Preslia, Praha, 52 : 1 —12, 1980

The genera *Tetrachlorella* and *Fotterella (Chlorococcales, Chlorophyceae)*

Rody *Tetrachlorella* a *Fotterella (Chlorococcales, Chlorophyceae)*

František Hindák

HINDÁK F. (1980): The genera *Tetrachlorella* and *Fotterella* (*Chlorococcales, Chlorophyceae*). — Preslia, Praha, 52 : 1—12.

Having analyzed the features of the genus *Tetrachlorella* KORŠ. and *Fotterella* BUCK, the author has come to the conclusion that the genus *Fotterella* is to be considered synonymous with the genus *Tetrachlorella*. The suggestion is made to transfer the species *Fotterella tetrachlorelloides* BUCK into the genus *Tetrachlorella* as *T. tetrachlorelloides* (BUCK) HIND. New findings are presented on the morphological variability of species of the genus *Tetrachlorella* along with data on their incidence.

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Characteristic of the genus *Tetrachlorella* KORŠ. 1939 is the formation of 4-celled coenobia, ± square-shaped, rectangular, rhombic to rhomboid, with cells ± in one plane; 2-celled coenobia with adjacent cells are less frequent. In the process of reproduction up to 16-celled syncoenobia may temporarily arise, with coenobia similarly in ± one plane. Cells in the 4-celled coenobium are arranged so that two form an inner pair touching by its ends or slightly obliquely by its sides and there is one cell attached to them from each side. The mucilage is hyaline, structureless and has been observed with all species. The cells are oval, with widely rounded or sporadically slightly rounded-apical ends. The cell wall is smooth, in some species there is an incrustation formed at the cell ends in the shape of a crown, a wreath of granules or in the shape of short transverse ribs. The chloroplast is parietal, troughy, with one pyrenoid. Mostly 4 autospores are formed, less often 2, by their growth they press the mother cell wall asunder which subsequently bursts, and its remnants are usually well visible especially among adjacent cells.

KORŠIKOV (1939) transferred the species *Crucigenia alternans* G. M. SMITH into the genus *Tetrachlorella* as *T. alternans* (G. M. SMITH) KORŠ. and established a new form *T. alternans* f. *coronata* KORŠ. Later (KORŠIKOV 1953) he raised this form to a species as *T. coronata* (KORŠ.) KORŠ. and described a subsequent species *T. ornata* KORŠ. In our preceding paper on chlorococcal algae (HINDÁK 1977) we established a new species *T. incerta* HIND., characterized by relatively small cell dimensions, by the absence of incrustation and by the predominant formation of 2-celled coenobia.

BUCK (1978) has established a new genus and the new species *Fotterella tetrachlorelloides*. As the author relates, he initially regarded this alga as being *Crucigenia irregularis* WILLE var. *pyrenigera* CHOD. [= *Willea irregularis* (WILLE) SCHMIDLE] which HUBER-PESTALOZZI (1955) had designated

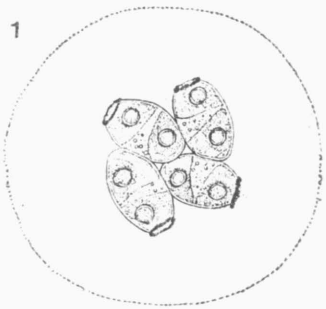
as the indicator of the eutrophization of the Swiss lakes. The arrangement of cells in the coenobium, however, differs from that in the type species *Crucigenia quadrata* MORREN in which no detachment of cells in the coenobium takes place. According to BUCK, *Willea irregularis* differs from *Fotterella tetrachlorelloides* by the absence of mucilage and by a small number of cells in the colony. The author relates that by the arrangement of autospores the genus *Fotterella* resembles young coenobia in the genus *Tetrachlorella*. BUCK believes that the characteristic difference between these genera lies in that the genus *Tetrachlorella* keeps the cells in course of the vegetation cycle always jointly coalesced, thus forming a typical coenobium (he refers to KOMÁREK 1974) whereas in the genus *Fotterella* cells are only tetrachlorelloid-like arranged and in course of their life-history they are in a process of mutual withdrawal.

It is evident that the genus *Fotterella* does not pertain, by cell arrangement, to the genus *Crucigenia*. A nearby genus, however, is *Willea* SCHMIDLE, where, in contrast to the genus *Fotterella*, there is a very frequent formation of flat colonies (syncoenobia?) with cells adjacent ± in one plane. As referred to in our preceding paper (HINDÁK 1977), *W. irregularis* (WILLE) SCHMIDLE forms only two autospores in the mother cell and only by the later division of these cells which may be relatively rather time-shifted, does the characteristic clustering of cells into tetrads arise, as they are typical of the genus *Crucigeniella* LEMM. Of course, such a procrastination in the division of cells that form a 4-celled coenobium, is encountered also with other species of this group of chlorococcal algae, e.g. with *Tetrastrum komarekii* HIND. (HINDÁK 1977) but of the species *Willea irregularis* this is characteristic. Close relations between the genera referred to are borne out also by the mother cell wall which expands in both genera mentioned and its remnants are usually well to be seen at the outward boundary of the group of daughter cells. This feature and the way cells are embedded make BUCK believe that the genus *Fotterella* does not pertain to the subfamily *Crucigenioideae* but to the family *Oocystaceae*.

