THE ORIGIN OF THE BLUE-GREEN ALGAE

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Blue-green algae are fascinating microorganisms which have an astounding cellular complexity all of their own. An illustrated discussion of cell structure, spores, and reproduction in blue-green algae is presented.

Fossil remains of blue-green algae are quite similar to living forms. Arguments from homology or parallelism show that in different aspects blue-green algae variously resemble red algae, green algae, Zea mays, or bacteria! Most evolutionists believe, however, that bacteria and blue-green algae have evolved from a close common ancestry. Much evidence is presented here from writings of Pringsheim and other workers to show that there are great differences in spores, pigments, biochemistry, and movement between bacteria and blue-green algae. These differences are strong evidence in support of the view that the various kinds of blue-green algae and bacteria were separately created.

Introduction

The origin of blue-green algae has been of perennial interest in biology. In this paper, evidences from the fields of paleontology, cytology, taxonomy, and biochemistry will be examined. Before the beginnings of blue-green algae are probed, however, a brief review of their basic structure will be presented.

Blue-green Algae Structure

Blue-green algae exist as single cells or simple multicellular colonies of variable shape. Generally a mucilaginous sheath surrounds the cell or colony of cells. Various photosynthetic pigments are present in the lamellar membrane system that is seen at the peripheral portion of the protoplasm in each cell. Other blue and red pigments are present in the soluble portions of the cytoplasm.

In the central region of the cell and ranging into the entire protoplasm is a nuclear zone that is relatively clear, non-pigmented, and irregularly shaped. Ribosomes and various droplets or granules are seen throughout the cells.

In cell division the new cell wall usually grows inward like a closing diaphragm in a camera. Various cellular inclusions are present and a common photosynthetic storage material in blue-green algal cells is glycogen.

Blue-green algal cells are noteworthy for the cellular structures that they do not possess. They generally have no flagella, no organized chloroplasts, no mitochondria, no endoplasmic reticulum, no nuclear envelope, no nucleolus, no mitotic figures, and no known protoplasmic streaming.[1,2,3]

Colonies

Colonial blue-green algae exist either in filamentous or non-filamentous colonies. Many of the families have thread-like colonies.

Filamentous threads result from cell division in one plane and may be straight (see *Oscillatoria* in Figure 1, or *Lyngbya* in Figure 2) or spiral *(Spirulina)*. One or more of such threads surrounded by a sheath is known as a "filament." The threads may have nearly the same width for cells throughout the entire colony (as in *Oscilatoria* or *Lyngbya*, Figures 1 and 2), or they may be wider at one end, tapering down to a cylindrical hair at the other end (see *Rivularia*, Figure 4).

The non-filamentous colonies seen in other species of blue-green algae may be in various shapes such as flat plates, cubes, or irregular cell clusters. In some forms spherical shaped colonies are produced.

Blue-green algal cells reproduce by a kind of simple cell division. Entire colonies can also reproduce by chance fracture. Certain cells within a filament may die, creating biconcave "separation discs" (Figure 3).[4,5,6] The thread then contains several short segments called "hormogonia" that are held together only by the mucilaginous outer sheath (Figure 3).

Fracture of the sheath subsequently liberates the hormogonia each of which may yield a new trichome by repeated cell division. The hormogonia segments possess an amazing degree of motility and thus serve as colonial reproductive units. The basis and mechanism of this movement of hormogonia is still one of the unsolved mysteries of microbiology.

Heterocysts

Although no gametes or flagellated spores have ever been noted among the various blue-green algae, resting spores of a sort have been reported.

Along the threads of certain blue-greens, cells known as "heterocysts" stand out because of their large size, thick wall, clear contents, and so-called "polar granules." Some "terminal heterocysts" (Figures 4 and 5) may arise at the tip of the thread. Others known as "intercalary heterocysts" (Figures 6 and 7) may form somewhere in the midst of the colony.

A cell destined to become a heterocyst enlarges its end walls, becomes rounded, and forms another wall internal to the existing cell wall.

