Meetings

Phylogeny and Morphogenesis in the Algae

The use of algae for phylogenetic and morphogenetic studies, especially since the advent of simplified methods for their culture and manipulation, has been seriously neglected by biologists in spite of the many advantages offered by their fairly simple body plan. The implications and the rich potential inherent in the use of algae were explored at a conference in December 1969 sponsored by the New York Academy of Sciences (*1*). Sessions were devoted to phylogenetic aspects of algal cytology, algal biochemistry, taxonomy and systematics, morphogenesis, and control factors in algal morphogenesis.

B. C. Parker (Virginia Polytechnic Institute) pointed out the possibilities of cell wall chemistry in algae for the discovery and support of phylogenetic schemes. Cell wall constituents have been little studied. Cellulose per se, because of its universal distribution, is almost valueless as a phylogenetic marker unless it is combined with studies of the polysaccharides, proteins, and lipids of the cell wall. Extensive studies of these constituents have justified the categorization of Cladophorales, Acrosiphonales, Dasycladales, Derbesiales, and Caulerpales among the siphonous green algae.

G. F. Leedale (University of Leeds) cautioned that the use of nuclear structure and mechanisms of division as phylogenetic indicators may be applied, but only in the broadest sense. Many algal groups such as the Rhodophyceae, Phaeophyceae, and Chlorophyceae have nuclei which undergo "classical" mitosis and meiosis. There is a feature of interphase nuclear structure, however, which may be of some taxonomic significance —the relationship between the nuclear envelope and the chloroplast endoplasmic reticulum, particularly in Chryophyceae, Phaeophyceae, and Xanthophyceae. The Cyanophyceae, on the other hand, have DNA regions very similar to bacteria, and in this group exploration of the close parallel evolution of pronuclear structures with those in bacteria could prove fruitful in establishing derivations.

S. Karakashian (State University of New York, Oyster Bay) described the polymorphism encountered in algal symbionts. *Chlorella* symbionts from *Paramecium* cultured under a variety of conditions both inside and outside the protozoan host displayed strikingly different morphologies. The normal intracellular environment of the host protozoa evokes a morphological response from the alga which is selected from a number of potential responses. As long as the internal environment of the host is constant, the morphology of the endosymbiont is constant. However, this can be varied. Hence, caution must be exercised in inferring phylogenetic relationships (or their absence) on the basis of structural comparisons, especially between intracellular symbiotic algae and free-living algae.

After S. P. Gibbs's (McGill University) presentation of the ultrastructure of algal chloroplasts, the session closed with R. Malcolm Brown's (University of Freiburg) résumé of algal cytology.

T. Iwamura (Tokugawa Institute, Tokyo) has found at least two DNA's in chloroplasts of *Chlorella* with different base compositions. The major component may be the main genetic DNA of the plastid, while the minor component may represent a "metabolic" DNA.

Phylogenetic aspects of nitrogen metabolism in the algae were presented by A. W. Naylor (Duke University) who stressed that whereas pyruvate was a required component for bacterial nitrogen fixation, it was not required for that of blue-green algae.

S. Aaronson (Queens College, City University of New York) suggested that the animal skeleton may have evolved from proteins or polypeptides akin to those found in the cell walls of algae. The similarity in the amino acid composition of collagen, with its high glycine content, presence of hydroxyproline, and absence of tryptophan, has its counterpart in the cell walls of most green algae and of many brown and blue-green algae. The cell-wall polypepides in these algae are not unlike collagen in amino acid content.

Studies on the polyglucan-synthesizing isozymes of algae have been continued by J. F. Fredrick (Dodge Research Laboratories, Bronx, New York) and show a definitive evolution of the three groups of enzymes (phosphorylase, synthetase, and branching enzyme) from a primordial molecule which probably combined the functions of all three groups. Differentiation of the primordial enzyme into two main lines of catalytic proteins, one capable of the synthesis of 1,4-glucosyl bonds, and the other capable of 1,6-glucosyl bond formation, has been followed in blue-green, red, and green algae. Further differentiation of the formers of 1,4 bonds into phosphorylases and synthetases and of the synthesizers of 1,6 bonds into Q enzymes and branching enzymes is particularly evident in these three algal genera.

The difference in the metabolism of glycolate in higher plants as compared to that in algae was delineated by M. Gibbs (Brandeis University). This substance, which is apparently derived from an intermediate in the photosynthetic carbon reduction cycle, is converted to glyoxalate by the enzyme present in higher plants, glycolate oxidase. In algae, although glycolate is excreted in substantial amounts by photosynthesizing cells of *Chlorella*, no metabolizing enzyme such as is present in higher plants has been detected.

Phylogenetic aspects of inorganic substances in algae were presented by J. A. Schiff and R. Hodson (Brandeis University) who traced the pathways of sulfate reduction, and by J. J. J. McLaughlin (Fordham University) who traced the minimum content required per cell for division of iron, phosphate, and nitrate with regard to phytoplankton.

A review of fossil algae and their implication in phylogenetic derivations was presented by E. S. Barghoorn (Harvard University), and H. C. Bold (University of Texas) stressed the importance of defined media and a return to the strict principles set forth by Pringsheim in order to resolve problems in algal taxonomy. Bold stressed the importance of changes in cellular morphology and pigmentation, texture and configuration, response to carbon and nitrogen compounds, and to antibiotics for criteria for classification, with particular emphasis on taxonomy of soil algae.

