BULL. BOT. SURV. INDIA
Vol. 45, Nos. 1-4 : pp.165-172, 2003

ON THE OCCURRENCE OF *GLAUCOCYSTIS* ITZIGSOHN IN EASTERN INDIA

PRASANTA MALLICK AND JAI PRAKASH KESHRI*

Department of Botany, The University of Burdwan,
Golapbag, Burdwan -713104, West Bengal

ABSTRACT

Glaucocystis Itzigsohn is an apoplastic alga containing blue-green endosymbionts (cyanelles). Status of this genus is being discussed in light of recent findings. Out of the five species known from Indian region, *Glaucocystis nostochinearum* Itzigsohn and *G. reniformis* Prasad are being described and illustrated. These two species are new records from West Bengal and Eastern India.

INTRODUCTION

Glaucocystis is an alga of interesting circumscription and position in the microbial world. The genus was erected by Itzigsohn (in Rabenhorst 1968) as a coccoid alga remarkable for its possession of several blue-green chromatophores which he named *Glaucocystis nostochinearum*. The genus *Glaucocystis* was variously assigned to Cyanophyceae, Chlorophyceae and Rhodophyceae by different workers. Most interesting feature of this alga is the possession of blue-green chromatophores which actually are the blue-green algae or cyanobacteria. It, therefore, is an example of endosymbiosis or endocytobiosis. This fact attracted phycologist and many evolutionary biologists since it is a case of symbiosis between heterotrophic host cells and modified autotrophic cyanobacterial endosymbionts functioning as chloroplasts. Such endosymbionts were named "cyanelles" by Pascher (1929). Pascher also introduced the terms "endo-cyanome' for the whole consortium and "endocyanosis" for this interesting type of endosymbiosis. This relationship arouses interest in evolutionary biologists as it reflects clear lights on the origins of algal plastids. The endosymbiotic nature of plastids was first proposed by Mereschowsky (1905) as endosymbiotic theory of chloroplast evolution. According to Mereschowsky (1920) 'I called this process symbiogenesis, which means: the origin of

Received on 11th July, 2003; accepted on 15th September, 2003.

organisms through combination and unification of two or many beings, entering into symbiosis" This theory proposes the origin of algal plastids as an engulfment of cyanobacteria by a heterotrophic protozoan which by a chance mutation not digested. It appears that this was a beneficial mutation that led host protozoan to receive good amounts of metabolites from the cyanobacteria. Cyanobacteria in turn received the opportunity to live in a protected environment. Moreover this composite organism provided a new advantage to go and live in an ecological niche where there were no photosynthetic organisms e.g. in a slightly acid body of water where free living cyanobacteria scarcely grow (Lee, 1999). But establishment of a cyanobacterium to a chloroplast was a long way because the cyanobacterium still had a peptidoglycan wall and many more physiological and genetical modifications were still to occur. The nature of cyanelles has thoroughly been investigated by various workers (Hall and Claus, 1967; Herdman and Stanier, 1977; Kies, 1980, 1984, 1988; Scott & al. 1984) to decipher the nature and the process of symbiosis. One of the most interesting finding is that *Glaucocystis nostochinearum* has been shown to have a peptidoglycan layer in its cyanelles (Scott & al., 1984). The wall is 7-10 μm in thickness (Kies, 1984) and upon treatment with penicillin cyanelles stops dividing and lose phycobiliproteins (Kies, 1988). It is concluded that the peptidoglycan wall of cyanelles is indispensable for the maintenance of the endosymbiosis in this type of organisms. Therefore it appears that the loss of peptidoglycan wall during the course of evolution necessitated the invention of new modes of division since like cyanobacteria peptidoglycan wall is essential for the division of cyanelles which, is accomplished by a centripetally in growing peptidoglycan septum (Kies, 1988). The *Glaucocystis nostochinearum* cyanelles have been found to have only about 10% as DNA as the free-living coccoid cyanobacteria (Herdman & Stanier, 1977). This is interpreted as evidence for the genomic reduction in symbiosis with time because it indicates consistent reduction in genetic autonomy (Kies & Kremer, 1990). In cyanelles the thylakoids are concentrically arranged and interthylakoidal phycobilisomes are present. The cyanelles possess pigments: - chlorophyll-a ß-carotene, zeaxanthin, ß-cryptoxanthin, allophycocyamin and c-phycocyanin but lacks carotenoids like echinenone and myxoxanthophyll. Unlike free-living cyanobacteria which synthesize sucrose, the carbohydrates synthesized are glucose and fructose. Glucose is transferred and accumulated in the host cytoplasm as maltose. Cyanelles have lost the ability to synthesize highly branched glucans. Predominant lipid in cyanelles is monogalactosyl-diacylglycerol. The features mentioned and many others indicate that cyanelles show

