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TAXONOMY OF ALGAE

T. V. DESIKACHARY

University Botany Laboratory, Madras-5, India

ABSTRACT

Principles of Taxonomy, especially pertaining to the Algae are discussed at length. Though primarily based on morphology, other criteria, such as reproduction and life history flagellation, cytological details, pigmentation, nature of metabolic products, etc., play a distinct and sometimes a significant role at different taxonomic levels in the Algae. In referring to the place of Phylogeny in the Taxonomy of Algae, it is shown that Phylogeny has played a vital role in the past and would, equally in the future, play its part in Taxonomy of Algae like any other discipline.

It would be a near impossibility that I can deal at any great length the problems in the Taxonomy of Algae. I intend to deal with the aspect in a lengthier article elsewhere. In the present paper I intend to summarize what appear to be the criteria used in the Taxonomy of Algae. Taxonomy as such has been subject of many erudite papers in the past two decades. With more knowledge accumulating from disciplines other than morphology the discussion has tended to shift on the value of evidences or criteria derived from disciplines other than morphology in taxonomic practices. Naturally controversies have developed and are no where more evident than in the Angiosperms. Algologists and Algae are probably in a more fortunate position. While there has been a certain amount of disagreement on the Classification there has not been that intense controversy. Naturally I do not intend to analyze taxonomic criteria from a debating angle but from an elucidative angle as a student of algal taxonomy. The present analysis is borne out of a study of a number of papers by eminent algologists who have in discussing taxonomic categories have expressed opinions which made them to retain, create or abolish the taxa. In other words these criteria have evolved out of time by the accumulated contributions of great minds to whom we owe our present systems. These criteria are presented more as lines influencing thought rather than as rules or principles that bind taxonomists. In other words rigid positions need not be taken in fields which are growing both in quality and quantity.

Morphological characteristics have been and will remain the main bases for classification and taxonomy of Algae as of any other group of plants. Morphology has been the only basis of classification till about the beginning of this century when other criteria gradually emanated evolving as it were. Most genera and families of Algae are based today on morphological characters. At the ordinal ranks there has been a tendency for stabilization of the different orders on a morphological basis. The pioneer contribution in this is that of Pascher (1913, 1914, 1921, 1929, 1931, 1937, 1939) who stressed the parallelism that exists between certain groups of Algae in their morphology and to Fritsch (1928, 1929, 1935) and to Smith (1933) we owe for the elaboration of this concept. Fritsch (1935, p. 27) stressing on this point says, "The history of algal taxonomy is full of examples of the non-recognition of this fact having led to the grouping together of species that belonged to quite different classes". Naturally orders have been established in other phyla in a manner similar to the orders that have gradually evolved in the green algae during the last century and in the present century. These orders were primarily based on thallus construction. Notwithstanding this apparent uniformity there has been a divergence of opinion followed by a progressive or gradual elaboration of more orders based on cytological characters, modes of reproduction etc. The arguments for and against these orders rest on the stress laid by a taxonomist on one or more of the other criteria which I shall discuss a little later here.

Much knowledge has accumulated on the submicroscopic morphology of Algae based on Electron Microscope studies. Many aspects of taxonomic importance have been derived from these studies. The extent to which these can be used successfully in classification cannot be very definitely stated. Kolbe (1948, 1951), Helmcke and Krieger (1953/54), Braarud (1954, 1955), Halldal and Markali (1954 a and b, 1955), Harris and Bradley (1957) and Petersen and Hansen (1956) working on different groups of algae envisage the use of Electron Microscope studies in taxonomy. Hustedt (1952, 1955) doubts their taxonomic value. Parke *et al.* (1954, 1956) and Desikachary (1956, 1957, 1958, 1959) favour a cautious and positive role, for Electron Microscopic studies in taxonomy. Electron Microscope studies so far as taxonomic utility is concerned are still in their first step. A real assessment of their taxonomic role can be made only after many existing taxa are studied and a fuller understanding of their relation to evidences derived from studies with the optical microscopes. In a

recent paper Parke (1961) very aptly summarized the position. "From the relatively few electron microscope studies—few compared with those on diatoms —on members of the Chrysophyceae, it is obvious that the results obtained so far that electron microscope observations are essential, most particularly for the very small forms, before they can be adequately described and placed in their true position in the class. But, data from this source must very definitely be supplemented by observations under the light microscope on gross structure, and particularly on behaviour of living cells, so that if it is humanly possible, a species can be recognized by future workers, without having recourse to an electron microscope check for every single small individual observed before being able to name it." "The greatest value of the electron microscope observations on chrysophycean forms will be in the help they will give in finding the true phylogenetic relationship between the forms placed in this class."

