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THE HUMBLE SHALL INHERIT THE EARTH*

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ABSTRACT

The change in the structure of an organism is primarily due to the fact that it has to successfully cope with the physical environment for survival. Prolonged changes in physical environment induce subtle changes in life forms involving innovations. The organism changes owing to its inherent weakness. The larger the organism, the more vulnerable it is to extinction in response to adverse changes in the physical environment. The Cyanophyceae, also known as blue-green algae, are typified by smaller magnitude and cannot even afford a small, organised nucleus; they are the earliest known algal fossils surviving for more than 3 billion years and reported from several parts of the world. *Animikiea septata* described from the Gunflint Chert could very well match with the extant Nostocales, while *Entosphaeroides amplus* closely resembles Chamaesiphonales. Cyanophyta are reported to occur as single cells of microscopic size or as small cell colonies of various shapes and as multicellular filaments. They have flourished in all possible habitats, i.e. fresh or salt water, in anaerobic or aerobic conditions from arctic cold water to hot spring. Though the blue-green algae undergo cell division by an ingrowth of the septum, lack a well-defined nucleus and do not exhibit sexual reproduction, they still have the most ancient fossil history and even today thrive as a formidable group. The acid test for the fitness of a population is its inherent strength for survival . If a particular group could exist for more than 3 billion years braving all possible hazards of climatic vicissitudes, then one should seriously assess the cause of its enormous strength. The obvious answer to such a query, firstly lies in the tiny or humble magnitude of the members of this group superbly maintained through millions of years of earth's history. Secondly, the lack of nuclear membrane in its members is dictated by the small cell size permitting the dispersion of nuclear material in prokaryotic architecture, demanding least energy for reproduction. It would indeed be an utter understatement to call blue-green algae the most primitive: rather, they should be hailed as the most practical, successful and, at the same time, flexible group, which has been ruling the earth since its inception.

Key words : Blue-green algae, procaryotic architecture, environment, eucaryotes.

INTRODUCTION

Perhaps the only universal truth in this world is that anything which belongs to this earth is susceptible to change. The earth, since its very inception, has been changing with the molten magma cooling to give rise to solid, hard rocks; these are eroded to form sediments. The two, with the passage of time, undergo change to form metamorphic rocks. In due course the atmosphere was enriched with oxygen, the hydrosphere with mineral salt and the biosphere teemed with life. So the dictum "change is the law of nature" is true to its core.

Dobzhansky *et al.* (1977) observed that during the entire period of earth's history, since the major phyla of organisms evolved, all the regions of earth underwent complete alterations of their biota and many of them experienced several ecological revolutions. Pearson (1995), with the help of tables and charts, showed that the first unicellular prokaryotic organisms evolved around 3.5 billion years ago, and after, two billion years, gave rise to eukaryotes. Doolittle (1998) observed that in prokaryotes, the simple, circular chromosome is in contact with the cellular cytoplasm while in eukaryotes highly structured, linear chromosomes are separated from the cytosol by a nuclear envelope. It is generally believed that the eukaryotes evolved from prokaryotes through 'endosymbiont hypothesis' of Margulis (1970).

Martin and Muller (1998) suggested that eukaryotes might have arisen through symbiotic association of an aerobic, strictly hydrogen dependent, strictly autotrophic archaeobacterium with a eubacterium that was able to respire, but generated molecular hydrogen as a waste product of anaerobic heterotrophic metabolism.

Once the eukaryotes evolved, the other phyla such as euglenophyta, chlorophyta, pyrophyta and chrysophyta also evolved gradually. These groups in due course of time gave rise to higher plants. In a similar fashion, the animal kingdom may also have evolved from the simpler to complicated forms (fig. 1).