As already mentioned, it is the free position of cells in the genus *Fotterella* which is looked upon by BUCK as the main differentiating feature against the genus *Tetrachlorella*. In the course of our investigations into chlorococcal algae in the past, we have been in the position to observe all the four hitherto described species of the genus *Tetrachlorella* and the species *T. incerta* was studied also in a laboratory culture. In the course of the 2nd International Workshop of active phytoplanktonologists at Kastanienbaum in the summer of last year we found the species *Fotterella tetrachlorelloides* in the plankton of several lakes in this part of Switzerland and, later, we also obtained a pure culture of this alga. In this way documents are available, along with other literary data, to judge the aforementioned discerning feature between the genera *Tetrachlorella* and *Fotterella*.

In the type species *Tetrachlorella alternans* and in the species *T. incerta* as well as in *Fotterella tetrachlorelloides*, remnants of the mother cell wall were

Fig. 1. — 1 — *Tetrachlorella coronata* (KORŠ.) KORŠ. (from KORŠIKOV 1953); 2 — *T. ornata* KORŠ. (from KORŠIKOV 1953); 3 — *T. alternans* (G. M. SMITH) KORŠ. (from KORŠIKOV 1953); 4 — *T. tetrachlorelloides* (BUCK) HIND. (from BUCK 1978, as *Fotterella tetrachlorelloides* BUCK); 5 — *T. tetrachlorelloides* (BUCK) HIND. (from HUBER-PESTALOZZI 1955, as *Crucigenia irregularis* var. *pyrenogera* CHODAT).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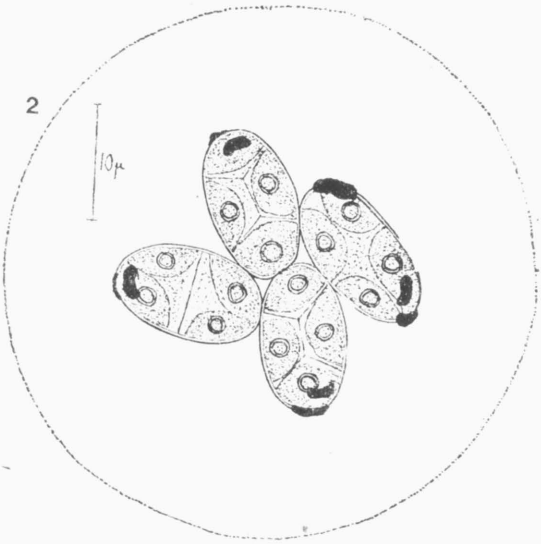
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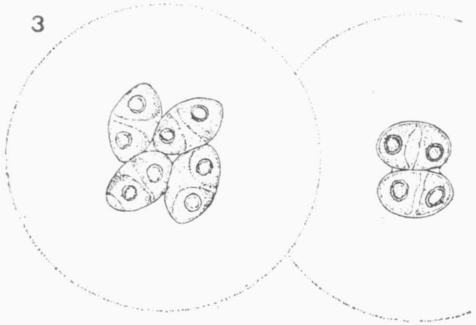
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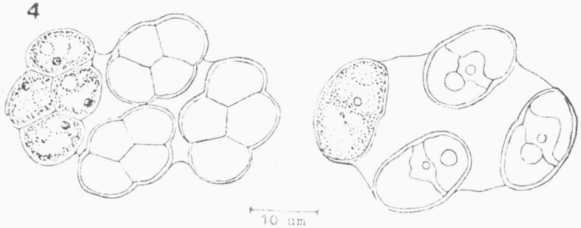
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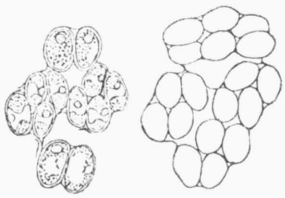

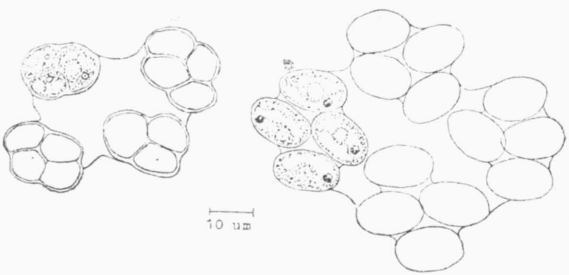
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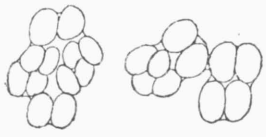


