

Taxonomy of Blue-Green Algae – Problems and Prospects¹⁾

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For a long time blue-green algae did not incite the enthusiasm of many workers, and the taxonomy of this group was taken for granted. Almost all workers depended on classical treatises like those of GEITLER [7]. Ideas on polymorphism, though known for more than a century, did not greatly affect the taxonomy of the group. Documented evidence based on culture studies was lacking. Since the beginning of the last decade, there has been intense activity in this group not only on the physiological aspects but also on taxonomic aspects. I would deal here only with the problems in the latter aspect.

We are grateful to DROUET [2] for having awakened algologists to the potentials of the blue-green algae. They have become aware not only of the extent of variability shown by some of the forms but also of the pitfalls in basing decisions on ideas of variation derived solely from herbarium specimens and more so from herbarium material of aggregates of freshwater species. What we need is a test of taxonomic concepts, that emanate from such studies by experimental work, both autecological and synecological studies.

The difficulties inherent in accepting straightaway any gross taxonomic revisions are apparent. Comments on the DROUET and DAILY's [2] revision of the coccoid forms (1956) have appeared repeatedly, and I have summarised these in our paper (PADMAJA and DESIKACHARY [9, 10]). If there are any doubts in respect of the totality of this revision, it would be advisable not to implement it or to use the newer concepts until we are able to adduce more convincing evidence in support of *this revision*. I would appeal for a cautious approach in accepting any wholesale revision of this type. Should other biologists use the binomials in the revised concepts, we would be faced with problems in integrating knowledge thus published under a single binomial which probably may later prove to be made up of a number of recognizable species. The process of verification and analyses would be more cumbersome than if we used the binomials with a restricted circumscription. It is relatively easier to compare and analyse biological material even though the data are published under different binomials should it prove later that they are really conspecific or denote one and the same taxon or organism. In a sense, this should caution us against accepting any drastic revision of large groups of organisms leading to the recognition of only a few entities

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before a thorough understanding and evaluation of reasons have been made. It must be remembered that DROUET and DAILY's [2] revision is based on their own observation and not the cumulative effect of a number of investigations presenting data compelling a revision. Their observations are not fully documented according to the desires of an experimentalist in modern biology.

DROUET's [2] revision of the Oscillatoriaceous members (1968) has forwarded newer concepts and problems before we had even stabilized our ideas on the coccoid forms. Probably it is time that we turn our attention to these and, even more so, to the heterocystous forms at an early date. Till then we have no way of either accepting or rejecting these taxonomic revisions. For a long time to come his ideas will remain concepts.

The situation as it now exists really does not allow any rest but must compel us to plan and put into action a systematic and organized study of existing taxonomic criteria and a search for newer criteria. Only after such studies we will be able to assess and arrive at a relatively accurate and better understanding of blue-green algal taxonomy. In other words, we may have to depend on experimental taxonomy involving methods well known to bacteriologists. It appears the existing system of classification serves our purposes very well though one cannot rule out that fresh circumscriptions may be called for.

In a recent paper we have presented evidence of morphological and biometrical variations in the alga often called *Anacystis nidulans* (PADMAJA and DESIKACHARY [10]). We, as well as many other workers, have studied other coccoid species and genera in the past few years (see PADMAJA and DESIKACHARY [9]). In the past, cell dimensions were represented as ranges expressing minima and maxima. This naturally lead to difficulties in the description of a species when other species had overlapping ranges. Suggestions have been made that we can as well give frequency distribution, arithmetical mean, and S.D. (see PADMAJA and DESIKACHARY [9, 10] for references; see also WHITTON [11]). Other methods of data analyses have been adopted by GOLUBIĆ (8). We have tried using cumulative frequency curves and IQR values and found that they are expressive of the range of dimensions and may be considered useful in circumscribing species. We would request that other investigators try the validity of using IQR values in their studies.

The position is probably easier when we come to the Hormogonales. Here we can use many characteristics such as cell length, breadth, number of cells per filament, heterocyst dimensions, spore dimensions, ratio of number vegetative cells to heterocysts and spores, heterocysts to spores, type of heterocysts (terminal or intercalary), branching, etc. The characteristics may be studied under varying conditions and methods evolved to express these variations in less empirical terms. We have become accustomed to studying these algae under natural condition (i.e. see FJERDINGSTAD [3, 4, 5, 6]). But it is now essential to study the extent of variation in these characteristics in any taxon under different milieu i.e. under different culture conditions. Presence or absence and even size and frequency of heterocysts can be affected or influenced by lack or concentration of nitrates in the medium, organic sources of nutrition, etc. Similarly spores are affected by nitrates, sulfate and phosphate concentrations (see WOLK [12]). Sodium chloride is said to promote spore formation. We do not know, of course, whether all the species of a genus behave similarly or identically and how

