

## Biology and ecology of snow algae

### 3. Sexual reproduction in *Chloromonas rostaffiński* (Starmach et Kawecka) Gerloff et Ettl (Chlorophyta, Volvocales)

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**Abstract** — The gametes of *Chloromonas rostaffiński* were morphologically identical with the vegetative cells. The fusion of gametes, both uniform and variously shaped, was observed. Three phases of the reproduction process were differentiated: 1. The gametes unite in pairs and adhere in the area of contact; 2. A protoplasmic bridge is formed between the gametes; 3. A zygote is formed by the fusion of protoplasts within the cell wall which was formed through the connection of cell walls of the two gametes.

**Key words:** snow algae, life cycles, sexual reproduction.

#### 1. Introduction

The life cycles of numerous species of snow algae are little known or not known at all. Included among them is the species *Chloromonas rostaffiński* which causes the greenish-yellow coloration of the snow in the period of blooming. *Ch. rostaffiński* occurs in the Polish part of the High Tatra Mountains and has not been reported from other mountain or arctic regions. Only Stein and Amundsen (1967) found specimens called *Chlamydomonas* sp. 1 on snow patches in the Rocky Mts. According to these authors, the specimens resemble *Ch. rostaffiński* but are slightly smaller.

The species was found in 1881 by the Polish botanist Rostafiński and named *Chlamydomonas flavo-virens*, though it was not then described

in detail. In 1965 Starmach and Kawecka found what was most probably the same species in the Tatra Mts, and described it as *Chlamydomonas rostafiński*. In 1970 Gerloff and Ettl carried out a revision and transferred the species to the genus *Chloromonas*.

*Chloromonas rostafiński* is known in immotile and motile stages and in the division stages. Its sexual reproduction has not been reported so far. Some information on the biology and ecology of this species has been given by Kawecka et al. (1979).