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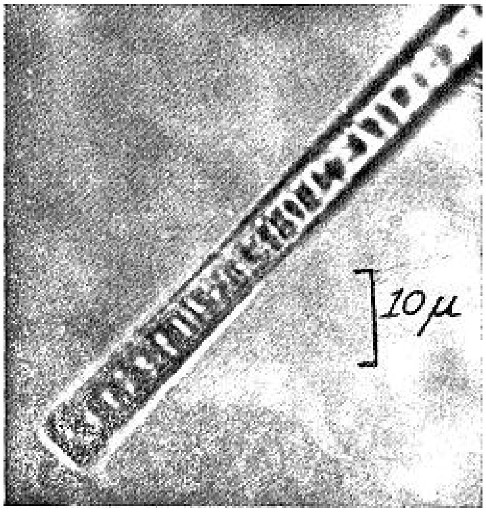

Figure 1. ***Oscillatoria sp.*** **1000X.**

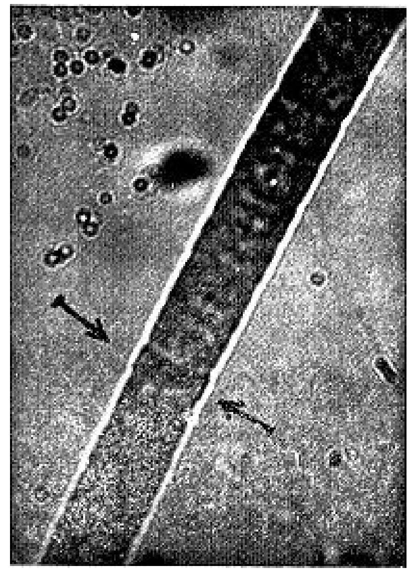

Figure 2. ***Lyngbya sp.*** **1000X. Typical "separation disks" are seen at arrows.**

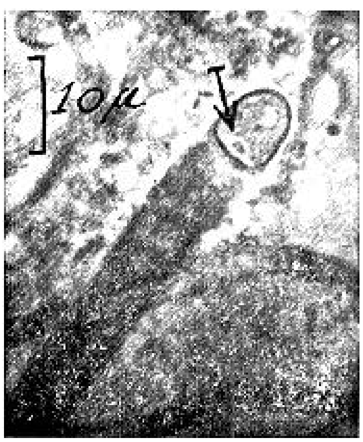

Figure 3. ***Lyngbya sp.*** **1000X. Biconcave "separation disks" at arrows indicate dead cells.**

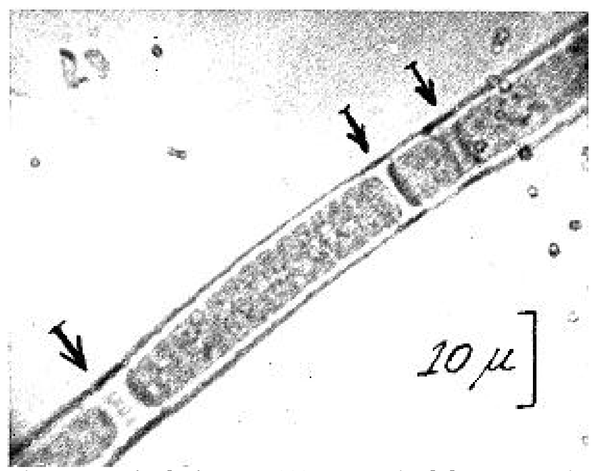

Figure 4. ***Rivularia sp.*** **1000X. Terminal heterocyst is visible. Arrow points to polar granule inside heterocyst.**

Each end of the developing heterocyst appears to connect to its neighboring cell in a filament by a protoplasmic connection which apparently passes through an end pore. A thickening of the new cell wall around these two end pores creates a collar or nodule visible at either end of the heterocyst—the "polar granule" (Figures 4 and 5).