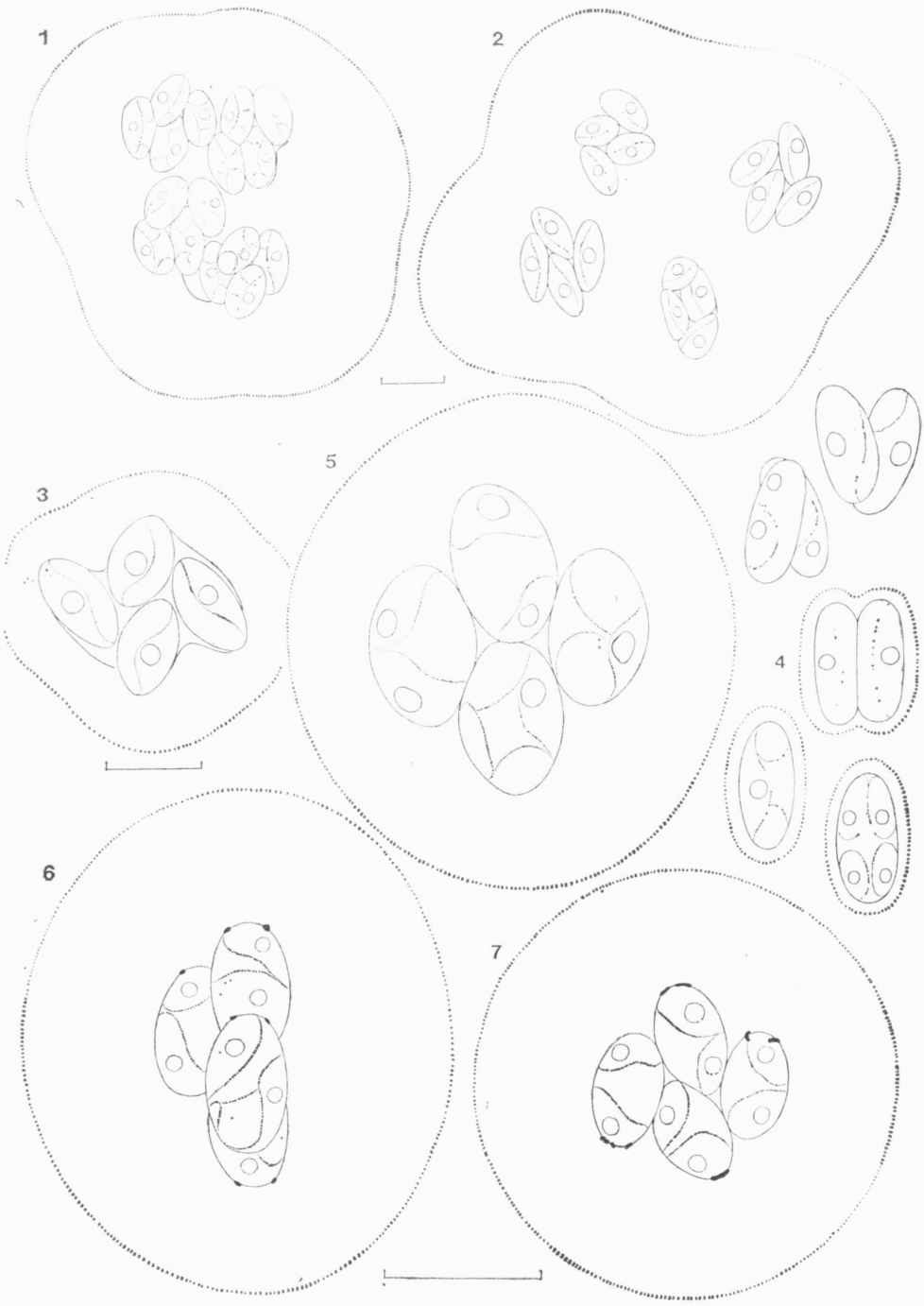
observed between the cells of the coenobium. The mechanism of autospore release in these species will probably be the same (obviously also in species *T. coronata* and *T. ornata*). By growth, the daughter cells press the mother cell wall asunder which borders on the autospores closely and does not withdraw from them uniformly as in many representatives of the family *Oocystaceae*. When, at a later period, the formation of the daughter cells (of the 2nd generation) sets in, the original mother cell wall (1st generation) changes into a flat plate-like substrate on which the cells of subsequent generations are embedded. How closely the mother cell wall borders on the wall of the daughter cells of *T. incerta* may well be seen in 2-celled coenobia, but in 4-celled coenobia we did not observe them, nor with the species *T. ornata* and *T. coronata*.

Our recent observations in the genus *Tetrachlorella* and *Fotterella* as well as other references from literature bearing upon this feature (Koršikov 1953, Komárek 1974, Buck 1978) do not offer proofs to differentiate these genera, on the contrary, they point out the relatively low variability of this feature. Naturally, between species markedly differentiated by size, such as e.g. *T. incerta* and *F. tetrachlorelloides*, a relatively considerable difference as to the remnants of the mother cell wall in 4-celled coenobia may be laid down, but in 2-celled coenobia there is no difference: the remnants of the mother cell wall are conspicuously among the cells of the coenobium in both species. In the 4-celled coenobia of the species *T. alternans* and *F. tetrachlorelloides* there is neither any difference as to the remnants of mother cell walls nor as to the formation of daughter cells in the coenobium.