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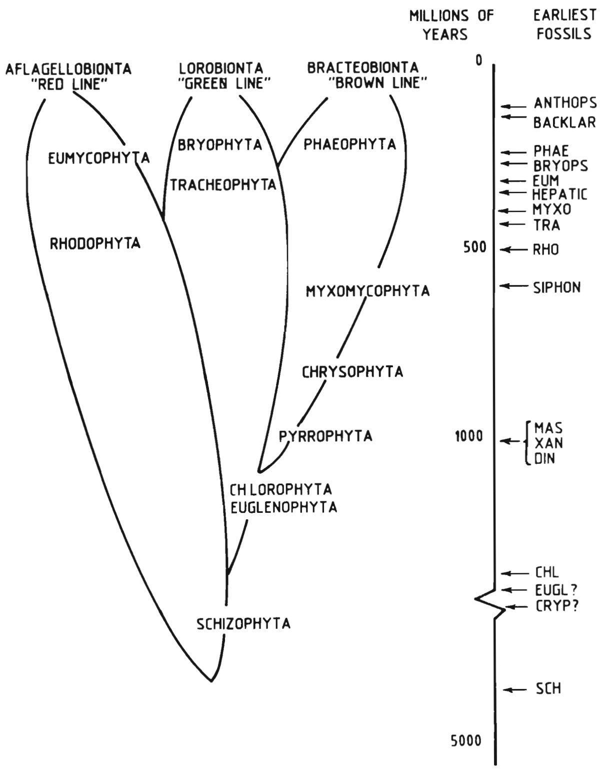

Fig.1. Showing the traces of evolution of plants from the earliest primitive bacteria and blue-green algae to the three kinds of extant plant groups (after Pearson, 1995).

WHY DO WE CHANGE ?

The change in an organism is primarily due to the fact that it has to cope successfully with the environment. Physical and biological environments of a species do not remain constant for a long time. Prolonged changes in environment induce subtle changes in life forms involving innovations. But all these changes do not necessarily induce genetic changes. Darwin (1859) observed that the natural selection is daily and hourly scrutinising the slighest variations among organisms, rejecting the bad ones and preserving those which lead to improvement of each organic being in relation to its biological and physical environments (fig.2).

Dobzhansky *et al.* (1977) remarked that the diversity of population-environment interactions is responsible for the fact that natural selection can either promote constancy, direct continuous change or promote diversification depending on the nature of environmental changes. If population-environment interactions remain constant through time, normalizing (stabilising) selection prevails and evolutionary process involves improvement of an organisms in an unchanging environment, arresting any major change. They further observe that if a particular sequence of population-environment interactions changes constantly in one direction, the result is *directional selection*. They assert that the organic evolution is a series of partial or complete and irreversible transformations of the genetic composition of populations based principally upon the altered interactions with their environment. It consists chiefly of adaptive radiations into new environments, and adjustments to environmental changes which sometimes give rise to better complexities to interact between population and environment.

CHANGES ARE DUE TO INHERENT WEAKNESS

Any organism that changes, explicits its incapability to cope with the surrounding environment. Any organism satisfied with the outer world, protected, well fed and populated, would lack the urge to change. Besides, an inborn flexibility,

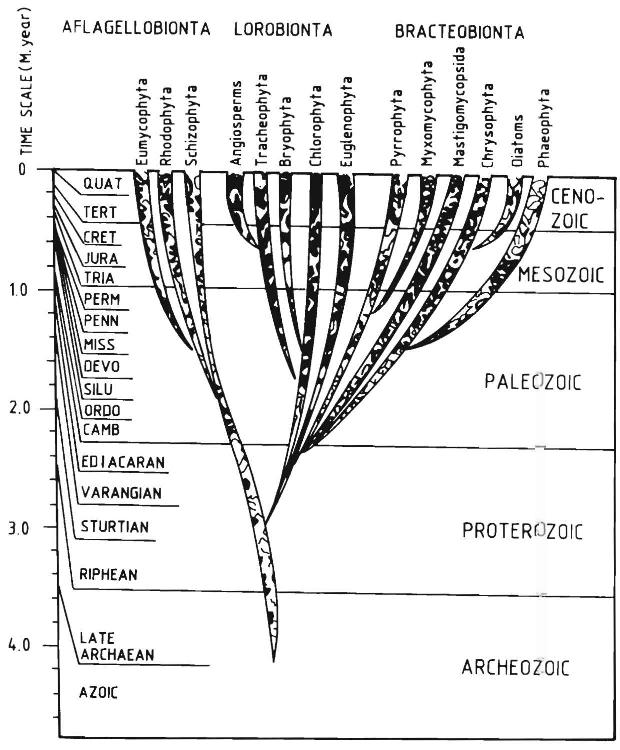

Fig.2. Showing the evolution of present-day eleven divisions of plants (after Pearson, 1995).

strength and accommodating capacity of a species may withstand all possible hazards of environment for billions of years without undergoing perceptible modifications in the body structure.