Heterocysts have been observed to germinate and form new thread-like colonies. In some species 80% germination has been noted and this fact suggests that the heterocyst serves in reproduction as a resting spore. Even in a structure so apparently simple and transparent there is structural detail and functional purpose that is in itself a testimony to the skill of the Creator.

Endospores

In certain blue-green algae the protoplasm of one cell divides many times within the old wall, giving rise to numerous small cells known as "endospores." The endospores secrete a thin wall around themselves when they are liberated from the old cell wall which ultimately dissolves, The two families that show such endospore formation have a complete absence of normal cell division and thus the endospore formation appears to be their sole reproductive mode.[7]

Nuclear Material and DNA

One of the most puzzling features of the blue-green algal cell is its nucleus which apparently has no membrane, no chromosomes, and no

Figure *5. Rivularia sp.* 1000X. Two filaments of *Rivularia* are seen. Terminal heterocyst is visible on each filament. Cells farther back from the tip or heterocyst have a narrower width.

mitotic spindle. When viewed under a light microscope, the blue-green cells manifest a clear colorless central zone. This central region is known as the "nuclear material" because it gives a positive feulgen DNA stain.

The shape and structure of this nuclear region has been examined with the electron microscope. It is apparently an irregular network of channels and lobes which may extend some distance out into the cytoplasm. Many fine fibrils are noted in the nuclear region under the electron microscope. Such fine fibrils have been located in the same cellular zones that yield the feulgen DNA response. Thus the cytologic structure of a blue-green algal nucleus is somewhat like the nuclear region of a typical bacterial cell.

Blue-green Algal Origins

Paleontology

The most direct evidence bearing on the history of any group is its fossil record. Fossil remains of the blue-green algae indicate that very little change has occurred in these types since the time that the deepest fossil layers were deposited. "The fossil record contributes little to our understanding of evolutionary trends in the blue-green algae . . . Other fossil cyanophyte [blue-green algal] genera have been described, but in general the structure of fossil forms is

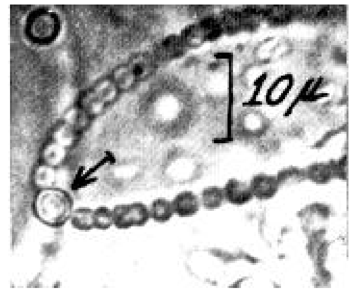

Figure 6. *Nostoc sp.* 1000X. Intercalary heterocyst is seen at the arrow.

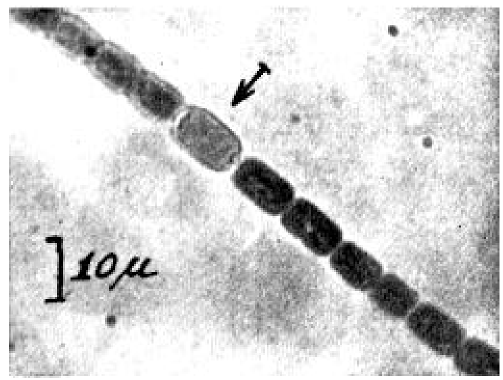

Figure 7. *Anabaena sp.* 1000X. Intercalary heterocyst is seen at the arrow.

similar to that of modern ones."'[8] This clear resemblance between fossil forms and living types is a strong argument favoring the persistence and fixity of distinct kinds. In four instances that follow, this fact will be demonstrated.

(a) *Gloeocapsamorpha* is a fossil that appears to have been a blue-green alga. It is quite similar in appearance to the *Gloeocapsa* types found on earth today. "*Gloeocapsamorpha* is found in Ordovician deposits, and as the name implies, bears considerable resemblance to the familiar *Gloeocapsa."*[9]

(b) Girvanella, a fossil of so-called Cambrian rocks, is quite like the modern blue-green alga *Symploca.* Speaking of *Girvanella,* Desikachary has said that it ". . . may be related, if not identical to the modern *Symploca."*[10]

(c) The blue-green *Maripolia* of British Columbia mid-Cambrian layers closely resembles *Schizothrix* types alive today.[11]

(d) *Archaeothrix oscillatoriformis* of the famous Devonian Rhynie chert beds of Scotland is like the modern *Oscillatoria* (Figure 1) seen nowadays.[12]

Thus evidence for an evolutionary origin of blue-green algae or of any wholesale transformism within the groups of blue-green algae is completely lacking in the fossil series.