In our view, coenobia in the species of the genus *Tetrachlorella* may not be looked upon as being so called typical coenobia, i.e. as coenobia with always coalesced cells as stated by Komárek (1974) and Buck (1978). It is just the observation of Komárek with *T. alternans* (1974 : 44) and our data (Hindák 1977 : 146) that point out that the cells border on each other closely indeed, but in the process of autospore formation they may get easily detached and hence they are not mutually coalesced such as e.g. the cells in the coenobia of several species of the genus *Scenedesmus* Meyen [*S. communis* Heg., *S. armatus* Chod., *S. ecornis* (Ralfs) Chod., *S. denticulatus* Lagerh. etc.]. This is obvious mainly in 2-celled coenobia of the species *T. incerta* where the cells in pairs are freely attached and linked up only by the mother cell wall. Because of this linkage, the cells are frequently not in one plane but rather slightly up to markedly turned round one to another. In natural material as well as in laboratory cultures of the species *T. incerta*, the cells show up rather often even soliratily. It may be summarized, in conclusion, that if we assess the discussed feature in the genus *Tetrachlorella* and *Fotterella* referred to by Buck as a discerning feature between these genera, no essential difference may be found here.

On these grounds it is believed that the establishment of the genus *Fotterella* Buck is not sufficiently justified. The species *F. tetrachlorelloides* Buck differs

Fig. 2. — 1—2 — *Tetrachlorella alternans* (G. M. Smith) Korš. (from Hindák 1977); 3 — *T. alternans* (G. M. Smith) Korš., specimen from the gravel pit lake at Kľúčovec; 4 — *T. incerta* Hind., specimens from the gravel pit lake at Trávniky, Bratislava; 5—7 — *T. coronata* (Korš.) Korš., specimens from the inundation lake near the Morava river at Devín, Bratislava. Scale: 10 μm.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from the hitherto known species of the genus *Tetrachlorella* Korš. only by cell size. We therefore suggest that the genus *Fotterella* be considered as being synonymous with the genus *Tetrachlorella* and to transfer the species *F. tetrachlorelloides* into the genus *Tetrachlorella* as *T. tetrachlorelloides*.

Tetrachlorella Koršikov Učen. Zap. Gork. Gosud. Univ. 9 : 118, 1939

Syn.: *Fotterella* Buck Arch. Hydrobiol./Suppl. 51 Algol. Studies 20 : 299, 1978.

Coenobia 4-celled or 2-celled, in the process of reproduction they may temporarily form up to 16-celled syncoenobia with detached coenobia in one plane, mucilage present. Cells in the 4-celled coenobium are touching and embedded in the way that two are in the centre ± perpendicularly or obliquely one above the other and one cell is attached to them from each side by its longer side. Cells in the 2-celled coenobium are adjacent by their longer side ± in one plane or they are sometimes slightly up to markedly shifted in their mutual positions. The cells are oval, with widely rounded ends. Cell wall smooth, in some species with incrustations at the cell ends in the shape of a crown, of a wreath of granules or short oblique ribs. Chloroplast parietal, troughy, with a pyrenoid. 4 or 2 autospores are formed, pressing the mother cell wall asunder by growth. The mother cell wall borders on the autospores ± closely and may frequently be seen between the cells. The mother cell wall gelatinizes with the passage of time in some species. It expands and forms a ± flat plate-like substrate for cells.

Type species: *T. alternans* (G. M. Smith) Korš.

Thus conceived, the genus *Tetrachlorella* includes 5 species that may be distinguished in terms of the following key:

1a Cell wall without incrustation
  2a Cells 4.5—8×2—4 μm; syncoenobia not formed; the formation of 2-celled coenobia usually more frequent than the formation of 4-celled coenobia ..... *T. incerta* Hind.
  2b Cells larger; flat syncoenobia with detached coenobia are frequently formed; formation of 4-celled coenobia outstrips more common than that of 2-celled coenobia
    3a Cells 7—13×4—7.5 μm ..... *T. alternans* (G. M. Smith) Korš.
    3b Cells (7—)10—20×(4—)6—10 μm ..... *T. tetrachlorelloides* (Buck) Hind.
1b Cell wall with incrustations at the cell ends in the shape of a small crown, of a wreath of granules or short oblique ribs
  4a Incrustation at the "free" cell end, arranged into a continuous or sketchy little crown or wreath of granules ..... *T. coronata* (Korš.) Korš.
  4b Incrustation in the shape of short, obliquely oriented ribs ..... *T. ornata* Korš.

Tetrachlorella alternans (G. M. Smith) Korš. Fig. 1 : 3; 2 : 1—3

On the depicted 4-celled coenobium (Fig. 2 : 3) from the g ravelpit lake at Kľúčovec, S. Slovakia, it may be seen that the cells in the coenobium are not firmly coalesced but rather slightly detached from one another. The cells were sized 10—12×6—7 μm. As it is also visible from the preceding key for species definition, the limit values of cell size overlap in the species *T. alternans* and *T. tetrachlorelloides*. Nor may the possibility be excluded that *T. tetrachlorelloides* is only an ecomorph of the species *T. alternans* living in the big lakes. Since there are not sufficient data available to appraise the issue, we leave the problem open and preliminarily accept both species referred to.

