# B I O L O G Y

# Progress Report on Microbiological Studies on Surtsey and the Icelandic Mainland

by

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## Summary of Work

We used the opportunity of visiting Iceland to pursue three independent but related problems, which will be discussed separately below.

## I. Biochemical ecology of *Leucothrix mucor*.

*Leucothrix mucor* (Oersted) is a marine microorganizm that has been studies mainly in the laboratory. *L. mucor* is excellent for autecological investigation because it is large and has characteristic morphological features that can be recognized in natural collections; it grows as an epiphyte on marine algae, and usually its filaments project perpendicularly from the surface of algal fronds, permitting easy microscopic study; it undergoes characteristic morphogenetic changes that are probably of ecological significance; and it is widespread in marine environments, and a study of its ecology may be expected to have some relevance to broader problems of marine microbiology. It is often the most common marine microorganism when viewed microscopically, but it rarely appears on agar plant cultures unless special precautions are taken.

In nature, a wide variety of filamentous and leafy red algae has been found to be colonized with *L. mucor*. The reason that red algae are so readily colonized may be the nature of the algal surface. Red algae do not produce large amounts of mucus or slime, and it would be expected that their surfaces would provide a reasonable degree of stability. Because *L. mucor* will attach to glass or cotton, it does not seem likely that any specific surface properties are required for attachment. Further the red algae comprise many filamentous species, and filaments provide a greater surface area for attachment than would a similar volume of leafy material.

Where the water is still or slow moving, L. mucor is rare, but it occurs at extremely high densities on red algae growing in rapidly moving water. Thus, rocky areas with much wave action or tidal current always provide seaweeds that are heavily covered with L. mucor filaments. Pure cultures of L. mucor grow well in liquid medium only when rapidly shaken, and this is consistent with the requirement of water movement for good growth in nature. It is not clear whether the requirement of water movement is for aeration or for some other purpose.

Geographically, L. mucor is widely distributed in temperate waters. I have isolated pure cultures from seaweeds collected in Puget Sound, Washington, Long Island Soung, Connecticut, Nattag-ansett Bay, Rhode Island and Cape Reykjanes and Faxifloi Fjord, Iceland.

The isolates from Icelandic material are quite typical of the species as a whole. DNA base compositions were run on these isolates in comparison with those from other areas. The data are presented in Table 1.

These data suggest that the Icelandic strains (isolated in both 1965 and 1966) are very similar to other strains isolated throughout the world. These results are consistent with the hypothesis that efficient dispersal mechanisms to Iceland for marine organisms exist.

The technique of microscopic autoradiography with tritiated thymidine was used to study the rate and manner of microbial growth of L. mucor directly in nature. The technique was developed initially with pure cultures, and by relating growth rate to the rate of accumulation of radioactive cells, it was possible to derive a constant which could be used to calculate growth rate in natural material and in two-membered cultures of L. mucor growing epiphytically on pure sultures of marine algae. The growth rate (generation time) in two-membered culture with the red alga Antithamnion sarniense was calculated to be 94 minutes under the conditions used. In nature the growth rate was calculated to be 678 minutes in a sample from Iceland and 660 minutes in a sample from Long Island Sound. There was no evidence of preferential growth in the basal portion of a bacterial filament nearest the algal surface. However, filamentous growth in nature but not in pure or two-membered culture was nonrandom, showing regions where growth was clustered and other regions which were relatively dormant.

These results show that the growth rate of L. mucor in Icelandic material is quite analogous to that in other marine environments.

## II. Ecological observations on Icelandic hot springs.

Ordinarily light and temperature are not independent environmental factors in nature, since the latter is correlated with the former, at least in a general way. Hot springs provide an exception, since temperature remains constant throughout the year, and only light varies. This is especially pertinent in Iceland, where during the winter days are quite short. We have performed biochemical studies on certain Icelandic hot springs, and especially one in the Geysir group which provided an excellent thermal gradient. In late summer (August, 1965) the upper temperature for algal development was around 60°C, which is over 10° lower than in Yellowstone. Chlorophyll, RNA and protain values (which measure standing crop) were also lower than in Yellowstone.

In May 1966 we returned to this same spring to find it completely changed. There was no algal growth above $45^{o}$, and at any temperature the standing crop was so low that we could not take quantitative samples. Clearly, the algae had disappeared during winter, and were just returning. This is surprising when it is recalled that day length in early May is about 17 hours. These results need to be greatly extended. It is especially important to know what happens to the algal mat during the winter.