Xiao *et al.* (1998) observed that phosphorites containing algal thalli from the Doushantuo Formation of the Late Neoproterozoic age, southern China already possessed many of the anatomical and reproductive features seen in the modern marine algae.

This tendency and capacity of an organism to remain static but at the same time to continue for a long geological time, has unfortunately been labelled as an *archaic* or *primitive* feature. In the ladder of evolution, they have been placed at the bottom from which the so-called evolved species with complexities, ramifications and highly specialized structures originated. The geological history of a species or a group has hardly been taken into consideration in demarcating the advanceness. Dobzhansky (1955) remarked that this idea of evolution has become an integral part of the intellectual equipment of western civilization. In biological science, this idea is pivotal. Venkatachala *et al.* (1998) observed that extinction of any species is by no means a catastrophe, rather a progressive evolutionary sequence, for each one of them has been answered with more dynamic cause and effect modifications.

The clarion call of a dying species has been hailed as the stepping stone for the advancement of other species; the failure of the previous species has been regarded as the pillar of success for the next batch. Unnecessary elaboration, sophistication and dependance on others have been regarded as the zenith of development. The pursuit of life is not basically for adaptive adjustment to cope with the environment but to live hail and hearty and propagate without any difficulty. The moment an organism starts changing to cope with the outer world, there is no end of it. The more it changes to adjust with the environment, the more it becomes vulnerable to extinction. At last, a stage comes when the organism loses all its resources and ingenuities to change further and is wiped out. The sedimentary rocks are the mute spectators of this event as they eloquently reveal many forms of life which breathed last and were lost for ever. The index fossils may be important for palaeontologists to correlate and assign age for the sediments, but they also reveal their unworthiness to live long in spite of their maximum horizontal distribution for a short period of time.

Adaptive changes for new environment generally give rise to further complexities of the organism. But it is an unending process and the species, in spite of its best effort, is ultimately perished. So the inbuilt mechanism of an organism to fight the external world without undergoing any perceptible change in body structure is better adapted and more suitable for survival for a longer period. Adaptation and adjustment to the ever changing environment by introducing new characters are like a mirage in a hot desert – it always allures and the goal is never attained.

BLUE-GREEN ALGAE

These are also known as Cyanophyceae, Cyanophyta, Myxophyceae, Schizophyceae or Cyanobacteria. They occur as single cells of microscopic size, as small cell colonies of various shapes and as multicellular filaments. The individual cell comprises a prokaryotic protoplast surrounded by a cell wall which is usually covered by a gelatinous sheath composed of pectic compounds. They are generally divided into non-filamentous or

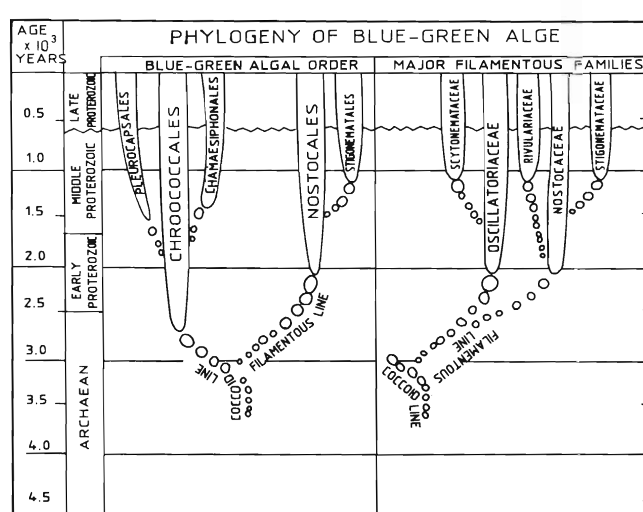

Fig. 3. Showing the inferred "Phylogenetic trees" of blue-green algae (after Schopf, 1974).

coccoid and palmellate forms and filamentous forms (Desikachary, 1959) (fig.3).