all the genera of a single family behave. Their tolerance of higher levels of NaCl concentrations may vary. Knowledge of this may help us to decide whether there are purely marine or freshwater species or whether there are species which can withstand extremes of salinity conditions such as exist in estuarine habitats. Sulfates do influence the size of cells and cause involution forms. Similarly phosphate and potassium increments influence blue-green algae in other ways. The aim is to study the many species or isolates or entities simultaneously or comparatively in different nutrient media. Here again we do not have to fabricate fresh media. We already know a number of culture media which have been found as well suited for growing a number of organisms and these can be used with advantage. One could easily select a number of different culture solutions such as Chu No. 10, Allen and Arnon's, etc., and study the effect of varying the different constituents. These solutions may be used by others in similar studies and where facilities exist under different temperature and light regimes. It is one thing to find a nutrient solution which produces optimum growth of any given organism or to study the physiological effects of such ionic changes. These, of course, are fields in which a number of workers are concentrating but with fewer species. Such investigations certainly yield excellent ideas on the influence of different nutritional factors. What is needed at present in taxonomy is a comparative study of the pattern of variations exhibited by different isolates (species? or varieties?) and an assessment of the degree of distinction of each taxonomic entity. It would then be ideal to have a correlation with the existing concepts on species delimitation or even generic circumscription. It would therefore be necessary for purposes of these investigations not to get involved with typology. It would also be necessary to designate or use for these limited purposes an organism, a culture or an isolate of a species of a genus which is available and which has been studied by a number of workers. I am thinking, for instance, of species like *Anabaena cylindrica* when studying species of *Anabaena* and *Nostoc muscorum* when studying *Nostoc*. Other investigators who may make similar studies but would not like to deal with a large number of species or isolates and would like to restrict themselves to a study of locally available species or isolates may be persuaded to study one of these known species along with their isolates. Through such comparative studies, we might understand different entities and assess the taxonomic distinctness or taxonomic distance between them, and when the number of isolates are large enough, we can also arrive at a picture of their taxonomic distances from a central species. The concept is the same as that of a nomenclatural type in classical taxonomy. Only, as we are dealing with living material, we may have to perforce select another reference material (or species) which is available as a culture. If this reference organism happens to be the type of the genus itself it would be well and good. Until we are able to get the culture of an isolate of an organism relatable to the type we have to be satisfied with another species.

What is expected from such studies is not any quantitative data or precise ideas of every individual's reactions, but a broad and general comparative idea of the behaviour of different putative taxonomic entities. Can we hope to separate different entities by behaviour patterns? Or will we be able to separate these on the basis of what can be roughly put down as one taxonomic entity, one behaviour pattern or set of reactions? These are the questions that we may pose ourselves in using any data, qualitative or quantitative, that we may gather. I am optimistic.

When we have accumulated enough data and fully understood the variability of taxonomic characteristics and the relative stability of different entities, species or varieties, we could try to correlate them to species in classical concepts and arrive at a meaningful reconciliation between classical and revised taxonomy. Till then it would be appropriate that routine investigations dealing with floristics use the classical taxonomic treatises like that of GEITLER [7] (see also WHITTON [11]). This, according to me, is the only prospect that I can envisage for the present. It is only through the cooperative efforts of many individuals and divergent studies of the same isolates, species and genera under different ecological or cultural conditions that we can test and perfect taxonomic criteria, which one or more workers may have evolved. This is not to say that we will all agree on every taxonomic concept. Owing to the very nature of the algae that we are dealing with, divergent opinions are bound to exist, but we can neutralize differences and bring them to the level of discussion and understanding.

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Summary

Only in the past 10 years has attention again been focused on the blue-green algae. Physiological problems are doubtless the main point of interest. However, aside from this, several specialists are studying the taxonomy of this group of algae; they are unanimous in their conviction that the systematic of the blue-green algae must be revised with due consideration given to the plasticity, i.e. *polymorphism* of many kinds. Experiments were also carried out to this end (DROUET and DAILY). Yet the results were unsatisfactory because the revision was mainly based on herbarium material.

Many taxonomic groups must be redefined, which presupposes *autecologic* and *synecologic* studies. Moreover *statistics* of biometric-morphologic data and new taxonomic criteria are necessary. Particular importance must be attached to the *cultivation* of the forms in question by growing them parallel but in different culture media so that the degree of variation of the taxonomic characteristics can be determined. In this way the old classical system can be revised with the help and collaboration of all specialists.

ZUSAMMENFASSUNG

Erst seit den vergangenen zehn Jahren befasst man sich wieder mit den Blaualgen. Wohl bilden physiologische Probleme das Hauptinteresse. Ausserdem aber beschäftigen sich mehrere Spezialisten mit der Taxonomie dieser Algengruppe, wobei man einstimmig der Ansicht ist, dass die Systematik der Blaualgen unter Berücksichtigung der *Plastizität* bzw. des *Polymorphismus* vieler Formen revidiert werden muss. Es sind denn auch Versuche in dieser Richtung gemacht worden (DROUET und DAILY). Sie befriedigen aber nicht, da diese Revisionen hauptsächlich anhand von Herbariummaterial durchgeführt worden sind.

Viele taxonomische Einheiten sollten neu beschrieben werden. Dazu wären *autökologische* und *synökologische* Studien notwendig. Ferner wird die *statistische Bearbeitung* der biometrisch-morphologischen Daten alter und neuer taxonomischer Kriterien gefordert. Besonderes Gewicht muss

auf die *Kultur* der fraglichen Formen gelegt werden, indem sie in unterschiedlichen und parallelen Nährmedien gezogen würden, so dass die Variationsbreite der taxonomischen Merkmale festgestellt werden könnte. Auf diese Weise und in gemeinsamer Anstrengung aller Spezialisten wird es möglich sein, das alte klassische System zu revidieren.

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