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The Sphagnum Ponds of Simmelried in Germany: A Biodiversity Hot-Spot for Microscopic Organisms

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ABSTRACT. This study describes 656 species of bacteria, protists, and micro-metazoa occurring in the Simmelried, a three hectare-sized moorland near to the town of Constance, southern Germany. Each species is shown by an average of two colour micrographs. Further, the surface organization of most main groups and many ciliate species is demonstrated by scanning electron micrographs. The Simmelried formed after the last (Würm) ice-age, that is, about 15,000 years ago, when a regressing glacier tongue produced a terrain with water-filled depressions between streamlined boulder depositions. The investigations indicate that the 656 species documented represent only two thirds of the taxa actually present. Thus, a considerable diversity accumulated over 15,000 years, emphasizing the great distribution capacity of micro-organisms. On the other hand, some common species are lacking (e. g., the ciliate *Colpidium colpoda*, the euglenid *Phacus pleuronectes*, and rotifers of the genera *Proales* and *Floscularia*) and many undescribed species were discovered. While a mass of undescribed species is comprehensible in amoebas, flagellates and ciliates, which are poorly researched, this is surprising in well-known groups, such as euglenids and chrysophytes. Thus, we must face the possibility that some of the undescribed species are regional or local endemics. The high species richness, including many undescribed species, suggests the Simmelried as a regional biodiversity centre worth to be protected by law.

Supplementary key words. Autotrophic protists, bacteria, biodiversity, colour micrographs, heterotrophic protists, micro-metazoa, moorland ponds, protists, SEM micrographs.

1. INTRODUCTION

The variety of microscopic life forms is not as obvious for a microscopist as are plants for a botanist. The macroscopic organisms can be examined without specific aids. Although they may be temporarily not apparent, traces, such as seed capsules, footprints or food remnants document their presence. Thus, it is possible to record the macroscopic biocoenosis of a biotope within a growth period. In contrast, the microscopist is limited by the compelling requirement of tools (a good microscope and a variety of stains), the small sample size, and the incalculable appearance of the organisms in tightly bounded areas, the so-called microhabitats. These can develop by a local nutrient input (e. g. fallen leaves), pH-changes, or by temperature variations. All these factors will be superimposed by the effects of seasonal changes. Thus, a number of regional and seasonal examinations are necessary to obtain a detailed picture of the microscopic biodiversity of even a small biotope.

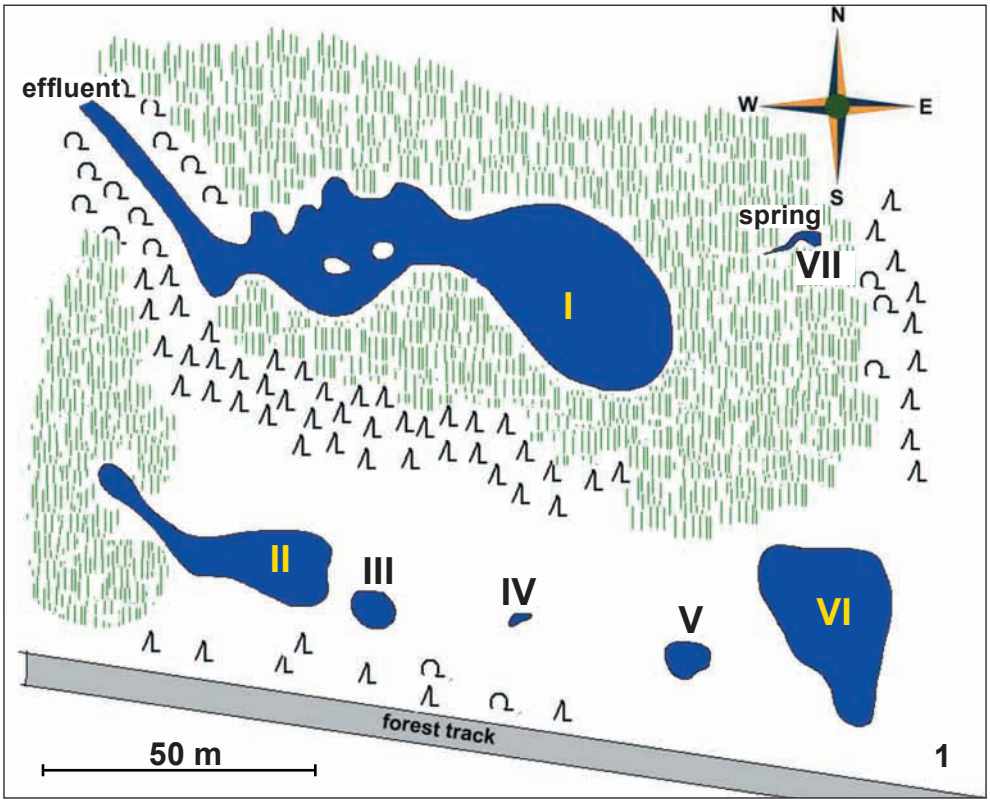
During the years 1994 to 2005, a wetland called Simmelried was investigated for microscopic organisms, including micro-metazoa. About 800 species were recorded; some of them are still unspecified; others are very rare; and rather many are possibly undescribed, especially ciliates and amoebae. Thus, the Simmelried is a diversity hot-spot worth to be protected by law.

Although being expensive and sometimes difficult, all organisms are shown by colour micrographs to document their natural appearance and beauty. We hope, this will stimulate amateurs and scientists to look more frequently into this fascinating, alien world.

2. THE SIMMELRIED

All species presented were found in the Simmelried, which is an approximately three hectare-sized wetland in southern Germany. It is 2 km off Lake Constance, near the village of Hegne, which belongs to the town of Constance. The position of the Simmelried was determined using a GPS navigation system: N 47° 43.05'/E 9° 05.61' (+/– 10 m accuracy). The area is 417 m above sea level. The Simmelried was formed after the last (Würm) ice age, 14,000–15,000 years ago, when a regressing glacier tongue produced a terrain with water filled depressions between drumlins (subglacial streamlined boulder depositions). The majority of these waters turned to moorland through a process of silting. However, the rise of the ground water prevented the formation of a highmoor. During the last hundred years, most parts of the moor were greatly disturbed by peat cutting. The remaining patches of peat were filled with water and commenced to silt up again. Today, the Simmelried is present as a silted-up moorland with a northwest main pond of about 0.5 hectare and five small ponds near the southern border (Fig. 1). The open water surface of the small ponds ranges from 5–50 m^2. The main pond is surrounded by a belt of common reed (*Phragmites communis*) and the great fen-sedge (*Cladietum marisci*), as well as by a thick mud layer. Thus, the main body of water is not accessible, except in winter, when the water frozens (Fig. 11). The small ponds are 50–100 m away from the large pond and are surrounded by Schwingmoor, which is mainly composed of sphagnum moss (*Sphagnum fallax*) and sedge moss (*Caricetum elatae* and *C. appropinquatae*). In summer, some of the ponds are covered with *Nymphaea alba*, the white sea-lily (Fig. 2). Moreover, scotch pines (*Pinus silvestris*) and some mountain pines (*Pinus mungo*) are growing in a belt about 50 meters width between the large pond and the small ponds (Fig. 3, 8). The water of the small ponds reaches a depth of 10–50 cm, followed by a mud layer up to 2 m deep or deeper. The mud is mainly composed of partially decomposed plant material. At the eastern margin of the Simmelried, a spring rises and forms a pool 4–5 m in diameter; in summer (Fig. 10), it is covered with watercress (*Nasturtium officinale*). The water of the spring has pH 7 and flows directly into the large pond. The dimensions of the spring pot and the course of the drain into the main pond can be recognized in winter because the flowing spring water does not freeze.

The outlet of the Simmelried is an artificial, straight canal in the northwest. It is filled with an up to 2 m deep mud layer, and active outflow occurs only after strong rain. Otherwise, the water stays in the canal and can even evaporate in a hot summer. The wetland is surrounded by hills covered by an approximately 50-years-old forest composed of beech, oak, and spruce. Near to the southwest margin of the Simmelried rises a range of hills to a height of about 100 m. No part of the wetland borders an agricultural area. Thus, there is no inflow of fertilizers or pesticides, and the nutrient input takes place through the spring water, and, especially, the leachate from the forested hills. Obviously, the leachate contains a lot of nutrients, especially in autumn when the leaves are decomposed. The varying water composition of the small ponds can be recognized by the different plant communities and the varying intensity of the brownish water colour. While the water seeps to the spillway through the Schwingmoor and the reed belt, the plants extract the nutrients, but the water does not acidify and leaves the Simmelried with pH 7. The pH of the small ponds is between 5 and 6. Such values were already recorded by Franke (1980), who studied the dragonflies of the Simmelried.



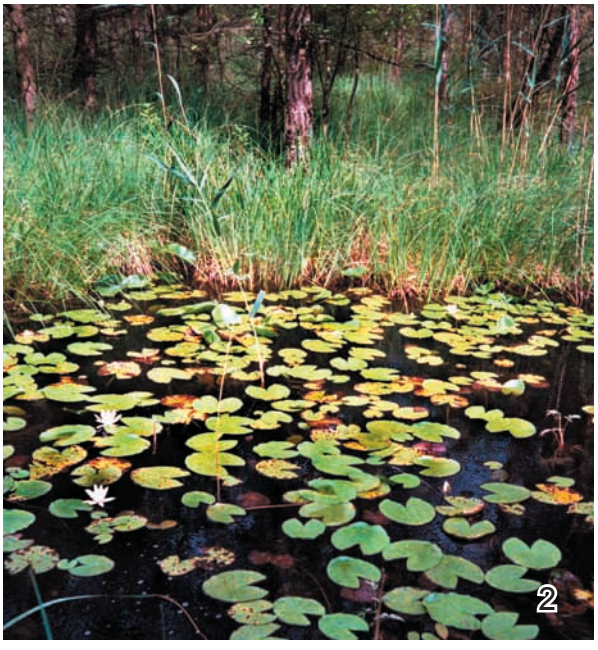


Fig. 1, 2: Simmelried. 1: This schematic map of the Simmelried shows the water surface of ponds I-VII. The large pond I is surrounded by a wide reed belt (*Phragmites communis*), while the small ponds II-VI are surrounded by Schwingmoor composed of great fen-sedge (*Cladietum marisci*) and sphagnum moss (*Sphagnum fallax*). The spring (VII) is at the eastern boundary and flows into the large pond I via a narrow drain. A belt of reed (*Phragmites communis*) and pines (*Pinus silvestris, Pinus mungo*) separates the large pond from the small ponds. **2:** A view of pond II in July. The surface of the brownish water is covered with the white sea-lily (*Nymphaea alba*).

Fig. 3 – 5: Simmelried. 3: A view from the west side of the Schwingmoor showing the region between the large pond I and the small pond II. **4, 5:** A view taken from the outlet canal of Simmelried in July (4) and in February (5). The bottom mud contains a rich diversity of ciliates.

Fig. 6, 7: Simmelried. 6: In July, the small pond VI is covered with floating pond-weed (*Potamogeton polygonifolius*). The average pH is 6. In the background, riverine vegetation of reed (*Phragmites communis*) and sedge moss (*Caricetum elatae, Caricetum appropinquatae*) is visible. **7:** In midsummer, the small pond V, which has a diameter of about 1.5 m, is covered with floating mud. Under this condition, the pond becomes anaerobic. In comparison to the other small ponds, the biodiversity is limited to specialists.

Fig. 8, 9: Simmelried. 8: Pond II in June. The water surface has a length of about 30 m. On the western end is a small island 2 m across (8, 9, arrows). The water is brownish. Note the dense vegetation, providing “food” for the ponds and organisms. **9:** In winter (February), the frozen surface offers the opportunity to examine the mud in the middle of the pond and around the island.

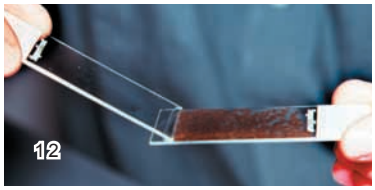
Fig. 10, 11: Simmelried. 10: The spring pot VII is near to the northeast boundary of Simmelried and is covered with watercress (*Nasturtium officinale*). The pool can be best recognized in winter, when the edge is not fully covered with vegetation. **11:** A side view of the frozen large pond I in February. At the western end is the outlet canal (arrow).

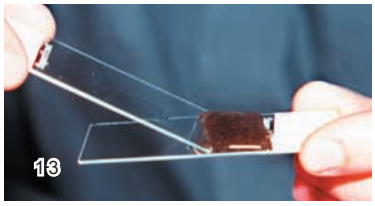
3. SAMPLING AND INVESTIGATION

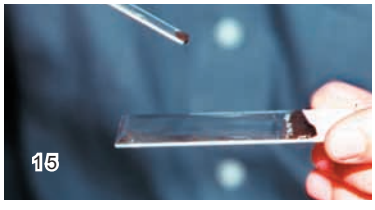
To investigate the microscopic organisms of the Simmelried, various sampling techniques were used. The mud was collected with a large pipette (125 ml) from several depths. Where open water was available, the plankton was collected with nets of 20–65 µm mesh size. Mosses and floating plants were collected in parts or the water was squeezed off the material. Periphytic organisms were brushed from various alive and dead materials, such as the stem of plants and decomposing twigs from the forest. Furthermore, microscope slides were exposed at various sites for 1–2 weeks.

The samples were collected in transparent 250 ml polypropylen vessels to allow the observation of colonization of the vessel wall and provide sufficient light for algae growth. The samples were investigated immediately after collecting, especially the plankton and the exposed slides. After a first examination, the samples were stored and protected from direct light for at least 3–4 weeks for further investigations. Often, interesting species developed considerable abundances during this time. Mosses and floating plants were prepared in petri dishes.

For a preliminary sorting of specimens, 1–2 ml sample were transferred to a slide without coverslip and examined under low magnification. Interesting specimens were selected with a pasteur pipette under permanent microscopic control and transferred to a second slide with a drop of clear habitat water. By this technique, very small specimens, such as flagellates and amoebae can be selected. This would be impossible under a dissecting microscope. To remove adherent contaminants, clear habitat water was added and the specimens washed several times.







Microaquariums were prepared for observation of, for example, reproduction and lorica formation. Furthermore, rare species were transferred into microaquariums in order to obtain population growth. To prepare a microaquarium, about 0.5 ml of the sample were transferred to a microscope slide and covered with a 24 x 36 mm coverslip without use of any distance regulators. The completed microaquariums were stored in petri dishes lined with moistened cotton pads.

Samples of anaerobic mud were not filtered because large protozoa and metazoa could be damaged. Thus, the “slide-on-slide” method was applied (Fig. 12–15). For this, about 2 ml of mud are transferred on a microscope slide and a second slide is put with the narrow cutting edge at an angle of about 45° near to the edge of the sample (Fig. 12). Then, the second slide is used to push the sample to the opposite third of the slide (Fig. 13). To separate the water from the mud, the first slide is slanted by about 30°, while the second slide is slightly (1–2 mm) tilted so that water and protists can pass through the slit between the

slides (Fig. 14, 15). The remaining mud-cake is discharged. The results depend on particle size and mud consistency. The technique provides excellent results when applied to organic mud with granular consistency, typically found in sapropelic ponds.

If not mentioned otherwise, the light microscopic images were taken from living specimens without using fixatives, dyestuffs or additives to enhance contrast and/or viscosity. This approach ensures that delicate structures like mucous envelopes and cilia remain intact. Moreover, the current fixation techniques often cause shrinkage and deformation of the specimens. Some fixation reagents like glutaraldehyde affect the refraction index. This can cause misinterpretations, particularly, when a contrast enhancing method is used. Another advantage of live investigation is the possibility to observe movement, which can be very characteristic and important for identification, for instance, in amoebae. The investigations were performed with an Olympus BX50 microscope equipped with bright field and DIC (differential interference contrast), using high-contrast plan fluorite objectives. The micrographs were taken with an Olympus OM-2n camera connected to an electronic flash (Metz T32) integrated in a double collector system and arranged between lamp house and microscope tripod. The double collector system was specially designed for the BX50 tripod by Stahlschmidt (1987, 1991) and provides a Köhler illumination for the flash tube as well as for the lamp bulb. The major part of the images was made on 100 ASA filmstrips from Fuji (Sensia) and Agfa (Precisa CT).

Most micrographs were taken with interference contrast illumination because it provides a sort of three-dimensional view. However, real 3D-images and high resolution can be obtained only with the scanning electron microscope. Thus, we added some SEM micrographs to most main groups of organisms to give the reader an impression of the general appearance of the organisms shown. In ciliates, which are difficult to document with conventional methods, we added bright field micrographs of silver-impregnated specimens to show the beauty of the complex ciliary pattern. See Foissner et al. (1991) for a description of methods.

For print, all micrographs were digitalized and, if appropriate, slightly improved with Adobe Photoshop. We emphasize, however, that the organisms remained unchanged, that is, only the background and/or the contrast were occasionally improved. To keep printing costs as low as possible, one of us (Kreutz) prepared the manuscript and micrographs camera ready.

4. THE SIMMELRIED, A PROTIST DIVERSITY HOT-SPOT

In our guide, we documented 670 species of bacteria, protists and micro-metazoa, which is only two thirds of the taxa actually seen. Certainly, further analyses will increase this figure considerably, likely to around 1000 – 1200 species. There is also a considerable diversity of micro-metazoa, especially of rotifers, where even some very rare species occur, for example, *Ploesoma lynceus* and *Taphrocampa clavigera*.

Most of the species we could not identify belong to the amoebae, heterotrophic flagellates, ciliates, and various (mainly fungal?) endoparasites. At least 40 undescribed ciliate and amoeba species each were noticed and about 20 undescribed flagellates. Thus, among the about 800 protist species seen, there are at least 100 undescribed. This figure is in accordance with those from other biotopes (Foissner

et al. 2002). The richest group are the ciliates, of which about 250 species were seen (Table 1), which is about one third of total protist diversity.

The diversity mentioned above accumulated over the 15,000 years passed since the last ice-age. Seemingly, this provides support for the hypothesis that, in microorganisms, “everything is everywhere” (for literature and detailed discussion, see Foissner et al. 2002). On the other hand, the Simmelried contains quite a lot of undescribed species, while some species common in other ponds are lacking, for instance, the ciliates *Colpidium colpoda* and *Ophrydium versatile* as well as the euglenids *Phacus pleuronectes* and *Euglena viridis,* and rotifers of the genera *Proales* and *Floscularia.* This shows that distribution and successful colonization may need long times. While a mass of undescribed species is comprehensible in amoebas, flagellates and ciliates, which are generally poorly researched, this is surprising in well-known groups, such as euglenids and chrysophytes. Thus, we must face the possibility that some of the undescribed species are regional or local endemics, produced by, e.g., specific habitat conditions and/or point mutations in certain conspicuous features recognizable in the light microscope.

Seen from a more general view, the Simmelried wetland can be classified as a biodiversity hot-spot for microscopic organisms. Many rare and undescribed species occur, suggesting that the area should be protected by law, for the benefit of genetic resources and the scientific community.

Table 1. Ciliates from the Simmelried. 202 species were identified, but many more were seen, including at least 40 undescribed species, some of which are shown in the plate section. Species marked by an asterisk are shown by micrographs. See Foissner (1993), Foissner et al. (1991, 1992, 1994, 1995, 1999, 2002) and Kahl (1930 - 35), for authors and dates of species.