Analogy and Cytological Parallelisms

Some widely different animal forms such as butterflies, bats, birds, and fossil reptiles have wings. When an organ of common function (such as the wing) is seen in creatures of diverse anatomy, biologists call the resemblance an "analogy." Analogy demonstrates that similar patterns can be seen in creatures that are not closely related.

The fact of analogy is one of the strongest arguments against the general evolution theory because it is almost impossible to imagine that such organs as wings could arise in entirely different groups by natural selection. A baffling analogy is seen among the groups of blue-green algae.

Heterocysts and Parallelism

The various families of the blue-green algae that bear heterocysts are otherwise quite separate in any evolutionary sense *(Rivulariaceae, Nostocaceae,* and *Stigonemataceae).* Tilden[13] has envisioned the families with heterocysts as ". . . apices of widely diverging lines of development." Yet all three families manifest heterocysts.

Such parallelism of a basic pattern in groups that are otherwise quite diverse is a roadblock to evolution theory. "Both the origin and the function of the heterocyst remain surrounded in mystery, although no algal structure has received more widespread or intensive study."[14]

However, as mentioned earlier, it seems quite clear that these heterocysts are resting spores designed to resist extremes of cold, drought, heat or other adverse environmental factors. Could it be that, here again, preoccupation with presumed evolutionary trends has blinded investigators to rather obvious examples of wonderfully designed structure?

Cytological Parallelisms between Red and Blue-green Algae

Certain members of the blue-green algae show definite connections between neighboring cells in a filament. This situation remarkably resembles the Floridean red algae in which "pit" connections of cytoplasm link all cells of the same strand together.[15]

Red algae and the blue-greens possess various prominent phycobilin pigments in common. The exact phycocyanin or phycoerythrin pigment molecules of the blue-green algae do not necessarily correspond to specific phycobilins of the red algae; nevertheless, such a general similarity of photosynthetic pigments is a noteworthy parallelism. On these cytologic bases, some workers suggest a close affinity (and presumed common ancestry) between the red and the blue-green algae.

Yet there are numerous reasons for recognizing that the red and the blue-green algae are probably not related. Blue-green algal cells have no organized nucleus, no organized chloroplasts, and only a relatively simple cell structure, which more closely resembles the bacteria than it does the red algae.

The red algal plants have nuclei, chloroplasts, and a more complex body organization. The two groups that are so different in many ways and yet so similar in other features point towards creative activity, not to an evolutionary ancestry.

Glycogen, Parallelism, and Phylogeny

Zea mays (common farm corn), mammals generally, and the blue-green algae all possess glycogen as a common storage product! When it is remembered that most other algae and most other flowering plants do not produce glycogen, such parallelism in widely different forms is hard to understand or even explain in terms of an evolutionary transformism.

Taxonomic Evidence and Blue-green Algal Ancestry

Green Algae

Even the non-biological reader will realize that it is helpful to classify similar plants together and to separate different plants into groups. This segregating and categorizing of living forms is known as "taxonomy". Taxonomists try to group on the basis of meaningful similarities and to separate because of key differences.

Certain plants are known as "green algae" and are put into a different category than the blue-green algae being studied. Green algae are really quite different from blue-green algae in that the greens possess an organized nucleus, an organized system of chloroplasts, and very frequently have motile gametes that function in sexual reproduction.

Despite all of these and other taxonomic differences between the two types of algae, certain blue-green algae bear a striking superficial resemblance in form to individual species or genera of green algae. Only three examples will be listed, but the interested reader will discover others in the reference given.

(a) *Elaktothrix* (a green alga by taxonomy) is amazingly similar to *Dactlylococcopsis* of the blue-greens.[16] Both forms have fusiform cells lying more or less parallel in a gelatinous matrix.

