THE CULTURE OF ALGAE AND ITS APPLICATIONS.

by M. Rosenberg.

During the past three years much time has been devoted to studying conditions of growth of microscopic plants under observation in the laboratory. The cultivation of these organisms has proved to be of importance in a number of related subjects and is of great help in the study of major freshwater problems. The purpose of this article is to point out how the methods and results have application to related problems.

By culture of algae one generally understands that conditions are provided which allow the organisms in question to grow and divide and remain in a healthy condition. The main point is that the conditions for growth provided, such as the nature of the medium, the amount and quality of light, and temperature, must be defined and reproduceable as far as possible. Only when a standard set of conditions is used can satisfactory results be expected concerning the importance of individual factors involved in influencing growth. Unfortunately the provision of standard conditions for these experiments is not yet fully attained because many technical difficulties had to be overcome; for example, the nature of the glass used for culture dishes, purity of chemicals and distilled water for making up synthetic nutritive solutions, have to be carefully controlled in order to get normal growth. The range of sensitivity to impurities and changes of conditions differs considerably among organisms of different groups and this fact is largely responsible for the distribution of algae in a state of nature.

Culture work in the laboratory and observations in the field can often help jointly in understanding causes for the occurrence of an organism in a given environment. For example, by observing the numerical variations of a plant in natural conditions throughout the year, combined with water analyses and measurements of light and temperature in the water, clues are obtained as to the optimum conditions for growth. These clues are then translated into a number of "sets of conditions" in the laboratory, and cultures, started with one single cell, are submitted to these conditions in order to study the combinations of factors. The great advantage of this method in treating problems such as distribution or productivity is that factors which are suspected to be important can be varied independently and their relative values can be assessed. Whereas all observations in the field necessarily have wide margins of error since they deal with very complex systems, laboratory work helps to reduce the number of possible interpretations, and in successful cases gives indisputable explanations. An apparatus for keeping the cultures under conditions of constant light and temperature has now been designed and assures a more exact control of the experiments.

One set of results obtained relates to the control of morphological variations in algae. Changes of shape in the desmid *Xanthidium* in response to different media were mentioned in last year's report, and a paper on that subject will soon be published. In another desmid, *Micrasterias*, which is now under experiment, a new set of conditions gave rise to remarkable half-cells which exhibited striking aberrations from the normal. The actual rate of division was not affected, but the aberrant structures were produced as long as the given conditions of culture were continued. Experiments are continuing in order to analyse in detail the causes of this change. Problems of this nature are of great interest in themselves, and at the same time they develop from a new angle the conception of " indicator organisms " for certain conditions in water.

The importance of the right balance between organic and inorganic nutrition (photosynthesis and salts supplied by the medium) can be shown in other cases, as, for example, with the diatoms *Asterionella*, *Tabellaria* and the bluegreen alga *Oscillatoria*. In the present stage of knowledge, however, a considerable period has to be devoted to trial and error to find the conditions of good growth for each organism before the main experiments can be started.

The fact that physiological requirements differ widely among algae belonging to different systematic groups is the basis of one branch of the theory connected with the evolution of lakes and reservoirs. Many observations in the field support the theory, but extremely little is yet known about the physiological reasons for it. Some of the algae which are held to indicate successive stages in the evolutionary process have been studied, and results so far obtained, even under the imperfect conditions available for culture, show that marked differences exist in their physiological requirements. This is illustrated by the following series of experiments in which the solutions used are similar to some natural waters in the Lake District :—

Milligrams per Litre			Amount of Growth Observed			
$CaCl_2$	K_2HPO_4	NH_4NO_3	*Staurastrum curvatum*	*Closterium Kützingii*	*Dinobryon*	*Asterionella*
2	6.25	12.5	+	+	—	—
4	12.50	25	—	—	—	—
8	25	25	+	+	++	—
12	50	50	—	—	++	+++

This study has yet to be developed by quantitative methods of estimating growth, but it is sufficiently significant that *Staurastrum* and *Closterium*, both characteristic of primitive waters such as Wastwater, flourished best at low concentrations of nutritive chemicals, while *Dinobryon* and *Asterionella*, common species in Windermere and Esthwaite, grew very abundantly at high concentrations and not at all in the more dilute solutions.