Acropisthium mutabile	**Calyptotricha pleuronemoides*
**Actinobolina vorax*	**Campanella umbellaria*
Amphileptus claparedii	**Chilodonella uncinata*
Amphileptus pleurosigma	**Cinetochilum margaritaceum*
**Amphileptus procerus*	**Coleps amphacanthus*
**Apertospathula armata*	**Coleps hirtus*
**Apsiktrata gracilis*	*Colpoda inflata*
**Askenasia volvox*	**Condylostomides tardus*
Aspidisca costata	**Cothurnia annulata*
Aspidisca lynceus	*Cristigera media*
**Atopodinium fibulatum*	*Cristigera penardi*
Blepharisma lateritium	**Cristigera phoenix*
**Blepharisma musculus*	**Cristigera pleuronemoides*
**Blepharisma persicinum*	*Cyclidium glaucoma*
**Blepharisma steinii*	*Cyrtolophosis minor*
**Bryometopus sphagni*	*Cyrtolophosis mucicola*
**Bryometopus viridis*	**Dactylochlamys pisciformis*
**Bursaria truncata*	**Dexiotricha granulosa*
**Caenomorpha medusula*	**Discomorphella pectinata*
**Caenomorpha sapropelica*	**Drepanomonas dentatum*
**Caenomorpha uniserialis*	**Drepanomonas revoluta*

(continued)

Table 1 (continued)

**Enchelyodon monilatus*
**Epalxella antiquorum*
Epalxella exigua
Epalxella mirabilis
Epalxella striata
**Epenardia myriophylli*
**Epispathidium amphoriforme*
Epistylis plicatilis
Euplotes affinis
**Euplotes diadalos*
Euplotes muscicola
**Euplotes patella*
Frontonia acuminata
Frontonia angusta
**Frontonia atra*
**Frontonia leucas*
Furgasonia rubens
**Gerda crassicaule*
**Glaucoma frontata*
Glaucoma scintillans
**Halteria grandinella*
**Heliophrya minima*
Hemicyclium lucidum
**Histiobalantium majus*
**Histiobalantium natans*
Holophrya discolor
**Holophrya ovum*
**Holophrya teres*
Holosticha monilata
**Holosticha pullaster*
**Homalozoon vermiculare*
**Ileonema simplex*
**Kahlilembus attenuatus*
**Kreutzophrya sphagnicola*
**Lacrymaria olor*
Lacrymaria sapropelica
**Lagynus elegans*
**Lembadion lucens*
Lembadion magnus
Litonotus cygnus
**Loxocephalus luridus*
Loxodes magnum
**Loxodes rostrum*
**Loxodes striatus*
**Loxophyllum helus*
**Loxophyllum meleagris*
**Luido parvulus*
**Mesodinium acarus*
**Metacineta cuspidata*
**Metacineta mystacea brevipes*
**Metacystis lagenula*
**Metopus acidiferus*
Metopus angustus
Metopus bacillatus
**Metopus campanula*
Metopus caudatus
Metopus es
Metopus extensus
Metopus fastigatus
Metopus fuscus
Metopus gibbus
**Metopus laminarius*
**Metopus mucicola*
**Metopus nasutus*
**Metopus propagatus*
**Metopus pulcher*
Metopus pullus
Metopus rediculus
Metopus rostratus
Metopus setosus
Metopus spinosus
Metopus tenuis
**Metopus vestitus*
**Microthorax costatus*
**Microthorax pusillum*
**Microthorax viridis*
Monilicaryon monilatus
**Mylestoma anatinum*
**Mylestoma discoideum*
**Mylestoma pusillum*
Mylestoma uncinatum
Nassula ornata
**Nassulopsis elegans*
Obertrumia aurea
**Ophryoglena flava*
**Opisthodon niemeccense*
**Paracondylostoma setigera chlorelligerum*
Paramecium aurelia-complex
**Paramecium bursaria*
Paramecium caudatum
**Paramecium putrinum*
**Parapodophrya soliformis*

(continued)

Table 1 (continued)

**Paraurostyla weissei*
**Pelagostrombidium viridis*
**Pelagothrix plancticola*
**Pelatractus grandis*
**Pelodinium reniforme*
Penardiella interrupta
**Phacodinium metchnikoffi*
**Phialina pupula*
**Plagiopyla nasuta*
**Platycola decumbens*
**Platyophrya sphagni*
**Pleuronema coronatum*
**Podophrya parasitica*
**Prorodon niveus*
**Pseudoblepharisma tenue viridis*
**Pseudochilodonopsis piscatoris*
**Pseudocyrtolophosis alpestris*
**Pseudovorticella fasciculata*
**Rhabdostyla inclinans*
**Rhinothrix barbatula*
**Rhinothrix porculus*
**Saprodinium dentatum*
Saprodinium integrum
Saprodinium putrinum
**Saprodinium reniforme*
**Sathrophilus vernalis*
**Scyphidia constricta*
**Spathidium chlorelligerum*
Spathidium stammeri
**Sphaerophrya parurolepti*
**Sphaerophrya stentori*
**Spirostomum ambiguum*
**Spirostomum caudatum*
**Spirostomum minus*
**Spirostomum semivirescens*
**Spirostomum teres*
**Stentor amethystinus*
**Stentor coeruleus*
**Stentor fuliginosus*
Stentor igneus
**Stentor muelleri*
Stentor multiformis
**Stentor niger*
**Stentor polymorphus*
**Stichotricha aculeata*
**Stichotricha secunda*
**Strobilidium caudatum*
Stylonychia mytilus
Stylonychia pustulata
**Thuricola folliculata*
**Thylakidium pituitosum*
**Trachelius ovum*
**Trachelophyllum sigmoides*
**Trichodina pediculus*
**Trichospira inversa*
**Trithigmostoma cucullus*
**Tropidoatractus acuminatus*
**Urocentrum turbo*
**Uroleptus caudatus*
**Urotricha agilis*
Urotricha armata
Urotricha ovata
Urozona buetschli
**Vaginicola subcrystallina*
**Vaginicola tincta*
**Vasicola ciliata*
**Vorticella chlorostigma*
**Vorticella convallaria*
**Vorticella convallaria citrina*
Vorticella striata

5. BACTERIA AND PROTIST PLATES

Histiobalantium natans

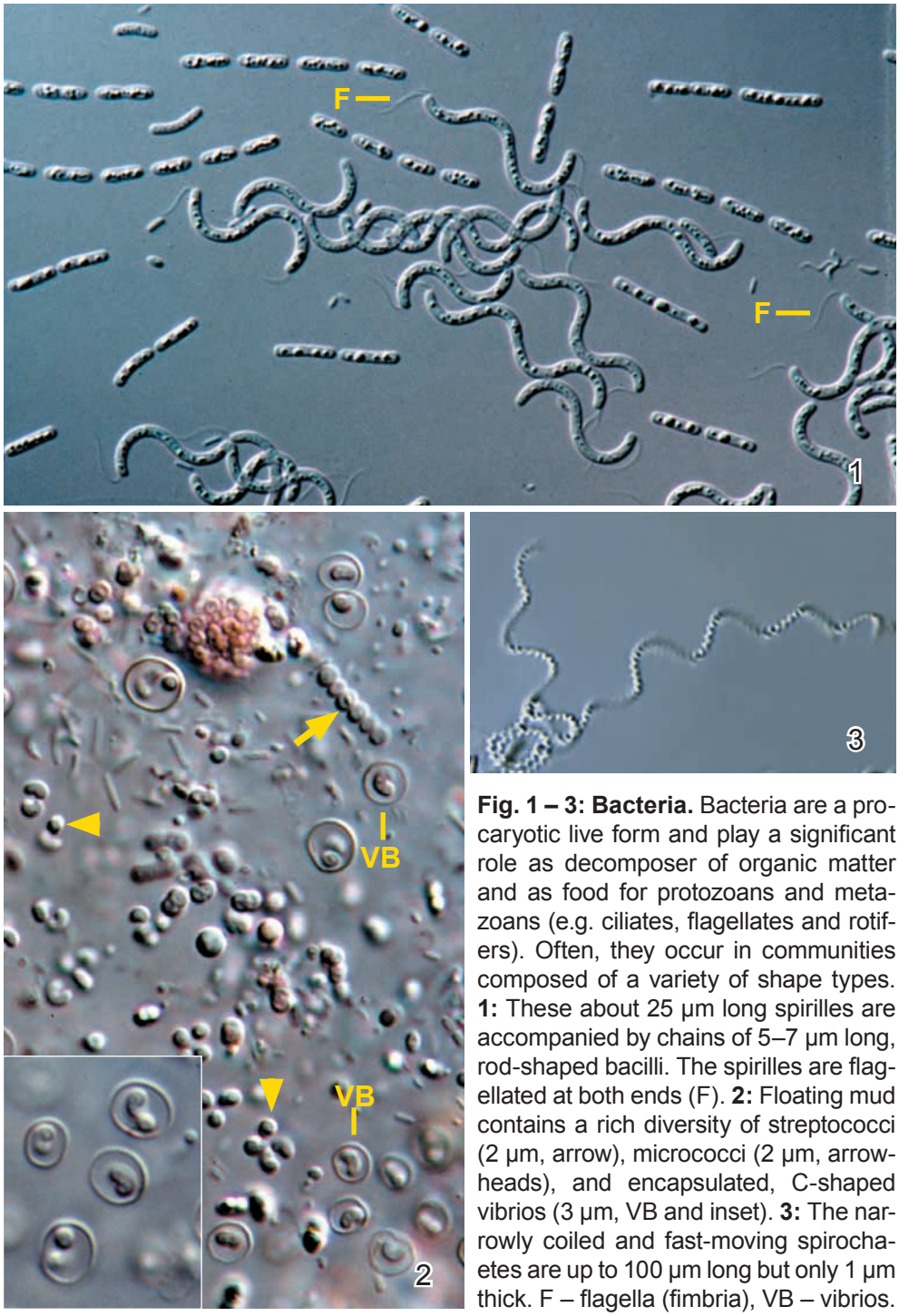


Fig. 1 – 3: Bacteria. Bacteria are a procaryotic live form and play a significant role as decomposer of organic matter and as food for protozoans and metazoans (e.g. ciliates, flagellates and rotifers). Often, they occur in communities composed of a variety of shape types. **1:** These about 25 µm long spirilles are accompanied by chains of 5–7 µm long, rod-shaped bacilli. The spirilles are flagellated at both ends (F). **2:** Floating mud contains a rich diversity of streptococci (2 µm, arrow), micrococci (2 µm, arrowheads), and encapsulated, C-shaped vibrios (3 µm, VB and inset). **3:** The narrowly coiled and fast-moving spirochaetes are up to 100 µm long but only 1 µm thick. F – flagella (fimbria), VB – vibrios.

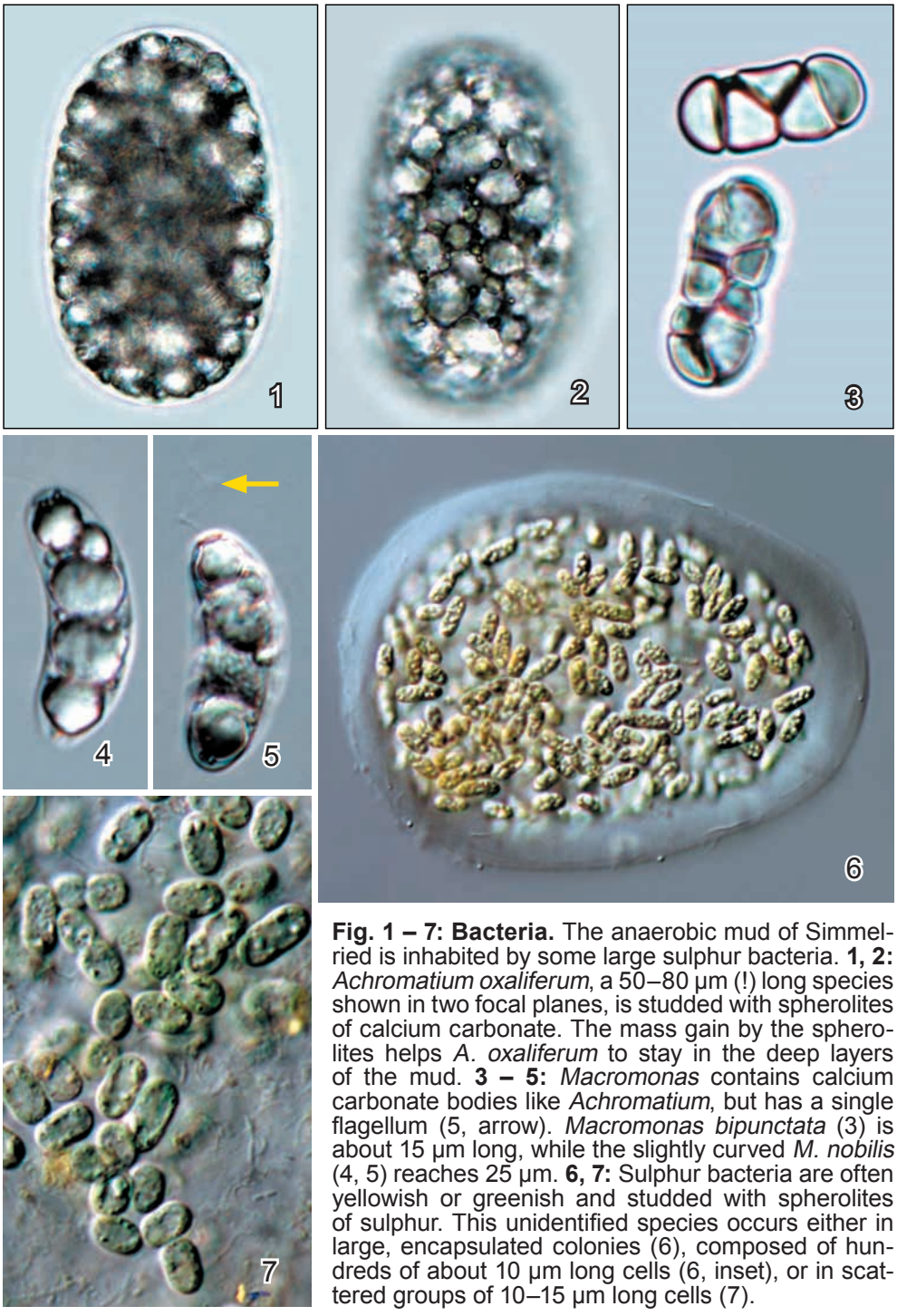


Fig. 1 – 7: Bacteria. The anaerobic mud of Simmelried is inhabited by some large sulphur bacteria. **1, 2:** *Achromatium oxaliferum*, a 50–80 µm (!) long species shown in two focal planes, is studded with spherolites of calcium carbonate. The mass gain by the spherolites helps *A. oxaliferum* to stay in the deep layers of the mud. **3 – 5:** *Macromonas* contains calcium carbonate bodies like *Achromatium*, but has a single flagellum (5, arrow). *Macromonas bipunctata* (3) is about 15 µm long, while the slightly curved *M. nobilis* (4, 5) reaches 25 µm. **6, 7:** Sulphur bacteria are often yellowish or greenish and studded with spherolites of sulphur. This unidentified species occurs either in large, encapsulated colonies (6), composed of hundreds of about 10 µm long cells (6, inset), or in scattered groups of 10–15 µm long cells (7).

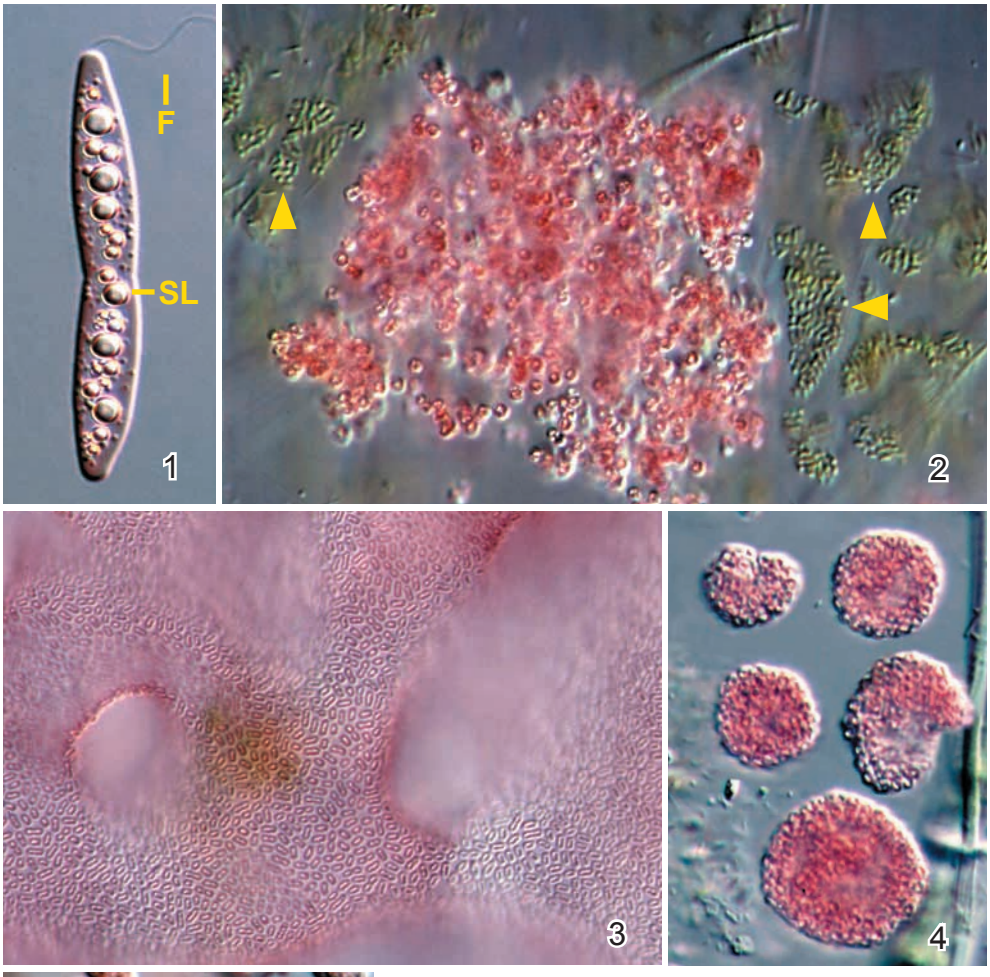


Fig. 1 – 5: Bacteria. Photosynthetic sulphur bacteria are often red or pink. This is caused by carotinoids, which cover the green colour of the bacteriochlorophyll (2). **1:** *Rhodochromatium roseum* is a motile, 20–50 µm long, purple sulphur bacterium with a distinct flagellum (F) and many sulphur granules (SL). **2:** A colony of *Thiopolycoccus* accompanied by greenish, photosynthetic sulphur bacteria (arrowheads). **3:** *Lampropedia* forms folded, monolayered mats. Each bacterium is about 3 µm long and has a gas vacuole to improve buoyancy. **4:** Spherical colonies (20–40 µm) formed by an unidentified coccal species with a diameter of only 1 µm. **5:** A common species in Simmelried is this unidentified purple sulphur bacterium, which is 5–10 µm long and forms irregular aggregations of hundreds of cells. F – flagellum (fimbrium), SL – sulphur granules.

