

A PROPOSAL FOR THE NOMENCLATURE  
AND CLASSIFICATION OF THE PROTEUS  
AND PROVIDENCIA GROUPS

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**ABSTRACT:** The biochemical characters of the bacteria of the tribe Proteeae are tabulated in order that conclusions may be drawn as to their taxonomic relationships. The evidence indicates that Proteus vulgaris, P. mirabilis, P. rettgeri and Providencia all belong in a major subdivision of the family Enterobacteriaceae of tribal rank which justifies the recognition of the tribe Proteeae. The biochemical characteristics include Providencia in the tribe. The biochemical differences between the above-mentioned members are at generic level and the division of the tribe into four genera—Proteus, Morganella, Rettgerella, Providencia—seems to be justified. P. vulgaris and P. mirabilis may be considered as two biogroups of the genus Proteus. The serotypes of the genera are composed of many infrasubspecific entities such as biogroups, biotypes and phage types; they are in reality more inclusive taxa and should be regarded as species. Proposals for the classification and nomenclature of the tribe Proteeae are outlined.

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I. Introduction

The last report of the Enterobacteriaceae Subcommittee, presented at the VII International Congress of Microbiology at Stockholm (1), did not discuss the problems of the nomenclature and taxonomy of the Proteus group and recommended the use of the classification devised by Rustigian and Stuart

Table 1. Earlier proposals for the classification of the Proteus-Providencia groups.

<p>Rustigian and Stuart 1945 (2)</p> <p>Genus <u>Proteus</u> Species:</p> <p><u>P. vulgaris</u> <u>P. mirabilis</u> <u>P. morganii</u> <u>P. rettgeri</u></p>	<p>Breed, Murray and Smith 1957 (5)</p> <p>Genus <u>Proteus</u> Species:</p> <p><u>P. vulgaris</u> <u>P. mirabilis</u> <u>P. morganii</u> <u>P. rettgeri</u> <u>P. inconstans</u></p>	<p>Kauffmann 1953, 1954, 1956 (6-8)</p> <p>Tribe <u>Proteae</u> Genera:                      Species</p> <p><u>Proteus</u>                      <u>P. vulgaris</u> <u>P. mirabilis</u></p> <p><u>Morganella</u> <u>Rettgerella</u> <u>Providencia</u></p>
<p>Kauffmann 1959 (9)</p> <p>Tribe <u>Proteae</u> Genera:                      Species:</p> <p><u>Proteus</u>                      <u>P. hauseri</u> (1:1) <u>Morganella</u>                      <u>M. morganii</u> (1:1) <u>Rettgerella</u>                      <u>R. rettgeri</u> (1:1) <u>Providencia</u>                      <u>P. inconstans</u> (1:1)</p>	<p>Ewing 1958 (4)</p> <p>Tribe <u>Proteae</u> Genera:                      Species:</p> <p><u>Proteus</u>                      <u>P. vulgaris</u> <u>P. mirabilis</u></p> <p><u>Morganella</u> <u>M. morganii</u> <u>M. rettgeri</u> <u>M. inconstans</u></p>	<p>Ewing and Edwards 1960 (10)</p> <p>Division <u>Proteus-Providencia</u> Species:</p> <p><u>Proteus</u> group                      <u>P. vulgaris</u> <u>P. mirabilis</u> <u>P. morganii</u> <u>P. rettgeri</u></p> <p><u>Providencia</u> group</p>

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in 1945 (2), and recognition of decisions relative to P. vulgaris and P. mirabilis made at the Congress in Rio de Janeiro in 1950 (3). The Subcommittee in 1958 dealt with the definition of the Providencia group and recommended the continued maintenance of this group as a separate entity (1).

Recently many biochemical methods have been developed which make possible the better delineation of the groups of the family Enterobacteriaceae and also a clearer insight into the tangled taxonomic problems of the Proteus-Providencia groups. The progress of serological grouping has contributed also to the solution of these problems. These facts serve as basis for development of new proposals of classification and nomenclature. A critical summary of these was recently made by Ewing (4). Table 1 shows the main proposals in tabular form taken from Ewing and other sources.

On studying the different proposals it is evident that the problems of the taxonomy and nomenclature of Proteus and Providencia have been clustered around the following questions:

1. Is it evident that the groups of Enterobacteriaceae with which we are dealing (Proteus vulgaris, P. mirabilis, P. morgani, P. rettgeri, and Providencia) all belong to a definite major subdivision of the Enterobacteriaceae? Is this division at the generic (2, 5) or tribal (9) level, or is a compromise needed (10)?

2. Are there differences which warrant the rank of genus for the members, or are the differences at the species level, or should the group designation be maintained (1-10)?

3. Is it justifiable to create a genus Morganella within the tribe Proteeae with the three members as species (4)?

4. Are Proteus vulgaris and P. mirabilis separate species or biogroups only (4, 6, 7, 8)?

5. As to the position of Providencia:

a. Is its inclusion in the tribe Proteeae justified (4, 10, 26, 27)?

b. Should it be regarded as a taxon of a rank lower than genus, or is it to be given generic recognition (4, 15, 28)?