(b) Both *Dictyosphaerium* (a green alga) and *Gomphosphaeria* (a blue-green alga) have a stalked, branched, gelatinous mass of threads holding the various cells together.

(c) Normal vegetative cell division is strangely lacking in both the *Chlorococcales* order of the green algae and in certain families of the blue-green algal order *Chamaesiphonales!*

Bacteria

Although there is some similarity (analogy) between the blue-green algae on the one hand and the red or green algae on the other, it is usually proposed that the blue-greens are most closely allied to the bacteria. Thimann[17] expressed the opinion that there is a close ancestral affinity between the bacterium *Rhodomicrobium vanniellii* and the blue-green algae. Thimann also stressed the similarity between the blue-greens and the bacteria in the matter of crosswall formation during cell division.[18]

It must be acknowledged that there are undoubtedly similar patterns of crosswall formation in both of these groups. Yet crosswall formation itself can be misleading taxonomically since some typically "plant" cells, such as the spore mother cells in flowers of certain flowering plants, have a cell wall formation by "cleavage furrow" that is strangely similar to the typical "animal" wall formation in division. Here is a case of parallelism between members of different biological kingdoms! Yet no one suggests that flowering plants and frogs are closely allied because they both can have cleavage furrows separating cells in cell division.

The bacteria and the blue-green algae both have "atypical" nuclei which generally lack a nuclear membrane and show no mitotic division figures. But here again nuclear parallelisms are no more of an absolute indication of ancestral affinity than are cell wall or chromosomal parallelisms.

Nuclear similarities between blue-green algae and bacteria are instructive but certainly do not indicate common ancestry. Concerning the supposed relationship between blue-greens and the bacteria, Kingsbury stated that the ". . . cells of blue-green algae have long been considered basically different from those of bacteria. Bacterial cells are, on the whole, much smaller."[19]

Evidence for the existence of a so-called bacterial "chromosome" is well-known. Both cytologic studies in the form of electron photomicrographs and genetic data indicate that in a process of sexual reproduction a "donor" bacterial cell injects chromosomal material (DNA) into a recipient bacterium. Enough genetic experimentation has been undertaken with the colon bacterium, *Escherichia coli*, to permit a provisional mapping of genes.

The blue-green algae have never been observed to reproduce sexually. Whether this indicates that they truly differ from bacteria in a complete absence of a sexual process or whether more studies will demonstrate sexuality is hard to predict. I am unaware of any extensive genetic studies on the blue-green algae.

As noted earlier, there is strong evidence for the presence of DNA in the central nuclear-region of each blue-green cell. This would suggest that future genetic analyses of blue-green algae will indicate the presence of genes and gene mutations. It can be concluded presently that in the possession of an "atypical" nucleus the blue-green algae indeed resemble the bacteria. In the absence of any observed or recorded sexual reproduction, the blue-greens differ markedly from the bacterial forms.

There are other salient objections to the suggestion that blue-green algae and bacteria might have evolved from a common ancestry. In his brilliant work, Pringsheim[20] has demonstrated the tenuous nature of such alleged relationships, Although Pringsheim did not completely agree with Dubos on the following statement, he quoted Dubos as having said,

> One finds among bacteria organisms which show strong resemblances to certain of the blue-green algae, to the fungi, to the myxomycetes, or to the protozoa, and which can only be distinguished from these microorganisms by their much smaller size. . . . It appears more likely, however, that these microorganisms [the bacteria] constitute a heterogeneous group of unrelated forms.[21]

Dubos' statement would indicate that the bacteria are not only unrelated to the blue-green algae as a whole, but various kinds of bacteria may very well be unrelated to each other!

Endospores

Some workers have argued that the endospores of certain blue-green algae indicate a relationship to bacteria. However, "No Myxophyceae [blue-green alga] produces endospores comparable to those of Bacteria."[22] The endospores of certain blue-green algae are formed in great numbers within one old cell wall, as seen earlier in this paper.

