THE OUTLINE CLASSIFICATION USED IN THE BERGEY MANUAL OF DETERMINATIVE BACTERIOLOGY

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The following outline classification has been developed from previous classifications by the Editorial Board of the Manual for use in the sixth edition of the Bergey Manual of Determinative Bacteriology. The authors gratefully acknowledge their indebtedness to those who have previously studied this subject, especially those whose outlines are given below. Many suggestions have also been received from the bacteriologists who are currently collaborating in the preparation of the new edition of the Bergey Manual. It is hoped that the new (6th) edition will be ready in 1945.

Historical Setting. In order to permit comparisons to be made readily, some of the outline classifications of the fission fungi developed since 1900 are given here in abbreviated form.

1. The outline used by Chester (1) is based on Migula's outline as given by Engler and Prantl (2).

Class *Schizomycetes.*

Family A. *Coccaceae*, spherical bacteria.
B. *Bacteriaceae*, rod-shaped bacteria.
C. *Chlamydobacteriaceae*, sheathed filaments.
D. *Beggiatoaceae*, filamentous sulfur bacteria.
E. *Mycobacteriaceae*, acid-fast rods, true and false branching filaments.

2. Orla-Jensen (3) developed an outline in which he included the purple and sulfur bacteria, and the actinomycetes.

Class *Schizomycetes.*

Order I. *Cephalotrichinae*, polar flagellate bacteria.
II. *Peritrichinae*, peritrichous bacteria.

3. Buchanan (4) formulated an even more comprehensive outline as it includes the slime bacteria and the spirochaetes.

Class *Schizomycetes.*

Order I. *Eubacteriales*, true bacteria.
II. *Actinomycetales*, diphtheria and tubercle bacillus, actinomyces.
III. *Chlamydobacteriales*, filamentous, alga-like bacteria.
IV. *Thiobacteriales*, sulfur bacteria.
V. *Myxobacteriales*, slime bacteria.
VI. *Spirochaetales*, spirochaetes.

4. In the preliminary report by Winslow *et al.* (5), emphasis is placed on the true bacteria, the remaining orders that are mentioned being listed by name and by brief description only.

Class *Schizomycetes.*

Order A. *Myxobacteriales*, slime bacteria.
B. *Thiobacteriales*, sulfur bacteria.
C. *Chlamydobacteriales*, filamentous bacteria.
D. *Eubacteriales*, true bacteria.

Supplement: Organisms intermediate between bacteria and protozoa,—*Spirochaetaceae.*

5. The final report by Winslow *et al.* (6), is more comprehensive as it includes the *Actinomycetales.*

Class *Schizomycetes.*

Order A. *Myxobacteriales*, slime bacteria.
B. *Thiobacteriales*, sulfur bacteria.
C. *Chlamydobacteriales*, alga-like bacteria.
D. *Actinomycetales*, as above.
E. *Eubacteriales*, true bacteria.

6. The outline classification as used by Bergey *et al.* (7) in the first four editions of the Manual is identical with that of Buchanan (4).

7. Lehmann and Neumann (8) do not include the purple, sulfur, slime or alga-like bacteria in their outline.

Class *Schizomycetes.*

Order I. *Schizomycetales*, true bacteria.
II. *Actinomycetales*, as above.

8. Kluyver and van Niel (9) include the true bacteria, and all purple and sulfur bacteria but do not list the actinomyces and slime bacteria.

Family A. *Pseudomonadaceae*, polar flagellate bacteria.
B. *Micrococcaceae*, spherical bacteria.
C. *Mycobacteriaceae*, diphtheria and tubercle bacillus.
D. *Bacteriaceae*, true bacteria.

9. Rahn (10) discusses only the groups found among the true bacteria in his outline.

Order I. *Eubacteriales.*

Sub-order A. *Endosporales*, spore-forming rods.
B. *Asporales*, non-spore-forming rods.

10. Bergey, Breed, Murray and Hitchens (11) in the 5th edition of the manual recognize a seventh order *Caulobacteriales* as organized by Henrici and Johnson (12).