6. What application to the question of species has Kauffmann's new principles of classification and nomenclature (9, 11)?

7. The question of nomenclature.

Table 2. Reactions of the majority of cultures of the genera of the tribe Proteeae in tests recommended for group-differentiation within the family Enterobacteriaceae.

Substrate or test	Genera			
	Proteus	Morganella	Retzgerella	Providencia
Gas from glucose	+	+	d	d
Lactose	-	-	-	-
Sucrose	d	-	d	+
Mannitol	-	-	+	-
Dulcitol	-	-	-	-
Salicin	d	-	d	-
Adonitol	-	-	+	d
Inositol	-	-	+	d
Indol	d	+	+	+
Methyl red	+	+	+	+
Voges-Proskauer reaction	-	-	-	-
Simmon's citrate	d	-	+	+
Ammonium glucose	d	-	+	+
H <sub>2</sub> S	+	-	-	-
Urease	+	+	+	-
Gelatin	+	-	-	-
KCN	+	+	+	+
Phenylalanin deaminase	+	+	+	+
Malonate	-	-	-	-
Glutamic acid decarboxylase	+	+	+	+
Ornithine decarboxylase	d	+	-	-
Motility	+	+	d	+
<u>Additional tests</u>				
Spreading capacity at 30°C	+	+	d	d
Phosphatase	+	-	d	d
Mannose	-	+	+	+
Glycerol	+	+	+	+

+ = positive 90% or more  
 - = negative 90% or more

(+) = delayed positive  
 d = different +/+/-/  
 reactions

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The basis of classification is a combination of biochemical and serological groupings (2, 9). According to Kauffmann (9), "Tribes and genera are biochemically defined subdivisions of the family Enterobacteriaceae."

To approach the problems we have first to study the biochemical properties of the groups of bacteria noted above. Tables 2-5 show the data upon which are based the proposals of the author of this article. The data have been collected from the works of Ewing et al. (12, 13), Kauffman (8, 14), Namioka et al. (15), Rauss et al. (16), Tomašoffova (17), and Lányi (24).

Table 2 shows the reactions of the majority of cultures within the tribe Proteeae in tests recommended for group (generic) differentiation (1) whereas Table 3 contains selected reactions which are common to the groups of bacteria with which we are dealing.

Table 3. Reactions which delineate the tribe Proteeae.

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1. Present in 100% of the genera

Lactose	not fermented
Glycerol	fermented
Methyl red	positive
Phenylalanin deaminase	positive
Glutamic acid decarboxylase	positive

2. Not present in all genera, but characteristic for the tribe

Urease	(except <u>Providencia</u> )
Phosphatase	( <u>Morganella</u> only 5%)
Spreading capacity at 30°C	( <u>Rettgerella</u> 60% <u>Providencia</u> 51%)

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The reactions presented in Table 3 are divided into two parts according to their frequency. The reactions of part 1 occur in 100% of the genera of the tribe and in this combination are unknown elsewhere in the family Enterobacteriaceae. They show a special arrangement of ferment systems which is characteristic for a certain larger division of bacteria by which certain smaller groups are linked together.

As a corollary, further evidence of their belonging to a larger division is given by some very characteristic reactions which are, however, not present in all groups. These are: the ability to decompose urea (lacking in Providencia); presence of phosphatase in 100% of P. vulgaris and in about 20% of Proteus rettgeri (Rettgerella) and Providencia. Proteus morgani (Morganella) does not usually show this reaction, which is absolutely absent in other tribes of family Enterobacteriaceae (18). The swarming phenomenon is characteristic for members of the tribe Proteeae but in Rettgerella and Providencia has so far not been demonstrated. According to our observations (19) soft agar plates (1.3-1.5%) on which other groups of Enterobacteriaceae fail to show this phenomenon, the swarming capacity can be demonstrated at 30°C in about 60% of the strains of Rettgerella and Providencia.

In summary, the evidence indicates that Proteus, Morganella, Rettgerella, Providencia all belong to a major division of the Enterobacteriaceae which bears all the marks of the concept of the tribe, because, as will be shown, this division unites biochemically further differentiable groups. The first question, in the author's opinion, can be answered as follows: according to Kauffmann, recognition of the tribe Proteeae is warranted.

In order to make proposals to answer the second question we must again review both the biochemical and serologic properties. Table 4 contains the reactions which delineate the different genera of the tribe.

The biochemical differences are evident and significant, since each group shows with respect to the other three some completely characteristic signs. Proteus is distinguished by H<sub>2</sub>S production and by the presence of the enzyme gelatinase. Morganella shows relative fermentative inactivity and is H<sub>2</sub>S and gelatinase negative; Rettgerella is characterized by relative activity and by the absence of H<sub>2</sub>S and gelatinase reactions; Providencia is significantly characterized by the absence of urease.

What characteristics are useful for the delimitation of species and of genera have not yet been determined. In the opinion of the author, among serologically unrelated groups, characteristic fermentative differences show generic delimitation irrespective of the number of these differences, whereas in serologically related groups fermentative differ-

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Table 4. The reactions which may be used to distinguish the genera of the tribe Proteeae.