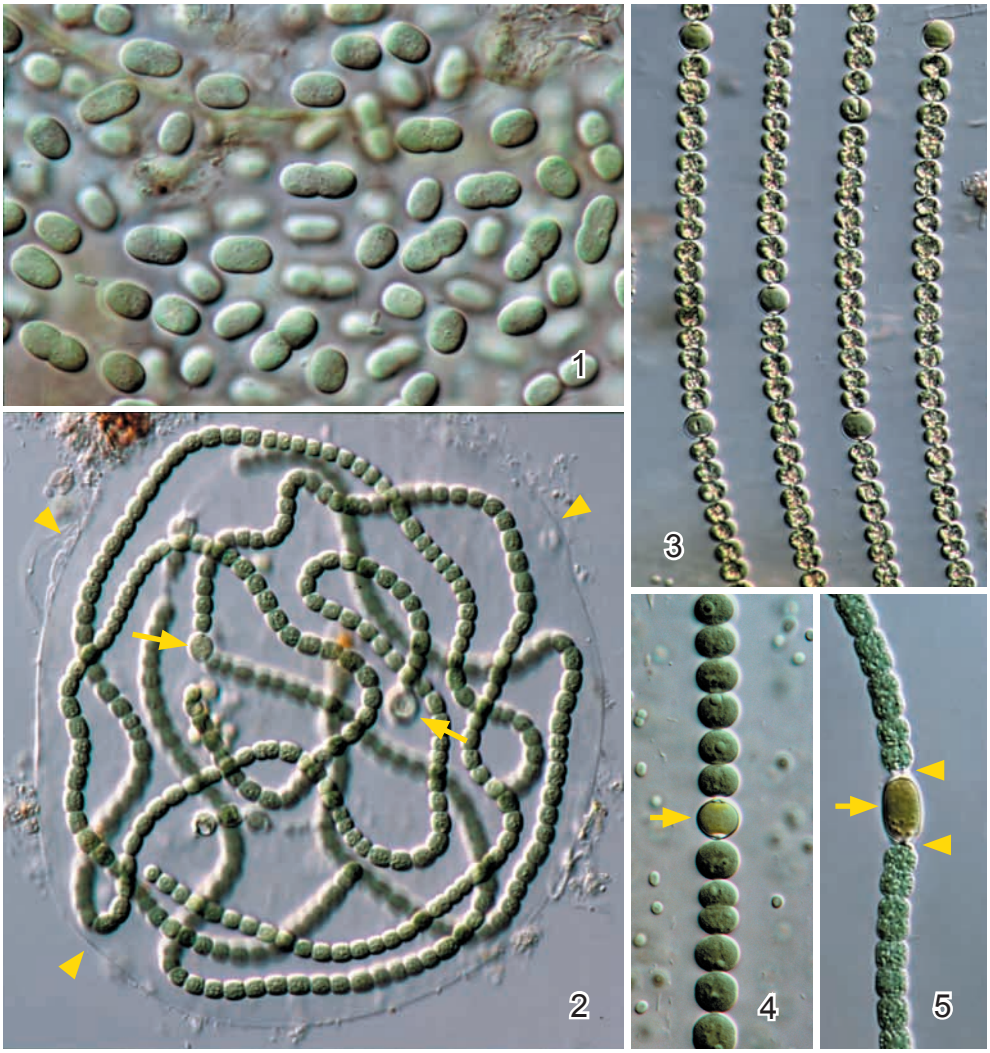


Fig. 1 – 5: Cyanobacteria. The cyanobacteria are photosynthetic, single-celled or colonial prokaryotes. Frequently, they live in a mucous sheath. Different groups contain various photosynthetic pigments like chlorophyll (a) or phycocyanin, which are responsible for the blue-green colour. Some genera are able to fix nitrogen in specialized cells termed heterocysts (5, arrow). The thickened wall of the heterocysts protects the protein nitrogenase from being damaged by oxygen. **1:** The ellipsoidal cells of *Aphanothece nidulans* are 5–8 µm long and are embedded in an irregularly formed mucous sheath. The colonies can contain hundreds of cells. **2:** The trichomes of *Nostoc zetterstedtii* are contorted within a sharply contured, slimy colony (arrowheads). Some about 12 µm-sized heterocysts (arrows) are scattered over the chain of barrel-shaped cells. **3 – 5:** *Anabaena* spp. are similar to *Nostoc,* but each trichome is covered by a very hyaline mucous sheath not recognizable in the micrographs. The heterocysts can be spherical (4, arrow) or ellipsoidal (5, arrow). The contact points to the adjacent vegetative cells are thickened (5, arrowheads).

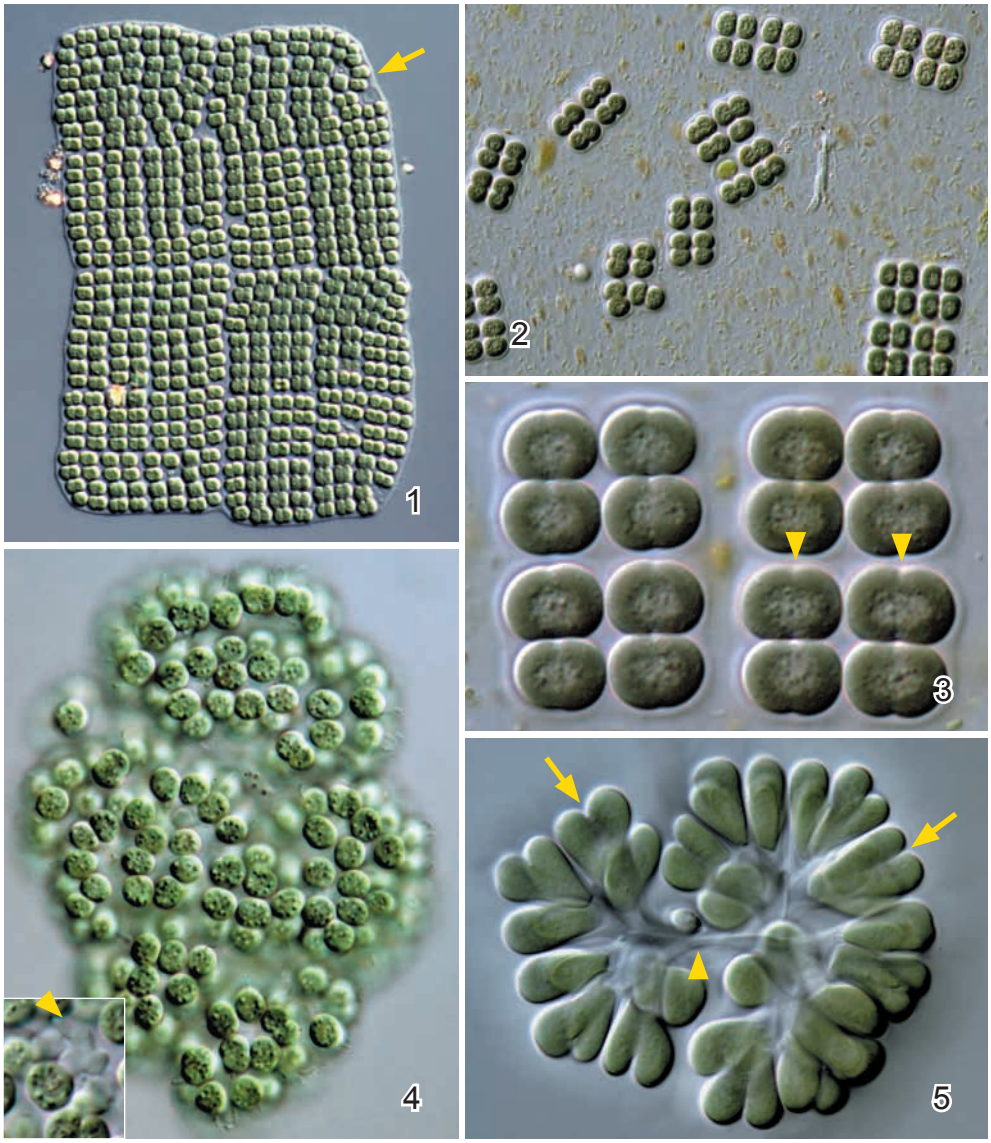


Fig. 1 – 5: Cyanobacteria. 1 – 3: *Merismopedia* spp. form tabular colonies with a sharply contured mucous sheath (1, arrow). The quadrangular colonies of *M. elegans* (1) reach up to 4 mm and comprise hundreds of cells 7–9 µm across. *Merismopedia glauca* (2, 3) forms much smaller colonies with up to 16 cells. The olive-coloured cells are 3–6 µm across and become dumb-bell shaped during division (3, arrowheads). **4, 5:** *Gomphosphaeria* spp. build colonies with a central system of branched stalks (4, inset; 5, arrowhead) with spherical or oval cells at the ends. The irregular colonies of *Gomphosphaeria botrys* (4) are 50–150 µm in diameter and composed of several subcolonies. The cells are 4–5 µm across and peripherally arranged. The drop-shaped cells of *Gomphosphaeria aponina* are 4–15 µm long and form cordiform couples when dividing (5, arrows). The colonies have a diameter of 30–60 µm.

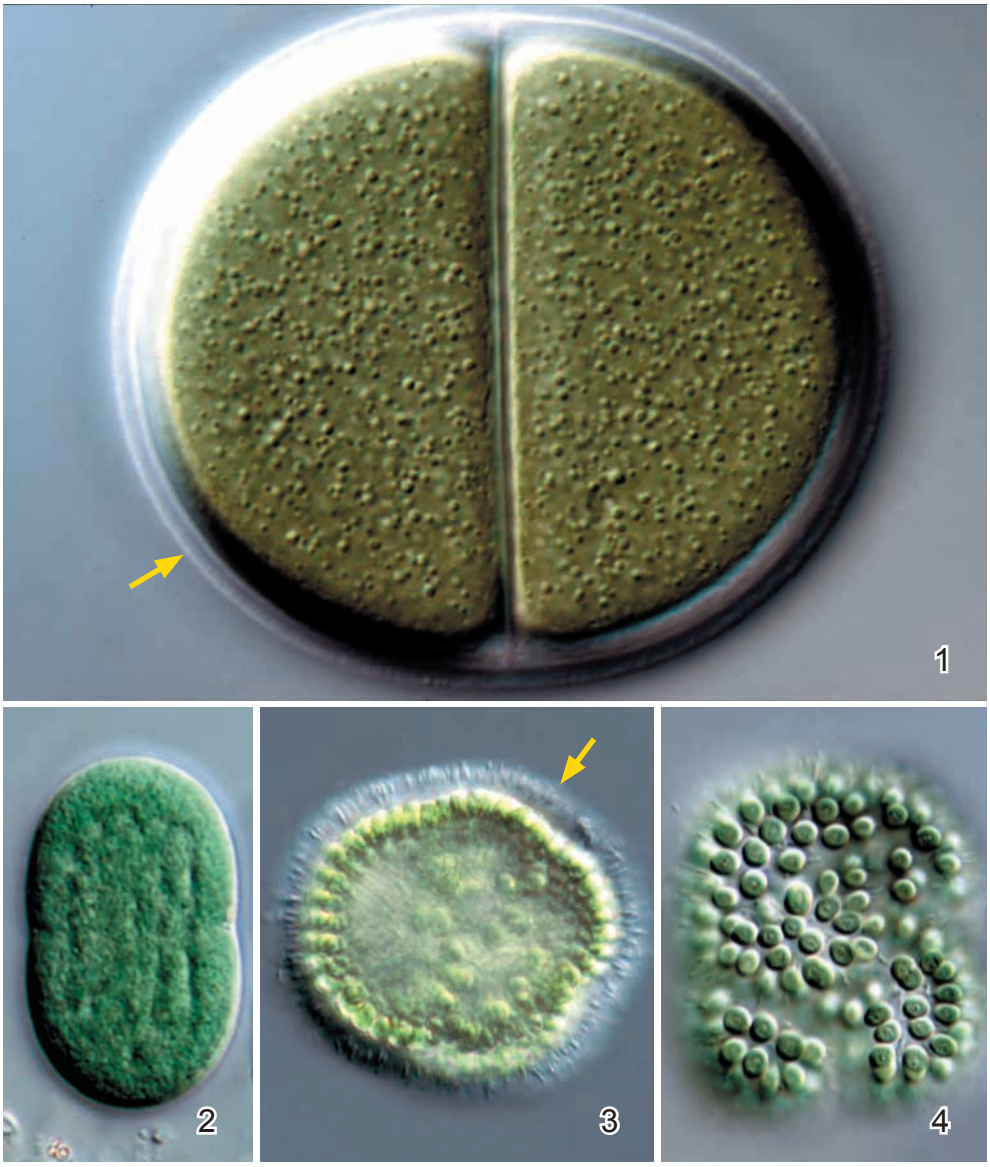


Fig. 1 – 4: Cyanobacteria. 1: *Chroococcus giganteus* reaches 60–80 µm in diameter and is one of the largest cyanobacteria in Simmelried. The cells are covered with a lamellated mucous envelope (arrow), and the the plasm is olive-green or grey-green. The specimen depicted is in division, showing the distinct cleavage furrow. **2:** *Synechococcus diachloros* is 15–30 µm long and can be distinguished from *Chroococcus* by the absence of a mucous envelope. Note the longitudinal chromatoplasm. **3, 4:** *Coelosphaerium kuetzingianum* forms hollow globules 80–100 µm across. The globules are formed by a monolayer of 2–4 µm-sized cells and are covered by a distinct, 4–5 µm thick mucus layer (3, arrow).

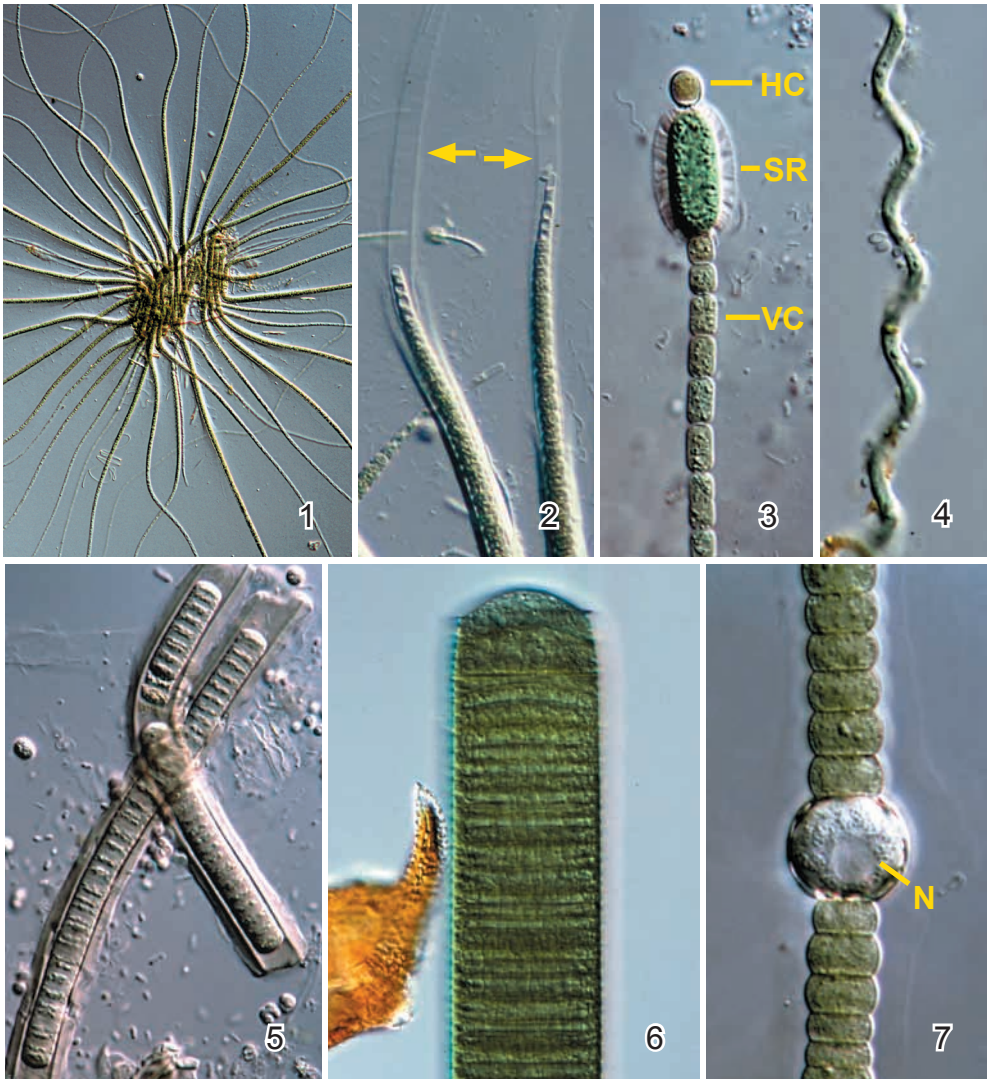


Fig. 1 – 7: Cyanobacteria. 1, 2: *Calothrix* forms tapered, about 500 µm long trichomes aggregated to conspicuous bundles (1). The trichomes are covered by a mucous sheath, which elongates to a hyaline, tapered tube (2, arrows). **3:** The filaments of *Cylindrospermum majus* are composed of vegetative cells (VC), spores (SR), and heterocysts (HC). The about 20 µm long spores are an asexual dispersal stage. **4:** The spiral trichomes of *Spirulina* are 4 µm wide and lack a mucous sheath. **5:** *Plectonema tomasinianum* has a distinct mucous sheath. The 11–22 µm wide cells of the trichomes are separated by granular cross walls. **6:** *Oscillatoria princeps* is one of the largest cyanobacteria. The trichomes are 20–70 µm wide and have slightly tapered ends. The individual cells are comparatively flat, producing a dense transverse striation. **7:** This specimen of *Anabaena* spec. is likely affected by *Phlyctidium anabaenae*, an about 7 µm-sized fungus with a distinct nucleus (N). HC – heterocyst, N – nucleus, SR – spore, VC – vegetative cells.

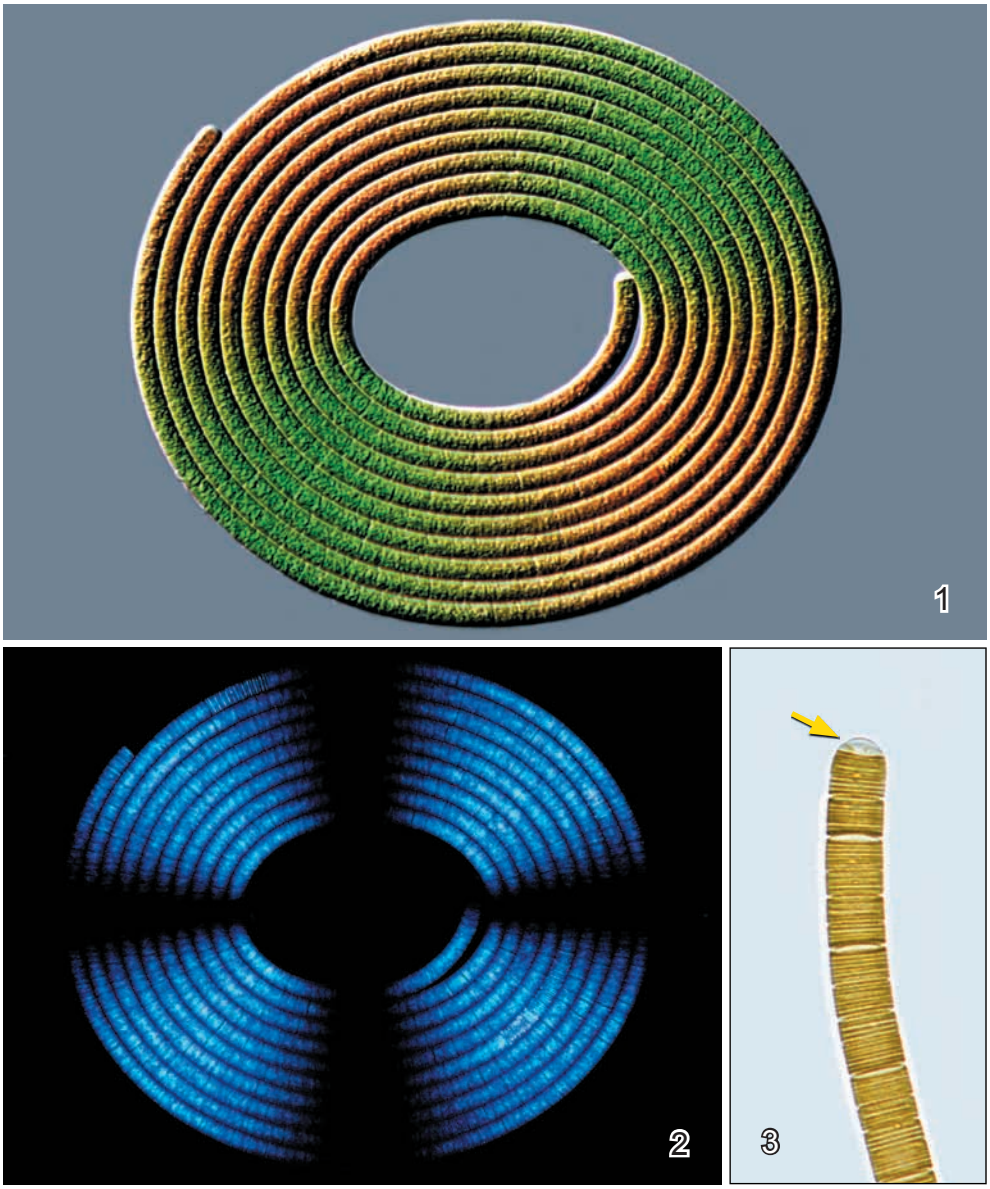


Fig. 1 – 3: Cyanobacteria. *Oscillatoria chlorina* is a common member of the genus in the mud of Simmelried. The trichomes are composed of cylindrical cells with a size of 3–8 x 3–5 µm. The dense transverse striation of the cell wall possibly causes the anisotropic properties, that is, the wonderful coloures in differential interference contrast (1). When a spirally coiled specimen is observed between crossed polarizing filters, a Maltese cross-shaped interference pattern appears (2). At higher magnification, the hyaline cell end (3, arrow) and the narrow transverse striation of the cell wall become visible. The real colour of *O. chlorina* is yellowish green and recognizable in bright field (3).

