MIXED POLAR AND PERTRICHIOUS FLAGELLATION OF MARINE BACTERIA

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Bacteria that are essentially polar flagellate, either monotrichous or multitrichous, may develop lateral flagella as well. These lateral flagella invariably have a shorter wavelength than the polar flagella. If this were not so, the organism could not readily be differentiated from the usual pertrichious types. The wavelength of the lateral flagella is generally about 1 μ, regardless of the wavelength of the polar flagella. These lateral flagella are morphologically very similar to the "curly" flagella commonly found on pertrichious flagellate bacteria.

Mixed flagellation has been observed with a variety of polar flagellate bacteria (see Leifson and Hugh, J. Bacteriol. 65:263, 1953; Leifson, J. Bacteriol. 71:393, 1956). Pseudomonads from soil and fresh water rarely show it. Aeromonads frequently show it but generally only if the culture is very young or in the early logarithmic phase of growth. Chromobacterium species typically show mixed flagellation.

In a study of marine bacteria, particularly the bacteria of the intestine of marine animals such as crabs, clams, oysters, and fish, mixed flagellation was found with considerable frequency. Among some 400 motile cultures isolated from the intestines of various marine animals were about 70 cultures showing mixed flagellation. All these bacteria were straight rods and could be divided into two major physiological groups: a fermentative group corresponding to Aeromonas and a nonfermentative group corresponding to Pseudomonas. Among some 350 motile cultures isolated directly from sea water, only 6 cultures showed mixed flagellation. None of the marine isolates with polar multitrichous (or lophotrichous) flagella, or with a curved soma (vibrio types), showed mixed flagellation.

Each of the two major groups included a variety of physiological types. All cultures in the pseudomonadlike group oxidized glucose, liquefied gelatin, and were relatively psychrophilic. The reactions on several other carbohydrates and on nitrate were variable. The aeromonadlike group was more uniform, in that the great majority of the cultures fermented glucose, sucrose, maltose, and mannitol, reduced nitrate to nitrite, and liquefied gelatin. A minority varied in one or more respects. All the cultures were negative on lactose and xylose.

The two groups also showed some differences regarding ease of detachment of the lateral flagella. When cultures of the pseudomonadlike group were stained from broth, after formalin fixation and washing by centrifugation, individuals showing mixed flagellation were quite numerous. When stained from slant cultures without fixation and washing by centrifugation, the picture was much the same (Fig. 1a, b). When cultures of the aeromonadlike group were stained from broth in like manner, only polar monotrichous individuals were seen (Fig. 2a and 3a). When they were stained from slant cultures without fixation or washing, the picture was entirely different. With some cultures, the slides showed mainly organisms with mixed flagellation (Fig. 2b) or organisms with curly lateral flagella only. With other cultures, the slides showed mainly loose (presumably detached) curly flagella, with only a few organisms with attached flagella, either lateral or polar (Fig. 3b). All the cultures with loose curly flagella showed the phenomenon of swarming, in the manner of Proteus species, over the surface of sea water nutrient agar. Detachment of the curly lateral flagella in the swarming cultures could be prevented to a great extent by suspending the growth from the agar slant in sea water (natural or artificial), adding formalin to about 10% concentration, and washing by centrifugation. Slides from such preparations showed relatively few loose curly flagella (Fig. 3c).

To detect all instances of mixed flagellation, it is necessary that flagella preparations be made from both liquid and solid media. With nonfermentative and nonswarming fermentative marine bacteria, the lateral flagella appear to be rather firmly fixed to the soma, and satisfactory flagella stains are obtained by simply suspending the growth from the agar surface in distilled water, without formalin fixation or washing.
FIG. 1a, 1b. Pseudomonadlike type, strain XQ87. With this group of bacteria, the stains from both broth and slant cultures showed much the same picture of mixed flagellation. Note the shorter wavelength of the lateral flagella. All figures are Leifson flagella stain, photomicrographs, X 2,000.

FIG. 2a, 2b. Aeromonadlike type, nonswarmer, strain YSC7. Figure 2a shows the typical polar monotrichous morphology of the organisms stained from broth. Figure 2b shows a typical individual with mixed flagellation stained without washing from distilled water suspension of growth on agar.

FIG. 3a, 3b, 3c. Aeromonadlike type, swarmer, strain XD1. Figure 3a shows a typical polar monotrichous individual stained from broth. The shadowy imprint at left of soma may have resulted from a movement on the slide. Figure 3b shows a section of a slide stained from a distilled water suspension of an agar slant culture. The loose curly flagella were scattered over the slide. Attached flagella, either normal polar or curly lateral, were rare on such slides. Figure 3c shows a typical individual with many curly lateral flagella. The normal polar flagellum may be seen coming from the upper end of the soma. In this case, the growth on the agar slant was suspended in sea water, formalin was added, and the organisms were washed by centrifugation.

With swarming fermentative cultures of marine bacteria, the lateral curly flagella appear rather loosely attached to the soma, and more satisfactory stains for showing the mixed flagellation are obtained by suspending the agar slant growth in sea water, followed by formalin fixation and washing.

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