From the amount of the species of the genus *Tetrachlorella*, this species is the most frequent one in our country. Relatively rare are the 2-celled coenobia (Fig. 1 : 3).

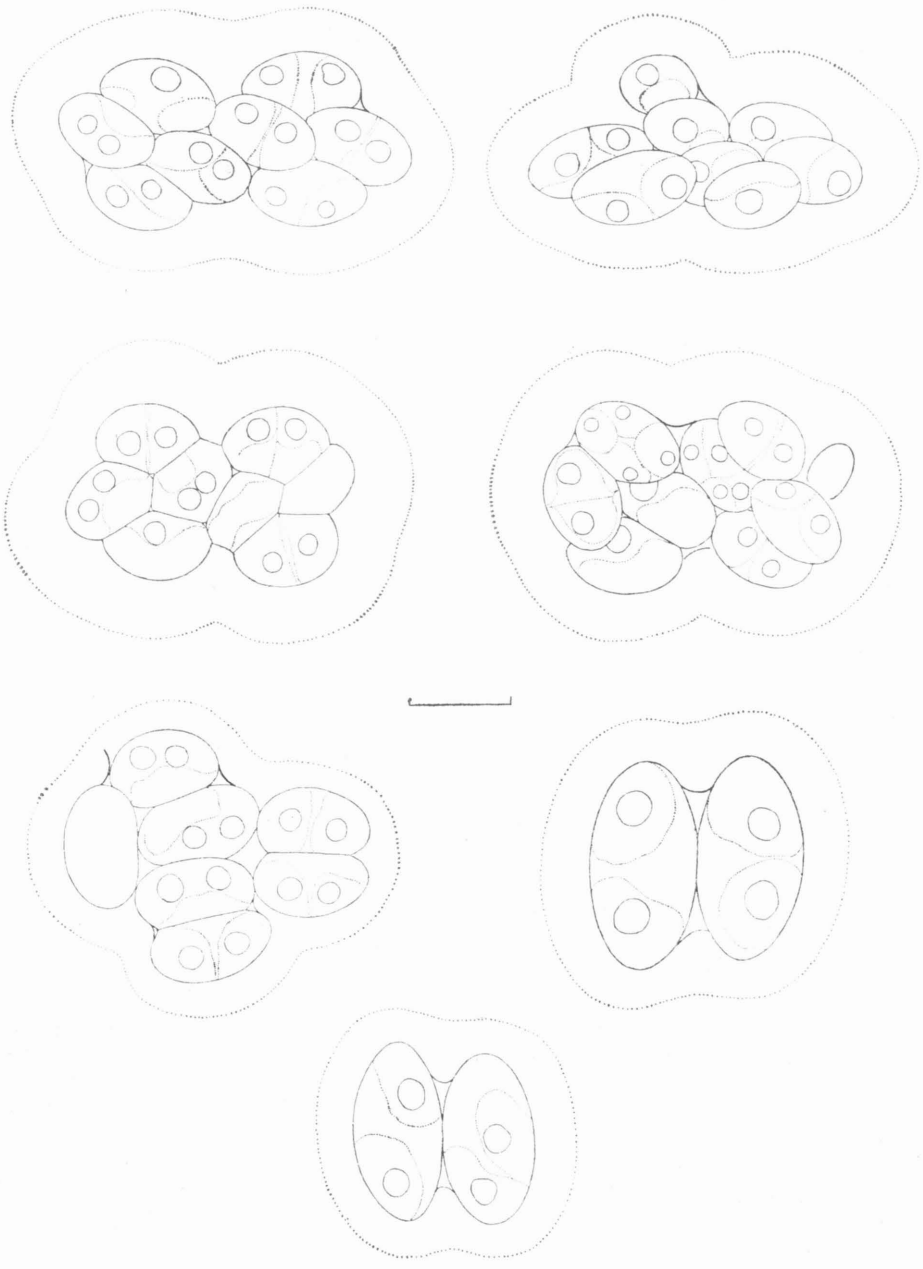

Fig. 3. — *Tetrachlorella tetrachlorelloides* (Buck) Hind., specimens from Hallwilersee-lake in Switzerland. Scale: 10 μm.

Tetrachlorella incerta HIND. Fig. 2 : 4

This species is characteristic of the phytoplankton of gravel pit lakes in Slovakia but it also occurs in the fish-ponds and in water supply reservoirs (see HINDÁK 1977). It stands out by relatively small cell dimensions and by an often small, sometimes even negligible layer of mucilage around the cells. From the other species it also differs by the prevailing formation of 2-celled coenobia in which the cells are sometimes slightly up to markedly shifted one against the other. As already mentioned, this labile linkage makes the cells detach easily grom one another and occur solitarily, both in free habitats and in the laboratory culture. The size of the depicted cells stemming from the gravel pit lake at Trávniky, Bratislava (Fig. 2 : 4) varies within the range of $7-8 \times 2.8-4$ μm. This species has also been found in the gravel pit lakes in the neighbourhood of Košice, in Eastern Slovakia.