only 60% similarity with the chloroplast (Kies & Kremer, 1990). Therefore, from a biochemical and physiological point of view cyanelles should best be referred as obligate photosynthetic endosymbionts of cyanobacterial ancestry. Margulis (1993) who enlighted in detail the causes and consequences of this endosymbiosis in light of serial endosymbiosis theory, like Fritsch (1935, 1945), however, believes that *Glaucocystis nostochinearum* should be considered as a product of 'reingestion' that lost its green chloroplast and reingested cyanobacteria that became endosymbionts. Ultra structural studies have confirmed this explanation (Hall & Claus, 1967). In *Glaucocystis* reduced undulopodia (a term applied for eukaryotic cilia & flagella by Margulis to distinguish them from prokaryotic flagella since they are ultra structurally different) are present. The cruciate kinetid contains four multilayered structures (MLS) which is a primitive character (Kies & Kremer, 1990).

Due to the nature of cyanelles the systematic position of *Glaucocystis* and many similar organisms were in great debate. *Glaucocystis* was placed in Cyanophyceae by many phycologists like Smith (1950) and Prescott (1962), although its relationship with Oocystaceae (Chlorococcales: Chlorophyta) has also been recognized. Others like Fritsch (1935, 45), Bourrelly (1972), Philipose (1967) & Chapman & Chapman (1973) have described the genus under Chlorococcales of Chlorophyta. According to them this genus is closely related to *Oocystis* since within the host cell 2-8 elliptical or ovoid to spherical cells could be found. Polar and equational nodes, the characteristic feature of *Oocystis* has also been found in some species of *Glaucocystis* such as in *G. oocystiformis*. Even then phycologists are unified regarding the nature of axial chromatophores appearing as a number of curved bands or vermiform projections radiating around the nucleus from the center towards the periphery, since the compelling evidence goes in favour. The chromatophores or cyanelles were raised to the rank of cyanobacterial taxa: *Skujapelta nuda*. Hall & Claus (1967) created a new family Skujapeltaceae to accommodate this taxon. But since cyanelles have only very limited biochemical and genetical competence (Kies & Kremer 1990) and attempts to grow them outside their host have failed, the identity of this taxon is warranted. It is, therefore, Skuja's treatment (Skuja 1954) of the group to accommodate *Glaucocystis* under a new division of algae as Glaucophyta is more justified. Skuja's treatment was adopted with modifications by Starmach (1966). Kies (1979, 1980) included some more genera like *Cyanophora*, *Gloeochaete* & *Glaucosphaera* to this group with the suggestion of reviving the class

Glaucocystophyceae that share similar ultra structural features but not encountered in other algae. This suggestion was accepted by most phycologists and evolutionary biologists. An emendation including the typification of several taxa of the Glaucocystophyta and its detailed account is given by Kies & Kremer (1986, 1990).

The Genus *Glaucocystis* in India is represented by five species: *Glaucocystis nostochinearum* Itzigsohn (Prasad, 1961; Prasad & Misra, 1992), *G. cingulata* Bohlin (Patel & Isabella, 1979), *G. duplex* Prescott (Patel and Isabella, 1979), *G. indica* Patel (Patel, 1981) and *G. reniformis* Prasad,-Mehrotra & Misra (Prasad & al 1984). In the course of investigations on the freshwater algae of West Bengal the authors recorded following two taxa:

