.....	927
Hucker, George J.	<i>Micrococcus</i>	455
	<i>Gaffkya</i>	466
	<i>Leuconostoc</i>	531
Huddleson, I. F.	<i>Brucella</i>	404
Janke, Alexander	<i>Thiobacteriaceae</i>	78
	<i>Thiobacterium</i>	79

† Deceased.

	<i>Macromonas</i>	80
	<i>Thiovulum</i>	81
	<i>Thiospira</i>	82
Kalz, Gertrude G.	<i>Salmonella</i>	368
Kelly, C. D.	<i>Noguchia</i>	421
	<i>Bacteroides</i>	424
Kirby, Harold, Jr.	Parasites of protozoa	927
Klayver, A. J.†	<i>Zymomonas</i>	199
Langford, G. C.	<i>Erysipelothrix</i>	599
Leathen, Wm. W.	<i>Ferrobacillus</i>	227
Lessel, Erwin F., Jr.	<i>Photobacterium</i>	193
	<i>Selenomonas</i>	258
	<i>Myconostoc</i>	260
	<i>Pasteurella</i>	395
	<i>Eubacterium</i>	552
	<i>Catenabacterium</i>	560
	<i>Ramibacterium</i>	563
	<i>Vitreoscillaceae</i>	844
Lochhead, A. G.	<i>Arthrobacter</i>	605
McClung, L. S.	<i>Clostridium</i>	634
McCoy, Elizabeth	<i>Clostridium</i>	634
Merchant, I. A.	<i>Pasteurella</i>	395
Morse, E. V.	<i>Vibrio</i>	229
	<i>Corynebacterium</i>	579
Murray, E. G. D.	<i>Enterobacteriaceae</i>	332
	<i>Morazella</i>	419
	<i>Bacteroidaceae</i>	423
	<i>Neisseria</i>	480
	<i>Lactobacillaceae</i>	505
	<i>Diplococcus</i>	507
	<i>Corynebacterium</i>	579
	<i>Listeria</i>	597
Neitz, W. O.	<i>Anaplasma</i>	981
Nellis, Lois	<i>Mycococcus</i>	707
Niven, C. F.	<i>Lactobacillaceae</i>	505
	<i>Streptococcus</i>	508
Ørskov, J.	<i>Microcylus</i>	253
Parker, C. D.	<i>Thiobacillus</i>	83
Pederson, Carl S.	<i>Lactobacillaceae</i>	505
	<i>Pediococcus</i>	529
	<i>Leuconostoc</i>	531
	<i>Lactobacillus</i>	542
Pelczar, M. J.	<i>Neisseria</i>	480
	<i>Veillonella</i>	485
Peshkoff, M. A.	<i>Caryophanales</i>	830
Philip, Cornelius B.	<i>Microtatiobites</i>	931 and 933
	<i>Rickettsiales</i>	934
	<i>Anaplasmataceae</i>	980
Pittman, Margaret	<i>Bordetella</i>	402
	<i>Haemophilus</i>	406
Pringsheim, E. G.	<i>Vitreoscillaceae</i>	844

† Deceased.

Rake, Geoffrey W.	<i>Chlamydiaceae</i>	957
Reed, Guilford B.†	<i>Mycobacterium</i>	695
Robinson, Elliott S.	<i>Diplococcus</i>	507
Robinson, George H.†	<i>Spirochaetales</i>	892
Schatz, Albert	<i>Hydrogenomonas facilis</i>	76
Seeley, H. W.	<i>Streptococcus</i>	508
Seeliger, H.	<i>Corynebacterium</i>	579
Sherman, James W.†	<i>Lactobacillaceae</i>	505
	<i>Streptococcus</i>	508
Skerman, V. B. D.	Artificial Keys.....	987
Smit, Jan	<i>Sarcina</i>	467
Smith, Louis DeSpain	<i>Lactobacillaceae</i>	505
	<i>Pepiostreptococcus</i>	533
Smith, N. R.	<i>Bacteroidaceae</i>	423
	<i>Bacillus</i>	613
Snieszko, S. F.	<i>Aeromonas</i>	189
Spray, R. S.	<i>Clostridium</i>	634
Stanier, R. Y.	<i>Myxobacterales</i>	854
Starkey, R. L.	<i>Nitrobacteraceae</i>	68
Steinhaus, E. A.	<i>Virales</i>	985
Stuart, C. A.	<i>Proteus</i>	364
Temple, Kenneth L.	<i>Thiobacillus</i>	83
Thjøtta, Th.†	<i>Alginomonas</i>	202
	<i>Alginobacter</i>	348
Tobie, W. C.	<i>Chromobacterium</i>	292
van Niel, C. B.	<i>Rhodobacteriineae</i>	35
	<i>Propionibacterium</i>	569
	<i>Achromatiaceae</i>	851
Vaughn, Reese	<i>Acetobacter</i>	183
Verona, Onorato	<i>Cellvibrio</i>	250
Waksman, S. A.	<i>Actinomycetales</i>	694
	<i>Mycococcus</i>	707
	<i>Actinomycetaceae</i>	713
	<i>Streptomycetaceae</i>	744
Wattie, Elsie (Mrs. Lackey)	<i>Zoogloea</i>	206
	<i>Spirochaetales</i>	892
Weeks, Owen B.	<i>Flavobacterium</i>	309
Weinman, David	<i>Bartonellaceae</i>	968
Wolff, J. W.	<i>Leptospira</i>	907
Yale, N. W.	<i>Escherichia</i>	335
	<i>Aerobacter</i>	341
ZoBell, Claude E.	<i>Desulfovibrio</i>	248

† Deceased.

INTRODUCTION

Suggestions for the Use of the Manual In Classifying Unknown Organisms

No organism can be classified before its morphological, cultural, physiological and pathogenic characters have been determined through a detailed study.

The characters used in the keys to orders, families and genera may ordinarily be determined by the use of a dozen or more of the procedures described in the Manual of Microbiological Methods issued by the Committee on Bacteriological Technic of the Society of American Bacteriologists. More complete examinations are required in special cases to identify and to describe individual species necessitating resort to the original literature. When those prevailing are inadequate, new criteria are desirable. This desideratum extends to some higher taxa to achieve more exact and distinctive definitions.

It is urged that beginning students be taught all of the techniques necessary for the identification of species in the hope that the taxonomic work of the future may be placed on a satisfactory basis.

After a complete study of the characters of the organism has been made, either of two courses may be followed. (1) Use the Keys in the body of the text as explained below. These follow what are believed to be the natural relationships that exist between various groups of bacteria. (2) The beginning student may, however, find the artificial key at the back of the MANUAL to be more helpful than the natural keys in determining the identity of an unknown culture.

In all cases it should be kept in mind that many descriptions of species of bacteria are not mentioned in this MANUAL. Failure to find agreement between an unknown culture and any of the descriptions given in this MANUAL does not prove that the unknown culture represents a species that has never been studied and described.

If the student wishes to follow through the natural keys he should turn to page 33 and ascertain first in which order the organism belongs. When the order has been ascertained, turn to the page of the MANUAL on which the key to that order is given. In this key ascertain the family or sub-family to which the organism belongs.

When the family has been determined, again refer to the page of the MANUAL on which the key to that family is given. In this key ascertain the tribe to which the organism belongs.

When the tribe has been determined, again find the page of the MANUAL on which the key to the tribe is given. In this key ascertain the genus to which the organism belongs.

When the genus has been determined, again refer to the page of the MANUAL on which the key to that genus is given. In this key trace out the species under investigation.