The morphological variability of a *Synechococcus* clone from postvolcanic substrate on the island of Surtsey (Iceland)

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Morphological variation can be studied only with a clone to assure genetically homogenous material. Such studies are particularly difficult with *Cyanophyceae* because of their small size and the poor morphological differentiation of their cells. The genera *Synechococcus* and *Synechocystis* were until now considered to show little morphological variability in contrast to e.g. some *Stigonemataceae* and *Rivulariaceae.* This was tested with material from the new volcanic island of Surtsey (Schwabe 1972 a,b, 1973, Schwabe & Behre, 1971, 1972).

A large-celled *Synechococcus* species which can be attributed to *S. aeruginosus* Näg. was found in one locality on Surtsey in the course of intensive investigations in respect to *Cyanophyceae* by the first author. The study of cell variability and growth characteristics of this species seemed rewarding because of its relatively large cells as well as of the rare occasion of earliest stages of ecogenesis found on that island. Here other species tend to thrive than in older biotopes.

The localities south of Lýsuhóll, the most recent lava bed of the big crater Surtur I, where *Synechococcus* was sampled is a favourite resting site for birds. Thus it can be assumed that *Synechococcus* was brought to the island by birds, a similar case might be with the accompanying species *Oscillatoria fracta.* Since the first sampling date of *Synechococcus* in summer 1972 the species has spread considerably in the vicinity during the following two years.

From a sample of wind-swept tephra (sampling date: 31 July 1974, start of culture: 27 August 1974) the *Synechococcus* clone was isolated in an nitrogen-poor modification of Zehnder medium. Contrary to other *Synechococcus* species (Syn.: *Anacystis*) this clone could not be cultivated on agar. During the first weeks *Synechococcus* sp. showed a relatively uniform and typical morphological appearance (Fig. 1) with a cell size of 5.5—7.5 × 11—24 µm. Only few larger cells (7—8 × 20—45 µm) were found. From 24 October 1974 the clone remained in the same medium until 24 August 1975. After 60 days the clone stopped growing, then covering only ca. 25% of the bottom of the culturing flask, where it mostly formed a single cell layer. The colour changed from bright blue-green in the beginning to dirty green towards the end of the growing period, which ceased long before nutrient depletion. Thus a resting phase, typical for many *Cyanophyceae,* was reached, conserving viability while resting almost at zero growth rate (Schwabe, 1966).

270 days after the start of the culturing experiment a surprising variety of cell forms was found (Fig. 3). Cells were mostly longer than wide (diameter 4.5—17 µm), rarely spherical, never shorter, which means that they divided rectangular to their long axis. Long cells were thinner (4.5—15 µm) than short ones (15—17 µm). Cell lengths varied between 10 and 90 µm, with exception 170 µm. The longest cells after 90 days measured 45 µm after 130 days 95 µm and 270 days 170 µm. Morphological variability was lower in the center of the colony than at the edges with fewer cells. Typical cell forms were relatively sparse in the senescent culture. Increasing cell length and disturbance of cell division were most frequently recorded. Plasma structure and cell colour indicated that the morphologically abnormal cells were possibly of reduced viability, yet no distinct limit between normal cells and cells with teratism could be found. Cell walls proved to be exceptionally thick; cell wall thickness might serve as a taxonomical criterion in *Synechococcus.*

It is essential to realize that the morphological variability of *Synechococcus* as demonstrated in Fig. 2,3 included the known typical morphological

Fig. 1: Raw culture of *Synechococcus* with *Oscillatoria fracta* and *Schizothrix lardacea.*

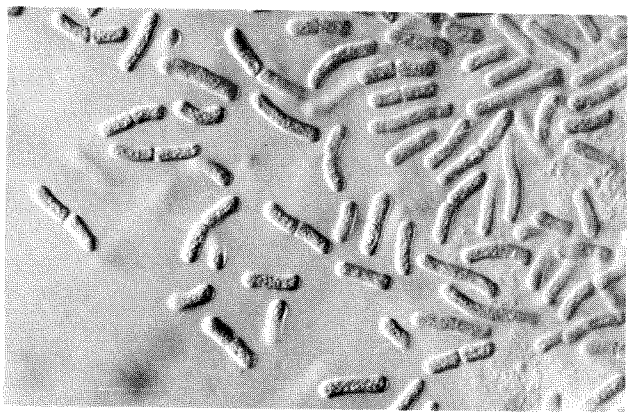

Fig. 2: Clonal culture of *Synechococcus* partly showing elongated cells.