1. **Glaucocystis nostochinearum** Itzigsohn (Itzigsohn in Rabenhorst 1868, p. 417; Philipose 1967, p. 188, figs. 101-102; Prescott 1962, p. 474, pl.108 fig. 2; Prasad & Misra 1992, p. 21, pl. 2, figs. 9, 13). **(Figs. 1a, c-h)**

Free floating blue-green colonies of 4-8 (usually 4) elliptical cells enclosed by the old mother cell wall; host cells reproducing by autospore formation; cell wall 1.5-2.5 μm in thickness; cells with several vermiform chromatophores or cyanelles radiating from the center towards the periphery, less than 20 in number; bright blue green in colour; cells 7.5-13.5 μm broad, 15-24 μm long; colony of 4 cells 30-36 μm broad and 30-48 um long.

The algae were found growing intermingled with desmids and angiosperms like *Hydrilla* sp, *Jussiaea repens* Linn. and *Ceratophyllum* sp. in a lake (Lalbandh, Bishnupur, Bankura district) having acidic pH (around 6-6.5) in the winter months of the year (October-January). The specimens were collected from similar habitats of Purulia district also.

Distrib.: INDIA : Kerala (Prasad 1961), Gujarat (Patel & Isabella1979), Andaman (Prasad and Misra 1992), West Bengal.

2. **Glaucocystis reniformis** Prasad, Mehrotra & Misra (Prasad, Mehrotra & Misra 1984, p. 79-84, figs.1-8). **(Figs. 1a, b)**