Substrate or test	Genera			
	<u>Proteus</u>	<u>Morganella</u>	<u>Rettgerella</u>	<u>Providencia</u>
Mannitol	-	-	+ (90)	-
Salicin	d (75)	-	d (45)	-
Adonitol	-	-	+ (94)	+ (94)
Inositol	-	-	+ (98)	d (15)
Mannose	-	+ (100)	+ (100)	+ (100)
Xylose	+ (100)	-	-	-
H <sub>2</sub> S	+ (100)	-	-	-
Urease	+ (100)	+ (100)	+ (100)	-
Gelatin	+ (100)	-	-	-

Figures in parentheses indicate percentage of strains giving a positive reaction.

ences show only fermentative variation: biogroups or types (for example, P. vulgaris and P. mirabilis).

According to the preliminary records the problems raised in questions No. 2-5, in the opinion of the author, can be answered as follows:

Query 2. The differences between the members are at the generic level and the tribe Proteeae should be divided according to Kauffmann's proposal into 4 genera: Proteus, Morganella, Rettgerella and Providencia.

Query 3. The differences between the genus Proteus, on the one hand, and the Morganella-Rettgerella-Providencia section, on the other, are not so significant as to separate them into two taxa (subtribes). The differences between the 4 genera of the tribe equate well enough to secure to each of them a taxonomic position of the same rank.

Query 4. The serologically closely related P. vulgaris and P. mirabilis are not to be considered as 2 separate species, but biogroups of the genus Proteus.

Query 5. The position of Providencia may be assessed from the premises detailed above. There seems to be evidence it should be considered as a distinct genus of the tribe Proteeae (see Table 3).

Table 5. The reactions which may be used to distinguish the biogroups and biotypes of the species of the tribe Proteeae.

a. Proteus vulgaris

Substrate or test	Biogroups	
	1. <u>vulgaris</u> (15%)	2. <u>mirabilis</u> (85%)
Maltose	+	-
Indol	+	-
Ornithine decarboxylase	-	+

b. Morganella morganii

Substrate	Biotypes		
	1 (85%)	2 (6%)	3 (4%)
Sucrose	-	-	(+)
Galactose	+	-	+

c. Rettgerella rettgeri

Substrate	Biotypes			
	1 (69%)	2 (18%)	3 (12%)	4 (1%)
Rhamnose	-	+	+	-
Salicin	+	-	+	-

d. Providencia inconstans

Substrate	Biogroups	
	1 (85%)	2 (15%)
Gas from glucose	+	-
Adonitol	+	-
Inositol	-	+



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Turning to the problem of the species (question 6), the author has accepted the latest definition of Kauffmann (11): "A species is a group of related sero-fermentative-phage types." This definition defines more exactly this basic category (species) than any thus far used purely biochemical determination. This definition may well be applied to the serotypes of the genera of the tribe Proteeae. If in the individual serotypes being analyzed it becomes clear that they are not homogeneous, they are composed of many infrasub-specific entities: of biogroups, biotypes and phage types. The main biogroups and biotypes are shown in Table 5.

One should not forget that in addition to those presented here, many smaller fermentative groups may be established. In Proteus sp. for example, 13 biotypes (7), in Morganella morgani 12 fermentative types have so far been encountered (16), and in Providencia sp. 31 biotypes have been recognized (13). The phage typing in the tribe Proteeae so far is not in an advanced state. P. vulgaris and P. mirabilis alone have been studied and 10 lysotypes established (20). No doubt with more extensive investigations more phage-types will be unveiled and other species may also be split into several subdivisions by means of phage typing.

There seems to be sufficient evidence to warrant the conclusion that the serotypes are in reality larger groups which include many fermentative and phage types. Therefore, to agree with Kauffmann, these fermentative types and the phage types should be regarded as subspecific entities, while the serotypes are the species.

The proper nomenclature (question 7) has been analyzed in Kauffmann's (6, 7, 8, 9) and Ewing's (4) reviews, and the priority of names established. In accordance with these statements, Table 6 shows the proposal of the author for the classification and nomenclature of the tribe Proteeae.

For the type species of the genus Proteus the name Proteus vulgaris has been proposed, since this term can alone be regarded as legitimate (29). In the author's opinion the two infrasubspecific forms of this species, P. vulgaris var. vulgaris and P. vulgaris var. mirabilis, should be recognized.

Table 6. Classification and nomenclature of the tribe Proteeae.

<u>Tribe Proteae</u>	
<u>Genera</u>	<u>Species</u>
<u>Proteus</u>	<u>Proteus vulgaris</u> 1a:1a, 1b, 1a etc. (21, 22, 23)
<u>Morganella</u>	<u>Morganella morganii</u> 1a, 1b:1 etc. (16, 21)
<u>Rettgerella</u>	<u>Rettgerella rettgeri</u> 1:1 etc. (15)
<u>Providencia</u>	<u>Providencia inconstans</u> 1:1 etc. (1, 13)

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