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Deoxyribonucleic Acid Base Composition of Myxobacteria

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The order *Myxobacterales* as presently organized (*Bergey's Manual*) comprises both fruiting and nonfruiting forms. Soriano (Antonie van Leeuwenhoek J. Microbiol. Serol. **12**:215, 1947) proposed that the nonfruiting myxobacters be removed from this order and united with other organisms demonstrating gliding motility and lacking cysts or fruiting bodies in the order *Flexibacteriales*. Soriano and Lewin (Antonie van Leeuwenhoek J. Microbiol. Serol. **31**:66, 1965) changed the spelling to *Flexibacterales*, but retained the organization.

The utility of the average base composition of the deoxyribonucleic acids (DNA) of organisms in assessing possible genetic and taxonomic relations has been reviewed by Marmur, Falkow, and Mandel (Ann. Rev. Microbiol. **17**:329, 1963). In this communication we report the DNA base compositions of a representative sample of pure cultures of fruiting and nonfruiting myxobacters.

Cultures of *Myxococcus* and *Sporocytophaga* were isolated from soils from Massachusetts, California, Wisconsin, and New York. These cultures were given specific designations on the basis of cultural and physiological characteristics (Leadbetter, *unpublished data*). Cells of these isolates and of the various *Cytophaga* species were harvested in logarithmic growth from appropriate fluid culture media by centrifugation. Cell harvests of *Sorangium cellulosum* strains were provided by John E. Peterson, two unidentified *Myxococcus* strains by Alan D. Elbein, *Chondromyces apiculatus* by Lois F. Nellis, *Cytophaga johnsonii* by F. D. Cook, and *C. hutchinsonii* by R. Y. Stanier. All harvests lysed readily with 2% sodium dodecyl sulfate.

The isolation and analysis of the DNA has been described previously (Mandel, Bergendahl, and Pfennig, J. Bacteriol. **89**:917, 1965).

The results of these analyses are given in Table 1. The molar percentages of guanine plus cytosine (GC) content of the DNA samples demonstrate that the fruiting forms of myxobacteria examined here can be closely related. The representatives of *Myxococcus*, *Sorangium*, and *Chondromyces* are all of high GC content (68 to 71%). Indeed, the "species" of *Myxococcus* appear to be indistinguishable by the criterion of difference of DNA base composition. The nonfruiting, amicrosporogenous *Cytophaga* species have DNA of low GC content (34 to 43%). *Sporocytophaga myxococcoides*, the microsporogenous nonfruiting "member" of the *Myxococcaceae*, has DNA of 36% GC, which is in the range found for *Cytophaga* but quite different from those found for the fruiting myxobacters. The implications of these data, together with the striking differences in nutritional requirements and bacteriolytic properties, are that the genus *Sporocytophaga* has little relation, if any, to *Myxococcus*. Leadbetter (*unpublished data*) has also noted apparent differences in cell wall characteristics between representatives of these two genera. Neither *Cytophaga* nor *Sporocytophaga* can have any reasonable amount of genetic information in common with representatives of the fruiting *Myxobacterales*. The "obvious relationships" of morphological properties which led Stanier (Bacteriol. Rev. **6**:143, 1942) to propose the inclusion of *Cytophaga* and *Sporocytophaga* in this family may be the result of a convergent evolution. The proposal of Soriano to include these genera in *Flexibacterales* should be given serious consideration. Preliminary analyses (Mandel and Lewin, *unpublished data*) of DNA of representatives of *Flexibacter* and *Saprospira* have shown GC contents in the range reported here for *Cytophaga* and *Sporocytophaga*.

Portions of this study were carried out by M. M. at the University of Massachusetts, Amherst, and Brandeis University, Waltham, Mass., and by E. R. L. at the Hopkins Marine Station, Pacific Grove, Calif.

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TABLE 1. *Characteristics of deoxyribonucleic acid isolated from species of Myxobacterales*

Organism	Source	T_m	GC*	Buoyant density	GC†
		C	%	*g/cc*	%
Myxococcus fulvus	Massachusetts	98.2	70.5	1.730	71
M. fulvus	California	97.9	69.8	1.728	69
M. virescens	New York	98.4	71.0	1.729	70
M. virescens	California	98.0	70.0	1.728	69
M. virescens	Wisconsin	98.5	71.2	1.728	69
M. virescens	Massachusetts	98.5	71.2	1.727	68
M. xanthus	Massachusetts	97.7	69.3	1.727	68
M. xanthus	Wisconsin	98.5	71.2	1.729	70
Myxococcus sp	A. D. Elbein (yellow)	—	—	1.728	69
Myxococcus sp	A. D. Elbein (pink)	—	—	1.728	69
Sorangium cellulosum	J. E. Peterson PY	—	—	1.728	69
S. cellulosum	J. E. Peterson PX	—	—	1.728	69
Chondromyces apiculatus	L. F. Nellis	—	—	1.729	70
Cytophaga fermentans	ATCC 12470	86.2	41.2	1.698	39
C. aurantiaca	ATCC 12208	—	—	1.701	42
C. johnsonii	HMS MYX 1.1.1‡	—	—	1.692	33
C. johnsonii	F. D. Cook 405	83.5	34.6	1.694	35
C. hutchinsonii	R. Y. Stanier	—	—	1.698	39
Sporocytophaga myxococcoides	Massachusetts	84.2	36.3	1.695	36
S. myxococcoides	California	—	—	1.695	36

* Calculated from melting temperature (T_m) in SSC (Marmur and Doty, J. Mol. Biol. **5**:109, 1962).

† Calculated from buoyant density in CsCl (Schildkraut, Marmur, and Doty, J. Mol. Biol. **4**:430, 1962).

‡ Hopkins Marine Station Culture Collection.