NOTES

Occurrence of Sheathed Flagella in *Campylobacter cinaedi* and *Campylobacter fennelliae*

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Campylobacter cinaedi and *Campylobacter fennelliae* possess sheathed flagella, a feature which, among organisms currently classified as campylobacters, had been associated previously only with *Campylobacter pylori*. No other *Campylobacter* or *Wolinella* species possesses sheathed flagella. This feature helps to characterize the phylogenetic group that includes *C. pylori*, *C. fennelliae*, and *C. cinaedi*; however, *Wolinella succinogenes*, the fourth member of this group, does not possess sheathed flagella.

Comparisons of the partial 16S ribosomal ribonucleic acid (rRNA) sequences of various members currently listed in the genus *Campylobacter* have indicated that *Campylobacter pylori* should be excluded from the genus *Campylobacter* and that this species is instead related to *Wolinella succinogenes* (8, 11-13). Studies by Thompson et al. (13) indicated that *Campylobacter cinaedi* and *Campylobacter fennelliae* also belong to the same rRNA similarity group (rRNA group II) that contains *C. pylori* and *W. succinogenes*; this rRNA group was considered to represent a separate genus. Regardless of whether this group represents a genus or a higher taxon, it is difficult at present to arrive at a suitable phenotypic definition of the group that distinguishes it from rRNA group I, which contains the true campylobacters and four putative anaerobes (11, 13). Thompson et al. (13) noted that one of the initial problems with rRNA group II (viz., the putative anaerobic nature of *W. succinogenes*) could be eliminated because, like *C. pylori*, *C. cinaedi*, and *C. fennelliae*, *W. succinogenes* is oxidase positive and, as shown by Wolin et al. (14), is able to respire with oxygen as a terminal electron acceptor under microaerobic conditions ($\leq 2\%$ O₂). The microaerophilic nature of *W. succinogenes* makes its inclusion with *C. pylori*, *C. cinaedi*, and *C. fennelliae* more feasible in phenotypic terms.

In the past, one phenotypic feature that seemed to be unique to *C. pylori* was the occurrence of sheathed flagella (6, 7). Sheathed flagella have also been reported in *Campylobacter pylori* subsp. *mustelae* (4) and other gastric spiral bacteria isolated from various animals, as summarized by Marshall (9). Sheathed flagella are relatively uncommon among bacteria and thus have taxonomic significance; e.g., among gram-negative bacteria they are characteristic of the genus *Vibrio* (1), the genus *Bdellovibrio* (2), *Pseudomonas andropogonis* (synonym, "*Pseudomonas stitzolobii*") (5), and two *Alteromonas* species (3, 10). Because of the relatedness of *C. pylori* to *C. cinaedi*, *C. fennelliae*, and *W. succinogenes*, we thought that these latter species might also possess sheathed flagella.

Cells of several strains were negatively stained by using the method described by Goodwin et al. (7). The rRNA

group I (11, 13) strains examined included *Campylobacter coli* ATCC 33569^T (T = type strain), *Campylobacter jejuni* ATCC 33560^T, *Campylobacter fetus* subsp. *fetus* ATCC 27374^T, *Campylobacter fetus* subsp. *venerealis* ATCC 19438^T, *Campylobacter laridis* NCTC 11352^T, *Campylobacter mucosalis* NCTC 11000^T, *Campylobacter concisus* ATCC 33237^T, *Campylobacter hyointestinalis* ATCC 35217^T, *Campylobacter sputorum* biovar *sputorum* strain ATCC 35980^T, "*Campylobacter upsaliensis*" CG-1, *Wolinella recta* ATCC 33238^T, and *Wolinella curva* ATCC 35224^T. (In addition, *Bacteroides ureolyticus* ATCC 33387^T and *Bacteroides gracilis* ATCC 33236^T, which are also members of group I [11], were examined and were found to lack flagella.) The rRNA group II (8, 11-13) strains examined included *C. cinaedi* ATCC 35683^T, *C. fennelliae* ATCC 35684^T, and *W. succinogenes* ATCC 29543^T. The rRNA group III (13) strains examined included *Campylobacter cryaerophila* NCTC 11885^T and *Campylobacter nitrofigilis* ATCC 33309^T.

Of the above-mentioned strains, only the *C. cinaedi* strain (Fig. 1A and B) and the *C. fennelliae* strain (Fig. 1C and D) exhibited sheathed flagella. Some *C. fennelliae* cells also had flagella with terminal bulbs resembling those described for *P. andropogonis* (5) and *C. pylori* (6, 7), but no terminal bulbs were observed in the *C. cinaedi* preparations. It is interesting that *W. succinogenes*, the fourth member of rRNA group II, showed no evidence of sheathed flagella, despite an exhaustive search. Our studies also indicated that *C. cinaedi*, *C. fennelliae*, and *W. succinogenes* cells possess a single flagellum at one or both poles, whereas *C. pylori* has been reported to possess multiple polar flagella (6, 7) and appears to be unique among the campylobacter-like organisms in this feature.

We regard the fact that three of the four species of rRNA group II had sheathed flagella and that the members of rRNA groups I and III did not as taxonomically significant. This finding also suggests that further comparisons of the members of group II may reveal other underlying phenotypic similarities that may help to define this phylogenetic group in phenotypic terms. For instance, we have found that all four group II species possess hydrogenase activity, as indicated by H₂-dependent reduction of benzyl viologen. However,

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FIG. 1. Electron micrographs of *C. cinaedi* (A and B) and *C. fennelliae* (C and D) showing the occurrence of a flagellar sheath. The preparations were negatively stained with phosphotungstate. Bars = 0.5 μm.

this feature is not unique to rRNA group II; some species in rRNA group I also exhibit hydrogenase activity.

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