M. H. Hommersand (University of North Carolina) enumerated major trends in algae with regard to phylogenetic criteria. These include the evolution of energy-trapping centers, development of collector pigments, compartmentalization of major biochemical processes within membrane systems, evolution of mitotic systems, development of rigid cell walls, and the evolution of a mechanism for plastic deformation of the walls to allow cell growth, division, and changes in shape and branching.

The probable derivation of the red algae from a modified, protoeukaryotic blue-green alga rather than from a green alga was presented by R. M. Klein (University of Vermont). Three major categories of information—chemical, micromorphological, and functional—were compared in an analogy: homology goodness-of-fit for the classes Chlorophyta : Rhodophyta and Cyanophyceae : Rhodophyta. Positive values were obtained overwhelmingly in the Cyanophyta : Rhodophyta classification. Research with *Cyanidium caldarium* suggests a "transitional" alga between the blue-greens and reds. Klein pointed out that *Glaucocystis* might also qualify in the transitional category. Discussion of Klein's paper ensued, led by A. Cronquist (New York Botanical Garden, Bronx) as to the possibilities that the structural characteristics of eukaryotic cells are really endosymbionts. Cronquist pointed out the unnecessary complexities introduced by the endosymbiont theory—the need for three different endosymbionts in order to explain the chloroplast, the mitochondrion, and the basal body in the eukaryotic alga. The possible origins for the endosymbiont theory are probably the result of thinking that DNA is exclusively a nuclear constituent.

P. S. Dixon (University of California, Irvine) delineated the need for the development of taxonomic systems which were compatible with the binomial nomenclature. Any system of classification must uphold the primary function for such a system to be strictly utilitarian.

P. Wolk (Michigan State University) indicated that localization of the enzyme nitrogenase in *Anabaena* is not exclusively limited to heterocysts but is generally distributed in vegetative cells as well. However, its activity is dependent upon a reductant which is reduced specifically in the heterocyst.

R. F. Jones (State University of New York, Stony Brook) found that during gametogenic differentiation in *Chlamydomonas*, net protein synthesis stops shortly after removal of nitrogen. Protein synthesis, however, continues, and cell division and the elaboration of mating components occur. Proteolytic enzymes of molecular weight between 43,000 and 65,000 have been isolated and their activity studied with regard to the protein turnover during differentiation. During gametogenesis the activity of some of these enzymes differs.

O. Kiermayer (University of Cologne, Germany) found that if the turgor pressure is osmotically reduced in *Micrasterias*, specific wall thickenings occur which indicate a pattern of deposition of wall material in the cortical protoplasm of the alga. The pattern seems to be formed in the protoplasm long before the actual growth of the new half cell or elongation occurs. Electron microscopy revealed different systems of microtubules, one of them in close proximity to the plasmalemma of the growing wall. These microtubules seem to be active in controlling the position of the nucleus and the chloroplast. The plasmalemma controls the pattern of the cell wall by guiding wall material to its proper position, and also probably controls the "shape" of the chloroplast.

In a study of the processes of gametogenesis and fertilization in *Caulerpa*, M. Goldstein and S. Morall (McGill University, Montreal) found that male and female gametes were produced in separate gametangia. The differentiation of the male and female gametangia was made possible by the appearance de novo of diffuse eyespots in the chloroplast of the female gamete.

The development and the fate of the eye-spot in *Fucus* sperm after fertilization was studied by G. B. Bouck (Yale University). Characteristic of eyespots is the remarkable structural consistency in widely separated algal groups, that is, a group of pigmented granules embedded within the chloroplast and usually oriented near the cell surface. In *Fucus* sperm, the eyespot arises as a culmination of a series of events, signaled by appearance of small electron-opaque granules in a well-defined row along one surface of the chloroplast.

In a series of histochemical studies in *Fucus* during morphogenesis, M. E. McCully (Carleton University, Ottawa) reported that the two major structural polysaccharides, alginic acid and fucoidan, appeared to be assembled intact within the cells and secreted as macromolecules. They vary greatly in both proportion and localization during morphogenesis in this alga.

The immediate cause of a change in shape of a cell is the deformation of the material present. In internodes of *Nitella*, P. B. Green (University of Pennsylvania) found that the expansion rate appears to be controlled by a balance between a wall-softening process which is metabolic and time-dependent, and a hardening process which is physical and is coupled to the degree of stretch of the wall. Highly directed expansion of cells is well correlated with oriented microfibrils in the cell wall.

W. P. Jacobs (Princeton University, intrigued with the apparent contradictory aspects of the algal giant coenocyte *Caulerpa* with regard to theory of development which propounds that organ-forming substances in multicellular organisms can become localized within specific cells and that cellular structure makes developmental polarity easier, reported that auxin is without effect on *Caulerpa prolifera* possibly due to the fact that this alga does not make its wall of the same components as do higher plants. He suggested that since the cell wall is based on xylan rather than cellulose, it might be a promising place to start investigations in order to unravel the mystery of the alga's success as a giant coenocyte and that it may not use hormones of any type.

W. H. Darden, Jr. (University of Alabama) reviewed the known hormonal mechanisms for the induction of male, female, and parthenosporic colonies in the genus *Volvox*.

The effect of nutrients on morphology was assessed by F. R. Trainor (University of Connecticut). He pointed out that several inorganic elements can trigger profound changes in cell size and shape, in colony formation, sexuality, auxospore formation, and zoospore formation. Organic factors such as chelating agents, hormones, and vitamins were also considered by Trainor. The importance of the factors, for example, in the misclassification of a well growing *Haematococcus* as *Chlamydomonas*, may well be repeated with other algae.

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Note

1. The papers presented at this conference will be issued as a monograph as part of the Annals of the Academy.