Reassignment of the Genus *Ectothiorhodospira* Pelsh 1936 to a New Family, *Ectothiorhodospiraceae* fam. nov., and Emended Description of the *Chromatiaceae* Bavendamm 1924

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I propose that the genus *Ectothiorhodospira* be placed in a new family, the *Ectothiorhodospiraceae*, as the only genus. The reasons for this proposal are discussed briefly, and a description of the new family and an emended description of the *Chromatiaceae* are given.

Two groups of phototrophic purple bacteria were distinguished by Molisch (13); these are the *Thiorhodaceae*, comprising all purple bacteria that are able to form globules of elemental sulfur inside their cells, and the *Athiorhodaceae*, comprising bacteria which lack this ability. These groups have been maintained and were treated as families of the *Pseudomonadales* (suborder *Rhodobacteriinae*) in *Bergey's Manual of Determinative Bacteriology*, 7th ed. (1). In *Bergey's Manual*, 8th ed., these two groups appeared as the *Rhodospirillaceae* Pfennig and Trüper 1971 and the *Chromatiaceae* Bavendamm 1924, respectively (16). In this latter edition the ability of the species to use sulfide as the sole photosynthetic electron donor and to form elemental sulfur as an intermediate oxidation product, inside or outside cells, was used as one of the major criteria to distinguish between the two families. Thus, because of its ability to form and oxidize elemental sulfur, the new (see below) genus *Ectothiorhodospira* Pelsh 1936 could be included in the family *Chromatiaceae*; within this family, only *Ectothiorhodospira* species deposit elemental sulfur outside their cells.

The ability of various *Rhodospirillaceae* species to oxidize sulfide is now well established (2–4, 12, 13a). Most of the species with this ability form either elemental sulfur or sulfate as the only oxidation product, but *Rhodopseudomonas* sp. strain 51 (2) and *Rhodopseudomonas adriatica* (13a), similar to *Ectothiorhodospira* species, deposit elemental sulfur during sulfide oxidation to sulfate intermediately outside their cells. Therefore, the ability to oxidize sulfide and elemental sulfur is no longer a suitable property to distinguish between the *Rhodospirillaceae* and the *Chromatiaceae*. A redefinition of these families is required, and it seems useful to return to the definition of the *Thiorhodaceae* of Molisch (13). This consequently leads to separation of *Ectothiorhodospira* from the *Chromatiaceae*.

The first description of an *Ectothiorhodospira* species, *Ectothiorhodospira mobile* (sic), was published by Pelsh (14), who later (15) distinguished these bacteria as members of the "*Ectothiorhodaceae*" from the "*Endothiorhodaceae*" (*Chromatiaceae* Bavendamm 1924, nomen conservandum proposed by Pfennig and Trüper in 1971) and the "*Ectothiochlorobacteriaceae*" (*Chlorobiaceae* Copeland 1956). The organism of Pelsh was lost, and knowledge about this work did not reach the literature of the western world until Trüper (17) reisolated and redescribed *Ectothiorhodospira mobilis*. Since then five more species of this genus have been described; these are *Ectothiorhodospira shaposhnikovii* Cherni et al. 1969, *Ectothiorhodospira halophila* Raymond and Sistrom 1969, *Ectothiorhodospira halochloris* Imhoff and Trüper 1979 (8), *Ectothiorhodospira abdelmalekii* Imhoff and Trüper 1982 (9), and *Ectothiorhodospira*

vacuolata Imhoff et al. 1982 (7). (*E. halochloris*, *E. abdelmalekii*, and *E. vacuolata* were effectively published by Imhoff et al. [7–9], and the publication of these names was later validated in the International Journal of Systematic Bacteriology (10, 11); the years given above refer to the dates of validation.) The *Ectothiorhodospira* species form a distinct group among the phototrophic purple bacteria, and the arguments below support treatment of this group as a taxon support treatment of this group as a taxon separated from both the *Rhodospirillaceae* and the *Chromatiaceae*.