Fig. 3: Same culture as in figure 2, showing more pronounced 'involutionary forms.'

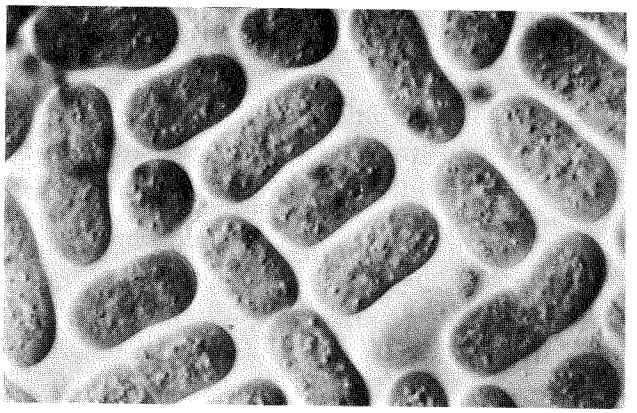

Fig. 4: Typical aggregation of *Synechococcus* in clonal culture.

variety of several species of the genera *Synechococcus* and *Synechocystis.* Taxonomical differentiation of *Synechocystis* from *Synechococcus* by cell morphology thus seems doubtful. However, morphological variability in a natural biotope under favourable growth conditions as well as in the beginning in cultures is much less pronounced (Fig. 1,4). No oblique dividing cell walls and inflated cells are then found except in extreme biotopes like thermal waters (Emoto & Hirose 1940 a,b).

Pure *Synechococcus* populations are rare under natural conditions, being rather found in small colonies in between other algae. Only in biotopes with running water (humid or coarse-grained soils, sprinkling water) they can be more abundant. This lack of larger populations of *Synechococcus* might be explained by the fact of an early growth stop before nutrient exhaustion (which is observed also in cultures of *Oscillatoria fracta*). It is obvious that the *Synechococcus* under discussion could tolerate the extreme physicochemical environmental conditions of Surtsey lava fields. On the other hand, it proves sensitive to competition with other algae.

Both *Synechococcus sp.* and *Oscillatoria fracta* can be considered as fugitive species (Hutchinson, 1951), which grow mainly on sites without competitors, typical for Surtsey at the early stage of ecogenesis. These pioneer species will disappear in the course of further succession, or become rare as on the mainland of Iceland (where *Osscillatoria fracta* does not occur at all).

The genus *Synechococcus* Näg. has been found on Iceland several times (Petersen, 1928, Schwabe, unpublished data). *S. aeruginosus* has been cultivated from a soil sample of Iceland by Møholm-Hansen (Petersen, 1928). The same species was found by Schwabe on crude soil of Iceland in the southern part of Hallormstadir forest (cell size 5.3 — 7 × 9.5 — 12.5 µm) in between *Plectonema* as well as on weathered lava between Reykjahlid and Grimstadir/Mývatn (cell size 6.8 — 9 × 13 — 20 µm) together with many other algae. *Synechococcus* found in Laugarvatnsheidi can be attributed to *S.maior* Schroeter (cell size 6.5 — 23 × 12.5 — 47 µm) according to the taxonomy of Geitler (1932). *Synechococcus* species of small cell size (6.5 × 12.5 µm) were rarely found in between *S.maior* stands together with *Tolypothrix* and some colonies of *Pleurocapsa minor.* Hansg. However, such fre-

quent *Synechococcus* populations as described from Surtsey have not been detected on Iceland. The rare occurrence of *Synechococcus* in apparently favourable biotopes on Iceland is in contrast to the abundant occurence in other thermal biotopes (Castenholz, 1969). The same is the case with the thermal alga *Cyanidium caldarium.*

In culture experiments Pringsheim (1968) and Komarek (1970) showed that a similar variability in morphological characteristics could be induced by different factors such as temperature (>20°C), medium nutrient content and length of cultivation period. This seems to be the case only with certain genera or clones.

In our experiment the small morphological variability ended towards the end of the growing phase. The maximal variability was observed at the bottom of the culturing 100 ml-flask under uniform environmental conditions for all cells. Yet a non-uniform variation in cell forms was observed, the greater variation being at the edges of the colony. Thus it is obvious that some sort of biotic factor may influence the morphological variability of *Synechococcus.*

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