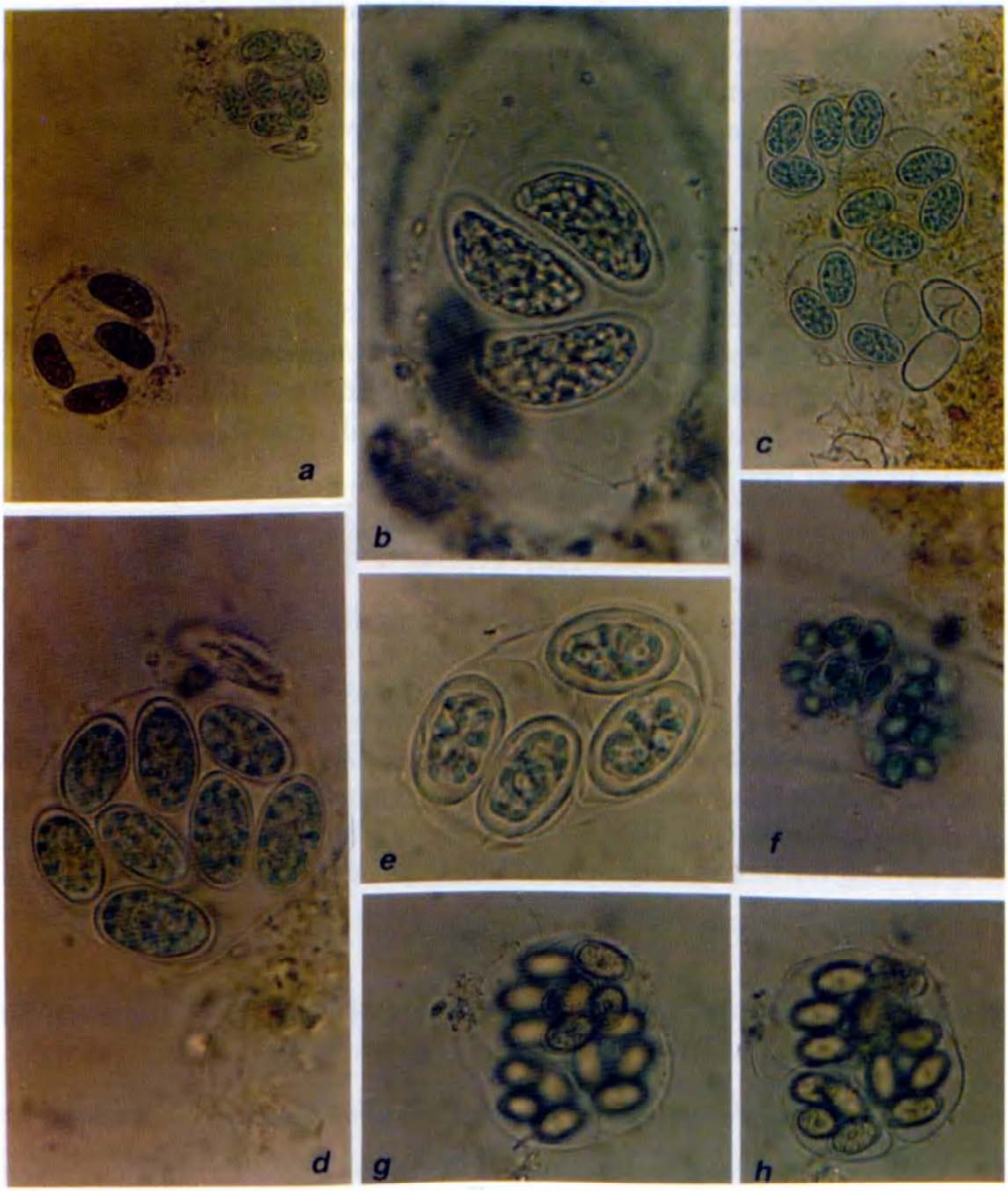

Fig1. (a-h) : a. Upper colony : *Glaucocystis nostochinearum* Itzigsohn.
Lower colony *Glaucocystis reniformis* Prasad (both × 480)
b. *G. reniformis* showing the nature of cyanelles (× 1200);
c,f,g.h. *G. nostochinearum* showing nature of colonies (× 480)
d.e. *G. nostochinearum* showing nature of colony and cyanelles (× 1200)

Free floating and attached colonies of 4 cells embedded in mucilage; cells kidney shaped, light blue green to brownish in colour, 12-30 μm in diameter, 25-32 μm long; cell wall 1.5-2.0 μm in thickness; cyanelles blue-green in colour, parietal, vermiform and scattered in nature, approximately 20 in number; colony of 4 cells 51-57 μm broad and 75-80 μm long.

Our specimens are larger than the type.

The algae were found intermingled with desmids and attached on submerged Hydrilla plants in the winter months of the year (November-December) in a lake (Lalbandh Bishnupur, Bankura district) having a pH of 6. It is interesting to note that this genus is not so uncommon and scarce as mentioned in the literature, at least in the desmid habitats of West Bengal.

Distrib.:INDIA : Andaman (Prasad, Mehrotra & Misra 1984), West Bengal.

Both these taxa are new records for West Bengal & Eastern India.

ACKNOWLEDGEMENTS

The authors are grateful to Prof. P.K. Pal, Head, Department of Botany, Burdwan University for Laboratory facilities and active help in taking photomicrographs; Prof. K.K. Gupta, Co-coordinator, DSA Botany B. U. and Prof. Pranjit Sarma for various help in carrying out this investigation and U.G.C. (New Delhi) for financial assistance.

REFERENCES

BOURRELLY, P. Les algues d'Eau douce. Initiation la systematique. I. Les Algues Vertes. N. Boubée. & Cie. Paris. 1972.

CHAPMAN, V.J AND D.J. CHAPMAN. The Algae. MacMillan & Co. Ltd. London. 1973.

FRITSCH, F.E. Structure and Reproduction of the algae. 2 vols. Cambridge University Press, Cambridge. England. 1935, 1945.

HALL, W.T. AND G. CLAUS. Ultra structural studies on the cyanelles of *Glaucocystis nostochinearum J. Phycol.* 3: 37-51. 1967.

HERDMAN, M. AND R.Y. STANIER. The cyanelle; chloroplast or endosymbiotic prokaryote? *Fed. Eur. Microbiol. Soc.* 1: 7-12. 1977.

KIES, L. Zur systematischen Einordnung var. *Cyanophora paradoxa*, *Gloeochaete wittrokiana* and *Glaucocystis nostochinearum*. *Berichte der Deutschen Botanischen Gesellschaft*. 92 : 445-454. 1979.

KIES, L. Morphology and systematic position of some endocyanomes in Endocytobiology. *In* : W. Schwemmler & H.E.A. Schenk (eds.). Endosymbiosis and cell Biology 1. Walter de Gruyer, Berlin, pp. 7-19. 1980.