(i) *Ectothiorhodospira* species are unique among the phototrophic purple bacteria in their requirement for saline to extremely saline and alkaline growth conditions, and therefore are enriched and isolated under conditions not suitable for other phototrophic purple bacteria (18). (ii) Analyses of 16S ribosomal ribonucleic acids show that *Ectothiorhodospira* stands clearly apart from the *Rhodospirillaceae* and is also distinctively different from the *Chromatiaceae* species that deposit elemental sulfur globules inside their cells (16a). (iii) The lipid compositions of all *Ectothiorhodospira* species are significantly different from those of *Rhodospirillaceae* and *Chromatiaceae* species. *Ectothiorhodospira* species lack glycolipids, which are characteristic of the *Chromatiaceae*, and they also lack ornithine lipids, which are characteristic of the *Rhodospirillaceae* (6). (iv) The major quinones found in the extremely halophilic species are menaquinones and ubiquinones with eight isoprenoid units in their side chains, like the quinones found in *Chromatium* and related genera. The species with lower salt requirements have only seven isoprenoid units in the side chains of their major ubiquinones and menaquinones. No other phototrophic purple bacteria are known to contain this combination of MK-7 and Q-7 (5). (v) The amino acid sequences of the cytochrome *c*₅₅₁ molecules of the extremely halophilic *Ectothiorhodospira* species, *E. halophila*, *E. halochloris*, and *E. abdelmalekii*, are not similar to the amino acid sequence of any cytochrome *c* analyzed from the *Rhodospirillaceae* or the species retained within the *Chromatiaceae* (T. E. Meyer, Abstr. IVth Int. Symp. Photosynthetic Procarvates, A46, 1982; R. P. Ambler, personal communication). (vi) Those *Rhodopseudomonas* species that oxidize sulfide to sulfate via intermediate deposition of elemental sulfur are significantly different from *Ectothiorhodospira* species, both physiologically and on the basis of molecular structure (2, 13a). (vii) In removing *Ectothiorhodospira* from the *Chromatiaceae*, this family becomes clearly defined; all of its members deposit elemental sulfur during sulfide oxidation inside their cells.

Therefore, I propose that *Ectothiorhodospira* be placed in the new family *Ectothiorhodospiraceae* as its only genus,

with *Ectothiorhodospira* as the type genus and *Ectothiorhodospira mobilis* Pelsh 1936 as the type species of this genus.

Description of *Ectothiorhodospiraceae* fam. nov. *Ectothiorhodospiraceae* (Ec.to.thi.o.rho.do.spi.ra'ce.ae. M.L.fem.n. *Ectothiorhodospira* type genus of the family; -aceae ending to denote a family; M.L. fem.pl.n. *Ectothiorhodospiraceae* *Ectothiorhodospira* family) cells are spiral, vibrioid, or rod shaped with intracytoplasmic membranes that are continuous with the cytoplasmic membrane and present as lamellar stacks. The photosynthetic pigments are bacteriochlorophyll *a* or *b* and carotenoids. Cells are motile by means of polar flagella and do or do not contain gas vacuoles.

Growth occurs in the light under anaerobic conditions or at low pO_2 values, and some species also grow at low pO_2 values in the dark. Photoautotrophic growth may or may not be possible. A number of organic carbon sources are photoassimilated or used as photosynthetic electron donors. Sulfide is oxidized to elemental sulfur, which is deposited outside the cells and may be further oxidized to sulfate. Sulfate may or may not be used as a sole sulfur source under photoheterotrophic growth conditions. No growth factors are required, but vitamin B₁₂ enhances the growth of some strains.

The deoxyribonucleic acid base composition ranges from 50.5 mol% guanine plus cytosine (*E. halochloris*) to 69.9 mol% guanine plus cytosine (*E. halophila*).

Most characteristic is the dependence on saline and alkaline growth conditions. The presently known species grow optimally between pH 7.5 and 9.1 and at a total salt concentration of 3 to 30%. Accordingly, members of the *Ectothiorhodospiraceae* are found in nature in marine to extremely saline environments containing sulfide and having alkaline pH values and can be selectively enriched under such conditions. They may also occasionally be found in soil, but not in nonalkaline freshwater habitats.

Emended description of the *Chromatiaceae* Bavendamm 1924. The description is essentially the same as that given by Pfennig and Trüper (16), except as noted below. Individual cells are spherical, ovoid, rod shaped, or spiral shaped, rarely vibrioid. During sulfide oxidation globules of elemental sulfur accumulate intermediately inside the cells in all species; such globules never accumulate outside the cells. This property clearly distinguishes the *Chromatiaceae* from the other families of phototrophic purple and green bacteria, as previously recognized as a characteristic feature of the "*Thiorhodaceae*" by Molisch (13).

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