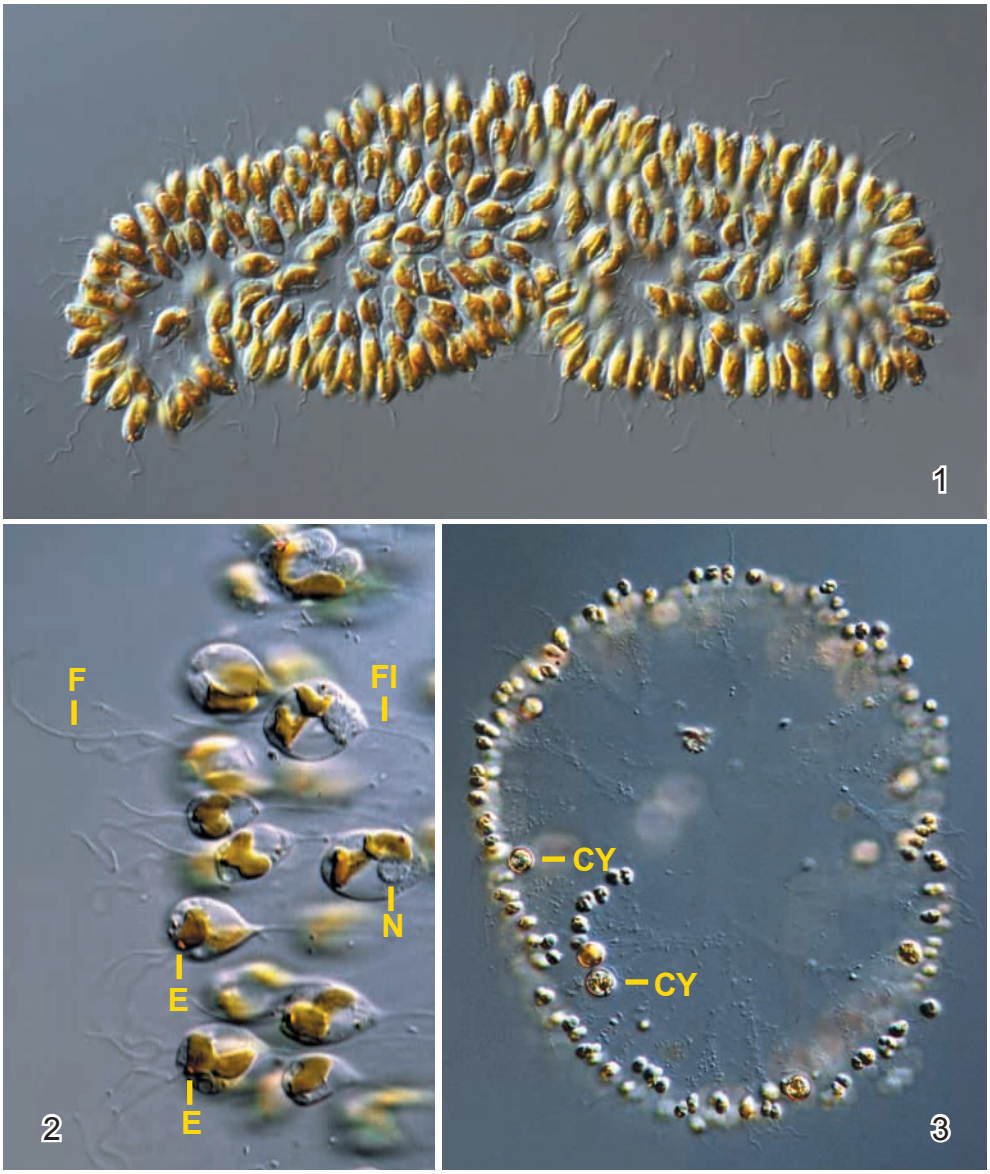
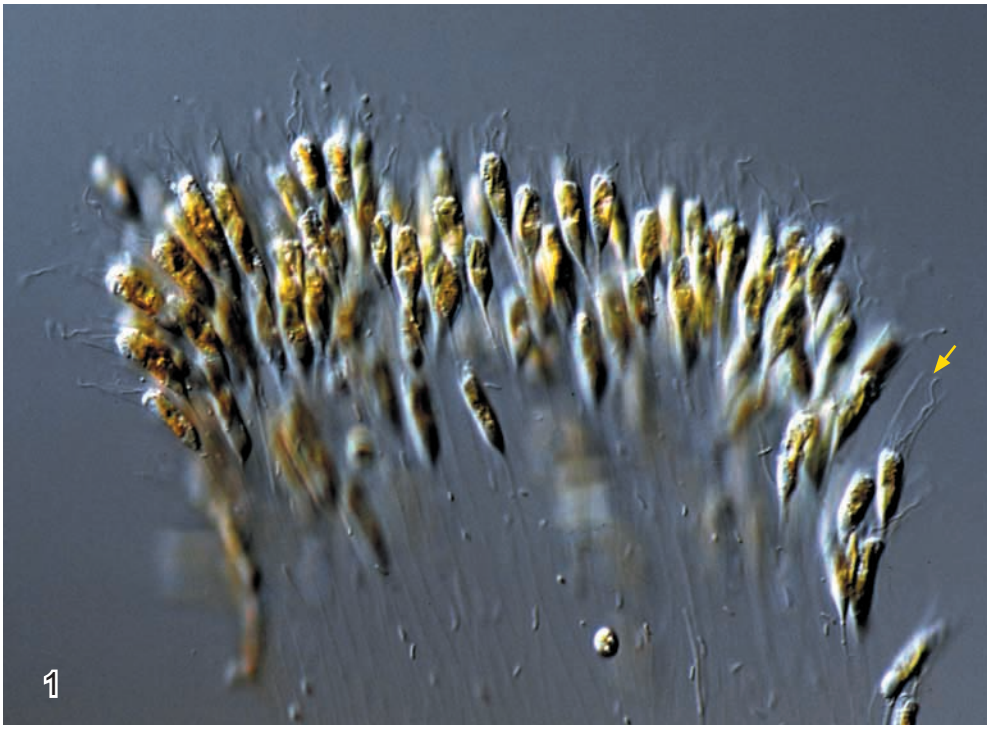
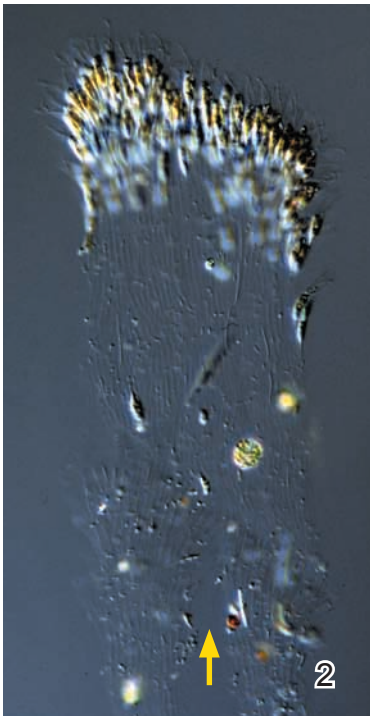


Fig. 1 – 3: Chrysophytes. *Uroglena* forms free-swimming colonies with cells arranged in the periphery of a gelatinous matrix. The cells have two flagella of different length and a yellowish to greenish chloroplast. *Uroglena* can be distinguished from *Synura* by the absence of siliceous scales. **1, 2:** *Uroglena volvox* is common in Simmelried and occurs in 40–400 µm long colonies with > 100 cells. A minute eyespot (E) is at the anterior end of the spiralized chloroplast. The posterior end tapers to a filament (FI). **3:** *Uroglena americana* forms slightly irregular colonies 150–300 µm across. The cells and some globular cysts (CY) are loosely spread on the surface of the colony. CY – cysts, E – eyespot, F – flagellum, FI – filament, N – nucleus.





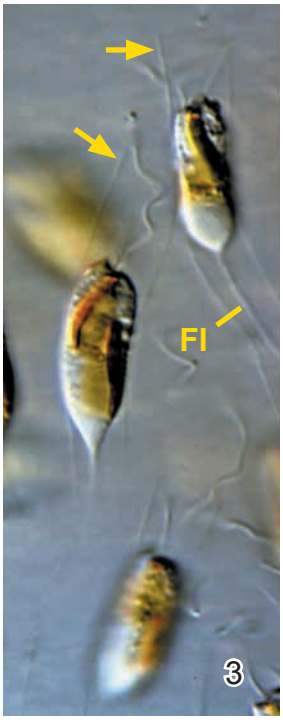


Fig. 1 – 3: Chrysophytes. A likely undescribed species of chrysophytes occurs between floating plants of Simmelried. The columnar colonies are up to 1 mm long and are made from bundles of long, gelatinous tubes, which reach beyond the flagella (1, 3, arrows). At the end of each tube is the monad, which has a chloroplast and two flagella of different length. The 24–34 µm long monads are attached to the tube with a filamentous (Fl) body elongation. Frequently, the colonies are branched in the lower third (2, arrow). Possibly, individual tubes fuse in an early stage of growth. Fl – filament.

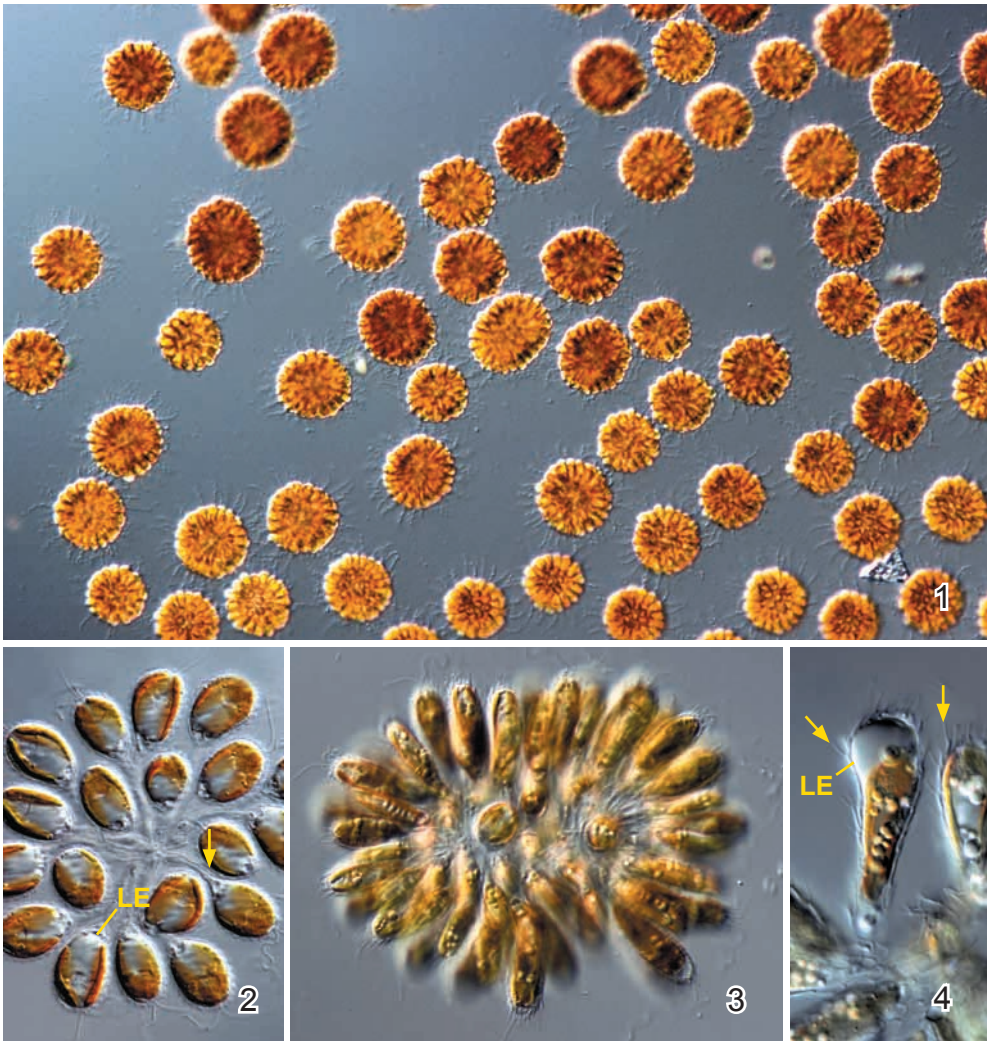


Fig. 1 – 5: Chrysophytes. *Synura* is one of the most common planktonic chrysophytes. Blooms of *Synura* (1) can turn the water brownish and make it smell like ripe cucumbers. The colonies are composed of 10–100 cells covered by minute, siliceous scales lacking in *Uroglena*. **1, 2:** *Synura uvella* has ovoid, 20–40 µm long monads with the tapered ends (2, arrow) connected in the centre of the colony. The scales have a very short spine. **3, 4:** The scales of *S. spinosa* have longer and thus distinct spines (4, arrow). The clavate monads are 20–40 µm long. **5:** *Synura sphagnicola* is 15–20 µm long and has conspicuous, red oil droplets in the anterior end. LE – leucosin.

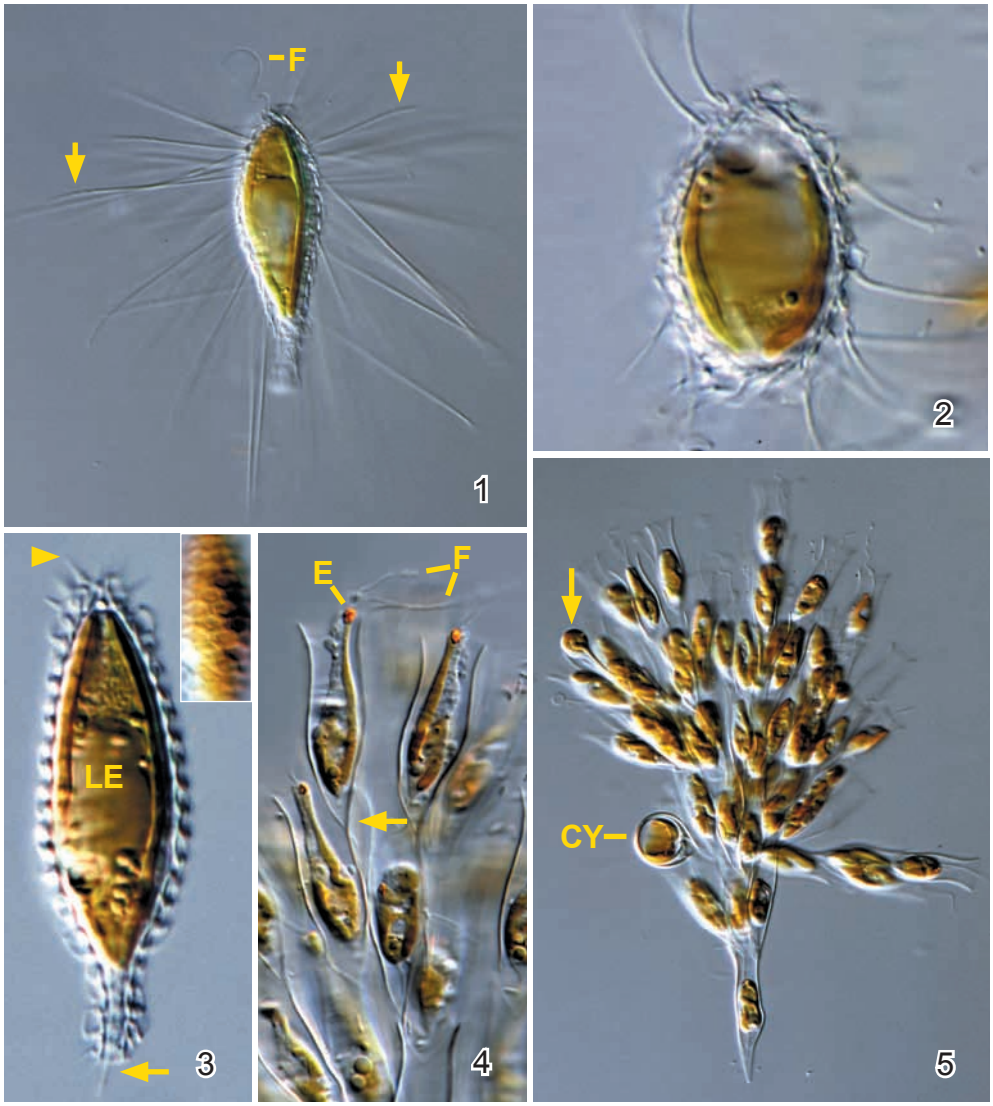


Fig. 1 – 5: Chrysophytes. 1 – 3: *Mallomonas* is a planktonic monad and is covered with siliceous scales often having long spines. **1:** *Mallomonas caudata* is 40–100 µm long and has long, straight spines with a serrated distal end (arrows). **2:** *Mallomonas acaroides* is 20–45 µm long and has 12–20 µm long, curved spines. **3:** *Mallomonas insignis* is covered with overlapping, dish-shaped scales (inset) having spines only in the anterior region of the ~ 90 µm long cell (arrowhead). The body is tapered to a blunt tail from which a thread of plasm emerges (arrow). In the centre is a large storage body of leucosin (LE). **4, 5:** *Dinobryon sertularia* builds colonies composed of vase-shaped, 30–45 µm long loricae. Each daughter lorica is attached to the anterior margin of the parental lorica (4, arrow). A specimen of the colony formed a resting cyst (5, CY) 16 µm across, and another one begins to encyst (5, arrow). CY – cyst, E – eyespot, F – flagellum, LE – leucosin.