The fossil remains of blue-green algae generally found in microcrystalline cherts, are preserved by silica permineralization as three dimensional, structurally intact, organic residues. Dobzhansky (1955) remarked that in such deposits, clear-cut evidence of ecological setting, growth habit, general morphology, detailed cellular anatomy and mode of reproduction is rather commonly present. The fossil history of this group reveals that both the coccoid and the filamentous forms originated during the Early Precambrian, diversified moderately by the Middle Precambrian and became highly ramified and presumably quite modern in character by the Late Precambrian. Schopf (1974) opined that the Precambrian Era, encompassing the earliest seven-eighths of geological history, can be termed the age of the blue-green algae.

STRIKING CONSERVATISM IN BLUE-GREEN ALGAE

The morphological similarities between the fossil and present-day blue-green algae are striking. According to Dobzhansky (1955), the Bitter Springs microbiota are comparable to the extant genera *Lyngbya, Oscillatoria, Phormidium, Porhpyrosiphon, Schizothrix, Microcoleus, Spirulina, Nostoc, Anabaenopsis* and *Homeothrix* of filamentous form and *Anacystis, Chroococcus* and *Gloeocapsa* of coccoid form. It seems that once the Cyanophytes diversified and established themselves in the surrounding environment, there were hardly any subsequent morphological modifications. Schopf (1974) opined that the earliest blue-green algae would have been a coccoid, sheathless, non-colonial chroococcacean of generalized type, perhaps similar to *Synechocystic*. *Archaeosphaeroides barbertonensis* recovered from the chert of the 3.1 billion year old Fig Tree Formation closely resembles the above-mentioned genus.

Dobzhansky (1955) remarked that the evolutionary conservatism of blue-green algae is striking both because of the high degree of comparability between fossil and extant taxa and because of the extremely long duration of various lineages, several of which exceed half the accepted age of the earth.

Schopf and Blacic (1971) presumed that the morphological conservatism of the blue-green algae was perhaps paralleled by a comparable degree of biochemical conservatism resulting in a wide ecological tolerance, versatile physiology and unusually stable genetic system characteristic of the group. They noted that the environmental limits for survival, growth and reproduction of blue-green algae are remarkably broad in comparison to all other photosynthetic organisms. They not only survive but often thrive at or near environmental extremes inimical to normal biological activity. Schopf and Blacic (1971) declared that in physiological characteristics, Cyanophytes are among the most versatile of living systems, a capability and versatility that free them from dependance on factors that inhibit the distribution of other photosynthetic entities.

Last, but not the least, blue green algae, like their allied bacterial prokaryotes, have a genetic system which is markedly immune to mutagens and perhaps more importantly they appear to be an almost exclusively asexual.

Absence of sexual reproduction apparently hinders the potentiality for genetic recombination which is the major source of variability in populations of higher organisms. The Cyanophytes in this way remain genetically stable and are highly successful generalists. A favourable ecological niche, relatively free from competition which emancipated them from the pressure of adaptive change, was available to them since the early geologic time.

SURVIVAL STRENGTH SHOULD BE JUDGED BY LONGEVITY

The first and only living thing for approximately 2 billion years in this world was prokaryotes comprising the bacteria and the blue-green algae. It was assumed that the eukaryotes evolved from the prokaryotes about 1.2 to 1.4 billion years ago. It is now established that microfossils were recovered from the North Pole, Western Australia in the formations reliably dated as 3.5 billion years in age

(Gurin, 1980). These seem to be prokaryotic, similar in size and form to bacteria. The blue-green algae of the same age were also reported by Schopf (1993). Schopf and Barghoorn (1967) also recorded bacteria and blue- green algae from the Fig Tree Formation of South Africa, dated approximately as 3 billion years in age.

