ON THE SYSTEMATIC POSITION OF *DIMORPHOCOCCUS* A. BR. AND *WESTELLA* DE WILD

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ABSTRACT

Up to the present the classification of the Chlorococcales is still in a state of great confusion. The chief reason is that an adequate taxonomic basis for this Order has not yet been established, and another is that some genera need to be reinvestigated.

Regarding the taxonomic basis for this Order, the writer maintains that the types of plant-body construction are of more importance than the methods of reproduction; this is thought to be so, in spite of the very simple structure of this group. A great variety of coenobium structure is met with, but they may be classified into two main groups: 1) the "protococnobium", in which the cells are separated from one another except for an indirect connection provided either by the remnants of the mother-cell wall, or a gelatinous material, giving characteristic forms such as those of *Dictyosphaerium, Sorastrum, Pectodictyn* etc. 2) The "eucoenobium", in which the cells are directly connected with eachother by their own cell-walls, and integrated as a definite structure, such as those found in *Pediastrum, Coelastrum, Scenedesmus* etc. Though all the types of coenobic plant-body are not multicellular in nature, it would seem reasonable to regard them as highly evolved types of plant-body, in comparison with unicellular and colonial forms. Moreover, the basic structure of the plant-body may be a useful indicator of phylogeny, and hence of taxonomic relationships.

Now the writer considers that three guiding principles may be followed in separating the taxa: species, genera and families. 1) Congeneric species should have the same kind of plant-body; 2) Unicellular, colonial, and coenobic genera should be placed in different families; 3) Mode of reproduction is a useful criterion for certain families. It is now proposed to adapt these principles to a fresh consideration of the systematic position and composition of the genera *Dimophococcus* and *Westella*.

1. **Dimorphococcus** A. Br.

The genus *Dimorphococcus* was established by A. Braun in 1855, with the genotype *D. lunatus* A. Br.[2] It is known to be one of the cosmopolitan species. According to the original diagnosis it is chiefly characterized by "cellulis in ramulis brevissimis quaternatim coniunctis, dissimilibus, binis intermediis oblique contiguis ovatis obtusis, binis lateralibus oblique oppositis discretis substipitatis lunatis". It is thus clear that the cells of this alga are united in 4-celled coenobia.

In 1868, L. Rabenhorst was the first to give accurate drawings of this alga[13], and they demonstrate clearly that the cells are united in 4-celled coenobia, of a similar type to some species of *Scendesmus* (Fig. 1:1 & 2).

Since its discovery in 1855, most algologists seem to have been content to emphasize that the cells of this alga are dimorphic, in groups of four, and the 4-celled groups held together by the non-gelatinous remnants of the mother-cell walls: they overlooked the significance, or even the fact,

of the nature of the plant-body being an eucoenobium. This resulted in confusingly divergent classification: the genus was referred to the Palmellaceae by A. Braun, 1855[2], by L. Rabenhorst, 1868[13], and by De Toni, 1889[7]; to the Selenastreae by G. S. West, 1904[18], and by J. Brunnthaler, 1916[3]; to the Dictyosphaeriaceae by G. S. West, 1916[19], by H. Printz, 1927[12], by F. E. Fritsch, 1935[9], and by G. M. Smith, 1920 & 1950[14,15]; while L. H. Tiffany, 1934 & 1951[16,17], and G. W. Prescott, 1951[11], considered it belonging to the Oocystaceae.

In 1909, F. S. Collins[5] placed this genus, together with a number of unicellular and colonial genera, in the family Scenedesmaceae: but this only confuses and obscures their affinities.

In 1953, O. A. Korschikoff[10] referred this genus to the subfamily Scenedesmoideae, under the family Coelastraceae; but as far as the writer is aware, this classification has not been used by other workers.

As has been shown, there is no agreement among algologists on the systematic position of *Dimorphococcus*. While attempting to form a judgment, it is highly appropriate to recall the early studies on this genus by K. Bohlin (1897)[1], in which he writes "Ich glaube ubrigens nicht, dass die erwahnten Ahnlichkeiten zwischen ihnen andeuten..... Als die nachsten Verwandten des *Dimorphococcus* sehe ich dagegen gewisse Formen der Gattung *Scenedesmus* an. Ein vierzelliges Individium von *Dimorphococcus* ist einem *Scenedesmus* ahnlich. Den Dimorphismus der Zellen findet man zum Beispiel bei *Scenedesmus acutus β dimorphus* (Turp.) Rabenh. in derselben Weise wie und das Verwachsen der Zellen erinnert sehr an den oben beschriebenen *Sc. curvatus*. Das Entstehen der Tochtertetraden ist jedoch die wichtigste Übereinstimmung, indem dasselbe bei *Dimorphococcus* wohl als eine Coenobien-Bildung aufzufassen ist". He mentioned again: "Bei *Dimorphococcus* kommt noch die Vereinigung der Coenobien durch die Membranreste der Mutterzellen hinzu, und die gaze Colonie durfte hier also als eine Art zusammengesetztes *Scenedemus*-coenobium anzusehen".

