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AN INTRODUCTORY ACCOUNT ON SOME ALGAL NANOPLANKTERS OF THE SOUTH WEST COAST OF INDIA

By SYDNEY SAMUEL

Department of Marine Biology and Oceanography
University of Kerala, Cochin-16

INTRODUCTION

NANOPLANKTERS are mostly of phytoplankton having a range in their size from 5-50 micron. These plankters are widely distributed throughout the ocean and play a very important part in the primary production and oceanic food chain. Studies by Steemann Nielsen and Jensen, 1957 ; Steemann Nielsen, 1938 ; Riley, 1941 ; Harvey, 1950 ; Butcher, 1952 ; Wood and Davis, 1956 ; Yentsch and Ryther, 1956 ; have shown that nanoplankton is an important part of the microflora. Miller, Moore and Kvammen (1953) found by chlorophyll estimation that they are up to 1,000 times as numerous as the net phytoplankton of Miami. Wood (1961) has estimated that the ratio of nanoplankton to net phytoplankton in the Tasman sea is of the order 100/1, while in the Coral Sea almost all production was found to be due to nanoplankton (Allen 1961). Experiments conducted by Cole (1936 and 1939) Bruce, and Knight and Mary Parke (1940) have revealed that oyster larvae depend for their food on these microplankton as they can ingest only organisms coming below 10 micron. Besides, larval stages of many of the plankton feeders and adult invertebrates depend on these plankters for their existence (Butcher 1952 and 1959).

In contrast to the relatively abundant information on other groups of phytoplankters such as diatoms and dinoflagellates is the extreme paucity of data on this group of smaller phytoplankters. This lack of knowledge of these smaller plankters is a serious gap in information about the organisms that are responsible for primary production (Allen 1961).

Though the importance of the part played by nanoplankton in the food chain and primary production in the tropical seas has been long recognised by the studies of Hasle (1959) and Norris (1961), no work has been done so far in Indian waters. Hence a study of these organisms of the west coast of India was taken up to augment the knowledge of these phytoplankters of this region.

MATERIAL AND METHOD

Dicrateria sp., *Chlorella* sp., and *Cryptochrysis* sp., were obtained from water samples collected during the off-shore cruises of R.V. Conch and R.V. Varuna, and *Tetraselmis* sp., and *Tetracystis* sp., were collected from coastal waters.

These organisms have to be examined alive, since they loose their shape and some of the important organelles on preservation. They were therefore inoculated in various media (Miquel's modified by Ketchum and Redfield 1938, Schreiber's modified by Foyns 1938) as recommended by Subrahmanyan (1952). Miquel's Solution was found to be more suitable for the thick growth of these species, and soil extract seems to be not essential for them.

Dilution method of isolation recommended by Allen and Nelson (1910) and Knight Jones (1951) was adopted in most cases except for some motile forms in which case their phototropic habit was exploited for isolation.

Daily observation of these organisms raised in these media give a clear understanding of the various stages in their life cycle and duration of each stage.

Taxonomy

CHLORPHYCEAE

CHLAMYDOMONADINEAE

Tetraselmis Stein

Platymonas West, G. S., 1916, *J. Bot. Lond.*, **54**, 3 ; Kylin, H., 1935, *Kungl. Fysiogr. Salki. Lund. Forhandl.*, **5**, 22 ; Manton, I and M. Parke., 1965, *J. Mar. Biol. Ass. U.K.*, **45**, 743-754 ; Butcher, R. W., 1959, *Fish Invest.*, Ser. **IV**, 67-71.

Green motile flagellates with the shape varying from ellipsoid to ovoid. This genus invariably possesses an apical, shallow or deep furrow from where the flagellae arise. Possession of clear eye-spot and pyrenoid is commonly noticed. They swim rapidly in a straight line with the flagellae directing forward, body at the same time twisting around. Reproduction which is as usual takes place by a longitudinal division of the protoplast within the mother cell into two daughter-cells. On maturity all of them form either one-celled or two-celled cysts. Though this genus is closely allied to *Carteria*, it is distinguished from *Carteria* by the flattening of the cell, lobing of the apex, position of the eye-spot and in the nature of the cyst.

Tetraselmis carteriformis Butcher

(Figs. 1-7)

Butcher, R. W., 1959, *Fish. Invest.*, Ser. **IV**, 69-70.

