ANALYSIS OF THE GENUS SELENOMONAS
WITH RESPECT TO ITS TRANSFER TO THE PROTOZOA

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Lewis (1884) described an organism from the human mouth which he considered to be related to the cholera vibrio of Koch. This was incorporated into the classification of Flügge (1886) and of Trevisan (1885), being named Spirillum sputigenum by the former author, while Trevisan earlier employed the name Pacinia lewisi.

Miller, in a number of papers (1887, 1892, 1906), described Spirillum sputigenum from the human mouth, but failed to culture it. This organism was described by Hoffman and von Prowazek (1906) as being peritrichously flagellate. The extreme instability of the component fibrils of the compound flagellum and its liability to produce such appearances are referred to later in this review.

Löwenthal (1906) appears to have been the first to describe any internal structures in this organism when he noted the presence of possible nuclear material, "one or two nuclei."

Certes (1889) found a similar organism in the rumen of cattle to which he applied the name Ancyromonas ruminantium. This organism, however, showed no resemblance to the generic diagnosis of Ancyromonas as given by Kent (1880). This has been pointed out by Wenyon (1926).

Kerandel (1909) observed organisms in the blood of antelope and other game shot in the Congo and noted the resemblance between his forms and those described by Miller (1887 *et seq.*) and by Certes (1889).

In the same year as Kerandel described his organisms, the flagellation and motility of Spirillum sputigenum (Miller) were studied by Yamamoto (1909) and Muhlens (1909). The latter reported the presence of 1-3 flagella, most cells possessing one thick flagellum, arising from the centre of the concave side.

Braune (1913) reported an organism from the rumen of the ox and named it Callimastix frontalis, presumably because it resembled the organism from the body cavity of a Cyclops sp. described by Wissenberg (1912). Braune's organism was spherical, possessing "a number of flagella,

arising from one small area of the spore, each being derived from a blepharoplast and possessing a complicated neuromotor-apparatus." Wenyon (1926) considers that this may be a stage in the life cycle of Selenomonas palpitans. In the present writer's experience the very rare occurrence of such organisms in the guinea pig caecum, even in relatively dense populations of Selenomonas, contra-indicates this conclusion. Those forms which have been noted in this situation appear to have been degenerate and may represent pathological changes rather than a life cycle. The possibility, however, of unknown forms occurring as part of a life cycle cannot be ruled out at present.

Braune (1913) also described his organism as possessing a single nucleus with a large caryosome and thus distinct from the nuclear apparatus of Selenomonas (Jeynes, 1955).

Wenyon (1926) in summing up gives the characteristic features of Callimastix frontalis as: (a) number of flagella arising from a row of blepharoplasts, and (b) flagella arranged in one plane and appearing as if united to form a band 30μ in length.

Fonseca (1916) also reports this organism from cattle, sheep, and goats in South America.

von Prowazek (1913), in a study of Spirillum sputigenum came to the conclusion that it was not a member of the genus Spirillum and suggested the generic name Selenomonas. This paper was published under conditions which fulfilled the Rules of the Bacteriological Code, with the exception that a type species was not described. The name which would arise as a result of this transfer, Selenomonas sputigena (Flügge) von Prowazek, was not in fact used in that paper. Von Prowazek also considered the organism described by Certes (1889), Ancyromonas ruminantium, to be a member of his new genus. Again, however, he did not actually employ the combination which would arise under the conditions of transfer, Selenomonas ruminantium (Certes) von Prowazek.

While the organisms observed in the blood smears are not known to be identical with those of Certes (1889), it is more likely that they are rumen or caecal forms than of oral origin. The flagellates examined in blood smears by Kerandel certainly resulted from mechanical damage to the gut and associated blood vessels, since his animals were shot prior to examination. In von Prowazek's examinations, other organisms of intestinal origin were found, confirming this

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view. This being the case, the type species obviously indicated would be Selenomonas ruminantium (Certes) von Prowazek.

Giesberger (1936) having re-examined the problem of the flagellation of Spirillum sputigenum placed it in the genus Selenomonas as diagnosed by von Prowazek.

Later in 1913, Woodcock and Lepage described in some detail an organism found in the rumen of sheep and goats. This they considered had a life cycle which involved the interconversion of two forms, flagellate crescents and aflagellate ovals. The crescents had the same form as those described by earlier workers. The ovals, although apparently aflagellate were said to be capable of motility and possessed a better defined cell wall than the crescents. The latter were also reported to be capable of motion independently of the flagellum, presumably by "muscular" movement of the cell wall.

The name applied to these forms was Selenomastix ruminantium (Certes) Woodcock and Lepage. The paper of von Prowazek transferring Ancyromonas ruminantium Certes to the genus Selenomonas antedates that of Woodcock and Lepage by a few months.

Selenomastix is to be rejected also on the grounds of having been applied to two distinct organisms. This has been pointed out recently (Oxford, 1955).

In discussing the taxonomy of the crescents, Woodcock and Lepage suggest that they may be "Proflagellates" or "Prop protozoa."

The observation of crescentic laterally flagellate organisms in the caecal contents of the guinea pig was made by Da Cunha (1915) and closely followed by Fonseca (1916).