III. Observations on Surtsey.

The visit to Surtsey was on May 5, 1966, by helicopter. The eruption was quite active from the small island on the south-east side, and most of this side of Surtsey was covered with a thick layer of volcanic ash. A complete circuit of the island was made on foot, but because of the precipitous cliffs it was not possible to examine the shore line as well as the inner island at the same time. Several attempts to climb down from the upper level to the shore line were unsuccessful. Many fumaroles were still active on the south side of the island. These fumaroles provided the only source of moisture, and in crevices surrounding fumaroles condensation occurred. From one rock in such a crevice, microscopic examination revealed a few bacteria, which were very narrow, thin rod-shaped forms ($< 1 \mu$ diam.). As yet these have not been cultivated in the laboratory, so that nothing can be said about their detailed characteristics.

The beach on the north side was washed with heavy waves and was hence a rather unstable environment for macrophytic algae. Sand collected from this beach was examined microscopically the interstitial water contained rare organic aggregates containing very tiny bacteria. These resemble those seen by the authors with Dr. A.L.S. Munro on the west coast of Scotland (Loch Ewe) and have yet been unidentified in both places. It is likely that organic matter from the sea water is absorbing to the sand particles and providing nutrients for the growth of bacteria, in the manner discussed by Brock, T.D., Principles of Microbial Ecology, Prentice-Hall, Inc.

The sea water lagoon on Surtsey was heavily colonized by gulls. When the helicopter landed these were frightened away, and numbered well over 100. The results of their residence alongside the lagoon are well in evidence - extensive fecal deposits in the water and along the edge of the lagoon. Indeed, this lagoon may be considered polluted, or at least eutrophic. Accordingly, it was the location where the heaviest microbial development was seen. On the surface of the lagoon bottom, just near the water's edge, a brownish layer had developed, and in this could be seen large numbers of unicellular chlorophycean algae, and rare flagellates. Since it is well established that water birds can transmit algae, this observation is not surprising. The pH of the lagoon water was 7.86.

No signs of terrestrial plants were seen during the circuit of the island. The continuing extensive deposition of ash on the south side makes any immediate plant colonization unlikely.

The following publications include work done on Iceland under sponsorship of the Surtsey Research Society, in 1965 and 1966.

Brock, T.D. and M.L. Brock. 1966. Temperature optima for algal development in Yellowstone and Iceland hot springs. Nature 209:733-734.

Brock, T.D. and M.L. Brock. 1966. Autoradiography as a tool in microbial ecology. Nature 209:734-736.

Brock, T.D. 1966. The habitat of Leucothrix mucor, a widespread marine microorganism. Limnology and Oceanography 11:303-307.

Brock, T.D. and M. Mandel. 1966. Deoxyribonucleic acid base composition of geographically diverse strains of Leucothrix mucor. Journal of Bacteriology 91:1659-1660.

Brock, T.D. 1966. Microbial growth in the marine environment: direct analysis by autoradiography. Science, in press.

Brock, T.D. Mode of filamentous growth of Leucothrix mucor in pure culture and in nature, as studied by tritiated thymidine autoradiography. Submitted to Journal of Bacteriology.

TABLE 1

| Strain of *L. mucor* | Source | Algal associate | Buoyant density | GC content (moles per cent) |
|---|---|---|---|---|
| | | | g/ml | |
| 1. | Puget Sound, Wash., 1963 | Monostroma | 1.7085 | 49.5 |
| 2. | Woods Hole, Mass., 1959 | Callithamnion | 1.708 | 49.0 |
| 3. | Puget Sound, Wash., 1964 | *Callophyllis haenophylla* | 1.708 | 49.0 |
| 4. | Puget Sound, Wash., 1964 | *Odonthallia flocosa* | 1.708 | 49.0 |
| 5. | California, 1955 | Ulva | 1.708 | 49.0 |
| 6. | Narragansett Bay, R.I., 1965 | None, isolated from sea water | 1.707 | 48.0 |
| 7. | Long Island Sound, 1965 | Polysiphonia | 1.7075 | 48.5 |
| 8. | Long Island Sound, 1965 | Unidentified red alga | 1.708 | 49.0 |
| 9. | Cape Reykjanes, Iceland, 1965 | Unidentified red alga | 1.7075 | 48.5 |
| 10. | Cape Reykjanes, Iceland, 1965 | Ulva | 1.707 | 48.5 |
| 11. | Cape Reykjanes, Iceland, 1965 | Laminaria | 1.706 | 46.9 |
| 12. | Portugal, 1966 | Red alga | 1.708 | 49.0 |
| 13. | Naples, Italy, 1966 | Red alga | 1.705 | 45.9 |
| 14. | Ischia, Italy, 1966 | Red alga | 1.708 | 49.0 |
| 15. | Sudurnes, near Reykjavik, 1966 | Cladophora | 1.709 | 50.0 |
| 16. | Sudurnes, near Reykjavik, 1966 | Red alga | 1.709 | 50.0 |