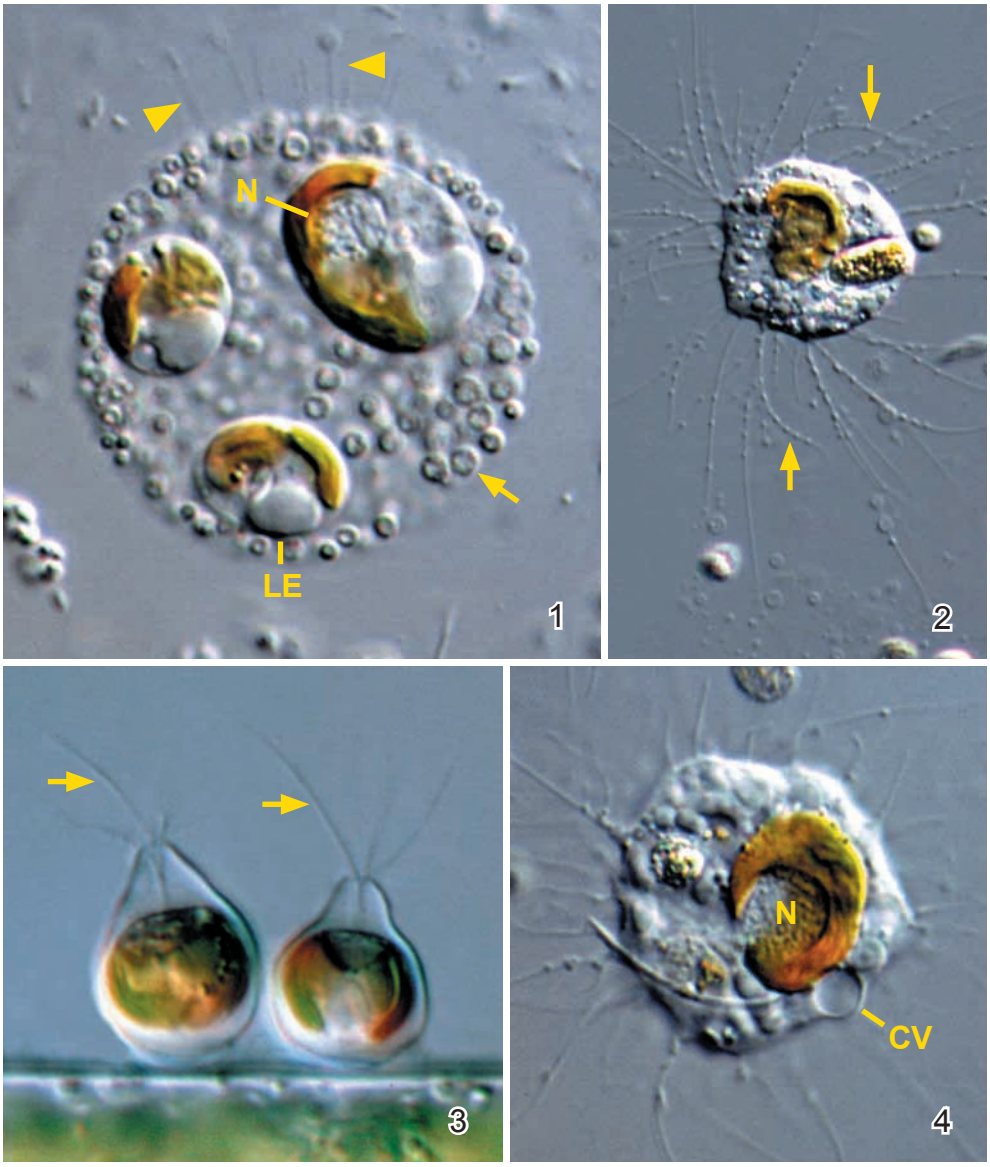


Fig. 1 – 4: Chrysophytes. 1: *Chrysostephanosphaera globulifera* makes colonies 30–90 µm across and composed of a maximum of 16 cells. The cells are 8–10 µm in size and are arranged in a layer enclosed in a gelatinous coat containing "excretion granules" (arrow). Bristle-like filopodia arise from the colony (arrowheads). **2, 4:** *Rhizochrysis nobilis* (15–25 µm) is an amoeboid chrysophyte with many radiating, granulated filopodia (2, arrows). The single chloroplast is cup-shaped and surrounds the nucleus (4, N). **3:** *Derepyxis ollula* var. *minuta* is a sessile, 10–15 µm long chrysophyte in an ovoid lorica, from which some branched filopodia (arrows) emerge through a minute, apical pore. CV – contractile vacuole, LE – leucosin, N – nucleus.

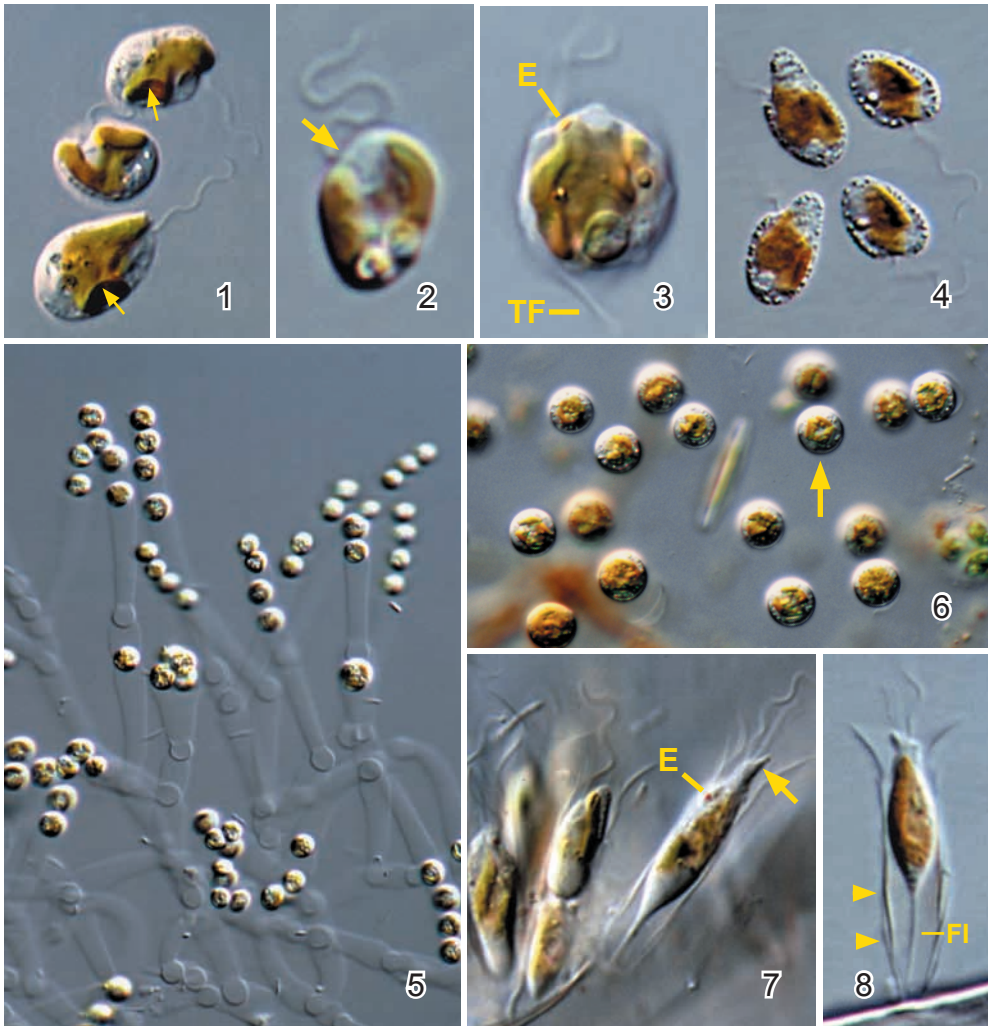
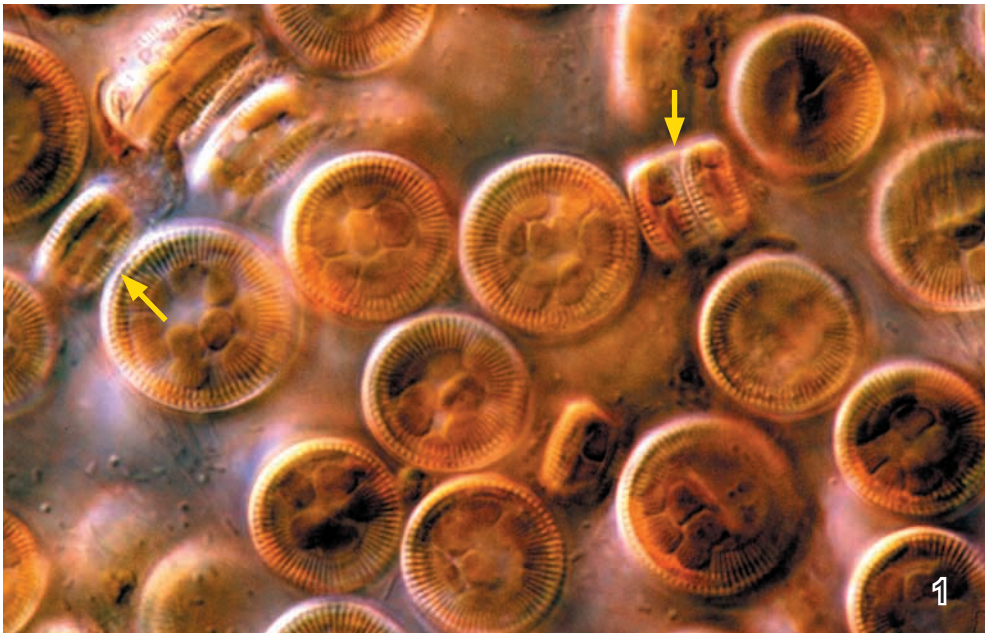


Fig. 1 – 8: Chrysophytes. 1 – 4: These are free-swimming chrysophytes with one (*Chromulina*) or two flagella (*Ochromonas*). **1:** *Chromulina freiburgensis* is 9–15 µm long and has a ribbon-shaped chloroplast with lobes at both ends (arrows). **2:** *Chromulina obconica* measures only 7 µm and has an oblique anterior end (arrow). **3:** *Ochromonas klinoplastida* is 12–18 µm long and has a squared shape and a trailing flagellum (TF). **4:** *Ochromonas perlata* is 15–25 µm in size and has a peripheral layer of refractive granules. **5:** *Mischococcus confervicola* builds colonies of branched, mucuos stalks containing three or four coccoid cells 5–8 µm across at the distal end. **6:** Likely, this is *Stichogloea* with coccoid cells 11–15 µm across and embedded in a gelatinous sheath. The branched chloroplast is in the centre (arrow). **7, 8:** *Hyalobryon lauterbornii* occurs in clustered colonies (7) attached to a substrate. The vase-shaped lorica is 25–50 µm long and composed of overlapping growth rings (8, arrowheads). The monads, which are 8–12 µm long, and have a characteristic apical lip (7, arrow), are attached to the lorica base by a long filament (8, Fl). E – eyespot, Fl – filament, TF – trailing flagellum.



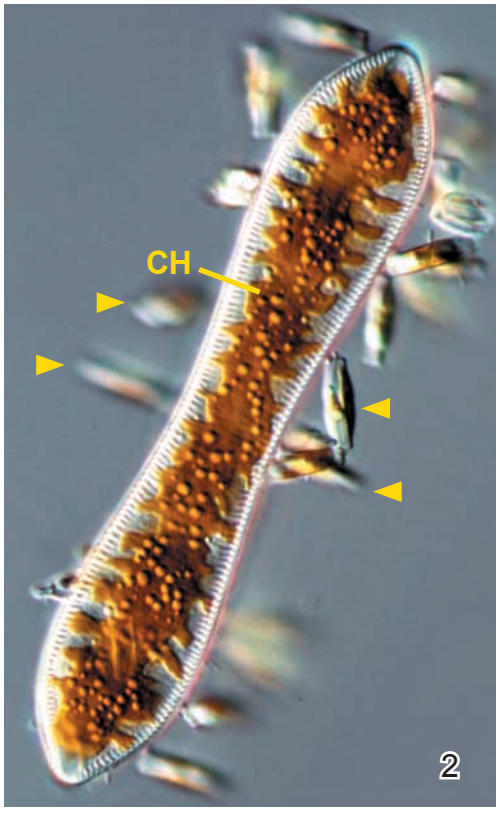


Fig. 1 – 2: Diatoms. Diatoms are single celled algae living in a shell of silica (frustule). The siliceous wall has a complex pattern of perforations. The chloroplast appears yellowish or brownish due to the abundance of carotinoid pigments. The carbohydrate reserve is chrysolaminarin, like in chrysophytes and xanthophytes. Diatoms can be attached to a substrate by a gelatinous stalk or joined to chains. Some species are capable of active movement by secretion of slimy material along a slit-like groove called raphe. **1:** The mass production of *Cyclotella kützingiana* is limited to the spring water in the east of Simmelried. Some of the specimens, which are 10–45 µm in diameter, are seen from the narrower girdle view (arrows). The cells can be stacked like coins by their valve sides. **2:** *Cymatopleura solea* is 30–300 µm long and is easily recognized by the waisted shape. The margin of the brownish chloroplast is lobate. This specimen is covered with very small diatoms (6–8 µm) of the genus *Achnanthes* (arrowheads). CH – chloroplast.

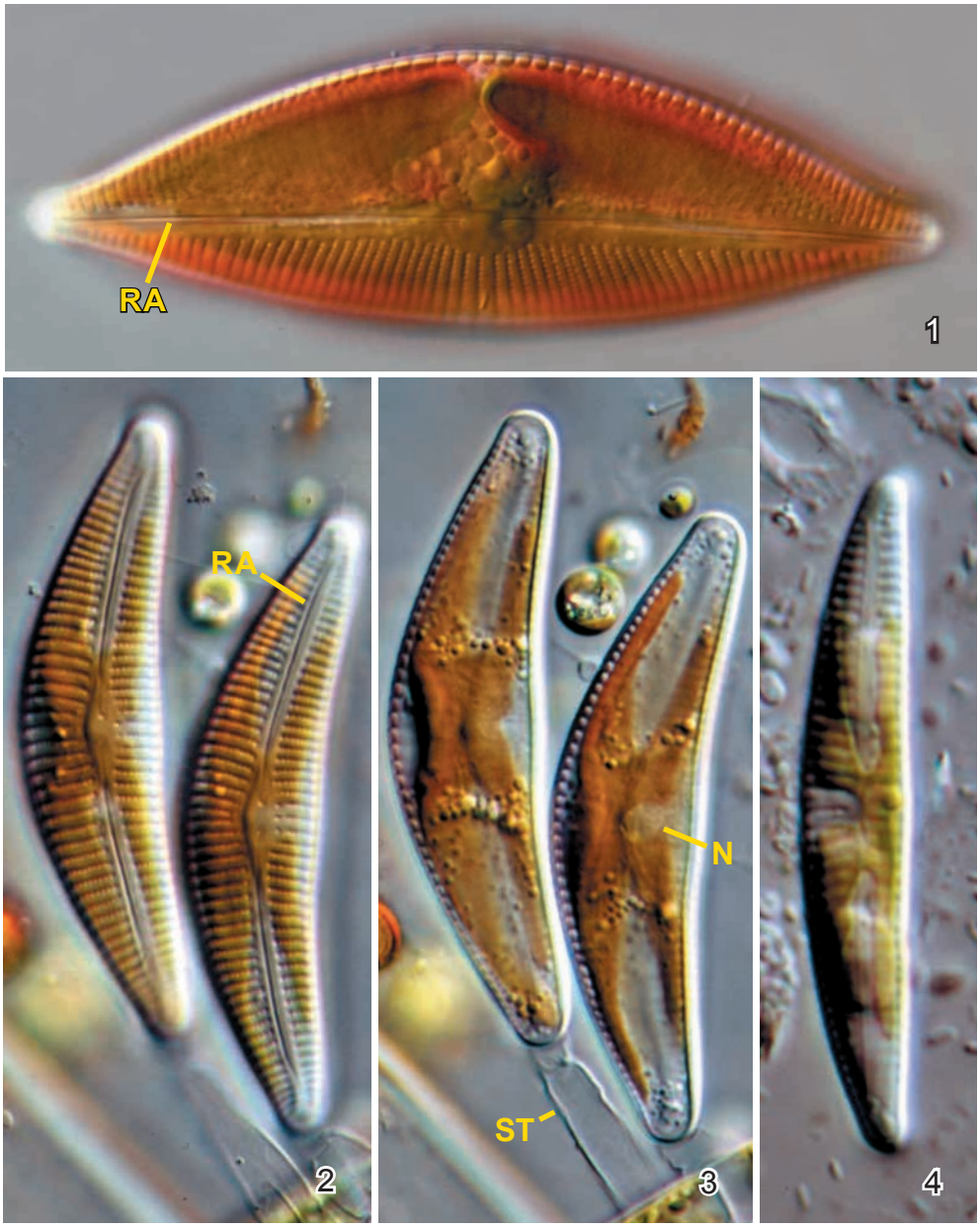
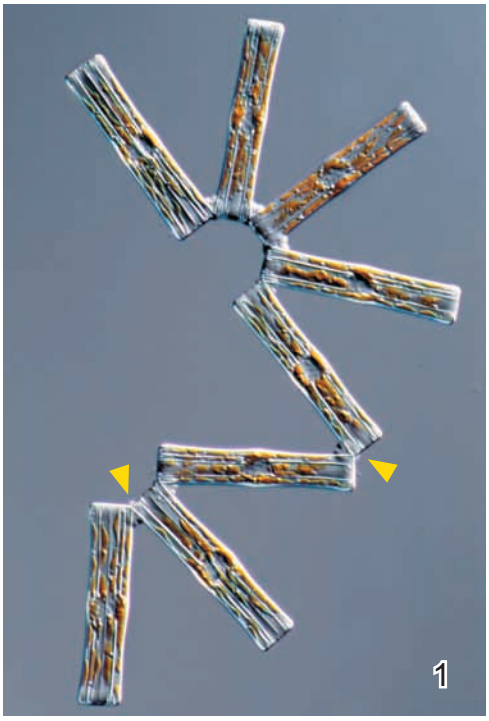


Fig. 1 – 4: Diatoms. Members of *Cymbella* can be recognized by the asymmetric shape and raphe (RA). Often, the species are crescentic. **1:** *Cymbella ehrenbergii,* which is 50–225 µm long and one of the largest members of the genus, is common in the mud of Simmelried. **2, 3:** *Cymbella helvetica* in two focal planes. The species, which is 40–160 µm long, is attached to plants by a gelatinous stalk (3, ST). **4:** The 20–60 µm long *Cymbella gracilis* is often attached to the gelatinous tubes of rotifers (e.g. *Collotheca*) or ciliates (e.g. *Stentor*). N – nucleus, RA – raphe, ST – stalk.



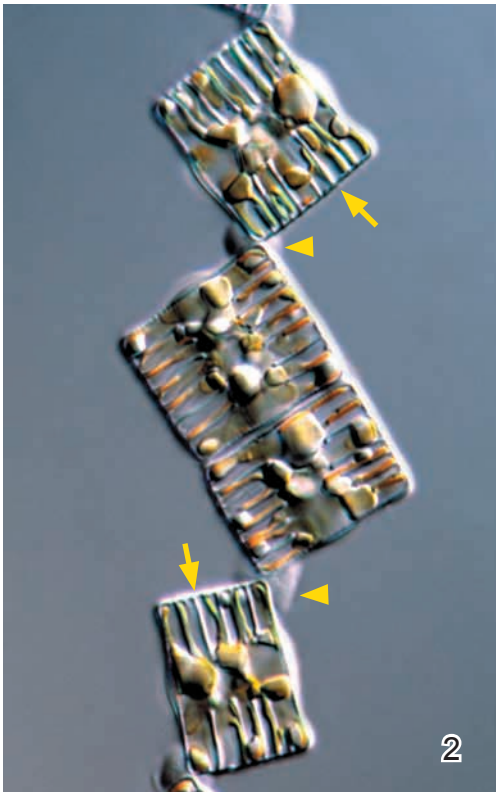


Fig. 1 – 5: Diatoms. 1, 2: Members of the genus *Tabellaria* are adapted to live in acidic water and occur in zigzagging chains of tabular cells connected by gelatinous slime (1, 2, arrowheads). The chloroplasts are golden by the carotinoid fucoxanthin. The genus can be distinguished from zigzagging chains of *Diatoma* by the central inflation of the valve side. The cells of *T. fenestrata* (1) are 30–140 µm long and are elongate quadrangular. *Tabellaria flocculosa* (2) is almost square with an edge length of 10–50 µm. The cells are divided by septa into several sections (arrows). **3, 4:** The raphe of *Nitzschia* is displaced towards the valve margin. The needle-shaped *N. acicularis* (50–150 µm) and the sigmoidal *N. sigmoides* (160–500 µm) occur in the mud of Simmelried. **5:** *Pinnularia interrupta* is 20–80 µm long and can be distinguished from similar species of *Stauroneis* by the absence of a thickened central nodule. RA – raphe.