Likewise it was noted earlier that endospores in blue-green algae are generally formed only in groups that have no normal cell division mechanism. Bacterial endospore formation occurs in cells that can likewise carry on the normal division process. Thus the so-called "endospores" of the blue-greens cannot be equated with the endospores of bacteria.

Pigments

Concerning pigmentation, the blue-green algal chlorophyll-a is different than the bacteriochlorophyll of photosynthetic bacteria. This criterion is enough to suggest that they should be put into separate classes or even divisions (botanical counterparts of the zoological phyla) if the same reasoning used in delineating the green, red, and brown algal divisions be used here, Pringsheim nicely summarized all of this information when he wrote, "The pigmentation does not afford any indication of relationship between bacteria and the Myxophyceae [blue-green algae]."[23]

Biochemical Versatility

The various bacteria manifest an impressive array of physiological activities such as causing diseases, enhancing decomposition, and fermenting numerous organic compounds. Pringsheim says:

> Nothing of the kind occurs in the Myxophyceae. In this respect the former [bacteria] approach more nearly to the Fungi, while Myxophyceae [blue-green algae] resemble the Algae, in correspondence with the possession of assimilatory pigments. Although some nitrogen fixating Myxophyceae exist, there is nothing like the "chemo-autotrophy" of bacteria.[24]

Movement

Bacteria can swim (although some either "creep" or "glide") whereas the blue-green algae creep only. Bacteria often possess flagella, but none of the blue-green algae are known to have such whip-like organs of motion. Likewise, gliding or creeping is a hallmark of blue-greens: "No true bacterial organism (i.e., excluding colorless Myxophyceae and Myxobacteria) exhibits gliding movements."[25]

Thus Pringsheim has suggested that those bacterial forms that creep are not typical bacteria. Despite a possible overlap of creeping forms in both groups, it is strikingly true that no blue-green algae have flagella while numerous typical bacteria do.

Pringsheim has written an extensive discussion on how each of the groups thought to be a "missing link" between the bacteria and the blue-green algae is not a link at all. Some of the groups are blue-greens, others are actually bacteria, and still others appear to be separate groups not related to either the blue-green algae or the bacteria.

These arguments against any close affinity between blue-greens and bacteria have been nicely summarized by a few succinct statements.

> From the consideration of facts given in this review, it emerges that there is no affinity between the Bacteria and Myxophyceae. . . . There is therefore no indication that any member of the Bacteria has originated from the Myxophyceae.[26]

Origins Summary

Some workers will always prefer to believe that the blue-green algae; the bacteria; the red, brown, and green algae; and all living things are somehow related to each other through branching of a theoretical ancestral tree, by some process of neo-Darwinian transformism.

On the basis of the scientific data available, however, it appears that life did not arise naturally from non-living matter; and, likewise, it appears that the various kinds of living organisms are not organically related to each other by any common evolutionary descent.

It is more in harmony with the scientific evidences to assume that life comes from life and that like begets like, as both Pasteur and Virchow have demonstrated. Although some minor variations (mutations, polyploidy, etc.) occur within the basic kinds, evidences in support of any comprehensive evolutionary "tree" are lacking.

It is suggested that more rapid progress will be made in discovering various unknown features of the many kinds of blue-green algae if each one is examined from the viewpoint of creative design. Thus, the heterocysts certainly need more detailed study as to precisely what environmental adversity they are designed to withstand. Likewise, investigation of the DNA structure of blue-green algae may very well lead to modifications in our ideas as to just how this complex mechanism functions both as regards regulation of heredity and development of the organism.

Evidence from many phases of biology (paleontology, cytology, taxonomy, and biochemistry) nicely supports the idea that many "kinds" of living organisms were originally designed and established by the Creator as outlined in Genesis chapters 1 and 2 of the Holy Bible. Such careful creation of distinct and virtually unchanging groups or "kinds" appears to apply not only to man, the larger animals, and the more complex plants, but also to the many discreet forms of microscopic life, such as the many separate types of blue-green algae and bacteria.

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