Cells $12\text{-}16 \times 8\text{-}11 \times 7$ micron, broadly ovoid in front view, and the base of the cell is somewhat acute in lateral view. The apex of the cell possesses a shallow furrow from where the four flagellae which are more or less equal to the length of the cell arise. Anterior part is four-lobed to the region of the pyrenoid. The contents of the cells include a large basal pyrenoid which is irregularly round with a reniform starch sheath, orange coloured large sub-median stigma, and a few irregularly arranged starch grains. Chromatophore is single, smooth, cup-shaped and pale green in colour, which becomes coarse and granular, as the cells grow old.

Reproduction asexual and takes place by the longitudinal division of the resting cell. Before the liberation, the young ones develop their flagellae.

Both one-celled and two-celled cysts (rarely 4-celled) begin to form in the culture after two weeks and this formation continues up to 40 days. These cysts are provided with thick striated cell-wall and a papillar outgrowth at the place of the furrow, as the cysts complete their development, the young ones inside the mother cell wall begin to move, and by the rupture of the wall they come out.

Found in the rock pools on the Isle of Cumbrae, Scotland. In India collected from the coastal waters of Cochin.

Tetraselmis gracilis (Kylin)

(Figs. 8-11)

P. gracilis, Kylin, H., 1935, *Kungl. Fysiogr. Salki. Lund. Forhandl.* Bdv., Nr. **22**; Butcher, R. W. 1959, *Fish. Invest., Ser.* IV.

Cells 8-12×6.5-8×4.5 micron cylindrical in lateral view and both ends appear to be rounded in dorsal view. The apex of the cell possesses a shallow furrow, from the base of which four identical flagellae, equal to the length of the cell emerge. A long narrow sinus passed from the furrow to the base of the cell. The cell includes a basal pyrenoid with 'U' shaped starch sheath, an orange-red stigma of median position and rows of starch granules arranged from the tip of the cell to the pyrenoidal region. Chromatophore axile, pale green and granular in appearance.

Reproduction is by the longitudinal division of the mother-cell contents into two daughter-cells. Cyst formation begins after one week and continues up to 3 weeks. One-celled and two-celled cysts having striated thick walls are formed with indistinct papilla at the anterior end.

This species differs from *T. carteriformis* in size, shape, position of stigma, shape of pyrenoid, presence of more granules, long narrow sinus in the chromatophore, and the indistinct nature of the papillae in the cyst.

Found in ditches, salt marshes and pools in Kent-isle of Wight and in the west coast of Sweden. In India it occurs in the Cochin coastal regions where slight back-water influence is present.

Chlorellaceae

Chlorella Beijerinck

Beijerinck, W., 1904, *Rec. Trav. Bot. Neerl.*, I, 14-27; Fritsch, F. E., 1935 *Structure and Reproduction* of Algae, Vol. I, Butcher, R. W., 1952, *J. Mar. Biol. Ass. U. K.*, 31; 179-181.

Non-motile unicellular forms with spherical or ovoidal shape. Cells are found singly or in aggregate patches. Reproduction is by the division of the cell contents into two to eight non-motile spores.

Chlorella marina Butcher

(Figs. 12-15)

Butcher, R. W., 1952, *J. Mar. Biol. Ass. U.K.*, 31 ; 179-181.

Cells 8-13$\times$5-8 micron in size, and are found in patches or singly, oval in shape and possess a smooth thin cell-wall. Chromatophore is a parietal plate, bright green in colour, finely granular and almost fills the whole cell. Pyrenoid and stigma absent. But in certain cells especially in older cells pyrenoid like bodies are noticed, but on test it is found to be not starch but oil. These bodies are mostly located at one end of the cell. As the cell grows the chromatophore becomes more granular, dark green and irregular in shape.

Propagation by the successive division of the mother-cell (size 16 micron) into 8-16 daughter-cells. The non-motile daughter-cells will be liberated by the rupture of the mother cell wall.

This species is found growing in the water samples collected from the off-shore waters of Quilon. It has been isolated formerly by M. Parke from Port Erin. This species resembles Butcher's *C. marina* in all the characters except for the difference in size.