Tetrachlorella coronata (KORŠ.) KORŠ. Fig. 1 : 1; 2 : 5—7

In the plankton of the inundation lake near the Morava river at Devín, Bratislava, an alga was repeatedly found in the autumn of 1978 which mostly resembled the species *T. coronata* by cell shape, by that of the coenobia and by the incrustation at the cell ends. The cells were widely oval, $7-11 \times 4.5$ to 7 μm, mucilage around cells 5—11 μm wide, coenobia 13—21 μm in ∅, with a mucilaáe up to 30 μm in ∅. The chloroplast was parietal, troughy, with a pyrenoid, there often were two chloroplasts, each with a pyrenoid. The small brown crown at the "free" cell end was not continuous but interrupted at one or several places (Fig. 2 : 7). Sometimes only granules were formed (Fig. 2 : 6) or there were no incrustations observed at all (Fig. 2 : 5).

The species *T. coronata* and *T. ornata* differ only by the shape of incrustations at the cell ends; the shape and size of coenobia and cells are approximately the same. Issuing from the experiences with the variability of the crown (the wreath of granules) e.g. in *Granulocystopsis coronata* (LEMM. in MARSS.) HIND. (see HINDÁK 1977 : 76) or of the equatorial ring in *Amphikrikos nanus* (FOTT et HEYNIG) HIND. (see ibidem p. 59), it is possible that the shape of incrustations conceived as characteristic of the species *T. ornata*, forms part of the natural variability in the process of crown formation with *T. coronata*. Of course, this presumption is to be backed up by evidence (in the best way by a culture). In the summer plankton of the fish-ponds of Southern Bohemia in the neighbourhood of Třeboň we have found several times, however, *T. coronata* with developed continuous and thick crowns at the cell ends in the way KORŠIKOV drew them (Fig. 1 : 1). To distinguish these two close species use could be made of the cell shape: in *T. coronata* the cells are broadly oval whereas in *T. ornata* they are elongately oval. On the iconotype of *T. ornata* (Fig. 1 : 2 as well as on other illustrations (HINDÁK 1977 : 146, Fig. 58 : 4, 5) it can be seen that on one of the outward cells incrustations are formed at both ends. This has hitherto not been observed with *T. coronata*.

Tetrachlorella tetrachlorelloides (BUCK) HINDÁK, comb. nova
Fig. 1 : 4, 5; 3—5

Bas.: *Fotterella tetrachlorelloides* BUCK Arch. Hydrobiol./Suppl. 51 Algol. Srudies 20 : 22, Fig. 1a, b, c (iconotype). — Syn.: *Crucigenia irregularis* var. *pyrenogera* CHOD. sensu HUBER-PESTALOZZI 1955. — *Scenedesmus arcuatus* LEMM. var. *irregularis* FLINT 1950.