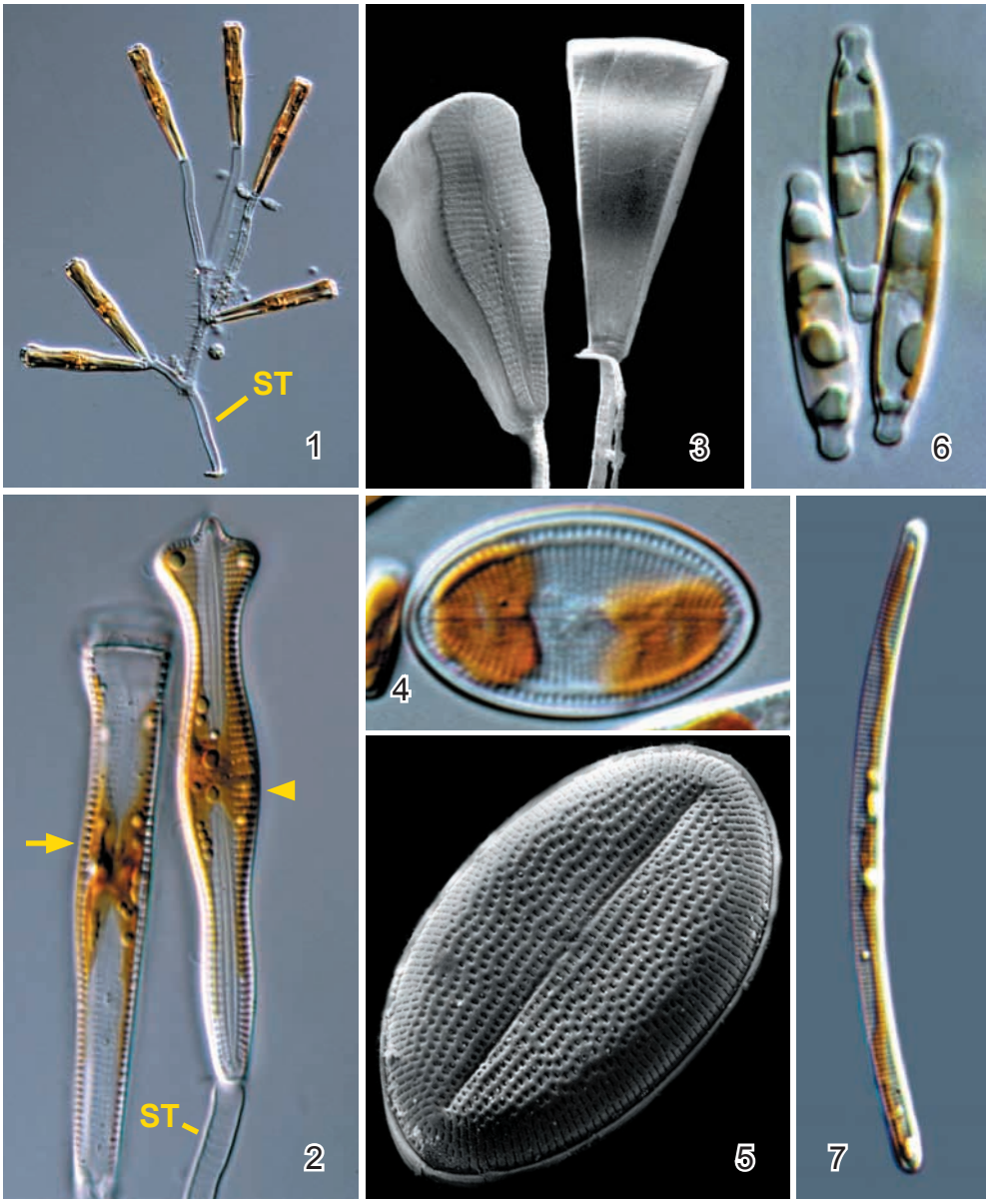


Fig. 1 – 7: Diatoms. 1, 2: *Gomphonema acuminatum* is 20–70 µm long and forms a branched gelatinous stalk attached to various substrates (1). The frustule appears waisted in valve view (2, arrowhead) and wedge-shaped in girdle view (2, arrow). **3:** Valve- and girdle-view of *Gomphonema* spec. in the scanning electron microscope. **4, 5:** *Cocconeis placentula,* shown in the light (4) and scanning electron microscope (5), covers every kind of substrate. **6:** The frustule of *Achnanthes minutissima* is 5–25 µm long and has capitated ends. Masses of this species were found on the spawn of frogs. **7:** The curved frustule of *Eunotia lunaris* is 20–150 µm long and finely striated. ST – stalk.

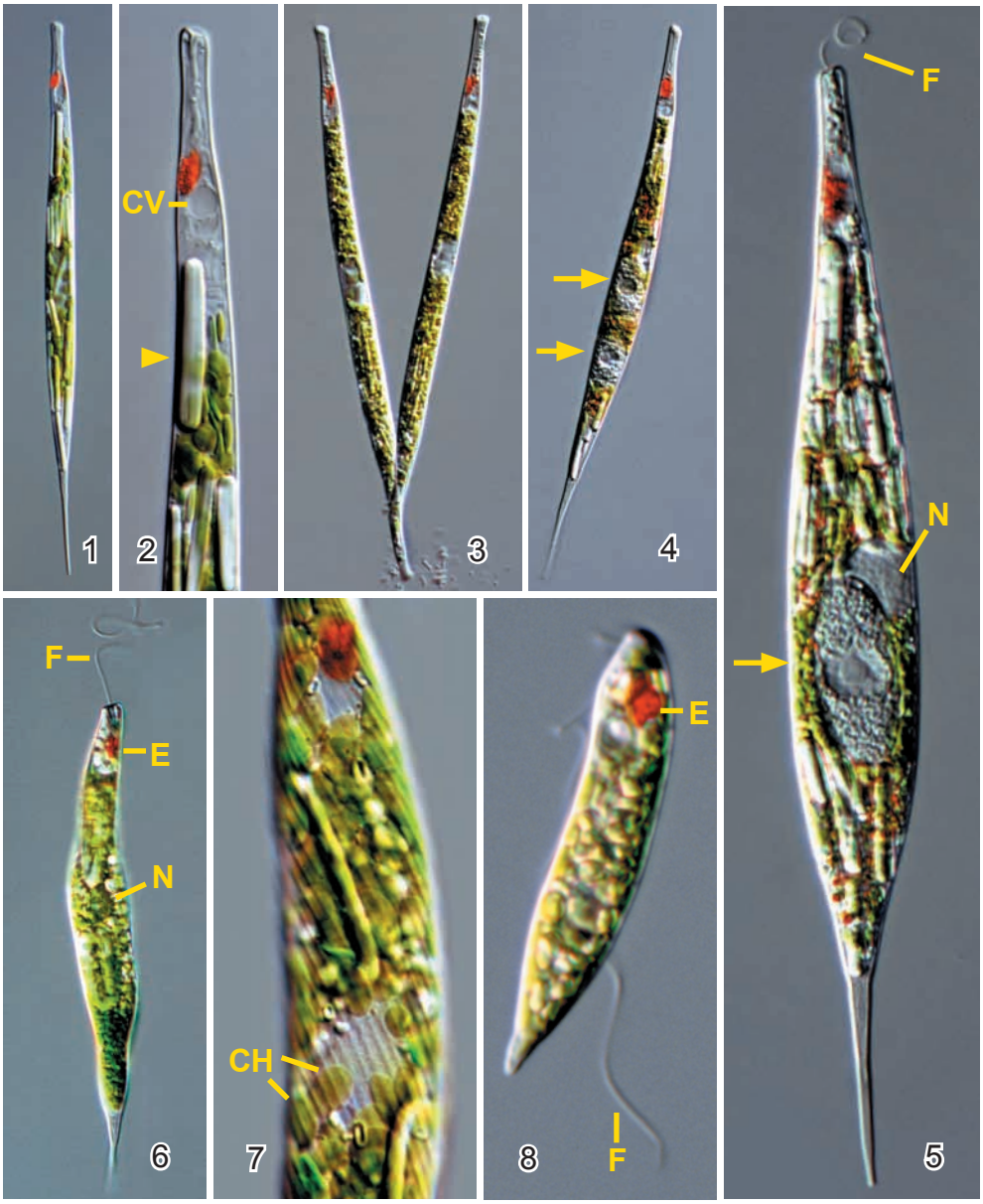


Fig. 1 – 8: Euglenids. Euglenids have a conspicuous, red eyespot and may contain large parasites, possibly fungi (arrows). **1 – 5:** *Euglena acus* is about 190 µm long, contains conspicuous starch (paramylon) grains (arrowhead), and divides longitudinally (3). **6, 7:** *Euglena tripteris* is 70–140 µm long and has a three-ridged or band-like shape. The discoidal chloroplasts are under the striated pellicle (7). **8:** *Euglena variabilis* is only 50 µm long, but has a comparatively long flagellum and large eyespot. CH – chloroplasts, CV – contractile vacuole, E – eyespot, F – flagellum, N – nucleus.

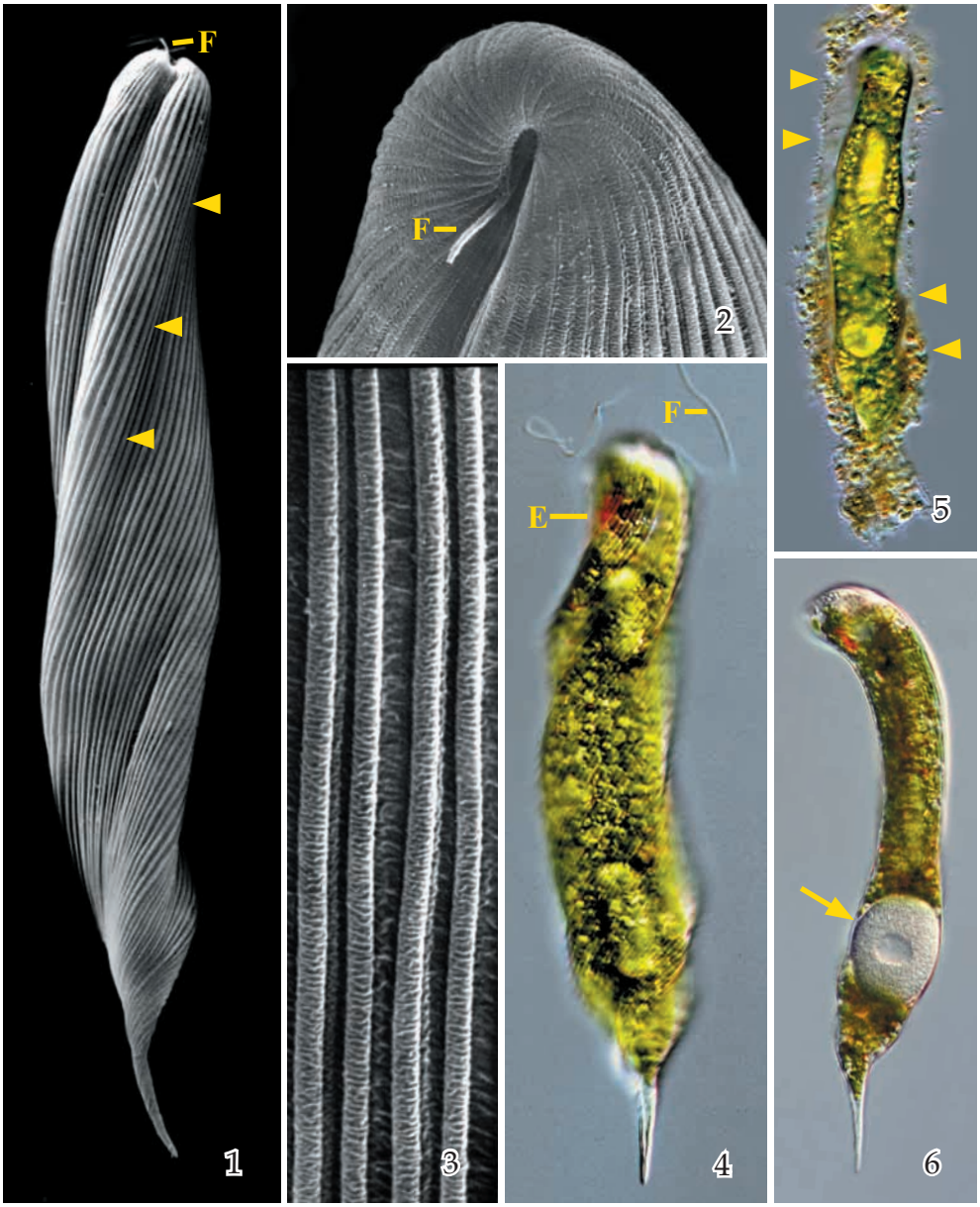


Fig. 1 – 6: Euglenids. *Euglena oxyuris (*syn: *charkowiensis)* in the scanning electron microscope (1 – 3) and from life (4 – 6). The species is 170–490 µm long and has a slightly twisted body with keel-like ridges (1, arrowheads). The pellicle is rigid (ametabolic) and longitudinally striated (3). **1, 4:** Freely motile specimens in nearly same position. The flagellum is about 100 µm long. **2:** Detail of the mouth opening. **5:** Immobile specimen with a mucous coat (arrowheads). **6:** In some specimens of *E. oxyuris,* a parasitic cell (arrow), which looks similar to the nucleus, is visible. E – eyespot, F – flagellum.

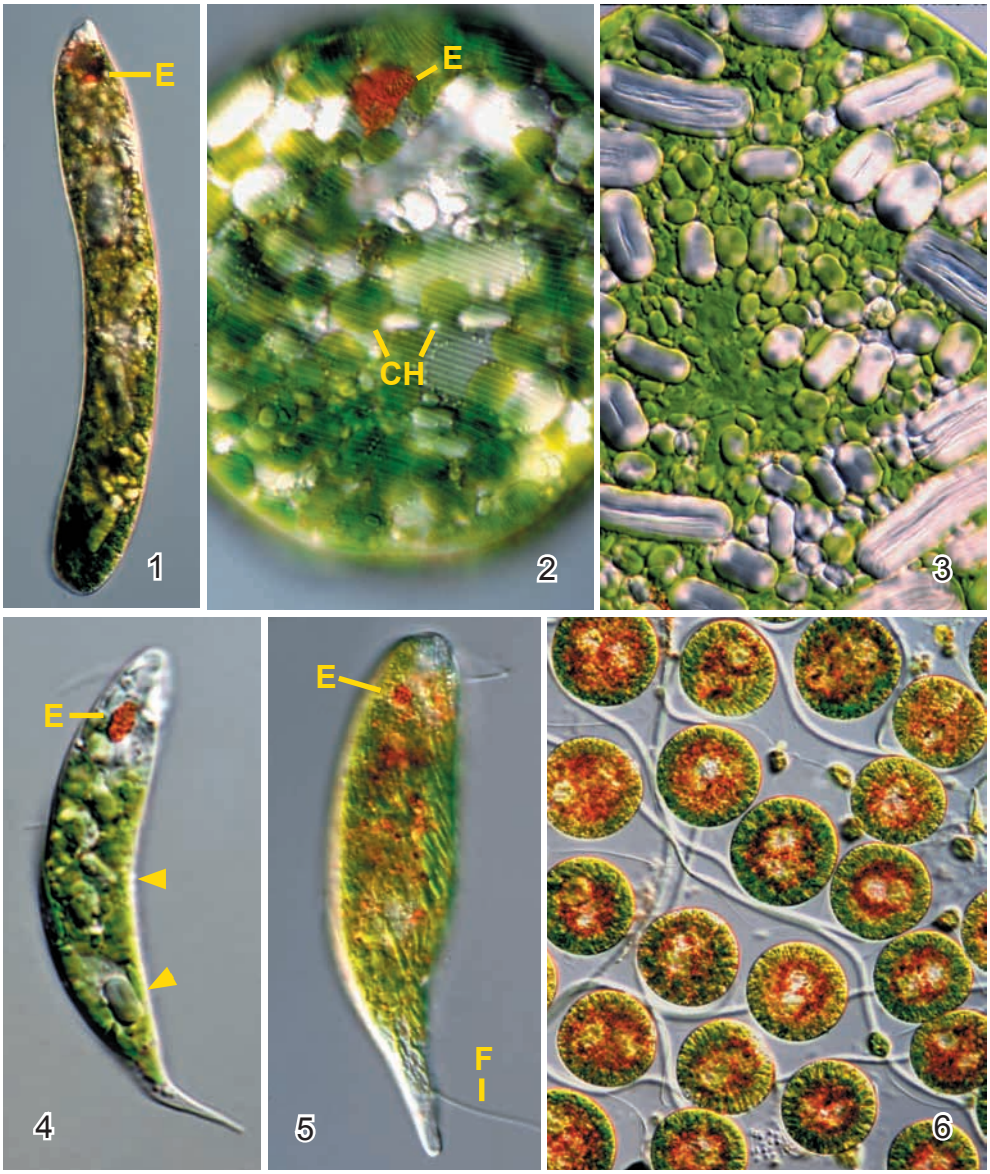


Fig. 1 – 6: Euglenids. 1 – 3: *Euglena ehrenbergii* is a 240 µm long member of the genus and ideal for observing the striated pellicle and discoidal chloroplasts (2). When squashed, the oblong starch (paramylon) grains become distinct (3). **4:** *Euglena spathirhyncha,* which is only 50 µm long and is fusiform, has a large, red eyespot. The anterior end is obliquely truncate and the body contains some ellipsoidal paramylon grains (4, arrowheads). **5, 6:** *Euglena sanguinea* is about 140 µm long and contains many red granules. Thus, it causes red water blooms when occuring in high numbers. When conditions become adverse, it forms a special, globular resting (palmella) stage (6). CH – chloroplasts, E – eyespot, F – flagellum.