Class *Schizomycetes.*

Order I. *Eubacteriales*, true bacteria.
II. *Actinomycetales*, as above.
III. *Chlamydobacteriales*, filamentous bacteria.
IV. *Caulobacteriales*, stalked bacteria.
V. *Thiobacteriales*, sulfur bacteria.

VI. *Myxobacteriales*, slime bacteria.
VII. *Spirochaetales*, spirochaetes.

11. Prévot (13) is primarily interested in anaerobic bacteria. He accepts the outline used in the 5th edition of the Bergey Manual but regards *Schizomycetes* as a kingdom, and the seven orders as classes.

12. Stanier and van Niel (14) have drawn up a comprehensive outline in which they regard the fission algae and fission fungi as comprising a separate kingdom.

Kingdom *Monera*.
Division I. *Myxophyta*, fission algae.
II. *Schizomycetaea*, fission fungi.
Class I. *Eubacteriae*.
Order I. *Rhodobacteriales*, purple bacteria.
II. *Eubacteriales*, true bacteria.
III. *Actinomycetales*, actinomyces.
Class II. *Myxobacteriae*.
Order I. *Myxobacteriales*, slime bacteria.
Class III. *Sphirochaetae*.
Order I. *Sphirochaetales*, spirochaetes.
Appendix: Group I. Filamentous unsheathed organisms.
Family I. *Leptotrichaceae*.
II. *Crenothricaceae*.
Group II. Unicellular organisms multiplying by transverse fission.
Family I. *Achromatiaceae*.
Group III. Unicellular organisms multiplying by longitudinal fission, or budding, or both.
Family I. *Pasteuriaceae*.

OUTLINE USED IN THE 6TH EDITION OF THE BERGEY MANUAL

The revised outline that is to be used in the 6th edition of the Bergey Manual (15) now in press is as follows:

Phylum *Schizophyta* (Fission plants).
Class I. *Schizophyceae* (Fission algae. Blue-green algae).
II. *Schizomycetes* (Fission fungi).
Order I. *Eubacteriales* (True bacteria. Rigid cells that are flagellate when they are motile.)
Sub-order I. *Eubacteriineae* (Unattached and do not possess photosynthetic pigments. Includes Family, *Corynebacteriaceae*).
II. *Caulobacteriineae* (Sessile and stalked, attached bacteria.)
III. *Rhodobacteriineae* (Sulfur purple and non-sulfur purple bacteria.)
Order II. *Actinomycetales* (Branching, non-motile, mycelial threads.)
III. *Chlamydobacteriales* (Filamentous, alga-like bacteria. App. *Beggiatoaceae*.)
IV. *Myxobacteriales* (Slime bacteria, creeping motility).

V. *Spirochaetales* (Flexuous, spiral cells).

Supplement: Groups whose relationships are obscure.

Group I. Family *Rickettsiaceae* (Intracellular parasites carried by arthropods).

II. Order *Virales* (Filter passers that grow in living protoplasm).

III. Family *Borrelomycetaceae* (Highly pleomorphic parasitic organisms).

In this outline, the arrangement of *Schizomycetes* as a class coordinate with *Schizophyceae*, both belonging to phylum *Schizophyta* of the Plant Kingdom, is maintained as in previous editions of the Manual. The number of orders is reduced from seven as given in the fifth edition to five, through recognition of the fact that the rigid, unicellular, rarely branching but never truly mycelial nor truly filamentous organisms belonging to three of the previously recognized orders are presumably more closely related to each other than they are to the organisms in the four remaining orders. Motility when present in the organisms placed in *Eubacteriales* is by means of flagella.

Breed, Murray and Hitchens (15) indicated that a change in the outline used in the 5th edition of the Manual that would reduce the number of orders was under study, and this is accomplished by the changes just mentioned. While this paper was being written, there has been an opportunity to study the report by van Niel (17) which is based on a first hand study of cultures of non-sulfur purple bacteria. He has suggested the existence of an even closer relationship between the non-sulfur purple bacteria and the non-photosynthetic, polar flagellate bacteria (*Pseudomonadaceae*) than is expressed in the outline that is proposed for the new edition of the Manual. Because of his new studies, van Niel would unite the *Pseudomonadaceae* and the purple bacteria into a new order, *Pseudomonadales*, a suggestion that deserves consideration.