Chlorella ovalis Butcher

(Figs. 16-21)

Butcher, R. W., 1953, *J. Mar. Biol. Ass. U.K.*, 31 ; 180-181.

Cells 3-5$\times$5-10 micron in size, and are found singly or in aggregate patches. Cells are oval or ellipsoidal in shape with a smooth thin cell-wall around it. Chloroplast green parietal, smooth occupying almost all the space, leaving a hyaline space at one end. This character is very predominant in younger cells. Pyrenoid absent.

Asexual reproduction is brought about by the successive division of the mother-cell content (size 10 micron) into 4-8 daughter-cells. These daughter-cells are released out by the rupture of the mother-cell. Usually the daughter-cells remain together and form patches.

First isolated from river Crouch Essex. In India, collected and isolated from Cochin coastal waters.

Chlorella salina Butcher (Figs. 22-25)

Butcher, R. W., 1952, *J. Mar. Biol. Ass. U.K.*, 31 ; 179-180.

Cells 5-7 micron in diameter in size. Smooth thin cell-wall can be seen very clearly in these bright green spherical cells. Chloroplast green, granular, and saucer-shaped. Pyrenoid present and it is large and centrally placed. Starch sheath is present around the pyrenoid.

Propagation is by asexual method as in all other chlorella. Successive division of the mother-cell contents into eight daughter-cells, and on maturity they come out by rupturing the mother-cell wall.

Collected from the Laccadive sea. First isolated from Conway tanks.

Chlorosphaeraceae

Tetracystis Brown and Bold

Brown, R. M., and Bold, H. C., 1964, *The University of Texas Publication*, No. 6417.

Vegetative cells spherical and are found singly or in aggregate patches of 2 to 16, chloroplast parietal cup-shaped with fissures here and there. Pyrenoid conspicuous.

Both asexual and sexual reproduction noticed. Asexual by the division of the mother-cell into 2 to 8 vegetative cells which lack motility, thus it differs from the aplanospores which arise from motile or potential motile pre-cursors. Asexual reproduction also can take place by the formation of zoospores from cells of all ages, even from young vegetative cells. Zoospore do not become spherical on quiescence.

Sexual reproduction by biflagellate gametes.

Tetracystis sp.

(Figs. 27-32)

Young vegetative cells ovoid, mature rapidly into spherical cells of diameter ranging from 13 to 16 micron. The cell-wall which is initially thin, becomes thick and striated as it grows. Chloroplast parietal cup, somewhat massive and fills the cell almost completely leaving a small clear cytoplasmic area either in the centre or on the side. The chloroplast in younger cells, is smooth and greenish whereas in older cells it is granular and pale green. The single large pyrenoid is median in position, and in most form irregular in shape. Starch grains are present around the pyrenoid. Occasionally brownish aggregate bodies of oily nature are noticed in older cells.

Asexual reproduction, by vegetative cell division and by zoospore formation are very frequent, and rarely by the formation of aplanospores. During vegetative multiplication, cells divide and form diads, tetrads and even octads of non-motile vegetative daughter-cells. These daughter-cells may sometime divide even before they dissociate from the mother wall, and form cell complexes.

Zoospore formation usually takes place between 9 and 11 a.m. Biflagellated, ovoid zoospores of 3×6-8 micron in size develop from the vegetative cells of all ages, even from the daughter-cells before they escape the mother-cell wall. Zoospores possess basal nucleus, parietal chloroplast, central pyrenoid, anterior stigma and contractile vacuole. The two flagellae are as long as the length of the cell. In almost all the zoosporangia, only 4 or 8 zoospores are produced. Spherical aplanospores are observed in old cultures.

Sexual fusion of the zoospore-like, biflagellated isogametes are noticed. Further development of the zygote is not observed.

This organism was obtained from the water samples collected from Cochin coastal waters having a salinity of 25 °/₀₀. Though this organism show some resemblances to *Chlorococcum* in appearance and life cycle, distinguishes itself in the production of diads and tetrads of vegetative cells, which are not aplanosporic in origin and nature, and in the ovoidal shape of the zoospores even after quiescence.

This species differs from other species of *Tetracystis* in the nature of its cell-wall, which is thick and striated, in the occasional presence of brown aggregate bodies in older cells and in its occurrence in the sea.