In recent years, the writer has examined a large number of specimens of *Dimorphococcus lanutus* collected from different localities in China. He found that not only its living cells are united in 4-celled eucoenobia similar in type to those of some species of *Scenedesmus*, but also the non-gelatinizing remains of the mother-cell walls are kept such a fashion of construction (Fig. 1: 3 & 4). The cells are never cruciately arranged, nor are they properly separated from each other, as has been stated or figured by most algologists. At maturity, the protoplast of any cell of a coenobium may divide and redivide to form usually 4, but occasionally 8, autospores. In the first case the 4 cells are united in a single coenobium; but in the second, the 8 cells always give rise to two 4-celled coenobia.

As a result of the writer's own observation, he can testify the accuracy of Braun's diagnosis, of Rabenhorst's drawings, of Bohlin's conclusions, and of Korschikoff's classification of *Dimorphococcus*: they are incontestable. Thus he can confirm that this genus, together with other genera with the same type of eucoenobium, either simple or compound, are best referred to the Scenedesmoideae under the family Coelastraceae. The generic diagnosis may now be partially emended as follows:

Dimorphococcus A. Br.——Eucoenobia compound, always 4-celled, curved, held together by the non-gelatinizing remnants of the mother-cell walls; cells dimorphic, arranged in a single alternating series, the intermediate two of each coenobium cylindric-ovate, alternately joined to each other by their broader ends, the two lateral cells reniform, each joined to of the intermediate cells by the middle of its convex side; chloroplast in young cells single, parietal, lami-

nate, with a single distinct pyrenoid, generally diffuse and rich in starch in old cells.

Reproduction by the division of any cell into 4, or occasionally 8, autospores that remain united in a single, or two, 4-celled coenobia after their liberation by an irregular splitting of the mother-cell wall.

Type species: **Dimorphococcus lunatus** A. Br. (Fig. 1: 1—4)

At present, *Dimorphococcus* is said to have three species: the type species *D. lunatus* A. Br.; *D. cordatus* Wolle 1887, found in North America; and *D. Fritschii* Crow 1932, found in Ceylon. In view of the construction of the plant-body, the writer considers that the last two must be excluded from this genus.

According to the original diagnosis of *D. Cordatus* given by Wolle (1887)[22], it is characterized by "cells cordate, ... single, or united in rather irregular clusters of 2—4—8 cells conjoined, sometimes forming coenobia, by smaller families of cells connecting by slender, colorless, radiating, gelatinous threads,....". Through Wolle says of this plant, "sometimes forming coenobia", this character is not recognizable from his figures (Fig. 1: 5 & 6). Practically, however, its cells are separated from one another. In 1902, H. Chodat recorded this species again from Switzerland[4], and his drawings also show that the cells are widely remote (Fig. 1: 7), though conjoined by very broad mucilage stalks, dissimilar to those in Wolle's figures. Judging from either Wolle's or Chodat's investigation of this alga, the writer concludes that it is excluded from the genus *Dimorphococcus* because its plant-body is not an eucoenobium, and its cells are not dimorphic. Furthermore, the species recorded by Chodat seems to be quite different from that described by Wolle, so in fact we are now removing two separate species from *Dimorphococcus*, and these are probably close relatives of *Dictyosphaerium*.

As defined by Crow[6], *Dimorphococcus Fritschii* is chiefly characterized by its plant-body being a protocoenobium, and its dimorphic cells arranged in quadrate groups; the cells being held together by short, delicate, mucilage-stalks to form partial protocoenobia with their own gelatinous envelops (Fig. 1: 8—10). On account of the cells of this alga being only indirectly connected with each other, the writer cannot regard it as a *Dimorphococcus*, in spite of its dimorphic cells, so a new genus is now erected for it: *Dimorphococcopsis Fritschii* (Crow) gen. nov., in the Dictyosphaeriaceae. The generic diagnosis may be:

Dimorphococcopsis, gen. nov. —— Protocoenobia compound, composed of partial protocoenobia of four cells each, embedded in a definite mucilage envelop; cells of each partial protocoenobium quadrately arranged and connected by short delicate mucilage stalks; cells dimorphic, disposed alternately: two cordate, and two cylindrical; chloroplast parietal; pyrenoid?.