Culture work not only elucidated the range of morphological variation but also has served as a tool for the elucidation of life histories. Of these latter the more important cases are those which have proved that certain algae have in their life-cycles stages which resemble one or more of the commonly recognised genera. Those life histories which have shown heteromorphic stages have aroused considerable interest not only as patterns of life cycle but also in the taxonomy of the genera (Pringshein, 1950). Papenfuss (1950) has reviewed these aspects in a very exemplary way and stressed the need for such studies. Instances of life histories such as have been reported in *Chlamydomonas variabilis* and *Carteria ovata* (Behlau, 1939), *Chlorobrachys gracillima* and *Pyrobotrys gracilis* (Strehlow, 1929; Behlau, 1935), *Schizochlamys gelatinosa* with *Placosphaera, Urococcus* and *Coelastrella* stages (Thompson, 1956), *Tetraspora gelationosa* with *Apiocystis* stages (Hirose, 1954), *Codiolum* and *Chlorochytrium* stages in *Urospora* (Jorde, 1933), *Acrosiphonia* (Jonsson, 1957, 1959) and *Spongomorpha* (Fan, 1959; Jonsson, 1959), *Halicystis* and *Derbesia* (Kornmann, 1938), *Bonnemaisonia asparagoides* and *Hymenoclonium serpens, Asparagopsis taxiformis* and *Falkenbergia hillebrandii* and *Asparagopsis hamifera* and *Trailiella intricata* (Harder and Koch, 1949; Segawa and Chihara, 1954; Feldmann, J. et. G. 1942), *Porphyra* and *Conchocelis* stages (Drew, 1949; 1954a and b) and *Cutleria* and *Agalaozonia* (Reinke, 1878; Falkenbey, 1879) do raise taxonomic and nomenclatural problems in someways very similar to that met with in the pleomorphic life cycles in Fungi. The situation, however, is not so vast but yet technically is the same. In many cases one does not know the behaviour of all the species of a particular genus as regards the life history patterns and naturally one may have to retain a 'form genus' to include the residual species of genera without creating more genera which may not ultimately stand. These 'form genera' may be considered purely as temporary rest houses for receiving the residues till their life histories are fully worked out.

Cell structure including Karyology has played a great role in distinguishing some orders. For example the elucidation of the segregative cell division by Boergesen (1913) led to the creating of the order Siphonocladales. The work of Hammerling (1931, 1934, 1944) and other workers on the nuclear behaviour in *Acetabularia* has largely influenced workers in recognising the order Dasycladales. The structure of the chloroplast has led some to the recognition of the Prasiolales. Multinucleate condition has been recognized as a characteristic feature of some orders, for eg., the Siphonales and similar orders in certain other classes. Chadefaud (1936, 1954, 1960) is probably the most eminent of recent workers who have worked to mould taxonomy on the basis of plastid and other cellular characters. While his work has attracted the greatest respect their impact on taxonomic practices is yet not felt or accepted (see also Feldmann, 1954). Phycology is yet to utilize evidences derived from cytogenetic studies and what is known of algae is no way comparable to that existing in the higher groups of plants. Studies on the structure of the flagella by Manton, Parke and their collaborators have helped us to understand the interrelationships of the Chrysophyceae and their taxonomy.

Biochemical studies though they do not play the vital role that they play in taxonomy of some other groups have acquired a significant position at higher as well as lower taxa levels. Among these the two important aspects are pigmentation and nature of photosynthetic reserve food material. Lamouroux (1813) and Harvey (1836) were probably the first who laid stress on the color of the alga in recognizing the algal groups. At the present day with intensive studies on algal pigments and with greater realization of the vital roles they play in photosynthesis Algae are divided into a number of classes based on pigment characters, and, together with other characteristics such as flagella etc., into a number of phyla. The importance of these criteria derived from pigment studies can easily be surmised from the fact that when one is in doubt of the systematic position of any alga it has now become a reliable taxonomic practice to clinch the issue by examining the pigments. I would cite here two examples of genera of algae in which the criteria used for deciding their taxonomic position reveal themselves very clearly, viz. *Vaucheria* and *Botryococcus*.

Vaucheria and *Botryococcus* represent two instances of genera which were included in the Chlorophyceae and Xanthophyceae and which workers consistently sought to include in Xanthophyceae and Chlorophyceae based on evidences derived from diverse disciplines.

Vaucheria was till recently included in the

Siphonales of the Chlorophyceae. The work of Vlk (1938) and Koch (1951) on the presence of two types of flagella, the tinsel type and the whiplash type, the work of Seybold, Egle and Hulsburch (1941) and Strain (1948) on the nature of pigmentation in the alga and its relation to the pigments known in the Xanthophyceae and the Siphonales and the still more recent investigation of Greenwood, Manton and Clarke (1957) showing that the compound zoospore has pairs of unequal cilia, all these evidences derived, as may be seen, during a period of years have cumulatively been responsible for the final transfer of the genus to the Xanthophyceae, after a lapse of 50 years since it was first suggested by Bohlin (1901) and Blackmann and Tansley (1902).

