Butler University Botanical Studies

Volume 12 Article 4

Morphology

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Butler University Botanical Studies

(1929-1964)

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The *Butler University Botanical Studies* journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana's vegetation in past decades. Authors were Butler faculty, current and former master's degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler's first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner , included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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species and the application of its name can be judged only from the literary excellence of its description and the artistic excellence of its illustration, not from the plants which the author studied.

A list of the active researchers on the coccoid Myxophyceae since 1890, in addition to those mentioned above, would be too long for inclusion here. Some of the more notable have been G. S. West, A. Forti, N. L. Gardner, O. Jaag, L. Geitler, H. Skuja, A. A. Elenkin, P. Frémy, M. M. Hollerbach, A. Ercegovic, Giuseppe de Toni, and Y. Bharadwaja.

General treatments of the classification of the coccoid Myxophyceae along Nägelian lines, with minor innovations, were made by O. Kirchner in Engler & Prantl, *Natürl. Pflanzenfam.*, vol. 1(1a) (1900), by A. Forti in de Toni, *Sylloge Algarum*, vol. 5 (1907), by J. Tilden in *Minnesota Algae*, vol. 1 (1910), and by others. In 1923, A. A. Elenkin in Not. Syst. Inst. Crypt. Hort. Bot. Petropol. 2 (5) introduced a classification of the Chroococcaceae which proceeded much farther than Nägeli's did to enhance the generic and suprageneric value of the gelatinous matrix. This system was elaborated in his *Monographia Algarum Cyanophycearum, Pars Specialis*, Fasc. 1 (1938).

Geitler in Beih. z. Bot. Centralbl., II., 41: 163—294 (1925) summarized the Nägelian classification of the Chroococcaceae with its attritions during seventy-five years and created a new series of families and genera in the groups treated in the present paper as Chamaesiphonaceae and Clastidiaceae. This classification has been further refined in his larger works in Rabenh. Kryptogamen-Fl., ed. 2, vol. 14 (1932) and in Engler & Prantl, *Natürl. Pflanzenfam.*, ed. 2, vol. 1b (1942).

In 1939 we (in Field Mus. Bot. Ser. 20: 67—83) published the results of a tentative inquiry into the life histories and nomenclature of species of Microcystis. Daily, using a similar procedure, treated the Chroococcaceae of Ohio, Kentucky, and Indiana in Amer. Midl. Nat. 27: 636—661 (1942). In *Manual of Phycology* (G. M. Smith, ed.), p. 159 ff. (1951), Drouet briefly summarized the morphology of the three families included in the present paper. We later published a synopsis of the present classification, with keys, and formally introduced the new family *Clastidiaceae* in Butler Univ. Bot. Stud. 10: 220—223 (1952).

MORPHOLOGY

THE PLANT.—This term is employed here to indicate a single free cell or a group of cells joined together, usually in a gelatinous matrix. A specimen or single collection may contain many plants of one or few cells

mixed with other algae; it may be a single entire globule, cushion, or stratum, or a part of one of these. In the Chroococcaceae and some species of Entophysalis, plants of the same species may be found in the form of strata, cushions, or globules (both microscopic and macroscopic), or as free unattached cells.

THE CELL.—In this paper, the term is restricted to the protoplast. Essentially the cell is a mass of protoplasm, containing no differentiated nucleus, and surrounded by a membrane. Gelatinous material is secreted through this membrane to form a sheath or gelatinous matrix about the cell. The protoplasm contains various chlorophyll, xanthophyll, and phycoerythrin pigments, and always the blue pigment phycocyanin. Granules of diverse natures and sizes may be distributed through the protoplasm. Glycoproteins are the end-products of photosynthesis. In some species, especially those of the plankton and those persisting under anaerobic conditions, pseudovacuoles are found. These are irregular in outline, black in transmitted light and red in reflected light. Cell division proceeds by fission, a process in which the cell constricts gradually until the two daughter cells separate and are pushed apart by the gelatinous material secreted; in other cells, membranes grow centripetally through the protoplasm as the constriction proceeds, until the daughter cells are separated by membranes, not by gelatinous material. After division has taken place, the daughter cells enlarge and change in shape so that they resemble the former mother cell. The rate of such regeneration is of course dependent upon environmental conditions, just as the rate of division must be. It is therefore reasonable to admit considerable variation in size of cells in a species, even in various parts of the same plant, according to the nature of the contemporary environment during growth. In the Chamaesiphonaceae, certain cells enlarge and divide internally into many small endospores. The single cells in the Clastidiaceae divide internally into usually uniseriate filaments of numerous cells. Geitler in Engler & Prantl, *Natürl. Pflanzenfam.*, ed. 2., 1b (1942) and F. E. Fritsch in *Structure and Reproduction of the Algae,* vol. 2 (1945) have reviewed the literature on the cytology of these plants.