Reproduction by autospores.

Type species: **Dimorphococcopsis Fritschii** (Crow), comb. nov. (Fig. 1: 8—10)

2. **Westella** De Wild.

In 1892, W. West established an algal genus *Tetracoccus* (genotype *T. botryoides* W. West)[21], but in 1897 De Wildeman pointed out that this generic name was preoccupied in Euphorbiaceae, so he proposed a new name *Westella* to replace *Tetracoccus* West, and he used the combination *Westella botryoides* for the type[8]. De Wildeman's proposal has been adopted by authors since 1916.

The systematic history of this alga has been as erratic as that of *Dimorphococcus*, and for

comparable reasons. For example, W. West (1892)[21], and G. S. West (1904)[18] placed it in Dictyosphaerieae of the Protococcaceae; Brunnthaler (1915)[3] referred it to Chlorelleae of the Chlorellaceae; Printz (1927)[12] placed it, along with some colonial genera, in Quaternatae of the family Coelastraceae; Fritsch (1935)[9] included it in the Dictyosphaeriaceae; Tiffany (1934 & 1952)[16,17], Smith (1920 & 1950)[14,15] and Prescott (1951)[11] put it in the Oocystaceae; and Korschikoff (1953)[10] referred it to Crucigenioideae of the family Coelastraceae.

Judging from the diagnosis of this genus given by most authors, it appears that only Korschikoff has realized the significance of the mode of connection of its cells and the persistence of remnants of the mother-cell walls. While investigating *Westella botryoides,* the writer found that its cells are not only grouped quadrately, with 4 in a plane, but that they are also joined in eucoenobia, similar in construction to those of *Crucigenia* and *Tetrastrum*. This character in commor may also be seen in the non-gelatinizing remnants of the mother-cell walls, by which the coenobia are held together to form a compound coenobium. Every cell in coenobium is capable of giving rise to four, or eight, autospores: in either case, the daughter coenobia are constantly 4-celled (Fig. 2:1 & 2). Since the genotype of *Westella* has this type of plant-body, the writer thinks it is closely allied to *Crucigenia* and *Tetrastrum,* and should therefore be placed in Crucigenioideae of the Coelastraceae, as has also been proposed by Korschikoff. The diagnosis of the genus must therefore be emended, and may be as follows:

Westella De Wild. —— Eucoenobia composed of four cells in a quadrate arrangement in a flat plate; all coenobia of the "thallus" are connected by the non-gelatinizing remnants of the mother-cell walls to form a compound coenobium, which may sometimes have a gelatinous envelope; cells globose; chloroplast single, cup-shaped or diffuse and entirely filling the cell, and with a pyrenoid.

Reproduction by the division of any cell, which gives rise to 4, or 8, autospores which in turn may produce a single, or two 4-celled coenobia, the daughter coenobia being liberated by an irregular splitting of the mothercell walls.

Type species: **Westella botryoides** (W. West) De Wild. (Fig. 2: 1 & 2)

In addition to the genotype, only two other species have been referred to this genus: *W. natans* (Kirchn.) Printz[12], and *W. linearis* G. M. Smith[14].

Westella natans is a doubtful species, and judging from the diagnoses and drawings of this alga given by former workers, it is certainly not a species of *Westella,* because its cells are not united in eucoenobia.

The cells of *W. linearis* are arranged in a linear series, and so entirely at variance with the type species of *Westella* in the nature of its plant-body, but it is fundamentally like that of some species of *Scenedesmus,* except that its cells are globose (Fig. 2: 3). Hence, it is proposed to make it the type of a new genus *Westellopsis* belonging to Scenedesmoideae under the Coelastraceae, with the following diagnosis:

Westellopsis, gen. nov. —— Eucoenobia of four cells united in a linear series, connected by inconspicuous remnants of the mother-cell walls to form the compound coenobium, without a gelatinous envelope; cells similar, globose; chloroplast single, parietal, without a pyrenoid.

Reproduction by the division of any cell to form 4 or 8 autospores.

Type species: **Westellopsis linearis** (G. M. Smith), comb. nov. (Fig. 2: 3)