KIES, L. Cytological aspects of bluegreen algal endosymbiosis. *In* : Wissner, W. D. Robinson, and R.C. Starr.(eds.). Compartments in Algal cells and their interactions. Springer-Verlag, Berlin, Heidelberg. pp 191-199. 1984.

KIES, L. The effect of penicillin on the morphology and ultrastructure of *Cyanophora*, *Gloeochaete* and *Glaucocystis* (Glaucocystophyceae) and their cyanelles *Endocytobiosis & Cell Res.* 5: 361-372. 1988

KIES, L. AND B.P. KREMER. Typification of the Glaucocystophyta. *Taxon* 35: 128-135. 1986.

KIES, L. AND B.P. KREMER. Phylum Glaucocystophyta. *In* : Margulis, L, J.O. Corliss, M. Melkonian, and D. L. Chapman (eds.). Handbook of Protoctista. Jones & Bartlett Publishers, Boston, MA. pp 152-166. 1990.

LEE, R.E. Phycology, 3rd Ed. Cambridge University Press. 1999.

MARGULIS, L. Symbiosis in cell Evolution. 2nd Ed. W.H. Freeman and Company, New York. 1993.

MERESCHKOWSKY, C. Über Natur und Ursprungder chromatophoren in pflanzenreiche. *Biol. Zentralbl.* 25: 593-604. 1905.

MERESCHKOWSKY, C. La plante considerée comme un complexe symbiotique *Societé des Sciences Naturelles de l'Quest de la France, Nantes, Bulletin.* 6: 17-98. 1920. [Cited in Khakhina 1979].

PASCHER, A. Studien Über Symbiosen I. Über einige Endosymbioseen von Blaualgen in Einzellen. *Jahribücher für Wissenschaftliche Botanik.* 71: 386-462. 1929.

PATEL, R.J. *Glaucocystis indica* Patel *sp. nov.* from India. *Geophytology* 11 (2) : 259-261. 1981.

PATEL, R.J. AND G. ISABELLA. Chlorococcales of Gujarat, India: *Gloeotaenium*, *Oocystis*, *Glaucocystis* and *Nephrocytium*. *Vidya, J. Guj. Univ.* 22(1): 1-9. 1979.

PHILIPOSE, M. T. Chlorococcales, I.C.A.R. New Delhi. 1967.

PRASAD, B.N. *Glaucocystis nostochinearum* (Itzigs.) Rabenhorst in India. *Bull. Bot. Soc., Univ. Saugar.* 13(1-2): 44-45. 1961.

FRASAD, B.N., R. K. MEHROTRA AND P. K. MISRA. *Glaucocystis reniformis* sp.nov. from Andaman Islands. *Cryptogamie, Algologie* 5 (2-3):78-83.1984

PRASAD, B.N. AND P. K. MISRA. Freshwater algal flora of Andamann and Nicobar Islands vol. II. Bishen Singh Mahendra Pal Singh, Dehradun. 1992.

PRESCOTT, G.W. Algae of the Western Great Lakes Area, 2nd Ed. Wm C. Brown, Company Publishers, Dubuque. I.A. 1962.

RABENHOST, L. Flora Europaea Algarum Aquae Dulcis & Submarine Sectio III. Lipsiae. 1968.

SCOTT, O.I., R. CASTENHOLZ, H.T. BONNETT. Evidence for a peptidoglycam envelope in the cyanelles of *Glaucocystis nostochinearum* Itzigsohn. *Archives of Microbiology*. 139: 130-138. 1984.

SKUJA, H. Glaucophyta. *In* : Melcher, H. and E. Werdermann (eds.). Syllabus der pflanzenfamilien Vol. I. Bortraeger. Berlin. pp. 56-57. 1954.

SMITH, G.M The Fresh-water algae of the United States, McGraw Hill. New York. NY. 1950.

STARMACH, K. Cyanophyta-Sinice, Glaucophyta-Glaucofity. Flora Slodkowodna Polski Vol. 2. Warszawa. 1966.