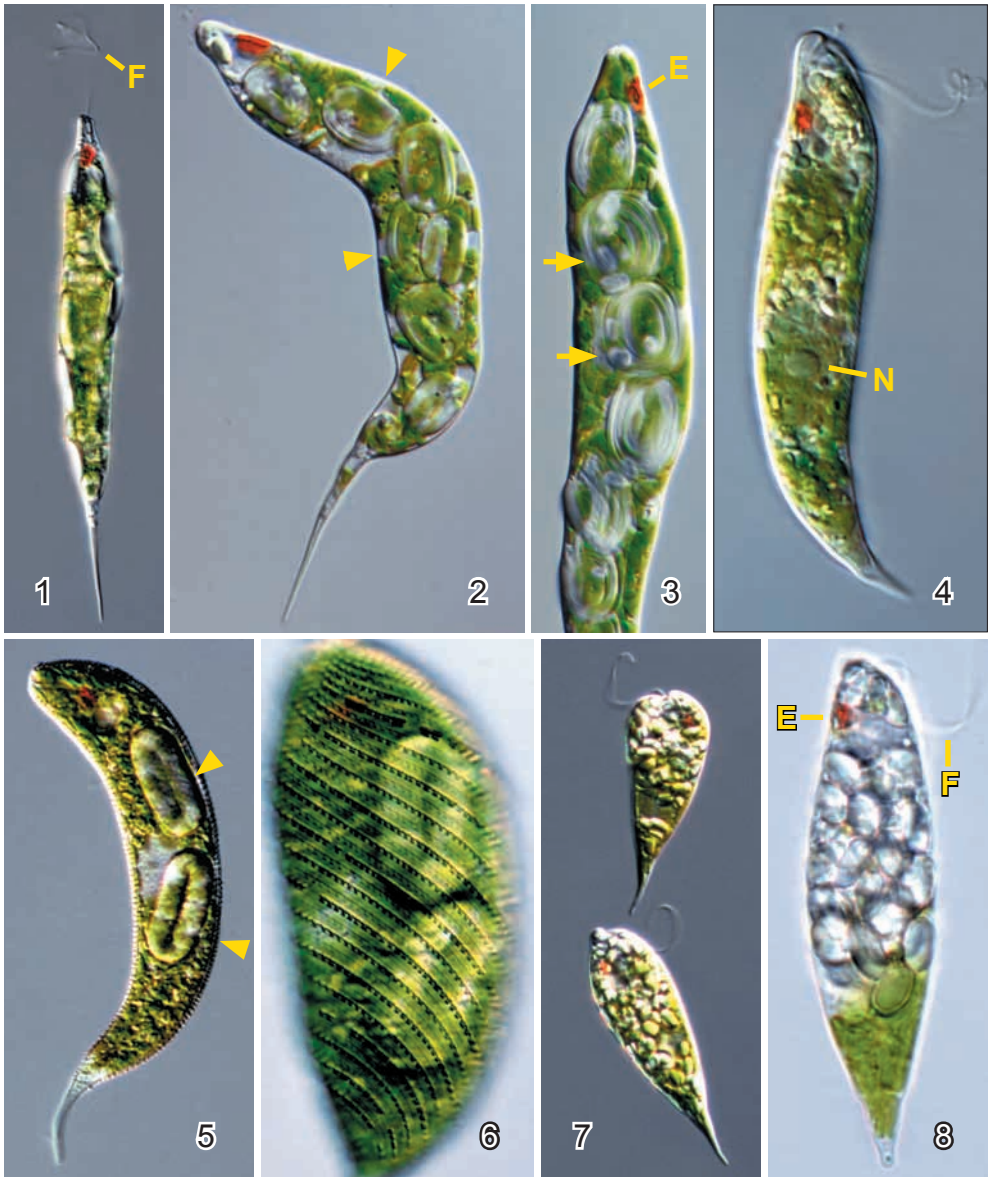


Fig. 1 – 8: Euglenids. 1 – 3: *Euglena convoluta* is 120 µm long and is a rare species with seven to nine concave paramylon grains (2, arrowheads). In squashed specimens, an oblong type of paramylon becomes visible (3, arrows). **4:** *Euglena sociabilis*, which is about 70 µm long and has a blunt tail, contains irregularly shaped chloroplasts. **5, 6:** *Euglena spirogyra* (140 µm) has a conspicuously spiraled pellicle and contains only two large paramylon grains (arrowheads). **7, 8:** *Euglena hemichromata*, which is about 90 µm long, is characterized by the location of the chloroplasts: either parietally (7) or in posterior half (8). E – eyespot, F – flagellum, N – nucleus.

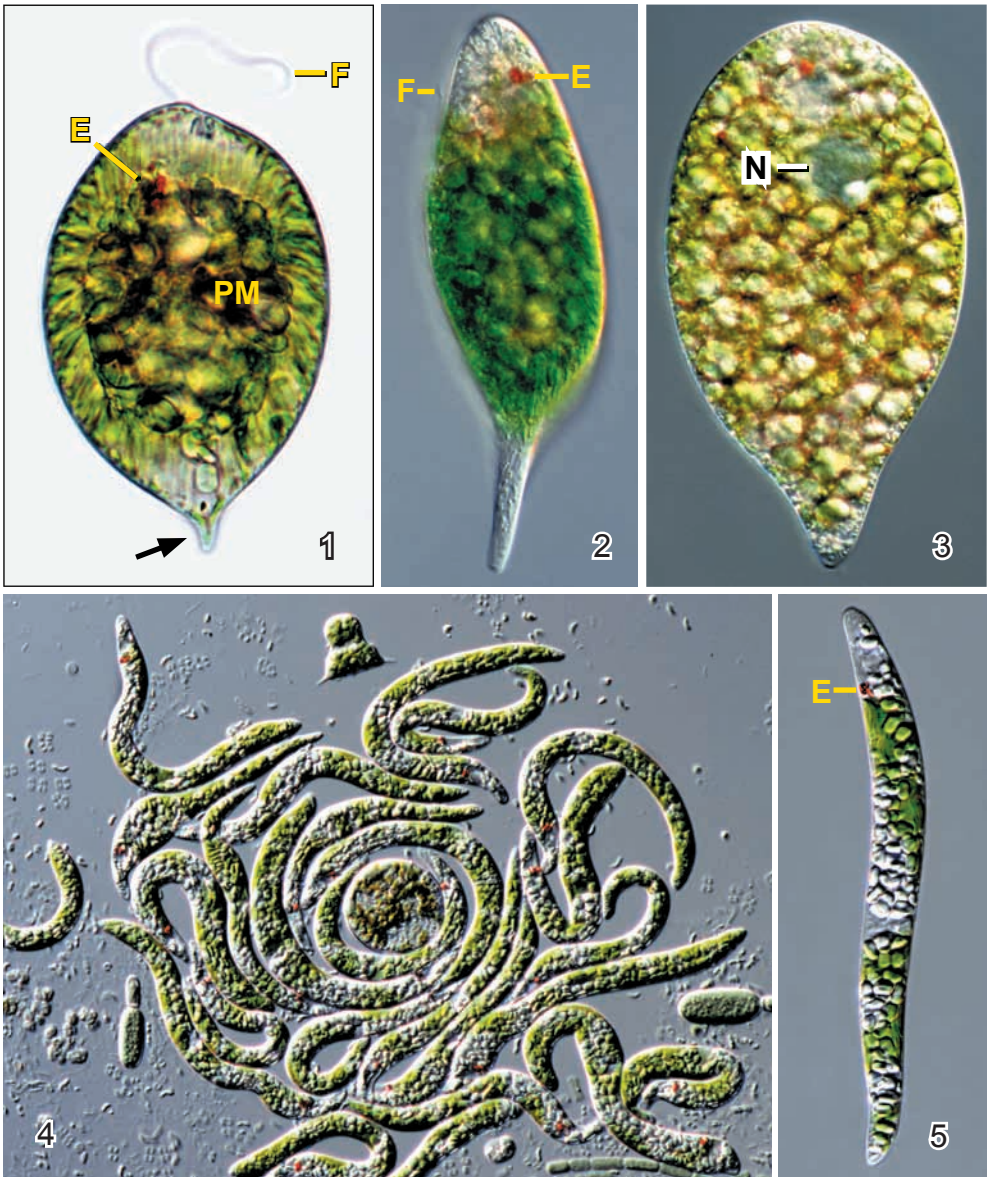


Fig. 1 – 5 : Euglenids. 1: *Euglena texta* is 45–55 µm long and has a broadly ellipsoidal shape with a short tail (arrow). The centre of the cell is studded with paramylon grains, while the discoidal chloroplasts are radially arranged. **2, 3:** The chloroplasts of *Euglena purpurea,* an about 170 µm long species, are aligned in spiral rows and do not extend into the bluntly pointed posterior end (2). This feature is lost in flattened cells (3, by coverslip pressure) which show the large amounts of haematochrome between the chloroplasts. **4, 5:** *Euglena mutabilis* is about 90 µm long and sometimes abundant in the mud. This species lacks flagella and thus moves metabolically. E – eyespot, F – flagellum, N – nucleus, PM – paramylon grains.

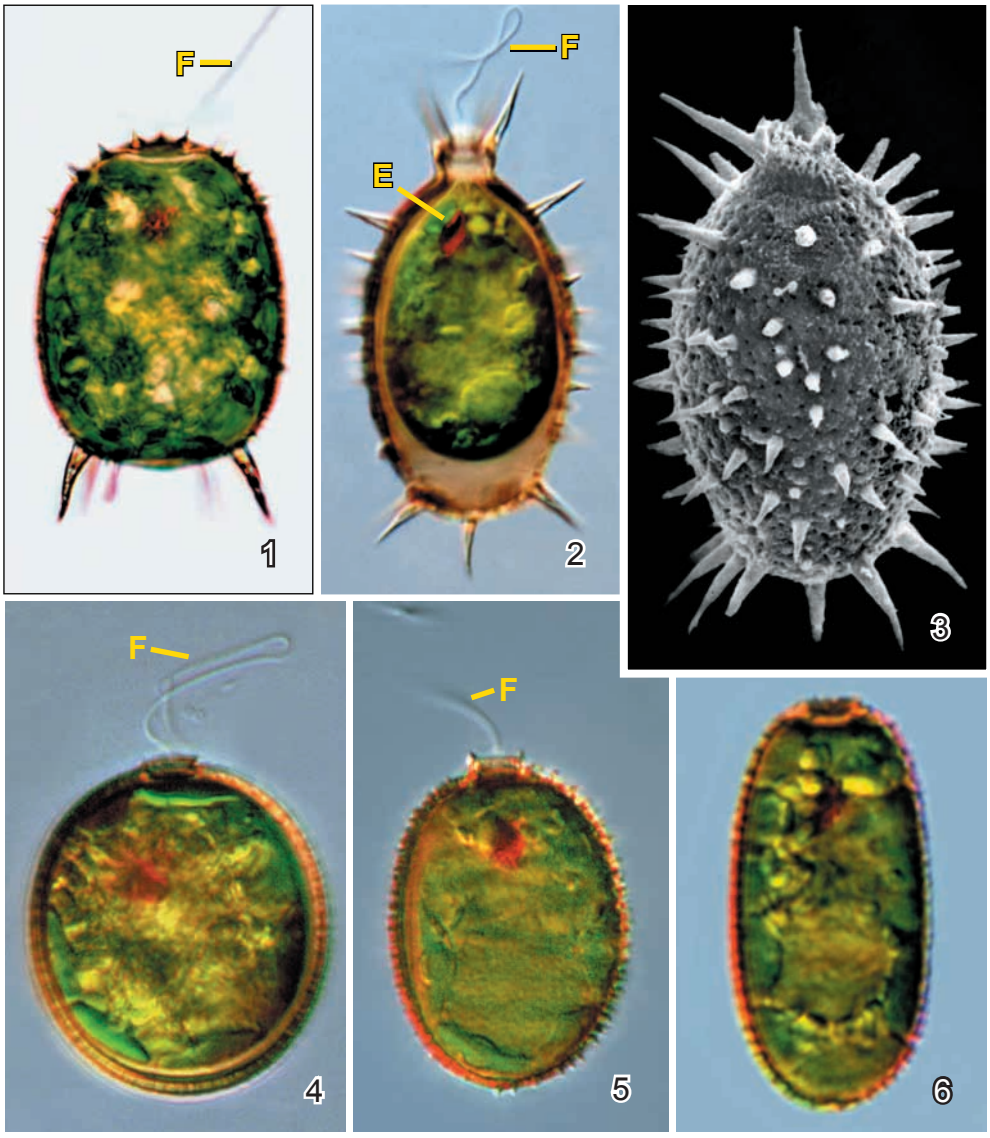


Fig. 1 – 6: Euglenids. *Trachelomonas* comprises euglenids enclosed in a lorica with an apical pore through which a long flagellum emerges. The lorica can be ornamented with warts or spines and is often brownish by ferric deposits. **1:** *Trachelomonas armata* is about 50 µm long and shows a ring of long spines at the posterior end and an area of short spines around the flagellar opening. **2, 3:** *Trachelomonas hystrix* in from life (2) and in the scanning electron microscope (3). The lorica of *T. hystrix* is about 30 µm long and armed with long spines on the collar and at the anterior as well as the posterior end. **4 – 6:** The taxa of the *Trachelomonas hispida* complex (25–35 µm) have a short collar and globular to ellipsoidal loricas, which are smooth or coverd with very short spines. CO – collar, E – eyespot, F – flagellum.

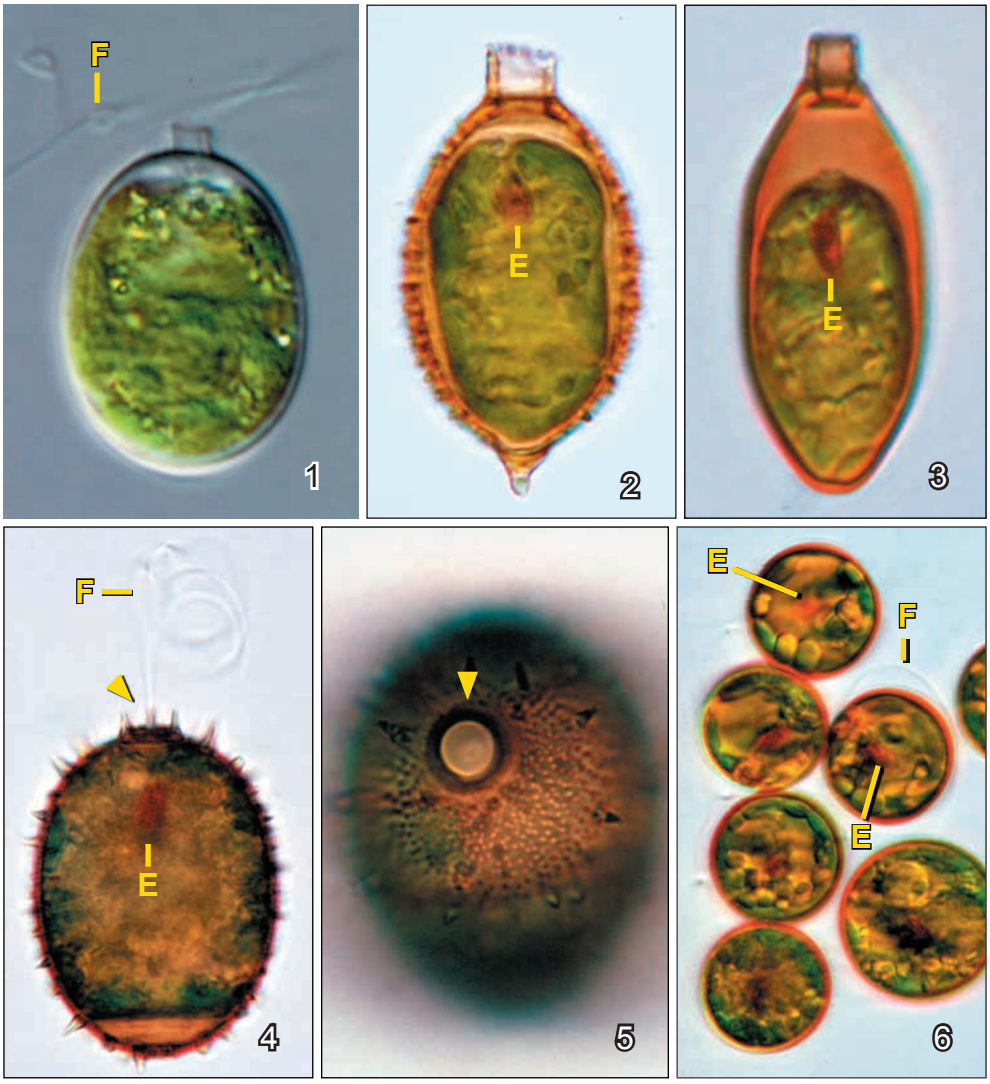


Fig. 1 – 6: Euglenids. 1: The about 20 µm long lorica of *Trachelomonas mucosa* var. *hyalina* is smooth and colourless. The typical slime coat is not visible in this specimen. **2:** *Trachelomonas caudata* is about 40 µm long and has a blunt spine on the posterior lorica end. **3:** The brownish lorica of *Trachelomonas hexangularis* is 35 µm long and is formed like an elongated hexagon. **4, 5:** *Trachelomonas superba*, which is common in Simmelried, is about 50 µm long and is thus a comparatively large member of the genus. The lorica is covered with numerous minute spines, which are elongated at the lorica's ends and on the collar (4, arrowhead). The apical view (5) shows the lorica opening (arrowhead) for the long flagellum. **6:** *Trachelomonas volvocina* is about 20 µm across and can be so abundant that it colours the water brownish. This species is known to collect high concentrations of iron from the ambient water. E – eyespot, F – flagellum.

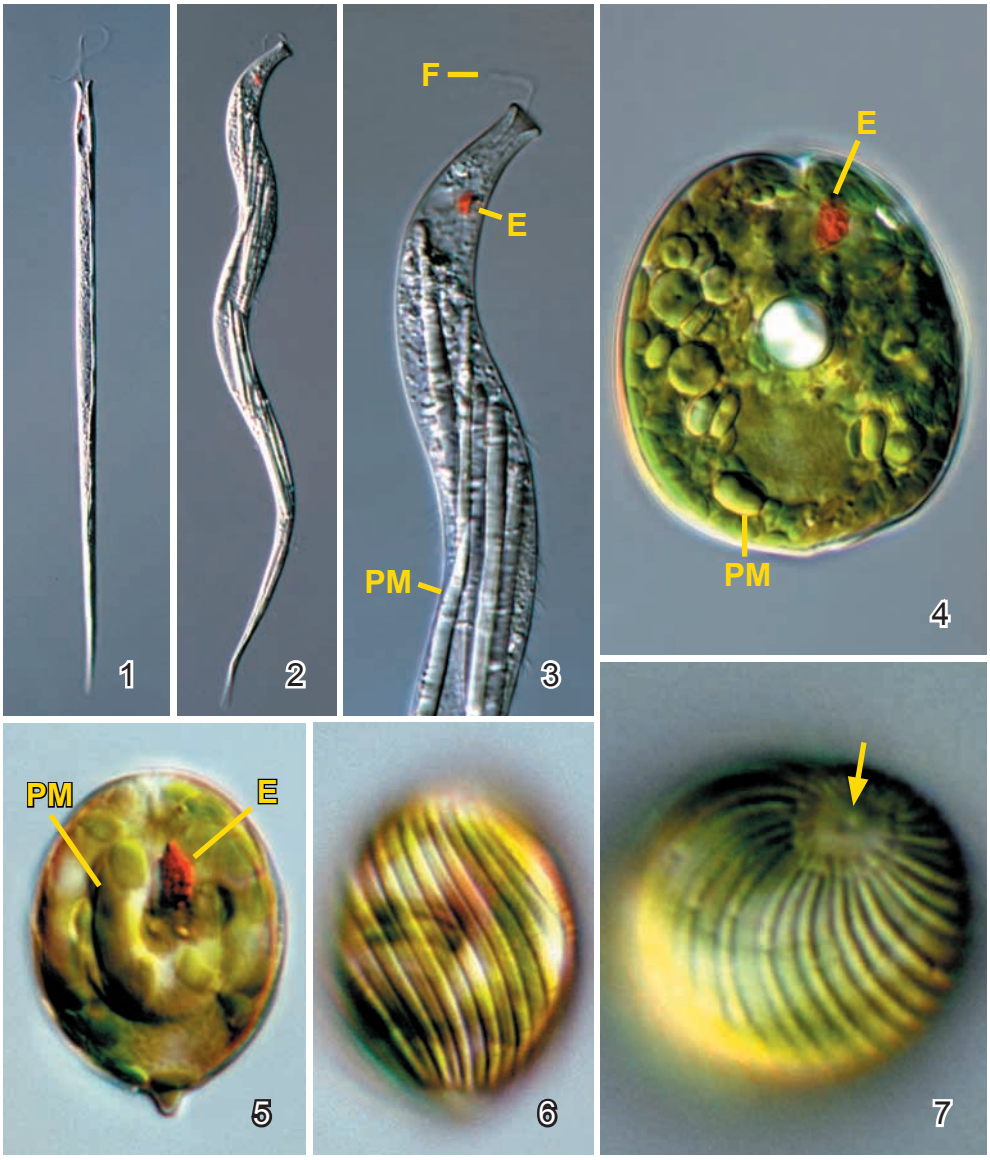


Fig. 1 – 7: Euglenids. 1 – 3: *Cyclidiopsis acus* is about 200 µm long and an osmotrophic member of the euglenids without chromatophores. The ametabolic cell occurs in elongated (1) or curved forms (2). The anterior end is slightly widened and shows an emergent flagellum (3). The paramylon "grains" are long rods or needles. **4:** *Lepocinclis texta* (40 µm) is ovoidal and lacks a tail. Large amounts of paramylon are deposited in discodial grains. **5 – 7:** *Lepocinclis ovum* (25 µm) has a blunt tail and large paramylon rings. The cell surface is helically striated (6), and the apical view shows the porus from which the flagellum emerges (7, arrow). E – eyespot, F – flagellum, PM – paramylon.