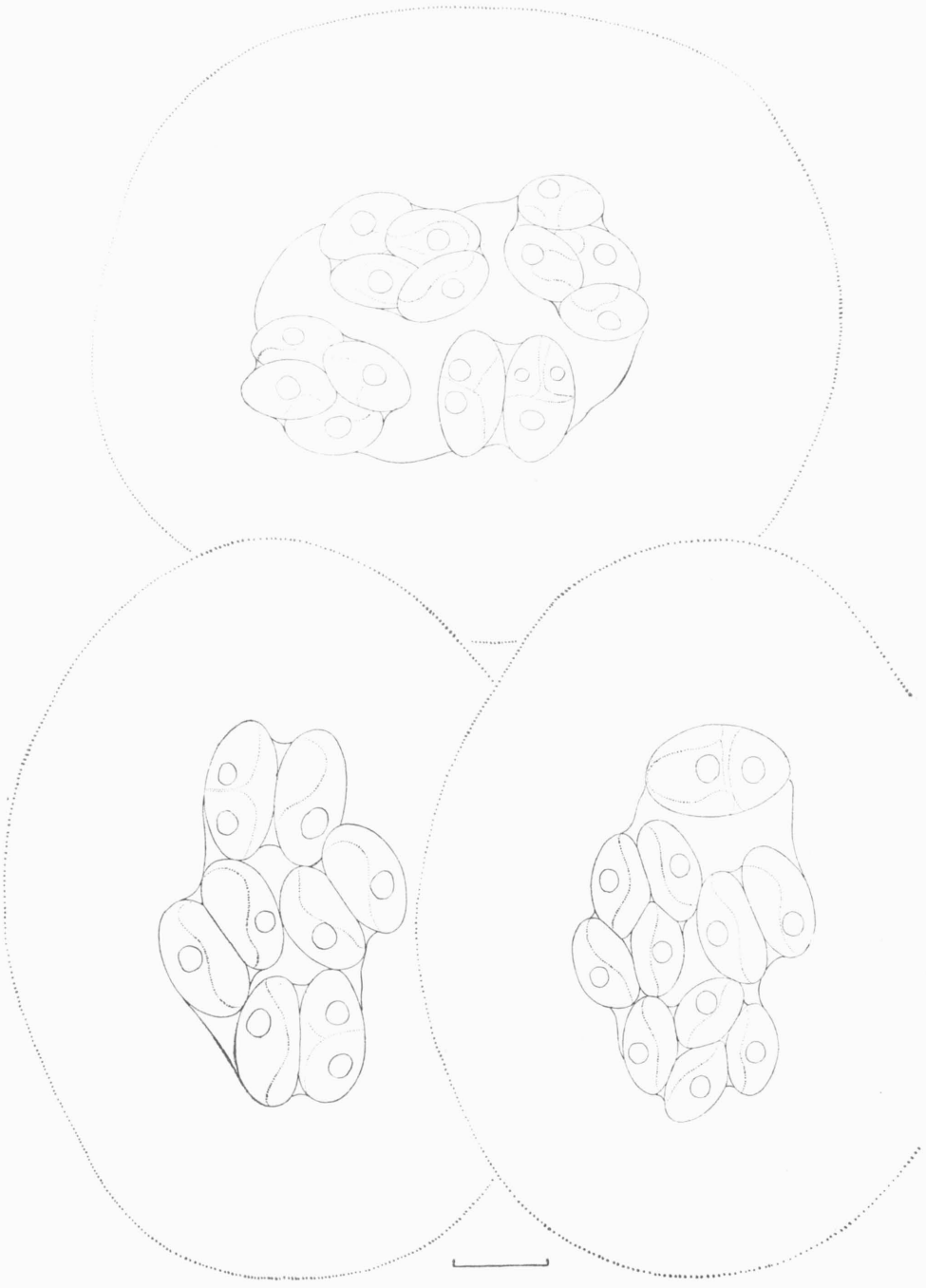

Fig. 4. — *Tetrachlorella tetrachlorelloides* (Buck) Hind., strain Hindák 1978/1, isolated from Hallwilersee-lake in Switzerland. Scale: 10 μm.

Coenobia floating freely, flat, 4-celled or 2-celled, in the process of reproduction the may form 8—16-celled syncoenobia. The cells are broadly oval, (7—)10—20×(4—)6—10 µm, coenobium size without mucilage: 2-celled coenobia 10—20×10—21 µm, 4-celled coenobia 17—20×17—20 µm, 8—16-celled syncoenobia 24—27×30—45 µm, coenobia with mucilage 20—90 µm in ∅, mucilage around cells 2—5—15 µm. Cell wall smooth. Chloroplast parietal, troughy, with a pyrenoid. Autospores 4 or 2, pressing the mother cell wall asunder by growth. The mother cell wall borders closely on the autospores and may be seen initially among the cells; later the mother cell wall expands and forms a ± flat, plate-like configuration with uneven margins on which the cells are placed (data according to our material).

Occurrence: In the plankton of Swiss lakes around Zürich and Luzern (Zürichsee, Greifensee, Vierwaldstättersee, Hallwilersee and other), relatively frequent, August 1978; studied strain HINDÁK 1978/1 isolated from the Hallwilersee-lake. Further data on incidence see BUCK (1978).

Our knowledge about this species which has belonged among the most frequently occurring species of the summer plankton of the Swiss lakes referred to, is in alignment with the recent observations presented by BUCK (1978). BUCK did not observe mucilage but in the material we studied it was clearly distinct especially after adding China ink to the preparation. In the coenobia stemming from the plankton mucilage was smaller: 2—5 µm around the cells as in the investigated culture: up to 15 µm around the cells. The mucilage was hyaline, structureless but relatively tough. In the phytoplankton samples, in the culture too, the formation of 4 autospores from the mother cell prevailed but two-celled coenobia were not rare, just as 8-celled syncoenobia made up of 4 two-celled coenobia (Fig. 3—5). However, the size of 2-celled and 4-celled coenobia and similarly also of 8- and 16-celled syncoenobia was approximately equal. Of course, cells in the 2-celled coenobium were much larger than the cells in the 4-celled coenobium.

As stages labelled by BUCK to be characteristic of both the genus *Tetrachlorella* and the genus *Fotterella*, it could be observed on the material referred to: the mother cells did not withdraw at all in the process of autospore formation or they did withdraw very conspicuously. The remnants of the mother cell wall were well visible among the cells also in the specimens from the plankton. In the 8—16-celled syncoenobium the cell wall of the original mother cell (1st generation) whence the coenobium (2nd generation) and later the syncoenobium (3rd generation) arose, is usually well visible but upon the maturing of 3rd generation cells and in the formation process of 4th generation cells it used to fall asunder (Fig. 5) so that even in the culture the formation of a more than 16-celled syncoenobium took place only temporarily. The cells in both the coenobium and syncoenobium were in ± one plane and the embedding of cells in the coenobium ± into the space took place mostly during reproduction only. The capacity of the coenobia cells to veer out of the area or not to align with the area of the coenobium also alludes to the lability of cell connection within the coenobium.