Its presence in the inshore marine region and its tolerance of a highly saline medium shows that it can be given the status of a marine species. Further studies on this species are in progress.

CHRYSOPHYCEAE

Dicrateria Parke

Parke, M., 1949, *J. Mar. Biol. Ass. U.K.*, 28, 255; Pierre

Bourrelly, 1958, *Review Algologique Memoir. Hors*; Serie 1, 229.

Dicrateria gilva Parke

(Figs. 33-35)

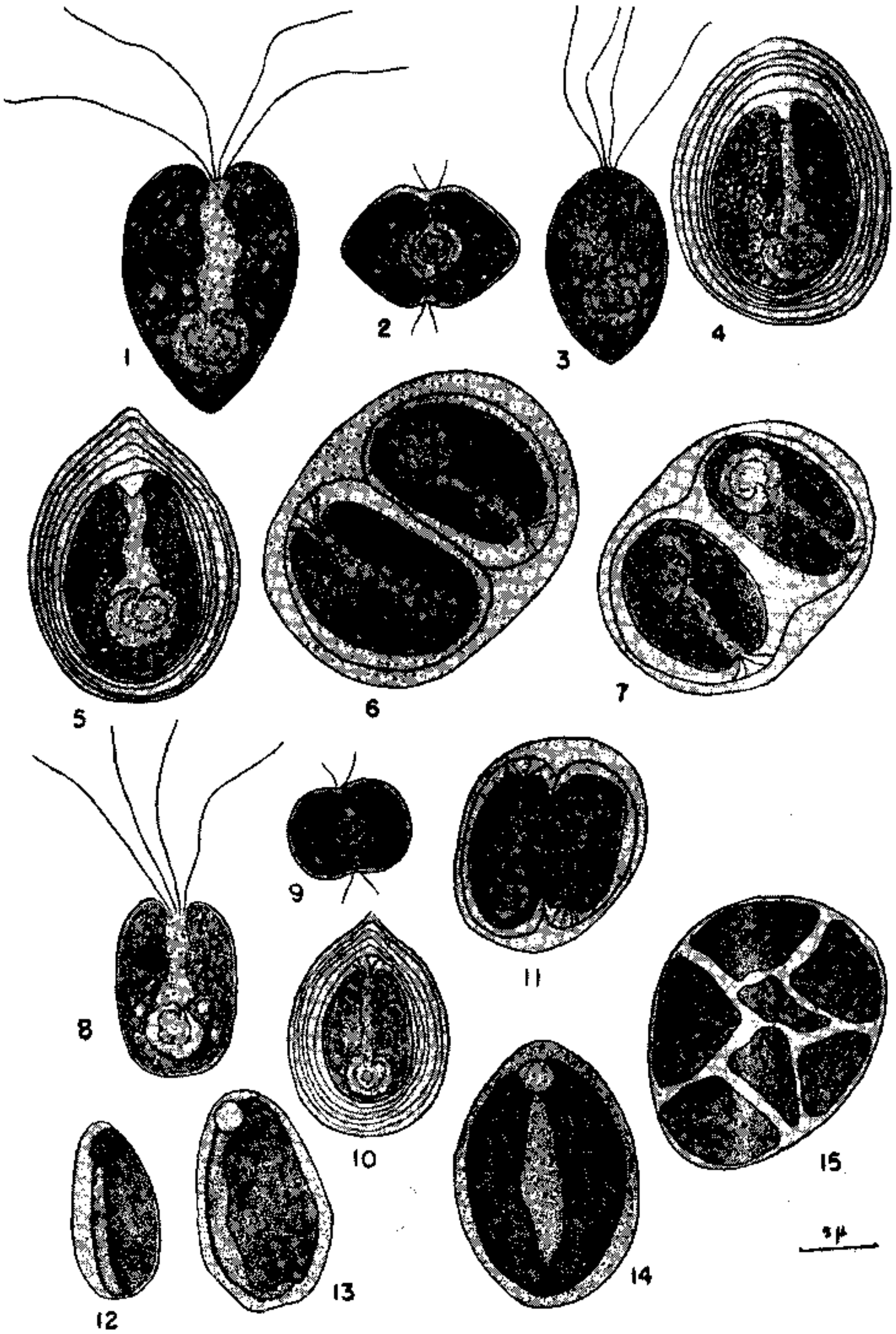
M. Parke, 1949, *J. Mar. Biol. Ass. U.K.*, 28, 225.