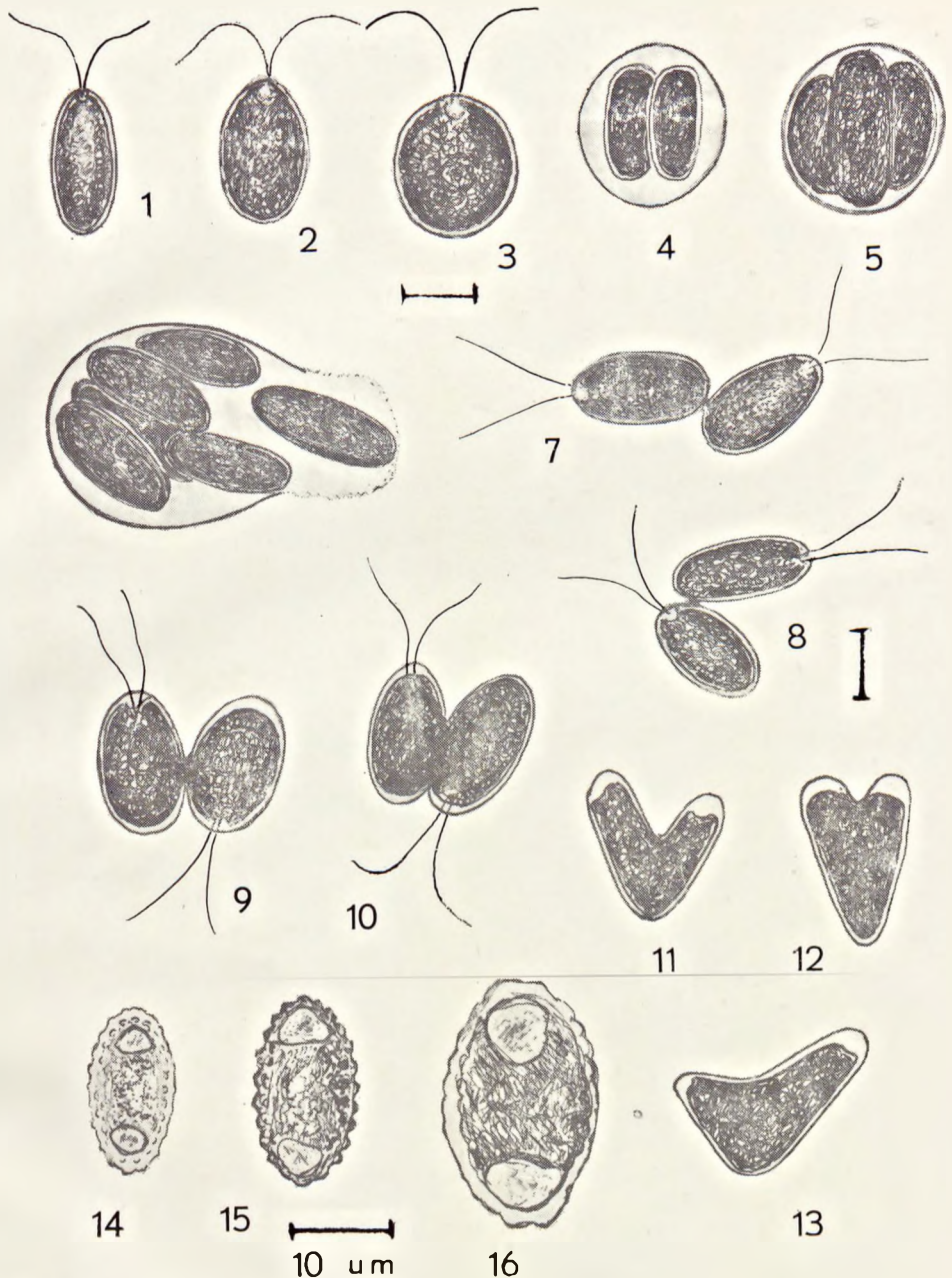
## 2. Material and method

*Chloromonas rostafiński* develops in the summer-autumn period in the Valley "Za Mnichem" on snow patches occurring on Lake Zadni Mnichowy (the High Tatra Mts, at 2080 m). The observations were carried out in the years 1977—1982. The algae were collected in thermos flasks and carried to the laboratory where the material with the snow was distributed in 100-mililiter Erlenmeyer flasks. The low temperature (about 2—4°C) of the water from the melting snow was maintained with ice. The losses of evaporated water were compensated with distilled water. On sunny days the algae were exposed to the sun for a few hours. They were frequently examined under the microscope on a "drop" slide with a small crystal of ice on it. A Zeiss microscope was used in the study.

## 3. Results

The population of *Chloromonas rostafiński* was composed of cells of varying shape (figs 1—3). There occurred bean shaped cells whose dimensions were 11—22.5  $\mu\text{m}$   $\times$  6.6—13.2  $\mu\text{m}$ , oval cells 15—25  $\mu\text{m}$   $\times$  12.5—22.5  $\mu\text{m}$ , and spherical ones with a diameter of 7.5—22.5  $\mu\text{m}$ . The bean shaped cells prevailed in the population. Many cells moved quickly in the water drop while some lost their flagella and became non-motile. Progeny cells enclosed in the integument of a mother cell were fairly frequent (figs 4—6).

Also in the investigated material there occurred cells with no flagellum and with ornamentation of the wall developed to a various degree (figs 14—16). The cell sizes found were 11.5—25  $\mu\text{m}$   $\times$  7.5—16.5  $\mu\text{m}$ . The ornamentation of the membrane was poorer in smaller cells (fig. 14) and more distinct in larger ones (fig. 15). The largest cells, determined as "mature" had particularly strongly thickened cell membrane and their interior took on an orange colour (fig. 16). All cells showed light areas at the two poles.



Figs 1—16. *Chloromonas rostraliński*. 1—3 — the most frequently encountered forms of cell; 4—6 — progeny cells; 7—8 — sexual reproduction: the phase of gametes uniting; 9—10 — sexual reproduction: the phase of formation of a protoplasmic bridge between gametes; 11—13 — sexual reproduction: the phase of formation of the zygote; 14—16 — zygotes?, akinetes?, *Chloromonas rostraliński*

The sexual reproduction of the alga was observed in the material taken directly from the field, collected during blooming, thus it had already been initiated there. The process was observed about two months in the laboratory. The function of the gametes was carried out by cells identical with the vegetative ones; they had a cell wall, two flagella, and their shape was differentiated.

Three phases were observed in the reproduction process: 1. The gametes united in pairs and adhered at the place of contact (figs 7—8). Most frequently the contact was lateral or basal, but more rarely between the apical poles or between the apical pole of one of them and the basal pole of the other. In the case of lateral contact the apical poles of the gametes were always directed to opposite sides; 2. At the place of contact the cell walls were dissolved and a protoplasmic bridge was formed between the gametes (figs 9—10). For a certain period the flagella were maintained but then they disappeared, the cells passing into the non-motile stage; 3. The zygote was formed. A slow fusion of protoplasts occurred while the cell wall of the zygote was formed from those of the two gametes which united around the protoplasmic bridge. In the investigative material gametes in the phase of fusion of protoplasts, before the final formation of the zygote, were fairly frequent (figs 11—13).

