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**Taxonomical Studies of Marine
Dinoflagellates.**

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In Northern coastal waters as well as in the ocean dinoflagellates occur at some seasons so abundantly that they are predominant in the phytoplankton. Although we are unable to estimate quantitatively their part as producers, it may be justified to characterize them side by side with diatoms and coccolithophorides as the main producers of the sea.

For the study of the ecology and physiology of this important group a knowledge of its taxonomy, the demarcation of the taxonomical units, is most essential. Recently an important contribution to this field has been issued. At his death in the spring of 1947 the late Danish botanist Professor Dr. Ove Paulsen left behind a manuscript: "Observations on Dinoflagellates", which recently has been published by Mag. scient. Jul. Grøntved (Paulsen 1949). Here professor Paulsen discusses a number of general problems of great importance for obtaining a satisfactory demarcation of the taxonomical units within this group.

When the terms species, forma and varietas have a different value within the various groups of organisms, the causes are several. One of them is the fact that within one group sexual reproduction may be predominant, within another the asexual form. In dinoflagellates sexual reproduction has only been recorded for freshwater forms (Diwald), while for the marine species the question is open. So far no direct observations are recorded indicating that sexual reproduction is of any consequence for the formation of the huge populations occurring in the sea. This fact, however, does not preclude that in certain periods of life sexual reproduction may occur regularly, f. i. in connection with the germination of resting spores or other resting stages. In his

discussion Paulsen assumes that in the sea only asexual reproduction occurs and his considerations are based upon this assumption. With a reservation as to this point, Paulsen's discussion is most valuable. He points out that the dinoflagellates — and here as in the following it is only referred to the marine species — in their taxonomy conform with groups of higher plants, where asexual reproduction is predominant. In such groups genotypic changes are fixed in the clone developing from the individual wherein the change has taken place. These clones are genotypically different from the rest, although the difference may be only small. Consequently, Paulsen argues, they represent taxonomical units which in dinoflagellates deserve to be named species.

In species with sexual reproduction the continuous recombination of genically different gametes leads to an uneven distribution of the small differences within a natural population.

Paulsen suggests that the variability in dinoflagellates is of two kinds, 1) modifications, possibly governed by external factors, which lead to phenotypes that are not constant, but capable of varying in different directions; the resulting differences should be called "forma"; 2) genotypic changes, possibly mutations, which produce new biotypes or what we may call "species". The abundance of morphologically different units would seem to have a similar cause in dinoflagellates as in such vascular plants which mainly reproduce asexually (*Hieracium*).

With the theoretical discussion as a background Paulsen discusses and criticises the larger taxonomical works of the last decades, since the publication of his fundamental monograph in *Nordisches Plankton* in 1908 (Lebour, Kofoid and Skogsberg, Lindemann, Lefèvre and Schiller). The most recent one of these is the two-volume monograph by Schiller in Rabenhorst's *Kryptogamenflora* (1933—37).

In his treatise Schiller tried to unite various types which had been described as species, into larger taxonomical units, merging a number of forms which seem to be connected through intermediates with the species lending its name to the unit. A work of clearing up is a natural step in the taxonomic study of a group. Paulsen finds, however, that Schiller has gone too far, in a number of cases having united forms which obviously have no direct con-

nection with each other. Paulsen's criticism is based upon his unique knowledge of the dinoflagellate populations of the North Atlantic and the Mediterranean. Considerable attention must, therefore, be paid to this part. Critical remarks are also made upon Schiller's demarcation of the large groups e. g. of sections within *Peridinium*, of the arrangements into families and orders, remarks which are going to be of great use for later monographical treatments of the group.

When the taxonomy of dinoflagellates is still rather unsettled, one of the causes is that for most of the forms too little material of observation is available. This is clearly illustrated in Paulsen's work. On the basis of a very large material from Icelandic waters Paulsen has given a taxonomic discussion of the genus *Dinophysis* of this region, and as far as one may judge, with excellent results. Everybody who has worked on phytoplankton, especially on quantitative samples where also the smaller forms may be found, have experienced that this genus represented a serious obstacle for the identification to species. The taxonomic demarcation of the species has not corresponded to conditions in nature. Paulsen's treatment, including *i. a.* a splitting of the forms previously named *D. acuminata*, leads to a taxonomic grouping which is felt to be convincing. The actual test of its validity, can, however, only be made when the new system has been used on material from various localities.

For the study of dinoflagellate ecology the present taxonomic basis is, however, on the whole still inadequate. The problem is how a further advance may be achieved. Paulsen suggests that cultures may be of great help.

In the following I may in a couple of examples indicate in which way persistent cultures, and primarily clone cultures grown from a single cell, may throw light upon taxonomical problems.

In 1905 Paulsen described a small *Peridinium* species under the name of *P. faeroense*. This species Schiller (*l. c.*) merged with *P. trochoideum*. Braarud (1935), from his examination of a material from the coast of Greenland, concluded that it was very difficult to distinguish the two species.

For a number of years I have cultured *P. trochoideum*, represented by two clones. The cultures were used for physiological

servations during the quantitative work were therefore difficult and required much time. A special apparatus, described by Haller Nielsen (1950), makes such observations considerably easier. In the sedimentation samples dinoflagellates may by means of this apparatus be turned over without difficulty and may also easily be transferred to a slide for further examination.

In order to get a sufficiently large material for observation larger samples ought to be collected for sedimentation than now commonly done.

Professor Paulsen's posthume work forms the conclusion of a life-long study of the taxonomy of marine dinoflagellates. It contains a wealth of observations and discussions based upon his long experience and sound judgement and represents a worthy inheritance for the benefit of coming generations. It is going to be of great value for the further study of the taxonomy of dinoflagellates, although in future also other lines of research may be followed than those which have characterised professor Paulsen's epoche in the taxonomical exploration of the plant plankton.

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