Most proximate to the species *T. tetrachlorelloides* is *T. alternans* whence it differs only by cell size. It may be stated that in all species of the genus the congruence in the shape of cells, coenobia, the troughy chloroplast with the pyrenoid and in mucilage formation is rather conspicuous, a fact that perhaps bears out the internal homogeneity of the genus *Tetrachlorella*. The

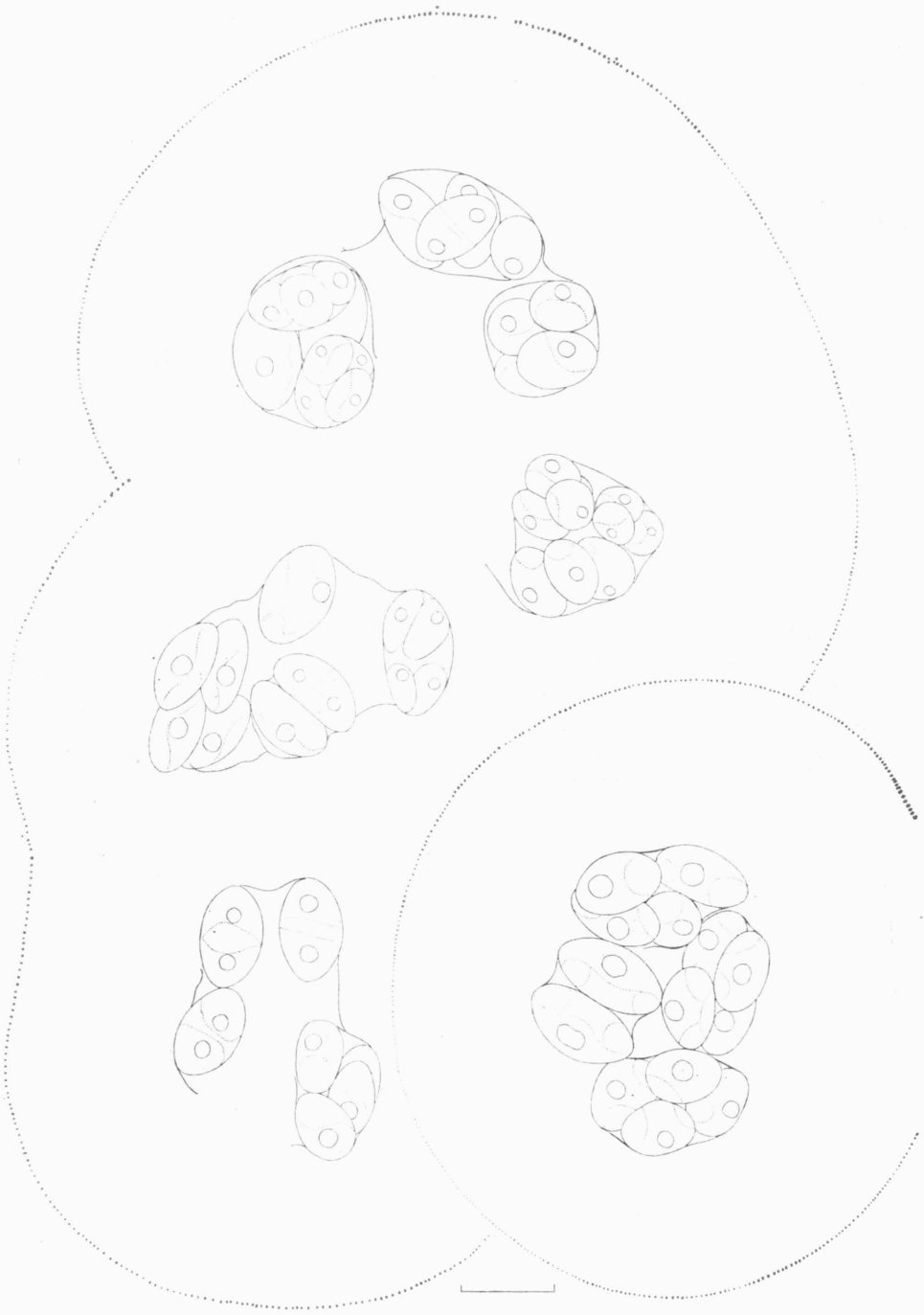

Fig. 5. — *Tetrachlorella tetrachlorelloides* (Buck) Hind., strain Hindák 1978/1, isolated from Hallwilersee-lake in Switzerland. Scale: 10 μm.

intrageneric taxonomy is based on the size of cells and on the capacity to form incrustations at the cell end.

HUBER-PESTALOZZI (1955) followed up the development of this species in the Swiss lakes and, on the basis of his experiences, labelled it as a thermophilic one that signalizes the eutrophization of these lakes. The observations of MÜLLER in the eutrophic Bodensee and of BUCK in the Rhein-Main-Donau-Kanal (Europakanal) (see BUCK 1978) corroborate HUBER-PESTALOZZI's view on the ecological claims of this alga.

SÚHRN

Na základe rozboru znakov rodu *Tetrachlorella* KORŠ. a *Fotterella* BUCK autor prišiel k záveru, že rod *Fotterella* treba pokladať za synonymum rodu *Tetrachlorella* a druh *Fotterella tetrachlorelloides* BUCK navrhuje preradiť do rodu *Tetrachlorella* ako *T. tetrachlorelloides* (BUCK) HIND. Autor uvádza ďalšie poznatky o morfologickej variabilite druhov rodu *Tetrachlorella* a údaje o ich rozšírení.

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