#### 4. Discussion

The process of sexual reproduction of the genus *Chloromonas* G o b i Emend. Wille was presented by Ettl (1970). He found that in some species of this genus no morphological differences appeared between the vegetative cells and the gametes. He also observed that in spite of the prevalence of isogamy, its pure form was rare because the size of the copulating gametes varied within definite limits. These two traits can also be found in the process of sexual reproduction of *Chloromonas rostaliński*. Ettl found that most frequently the gametes copulated by apical poles, or more rarely laterally, and that before fusion or during it the cell membranes of the gametes were discarded. In *Chloromonas rostaliński* the process was different: the gametes most frequently copulated laterally or basally, and more rarely by the apical poles, while the zygotes originated within the cell wall which was formed from the connection of the cell membranes of the two gametes. A similar process was observed during formation of the zygote in *Chlamydomonas nivalis* (K a w e c k a, D r a k e 1978).

On the basis of observations made over several years it can be claimed that the sexual reproduction of *Ch. rostaliński* is much rarer than in *Ch. nivalis*, though the process is very similar in the two species. The only difference is that in *Ch. rostaliński* no fusion of the gametes, per-

formed by the passing of the protoplast of one gamete to the other, as is observed in *Ch. nivalis* (Kawecka, Drake 1978), was found.

A considerable problem arises with regard to nonmotile cells with a thickened cell wall covered with sculpture (figs 14—16). Formerly they were regarded as the zygotes of *Ch. rostafiński* (Starmach et Kawecka 1965). However, their numbers in the material being high or sometimes very high, they cannot be the product of the fusion of gametes, which occurs rarely. At present the author rather regards them as resting cells of the akinet type. They are resistant to environmental stresses because they always appear in great numbers under unfavourable conditions, e.g., in the cold month of July 1977 when there were still numerous patches of frozen snow in the valley, these cells prevailed in the collected material together with *Ch. nivalis* aplanospores, equally resistant to hard living conditions (Kawecka 1981). Certain facts suggest that these cells are formed from vegetative cells through the gradual development of the sculpture on the cell wall. The material brought to the laboratory was observed every day for about 3 weeks. In this time no sexually reproducing cells of *Ch. rostafiński* were found, while the would-be akinets were numerous. Usually, the ornamentation of the cell wall of these cells was well developed (fig. 15) and some of them, the "mature" ones, had a remarkably thickened wall (fig. 16). After about 2 weeks the first small green cells with a delicate ornamentation of the cell wall appeared (fig. 14). It was assumed that they might be akinets in younger developmental stages. It is also possible that the discussed cells do not belong to the species *Ch. rostafiński* at all, but represent one or more other species; e.g.; „mature" forms are slightly similar to the species of the genus *Scotiella* Fritsch. Thus, the problem remains open. The structure of the cell wall has to be examined in detail and further observations on the biology of the organisms are necessary.

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## 5. Polish summary

### Biologia i ekologia glonów naślnięznych

#### 3. Rozmnażanie płciowe u *Chloromonas rostafiński* (Starmach et Kawecka) Cerlioli et Etti (Chlorophyta, Volvocales)

*Chloromonas rostafiński* rozwija się w okresie letnio-jesiennym na płatach śniegu leżących w Dolinie za Mnichem na wysokości 2080 m (Tatry Wysokie). Proces rozmnażania płciowego nie był dotąd obserwowany. Gamety są identyczne z komórkami we-

getalynnymi, a zatem posiadają błonę komórkową, dwie witki i zróżnicowany kształt od fasolowatego do sferycznego. Fuzja zachodzi pomiędzy gametami o jednakowym jak i różnym kształcie.

W przebiegu rozmnażania płciowego wyróżnić można trzy fazy. W pierwszej fazie gamety łączą się w pary i sklejają w miejscu kontaktu (ryc. 7—8). Gamety łączą się ze sobą najczęściej bocznie lub bazalnie, rzadziej pomiędzy biegunami apikalnymi lub pomiędzy biegunem apikalnym jednej a biegunem bazalnym drugiej. W wypadku kontaktu bocznego bieguny apikalne gamet skierowane są zawsze w przeciwną stronę. W drugiej fazie w miejscu kontaktu błony komórkowe gamet rozpuszczają się i wytwarza się most protoplazmatyczny pomiędzy nimi (ryc. 9—10). W trzeciej fazie formuje się zygota przez zlewanie się protoplastów w obrębie błony komórkowej powstałej z połączenia się błon komórkowych obu gamet (ryc. 11—13). Przebieg rozmnażania płciowego *Ch. rostaliński* jest podobny jak u *Chlamydomonas nivalis* (Bauer) Wille.

Problem stwarzają komórki ze zgrubiałymi i pokrytymi ornamentem błonami komórkowymi (ryc. 14—16). Nie wiadomo bowiem czy są to zygoty lub akinety *Chloromonas rostaliński* w różnych fazach rozwoju, czy też reprezentują inny gatunek.

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