The genus *Botryococcus* was established by Kützing in 1848. Even till 1954 (Fritsch, 1954; Smith, 1950) workers had doubts that this alga might be a Chlorophyceae but the presence of cell-walls which are made of two halves (Blackburn, 1936; Geitler 1925) and presence of oil have been responsible for its location in the Xanthophyceae (Pascher, 1925). Starch has been reported in this alga by Chodat (1896), Blackburn (1936) and by Vlk in Pascher (1937-1939). This has been the turning point in its taxonomic position and Pascher (1937-1939), Prescott (1951), Papenfuss (1955) and Fott (1959) have transferred Botryococcaceae with *Botryococcus* to the Chlorococcales in the Chlorophyceae. Fritsch (1954) opposes this idea and in fact he cites *Botryococcus* as an example of an anamoly if it were transferred to the Xanthophyceae because of oil in its cells. Fritsch considered that production of starch in *Botryococcus* and oil in *Vaucheria* as due to experimental or environmental conditions. He of course pointed out that the nature of pigments has not been worked out in *Botryococcus*. Blackburn (1936) has pointed out that the color is bluish green and not yellow green. Belchor and Fogg (1955) have found that starch is present in *Botryococcus* and that Chlorophyll *b* is present along with Chlorophyll *a* in the same proportion as they are in higher plants. Chlorophyll *b* is absent in Xanthophyceae. They have also shown that the other soluble material of *B. braunii* to be largely made up of unsaponifiable lipoid rather than true fat. Thus *Botryococcus* has become incontrovertible green alga.

Physiological and autoecological studies no doubt led to a better understanding of the variation of the form in the algae as in any living organism, really more so among some algae. But such studies have really led to another knotty problem viz. polymorphism. Blue green algae probably are the worst affected in this aspect. Polymorphism has been known among these algae for many years. Such variations have cast a doubt on the validity of many genera of the blue green algae especially the coccoid forms. Polymorphism has also been reported among the Hormogonalen forms too, both in nature and in culture too. One may doubt whether such variations represent taxonomic repurcussions leading to a basic doubt on the validity of families and even orders. Or do they represent certain plasticity of characters and reflected affinity. What is now needed is the working out of forms which are collected in nature representing variants of polymorphs and study if they have any significant variation and each variant collected in nature exhibit the total range of variations. In other words one would like to know if hormogonalen homocystous forms do produce heterocystous forms as the latter do produce the former in cultures. In other words one would need the range of variations in forms collected in nature representing the various culture variants and find if they all behave similarly giving rise to the whole range of forms. Such divergent and convergent studies of variation is needed before any taxonomic conclusions are drawn based on polymorphic behaviours of some forms. Probably it is better to leave taxonomy alone and study the polymorphism of more and more species and genera and await taxonomic revisions after a large amount of data accumulates.

Lastly we come to a very controversial aspect namely phylogeny and its place in taxonomy. Opinion in other plant groups have tended to extremes. As a scientist any evidence derived from all accessory disciplines must be welcome to the taxonomist and would ultimately lead to an integrated knowledge of life and life patterns. Hypothesis such as phylogeny though primarily derived from an understanding of the morphology and life history of organisms yet represents a mental synthesis of life processes in the past and the present and would naturally serve as summations of man's knowledge of the organisms. In any mental process classifications which tend to reflect man's understanding of the organisms must be welcome as then it would focus attention of the succeeding workers and would thus be open for revisions and alterations. Phylogeny then and taxonomy as always are progressive sciences and always open to changes. If one attempts to analyse taxonomic changes brought about by phylogenetic considerations probably the latter may be playing significant but smaller roles than the former. I plead that phylogeny be given no great stress and no great dishonour in taxonomy. Each thought process be allowed to play its role in taxonomy and the latter would then represent an ideal to which every discipline would contribute its might and make taxonomy more dynamic rather than a simple descriptive science.

Evolutionary considerations have played their part in the past in the recognition of taxa. Most often these are based on comparative morphology and more especially on ontogenetic studies. It would be beyond the limits of this paper to give a detailed

consideration to this aspect. For instance if one takes the arguments for the creation, retention and location of any of the orders Tetrasporales, Sphaeropleales, Chlorococcales or Chaetophorales one sees in the arguments of the various authors considerations of evolutionary significance tending to decisively influence them. Yet these very authors have in their study of the different algae have greatly contributed to our present day knowledge of not only the algae themselves but to phylogeny in general. It would be futile to cast the valuable thoughts put forward by these very authors. One should be cautious against too frequent changes in taxonomy on narrow evidences as against clinching facts derived from any discipline while at the same time the taxonomist should be receptive to all ideas brought into taxonomy.

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