Cells 3.5-7 micron in diameter, spherical in shape and golden brown in colour. Two long equal flagellae which are thrice the length of the cell, emerge from the anterior end. Chromatophore parietal, saucer-shaped, smooth (in young cells) and two in number. The space in between the two chromatophores is occupied by the reserved food materials such as leucosin granules and oil bodies, nucleus and contractile vacuoles are also present. Nucleus is very small and lies at the anterior end, along with the contractile vacuole. Leucosin granules are globular in shape and basal in position. In older cells these granules are very large and occupy the major portion of the cell.

This species differs from others in possessing long equal flagellae, slow rotatory movement with flagellae directed backwards, and the absence of eye-spot. Moreover, this species do not change its shape. As the cells grow old the leucosin granules enlarge in size, and the chromatophores divide and become more in numbers.

Reproduction takes place by the binary fission of the motile cells. Cysts with silicified walls are noticed in old culture. Palmelloid stages also occur commonly.

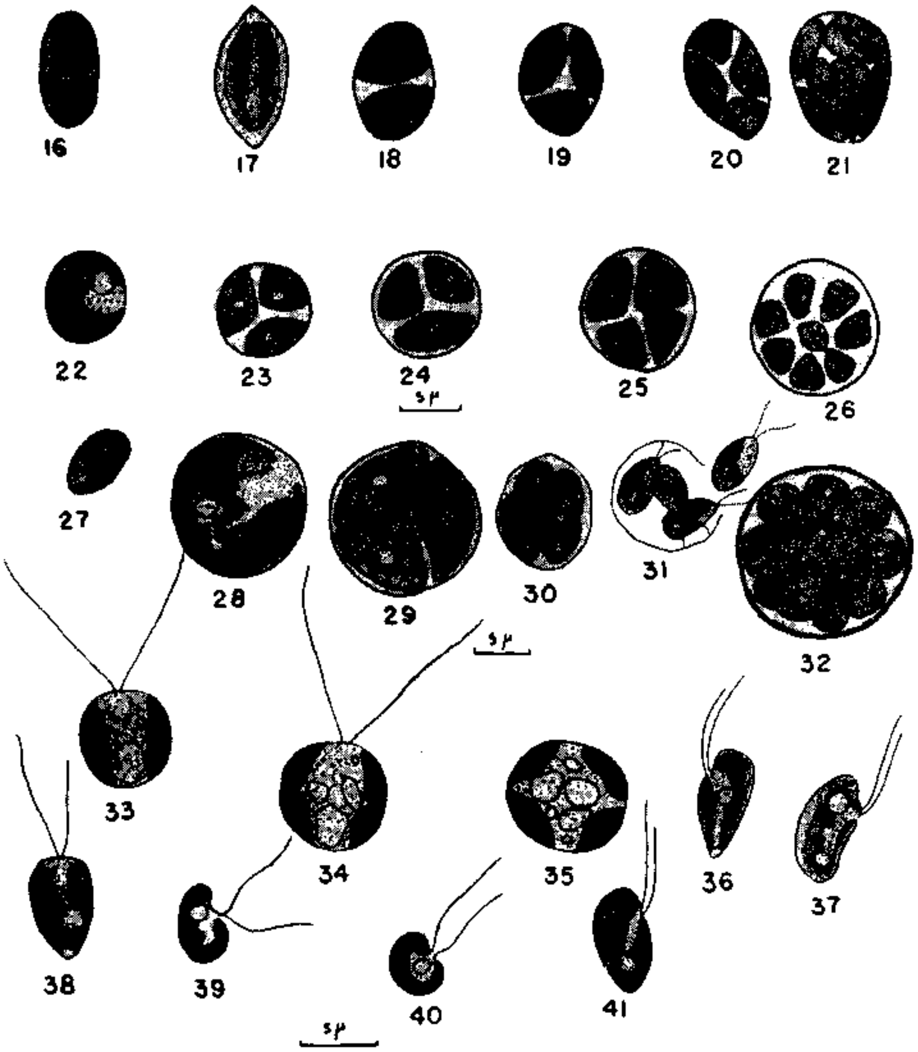
Found in European waters. In India collected from the Laccadive sea.