THE GELATINOUS MATRIX.—This term is here applied to the sheaths about the cells. In a several—many-celled plant, the matrix consists of the sheaths of not only the cells present but also those of the ancestral mother cells for as many previous generations as the plant has existed. The persistence of the ancestral cell-sheaths in the matrix thus often governs the size of the plant itself. The matrix consists of pectins, which, according to their chemical natures and the environmental conditions under which they were produced and have survived, exhibit various types of lamellations about the cells. Like all pectic substances, they hydrolyze readily and may

become dissipated into the surrounding medium; or they remain firm, in parts lamellose, in parts homogeneous. Red and blue coloring matter often develops in the matrices of plants subject to direct insolation and to drying, especially in *Anacystis montana* and several species of Entophysalis; these are "indicator" pigments, turning one or the other color in direct response to changes in acidity and alkalinity of the medium. Brown and yellow pigments develop in these and other species (especially in *Coccochloris stagnina* and *Entophysalis deusta*) under similar natural conditions; these pigments also seem to accompany the infestation of the matrices and the parasitization of the cells by fungi. In some species, as in *Coccochloris aeruginosa,* the gelatinous material appears always to hydrolyze as it is extruded. However, this condition of complete hydrolyzation of the matrix and dissociation of the cells occurs frequently in all the species of Chroococcaceae and Entophysalidaceae. In the Clastidiaceae, the thin gelatinous sheath eventually hydrolyzes in part or *in toto*.

PARASITIZATION BY FUNGI. — Except in purified cultures, fungi are present in most habitats occupied by these algae. Where algal growth is rapid, conditions favoring equally rapid growth of the fungi do not often obtain. But in habitats subject to periodic drying, the sheathed Myxophyceae, usually perennial, eventually become infested with fungi. Hyphae of saprophytic fungi, as well as bacteria and other algae, are to be found in the gelatinous matrices of most mature plants of the coccoid blue-green algae. Such fungi appear to be responsible for the production of brown pigments in the sheaths, as well as for changes in the consistency and in the acidity and alkalinity of the sheath material. Other fungi parasitize the cells, causing the latter to enlarge, change color, and cease the production of gelatinous material. In *Anacystis montana,* the hyphae often completely surround the cell and encase it in a wall. In most instances, parasitization by fungi results in the death of the Myxophycean cells. However, with certain species of fungi, the algae continue to live and grow; and together they develop as lichens. Lichens containing blue-green algae appear more often to result from an association of heterocystous, rather than coccoid, Myxophyceae with fungi.

ENDOPHYTISM. —Although various cases of intracellular endophytism of these plants within other organisms have been described and discussed in the literature [see Geitler in Rabenh. Kryptogamen-Fl., ed. 2., vol. 14 (1932) and in Engler & Prantl, *Natürl. Pflanzenfam.,* ed. 2., vol. 1b (1942)], we find no real evidence that the blue-green structures involved, if autonomous organisms at all, are coccoid Myxophyceae. If they are not chromataphores containing phycocyanin or a similarly colored pigment, then the behavior of the Nostocaceae and other heterocystous blue-green algae in culture and in conditions where they are parasitized by fungi would

suggest that the filamentous Myxophyceae are concerned here. Perhaps when they are cultured in a free state outside their host organisms, these alleged endophytes can be properly disposed in a system of classification.

PRESERVATION AND MICROSCOPICAL TECHNIQUES

Permanent preservation of these algae is most adequately assured by drying. The dried specimens can be placed in paper packets, labeled, and stored in the herbarium. Since most of the species thrive best in subaerial or temporarily inundated habitats, they exist for much of the year in the dried condition in nature. Wet algae can be laid top-side up on paper (newspaper is excellent) and allowed to dry in the open air. Drying in a plant press excludes the air, so that autolyzation of the protoplasm takes place; drying with heat often destroys the cells by cooking. If possible, part of the substratum should be preserved as part of the specimen. If the plants are microscopic and mixed with other algae, a good specimen should contain a sufficient number of the plants so that at least several may be found in every field of every mount made for microscopic study. Such small plants, as well as those in plankton collections, may be dried directly on sheets of mica or clear plastic or on glass slides. Plankton organisms are sometimes destroyed during the process of drying unless they are first killed by the addition of formalin. Old collections preserved in formalin etc. can likewise be dried on mica; the material should be spread in a film thin enough for light to pass through it under the microscope.

Dried specimens can be examined microscopically by soaking a fragment in water on the slide, then by crushing it down under a cover glass. If present, sand grains can be teased out with the forceps and removed. Dilute solutions of the common household detergents are excellent mounting media; they soften most of the sheathed Myxophyceae quickly and remove all traces of air imprisoned in and among the algae. By this method even many poorly preserved specimens can be restored to an appearance similar to that of living matetial. On the other hand, the detergents will remove permanently the pseudovacuoles from the cells of plankton algae. Carbonates can be removed by mounting in dilute solutions of nitric, hydrochloric, citric, or acetic acids or in vinegar or lemon juice. A dilute solution of iodine or a solution of methyl green in slightly acidulated water is useful for staining structures in the protoplasm and sheaths. If a specimen has been dried on mica, plastic, or glass, a drop of water and a cover glass can be placed on the alga; after the examination, the cover glass can be removed and the alga can be allowed to dry again in the open air.