In all some 30 species of algae have now been grown long enough to allow the statement that they could be kept in permanent culture if required. The Volvocales (*Volvox aureus* and *V. globator*, *Eudorina elegans*), Protococcales and Ulotrichales show high division rates in relatively concentrated solutions, while desmids will divide best in very low concentrations, 50 parts per million total concentration being a good average for a number of species. Diatoms, especially *Asterionella* and *Tabellaria*, show their optimum division rate with low light intensities, in media with a high ratio of nitrogen to phosphorus. *Oscillatoria*, on the other hand, shows good growth in solutions of low concentration at low light intensities.

Apart from the pure species cultures mentioned so far, parallel raw cultures of phytoplankton have been kept in different solutions, and changes in the proportions of the species present were observed. As a rule Protococcales survive best in these mixed cultures, and increase in proportion to the other species. The changes are interesting to watch because they reproduce, in a rough way, the changes occurring in the natural waters. These raw mixed cultures are necessarily impure : it is intended to set up similar artificially mixed cultures from specially grown pure species cultures, to study the question of competition and division rate in a controlled system, parallel with observations on division rate in the respective pure species cultures.

Studies of phytoplankton in the field have been carried on during the current year in some lakes of the district, and have included sampling many of the small tarns. A paper summarising most of the data obtained is in preparation. The interesting case of Loch Leven in Scotland was under observation for some months during 1937.

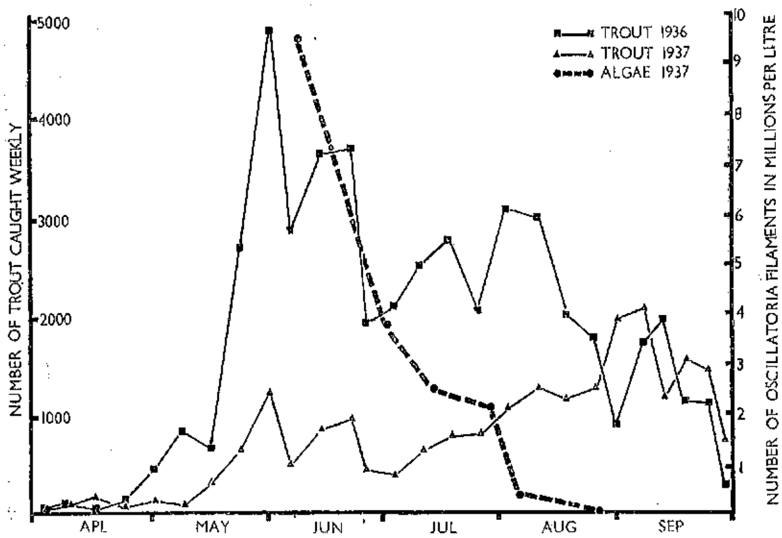

FIGURE 6. Algae and Trout in Loch Leven, 1937. The fishing season was extremely poor during the early part of the season, but improved to normal as the number of bluegreen algae decreased.

This important trout-fishing loch was suffering from a sudden maximum growth of a bluegreen alga *Oscillatoria Borneti*, which coloured the water brown. Parallel with this growth there was a marked decline in the numbers of fish caught as shown in figure 6. As the algae disappeared, however, the weekly catches of fish returned to the normal. The concentration of algal filaments, which is greatest in the surface layers, apparently forced the trout to remain in deep water, though the cause for this could not clearly be seen. The alga has been taken into culture and its physiological requirements are being worked out. This and other intense growths of bluegreen algae in fishing waters were discussed in a paper mentioned on page 32.