Considering the fossil history of Cyanophytes, Dobzhansky (1955) regarded them as really archaic. The prominence of this group, however, markedly declined with the advent of the eukaryotes in abundance in the Late Precambrian. The eukaryotes as the name implies are having true nucleus and capable of sexual reproduction. It seems that this group has overshadowed the Cyanopytes and cornered them in many habitats. But judging from their omnipresence in all possible habitats, the blue-green algae should never be underestimated in spite of their dwindled numbers. When the earth is teeming with the eukaryotes mostly of macroscopic size, no wonder the microscopic prokaryotes would be overlooked and may even be neglected.

The sexual reproduction of the eukaryotes has been hailed as the clue of this success as it opens a new realm of permutation and combination to produce efficient progenies. Smith (1971) and Williams (1975) questioned the adaptive value of the sexual cycle and pointed out that it should not be regarded as a panacea for success. Williams (1975) holds that a well-adapted diploid genotype, in order to produce offspring that are equally adapted to their particular environment, must pay a "50 per cent cost of meiosis" because each gamete contains only 50% of the parental alleles. The very adaptive gene combination of the organism is also at stake in this process as the other organism may not be that adaptive. Sexual reproduction in this case may be detrimental for the species. The waste of energy resources inc red by an organism in pursuit of sexual reproduction is often colossal. To fertilize a few ova in a Pine tree, billions of pollen grains are produced. Sometimes, the fertilization of egg cells precariously depend on some insects as in orchids. The conceived mother mammal has to feed the foetus in the womb for long and then nurse the baby carefully even for a couple of years. The sexual reproduction in this context should be regarded as a cumbersome and hazardous proposition. It is not only time taking but often risky.

The loss of asexual reproduction may thus be regarded as a lack of manoeuvreness and ingenuity. Williams (1975) noted that if an organism lives in a constant, homogenous environment, natural selection would favour the asexually produced offspring rather than the sexual ones because it may reduce the adaptive fitness.

The inbuilt flexible adaptive faculties of the Cyanophytes may thus favour asexual reproduction not out of compulsion but by choice. After all, facing favourable and unfavourable conditions for the last 3 billion odd years, the blue-green algae are still going strong. If this group could exist for such a long time braving all possible hazards of climate, then one should in earnest seek the cause for its enormous strength. The obvious answer to such a query, firstly lies in the tiny or humble magnitude of its populations superbly maintained through 3 billion years of earth's history. Secondly, the lack of nuclear membrane is dictated by the small cell size permitting the dispersion of nuclear material in prokaryotic architecture, demanding least energy for reproduction of the identical population. Grell (1967), after surveying the modern unicellular organisms, concluded that those organisms having least specialized cell structure such as Chrysomonadina, Cryptomonodina, Euglenoidea and Amoebina are devoid of sexual reproduction. It would indeed be an utter understatement to call blue-green algae the most primitive; rather, they should be hailed as the most practical, successful and flexible group which has been ruling the earth since its inception. Similar sentiment was also endorsed by Dobzhanasky (1955) when he expressed that if biological success is measured by longevity of existence, the Cyanophyceae constitute the most successful form of aerobic, photo-autotrophic organisation to have appeared in the long course of biological history.

Strangely enough, the algologists seem to be more conservative than the Cyanophytes in claiming the evolutionary linkage of this group from the oldest fossil records. Desikachary (1959), Desikachary and Padmaja (1970), Fritsch (1965) and Klein and

Cronquist (1967) are not at all enthusiastic on this score. Fritsch (1965) commented that should even some of the fossil types, referred to Cyanophytes, actually belong to this class as well as they may, they provide no morphological data that might help in the elucidation of structural features or the evolutionary sequence. Klein and Cronquist (1967) claimed that a fossil record of thallophytic evolution is lacking and further declared that it is a state of affairs unlikely to be remedied.

Schopf (1974), however, maintains that above-mentioned views are no more tenable. He thinks that the fossil record represents a rich source of significant data that can make a major contribution toward deciphering the course of thallophytic phylogeny.

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