As for the nine species of *Caulobacteriineae* (stalked bacteria) recognized by Henrici and Johnson (12), the chief difference between them and ordinary capsulated fresh water bacteria is that "the cells are asymmetrical in that gum, ferric hydroxide or other material is secreted from one side or one end of the cell to form a stalk". The differences between these bacteria attached by a stalk and those capsulated bacteria that live in similar habitats attached by ferric oxide secretions to lily pads and similar vegetation (*Siderocapsa* Molisch and *Sideromonas* Cholodny) are so slight that the latter genera are to be included as sessile forms in the sub-order *Caulobacteriineae* in the new edition of the Manual. Some or all of the sea water bacteria that grow attached to surfaces as described by Zobell and Upham (18) may be regarded as probably belonging to this same group of bacteria. Careful comparative study may indeed show that the attached bacteria found in water really belong in various genera of the *Eubacteriineae*.

The stalked species, *Pasteuria ramosa*, described by Metschnikoff (19) and included by Henrici and Johnson (12) in their *Caulobacteriales* may have been a protozoan. Certainly longitudinal fission and budding makes this species different in its mode of reproduction from all other known species of *Schizophyta*. These organisms were found growing parasitically in the body cavities of small fresh water crustaceans (*Daphnia sp.*); and they never again have been seen and

they have never been studied by modern methods. For these reasons, this species is placed in an appendix to the sub-order *Caulobacteriineae* in the new edition of the Manual.

The colorless, filamentous, sulfur bacteria (*Beggiatoaceae*) have been placed in an appendix to the order *Chlamydobacteriales* with other filamentous bacteria that are clearly related to the blue-green algae. While this marks the greatest deviation from the outline as previously used, and separates the colorless, sulfur bacteria from the purple, sulfur bacteria placed in *Rhodobacteriineae*, it is in accordance with the arrangement accepted by Lehmann and Neumann (20), Pringsheim (21) and others. *Rhodobacteriineae* is also limited to the purple and green bacteria (pigments photosynthetic) as suggested by Pringsheim (21) and accepted by Kluyver and van Niel (9), by Stanier and van Niel (13), and by others.

The species of *Rickettsiaceae* that are regarded by Buchanan (22) and Gieszczykiewicz (23) as forming an order, *Rickettsiales*, are placed with *Virales* in a supplement. While there are many who would accept these groups as groups which should be included in *Schizomycetaceae*, their relationships and nature are still so obscure that it is difficult to determine where to place them in relation to the organisms in other orders and families. Viruses and bacteriophages are accepted in the new edition of the Manual as being very minute living things capable of classification as are other living things. Both are included in the order *Virales* as arranged by Holmes (24). The group here recognized as a family, the *Borrelomycetaceae*, is also difficult to place in relation to other bacteria. Some would place these organisms near the family *Parvobacteriaceae* which includes *Pasteurella*. The probabilities seem to be that these three supplemental groups will eventually all be recognized as highly specialized parasites derived from some of the groups that include more typical species of bacteria.

Conclusion. Although this outline maintains the simplicity that distinguishes its predecessors, and provides a place for all types of microörganisms thus far described that may properly be grouped under the fission fungi, it should not be regarded in any sense as final or official. An attempt has been made to express natural relationships, but these are so frequently obscure or unknown that in many places utilitarian considerations have prevailed. As it is, this outline drawn up by the three of us represents a compromise between somewhat varied viewpoints. It is not probable that any real student of systematic relationships will find that it expresses his own viewpoint in all particulars. In some places in the complete outline, genera or even families of doubtful significance have been allowed to stand as they are in the present edition of the Manual out of a desire not to make unnecessary changes. It has appeared desirable to be conservative in making changes in the outline as used previously.

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