FIGS. 1-7. *Tetraselmis carteriformis* Butch. Fig. 1 Front view. Fig. 2 Anterior view. Fig. 3 Side view. Fig. 4 Single celled cyst without papilla. Fig. 5 Cyst with pappilla. Figs. 6 and 7 Stages of two-celled cyst.

FIGS. 8-11. *Tetraselmis gracillis* Butch. Figs. 8 Front view. Fig. 9 Anterior view. Fig. 10 Single-celled cyst. Fig. 11 Two-celled cyst.

FIGS. 12-15. *Chlorella marina* Butch. Figs. 13 to 14 different stages of the growing cell. Fig. 15 Division stages.



FIGS. 16-21. *Chlorella ovalis* Butch. Figs. 16 and 17 Individual cells. Figs. 18-21 Division stages.

FIGS. 22-26. *Chlorella salina* Butch. Figs. 22 Individual cell. Figs. 23-26 Division stages.

FIGS. 27-32. *Tetracystis* sp. Figs. 27 Young individual cell. Fig. 28 Older cell. Fig. 29 Tetrad. Figs. 30 and 31 Stages of zoospore formation. Fig. 32 Aplanosporangium.

FIGS. 33-35. *Dicrateria gilva* Parke. Fig. 33 young cell. Fig. 34 older cell. Fig. 35 Resting stage.

FIGS. 36-39. *Cryptochrysis fulva* Butch.

FIGS. 40-41. *Cryptochrysis virescens* Butch. Fig. 40 Lateral view. Fig. 41 Anterior view.

CRYPTOPHYCEAE

Cryptochrysis Pascher

Fritsch, F. E., 1935, *Structure and Reproduction of Algae*, Vol. 2.

Pierre—P. Grasse, 1953, *Traite De Zoologie*, 285-308; Pascher, A., 1911, *Ber. Deutch. Ges.* Bd. 29, 139-203; Butcher, R. W., 1952, *J. Mar. Biol. Ass. U.K.*, 31, 185-187.

Cryptochrysis fulva Butcher

(Figs. 36-39)

Butcher, R. W., 1952, *J. Mar. Biol. Ass. U.K.*, 31, 185-187.

Cells 6-8 × 3-4 micron, actively motile naked cells with an ovoid appearance in dorsal view. Apex truncate with slight flattening on the ventral side. Towards the base the cell tapers. From the flattened ventral side, just behind the apex starts a vertical furrow which runs down to the region of the pyrenoid. Trychocysts are noticed on the sides of the furrow. From the base of the furrow emerge two unequal flagellae, which are shorter than the cell. Chromatophore single, large, folded and brownish in colour, pyrenoid single, large, globular and basal in position. In older cells, two pyrenoids are observed and are placed at either end of the cell. Oil granules similar to the size of the pyrenoids are noticed but not in all. Contractile vacuole present.

Reproduction by longitudinal division of the mother-cell in both motile and resting state. Palmelloid stages seen occasionally in cultures. During this stage cells loose their flagellae, become round in shape and the contents turn dark brown in colour. Inside these cells division of chromatophores and other cell contents take place.

Seen in the shell fish tanks at Conway, Northwales. In India, collected from the coastal areas of the west coast.

Cryptochrysis virescens Butcher

(Figs. 40-41)

Butcher, R. W., 1952, *J. Mar. Biol. Ass. U.K.*, 31, 187.

Cells 5-7 × 3-4 micron, ovoid and asymmetrical with a convex dorsal and slightly flattened ventral side. It has a reniform appearance anteriorly. A shallow furrow is present on the lateral side just below the anterior tip, which runs down to the centre. Trychocysts noticed on the sides of the furrow. Two unequal flagellae which are equal to the length of the cells emerge from the furrow. Chromatophore single, large, bluish-green, smooth and almost completely fills the cell. Pyrenoid single, large and sub-median in position.

Propagation takes place by longitudinal division of the cell into two, in the motile stage. Palmelloid stage rarely noticed in the cultures.

It differs from the other species of *Cryptochrysis* in having an extra-ordinary bluish-green colour, the reniform appearance in anterior view, and the large single pyrenoid.

Occur at river Crouch, Essex. In India along the Cochin coast.

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