Simons (1920) mentions very briefly the occurrence in the guinea-pig caecum of an organism resembling those described by von Prowazek. This was followed by a further paper (Simons, 1921) in which he suggested that the organism from this source should be named Selenomonas palpitans.

Boskamp (1922) described the guinea-pig organism, apparently accepting Simons' specific epithet, and also termed Miller's mouth flagellate, Selenomonas sputigena. He agreed with the "muscular" movement hypothesis and suggested that the organisms should be included with the Spirillaceae. He adds, however, that further study should be undertaken before deciding upon a final classification.

Knorr (1922, 1923) described the culture of Spirillum sputigenum. He also draws attention to the symbiotic co-relationship of this organism with the mouth fusiform bacteria.

Ford (1927) confirmed the flagellation as normally consisting of a single thick compound flagellum attached laterally to the concave side of the crescent.

Wenyon (1926) places the guinea-pig strain in the family Monadidae Kent, with the generic diagnosis of von Prowazek (1913).

Dobell (1932) described the oral strain and shows that this is one of the human mouth organisms observed by van Leeuwenhoek in 1683 (Letter 39. Diagrams B, C, D). After describing its culture and cytology, Dobell states "Spirillum sputigenum" (Miller, 1890). This is not really a Spirillum at all, but belongs to the genus Selenomonas, Prowazek (1913)".

The genus Selenomonas was recognised by Neveu Le Maire (1942) and included in the Protozoa, as also by McGaughey and Sellars (1948).

Lessel and Breed (1954) reiterated the conclusions of Boskamp (1922) and classified it in the family Spirillaceae (Migula), although apparently not intending the use of the generic name Spirillum.

The status of the generic name Selenomonas von Prowazek has been discussed recently in these pages from the aspects of its validity for inclusion in Bacterial Nomenclature (Judicial Commission, 1955).

Oxford (1955) pointed out that as the crescents and ovals described by Woodcock and Lepage (1913) are almost certainly distinct organisms, the generic name Selenomastix as applied to the crescents is invalid on the grounds of uncertainty.

Quin (1943) having studied the ovals found in the rumen contents of Merino sheep, showed the fermentation of glucose and storage of glycogen by these organisms. Despite the motility which these ovals are reported to possess, Quin apparently considered them to be yeasts as he applied the name Schizosaccharomyces ovis. McGaughey and Sellars (1948) and van der Westhuizen and Oxford (1955) have pointed out the error of this conclusion and this has been reiterated by Oxford (1955).

The latter writer indicates that a case could be made for the application of the name Selenomastix ruminantium

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Woodcock and Lepage to the ovals; the crescents having been transferred to the genus Selenomonas. The derivation of the generic name seems rather unsuitable in this case, as the ovals bear no relationship to the shape of the moon. The name would, however, antedate Schizosaccharomyces ovis for the ovals, the latter name being invalid since it is legitimately applied to a genus of yeasts.

The affiliations of the genus Selenomonas with the protozoa have been pointed out on the basis of cytological observations (Jeynes, 1955) together with the error of classification among the bacteria.

The cytological appearance of bacteria and especially the spirilla are entirely different from those observed in Selenomonas (Bisset, 1955).

From the foregoing analysis it is felt that the following proposals are both logical and generally acceptable in the circumstances:

1. The generic name Selenomonas von Prowazek is valid and represents a genus of flagellate protozoa.
2. The type species should be Selenomonas ruminantium (Certes) von Prowazek.
3. The genus should be placed provisionally in the family Monadidae Kent.
4. Should transfer to a new family or subfamily prove desirable, when more information of taxonomic value is available, this should be named Selenomonadidae.
5. The following species should be recognized within the genus:
 - a. Selenomonas ruminantium (Certes) von Prowazek.

Type species. Unicellular crescents, motile by means of a single compound flagellum attached, typically, to the centre of the concave side. Motility irregular and tumbling. Possibly motile also by action of the cell wall. Strict anaerobe. Not cultured. Gram-negative c $6.0\mu \times 1.8$. From the rumen of sheep, goats, oxen, cattle, and antelope. Wide geographical distribution.

b. Selenomonas sputigena (Flügge) von Prowazek.

Unicellular crescents, sometimes almost rod-like, $1.0-2.5\mu$ long by $0.3-0.5\mu$ (the width may be slightly exceeded in rare cases). Motile by single compound flagellum attached laterally to the concave side of the crescent. Not observed to be motile by cell wall movements. Strict anaerobe. Culturable with difficulty, but more easily in association with oral fusiform bacteria. Gram-negative. From tooth deposit and oral cavity of healthy humans. Not known to be pathogenic. Widely distributed.

c. Selenomonas palpitans Simons.

Unicellular crescentic organism motile by means of single compound flagellum attached at the centre of the concavity of the crescent. Flagellum attached to a blepharoplast and neuromotor apparatus. Possibly motile also by "muscular" movement of cell wall. Gram-negative. Not cultured. Pleomorphic and variable in size, typically $6.5-9.5\mu \times 1.5-2.5\mu$. From the guinea-pig caecal contents.

The name S. palpitans is retained for the guinea-pig strain on the grounds of familiarity and also that the incomplete information available and its pleomorphic nature make an assessment of its relationships to S. ruminantium difficult.

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