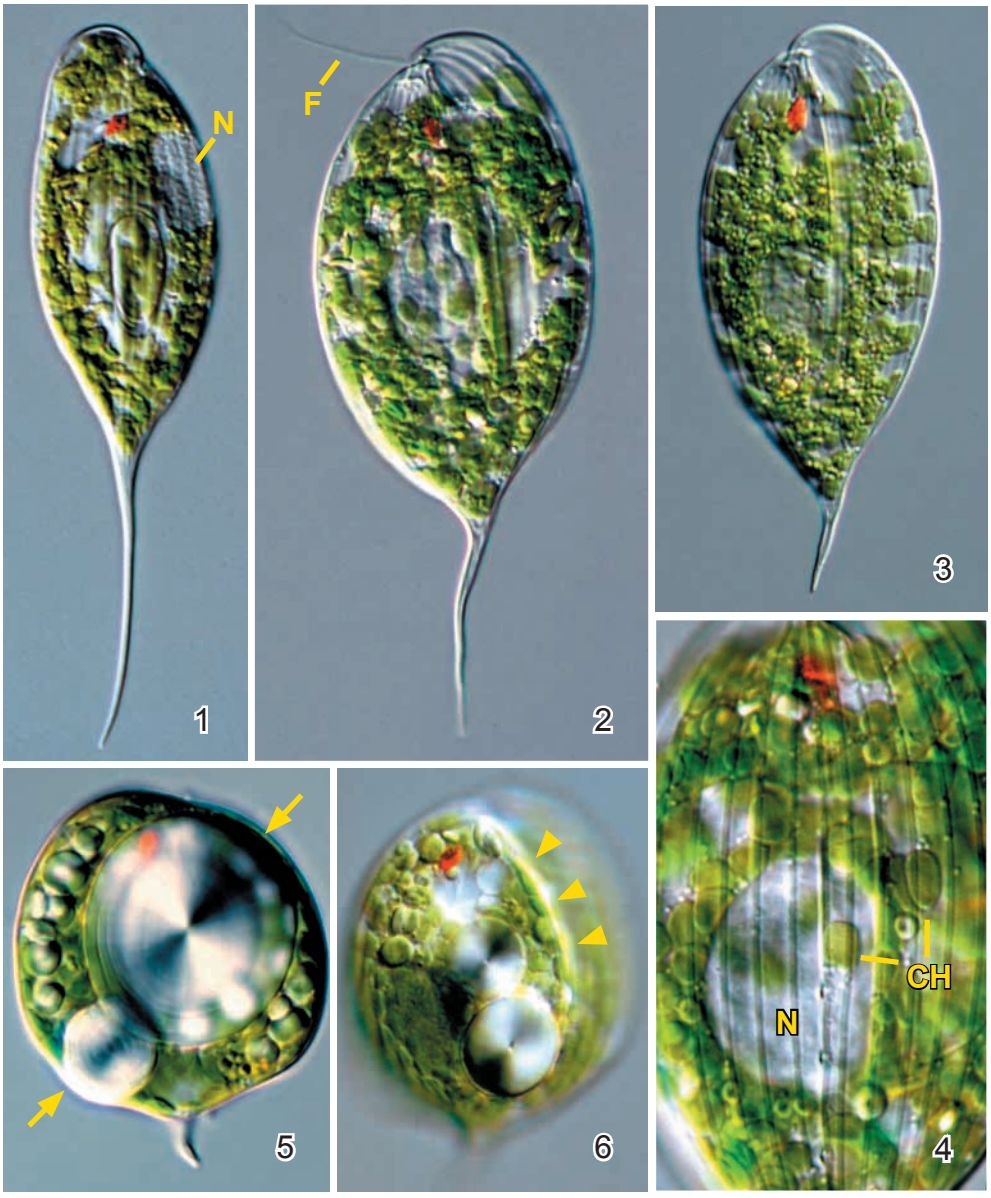


Fig. 1 – 6: Euglenids. The genus *Phacus* is distinguished from *Euglena* by the flattened and rigid body. **1:** The elliptical *Phacus lismorensis* is about 140 µm long and lives in mud. It has a long, almost straight tail. **2 – 4:** This are likely variations of *P. lismorensis* with either a curved (2) or a short tail (3). The specimens are 118 µm (2) and 102 µm (3) long and have a longitudinally striated pellicle (4). **5, 6:** *Phacus orbicularis* is about 40 µm long and occurs among floating algae and plants. It has a large, discoidal paramylon grain accompanied by a smaller one (5, arrows). The dorsal side shows a prominent ridge (6, arrowheads). CH – chloroplasts, F – flagellum, N – nucleus.

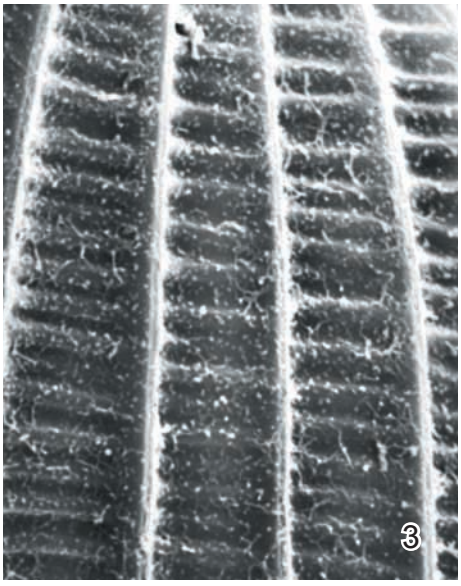
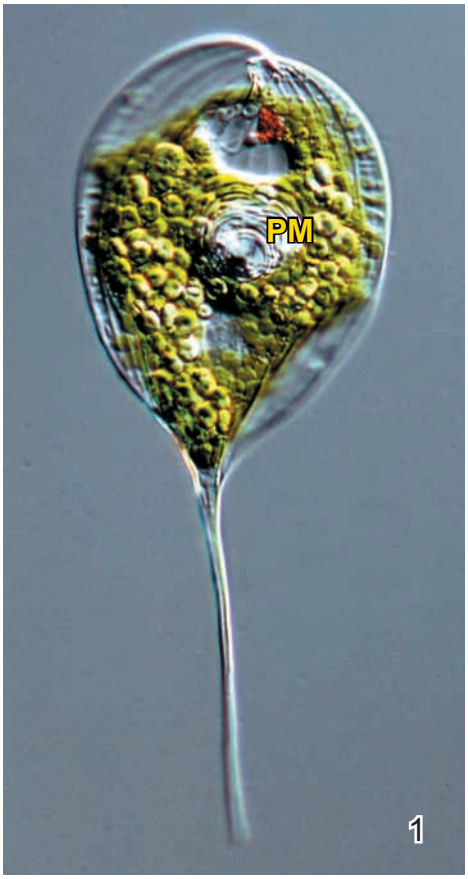
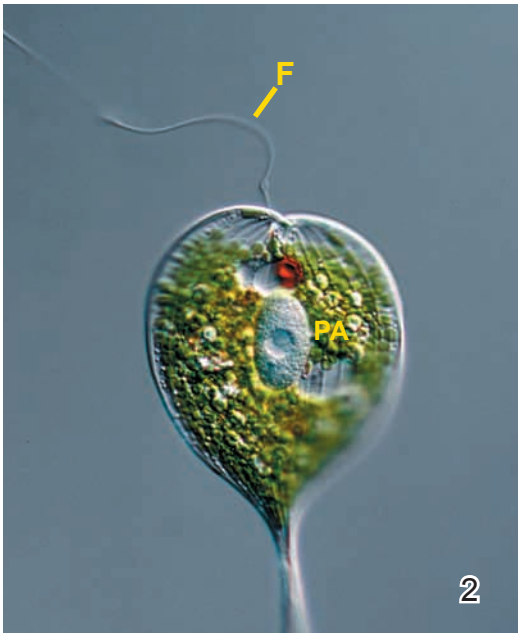


Fig. 1 – 3: Euglenids. *Phacus torta* from life (1) and in the scanning electron microscope (2, 3). The species is 80 –100 µm long and has a strongly twisted body with a long tail. The centre of the cell contains a small, but prominent paramylon grain (1, arrowhead). The longitudinal crests of the pellicle follow the twisted shape. The scanning electron microscope reveals a fine transverse striation between the longitudinal crests (2, 3). F – flagellum, N – nucleus.





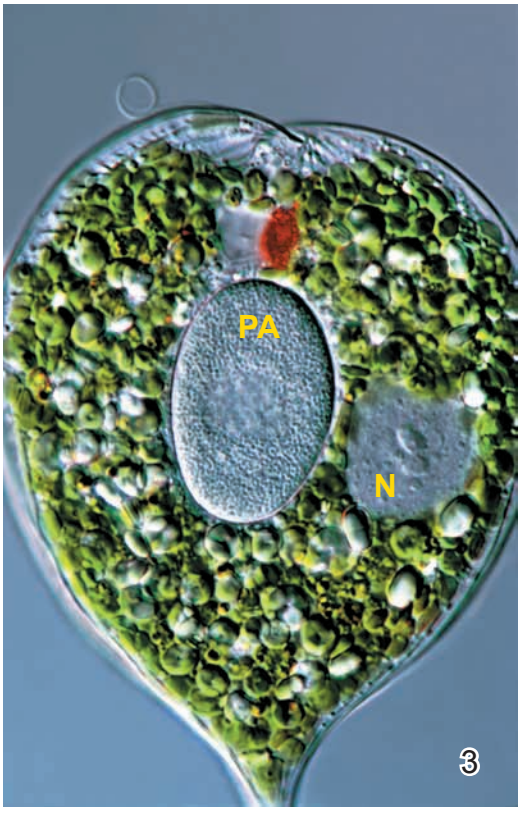


Fig. 1 – 3: Euglenids. 1 – 3: The long, prominent tail makes *Phacus longicauda* (170 µm) to one of the most characteristic members of the genus. The cell is studded with small paramylon grains surrounding a centrally located "dominant" grain. In some populations (especially in winter and spring), the centre is occupied by a large parasite (2, 3). Obviously, the parasite has no adverse effect on motility, because the flagellum is still beating (2). In squashed cells, the nucleus appears enlarged (3). Possibly, the parasite is identical with that one observed in *Euglena acus* and *Euglena oxyuris*. F – flagellum, N – nucleus, PA – parasite, PM – central paramylon grain.

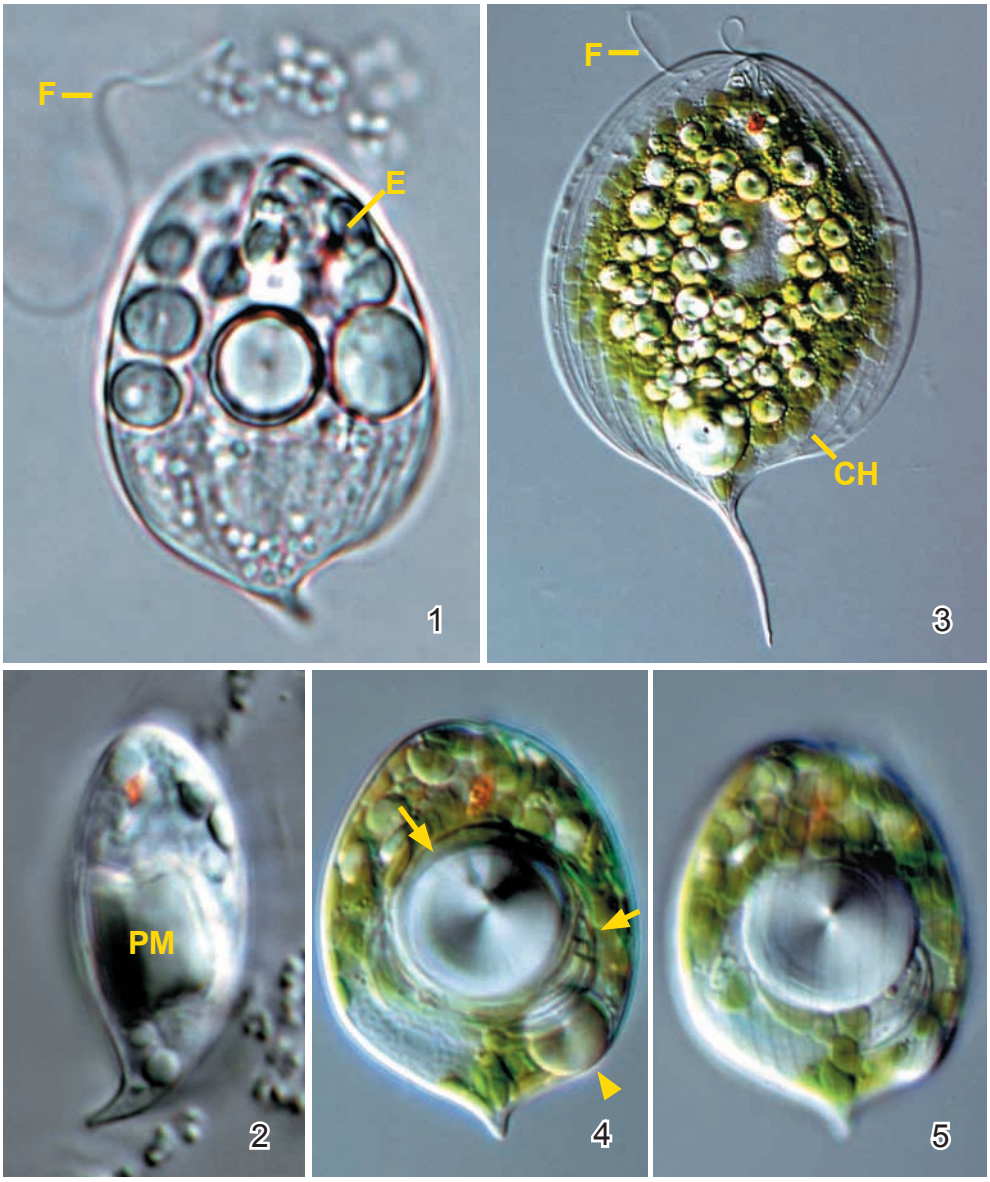


Fig. 1 – 5: Euglenids. 1, 2: Pringsheim created the genus *Hyalophacus* for species with the characteristics of *Phacus*, but without chromatophores. The sole member of the genus is the about 25 µm long *H. ocellatus*. In lateral view, it shows a ventrally curved tail and a large paramylon grain. **3:** *Phacus gigas* has a leaf-shaped body and is about 140 µm long. The chloroplasts are accumulated around the centre of the cell. **4, 5:** *Phacus brachykentron* is about 30 µm long and can be recognized by the very short tail and two overlaid, central paramylon grains (arrows). A third grain is in eccentric position (arrowhead). The pellicle is longitudinally striated (5). CH – chloroplasts, E – eyespot, F – flagellum, PM – paramylon grain.

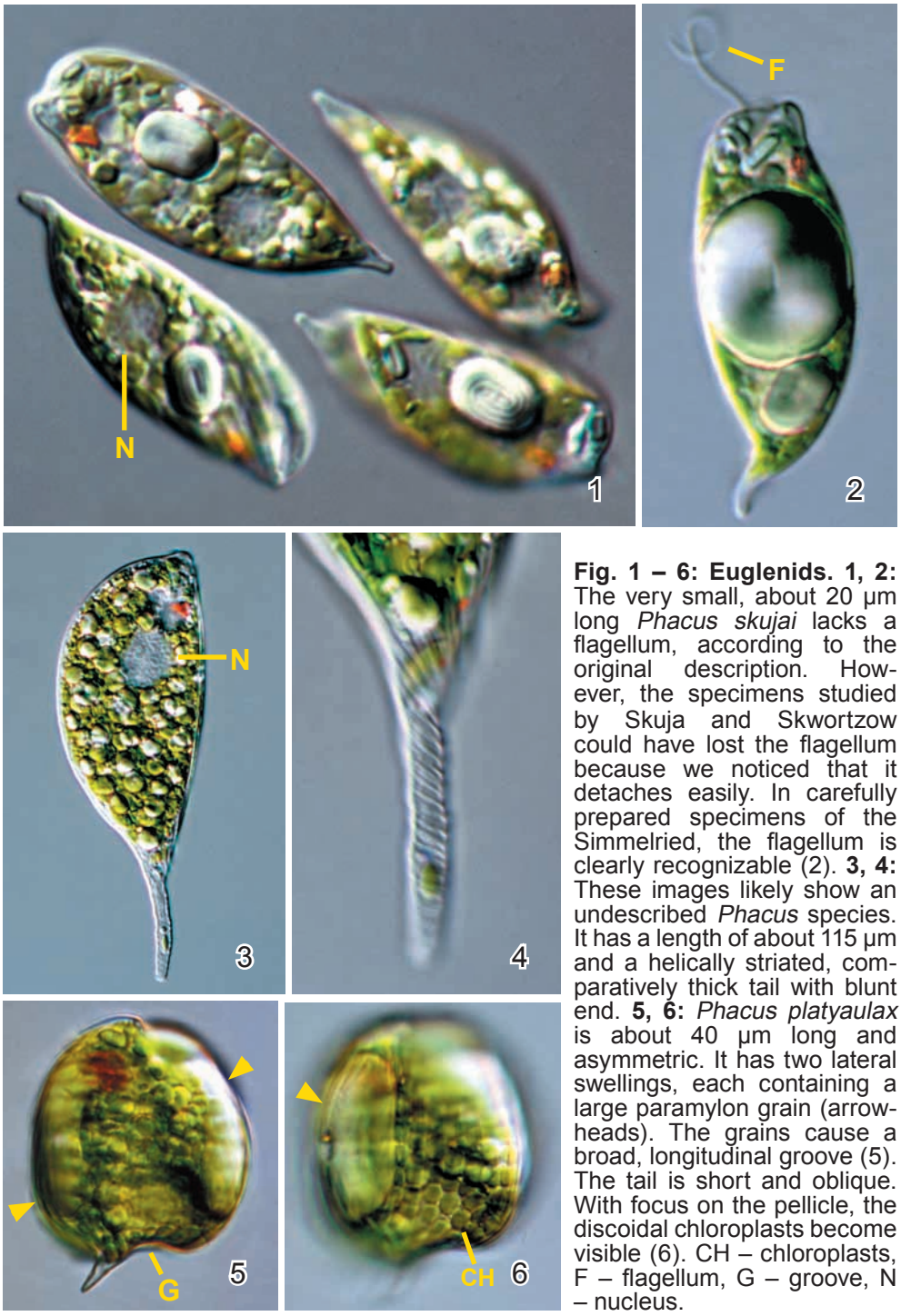


Fig. 1 – 6: Euglenids. 1, 2: The very small, about 20 µm long *Phacus skujai* lacks a flagellum, according to the original description. However, the specimens studied by Skuja and Skwortzow could have lost the flagellum because we noticed that it detaches easily. In carefully prepared specimens of the Simmelried, the flagellum is clearly recognizable (2). **3, 4:** These images likely show an undescribed *Phacus* species. It has a length of about 115 µm and a helically striated, comparatively thick tail with blunt end. **5, 6:** *Phacus platyaulax* is about 40 µm long and asymmetric. It has two lateral swellings, each containing a large paramylon grain (arrowheads). The grains cause a broad, longitudinal groove (5). The tail is short and oblique. With focus on the pellicle, the discoidal chloroplasts become visible (6). CH – chloroplasts, F – flagellum, G – groove, N – nucleus.

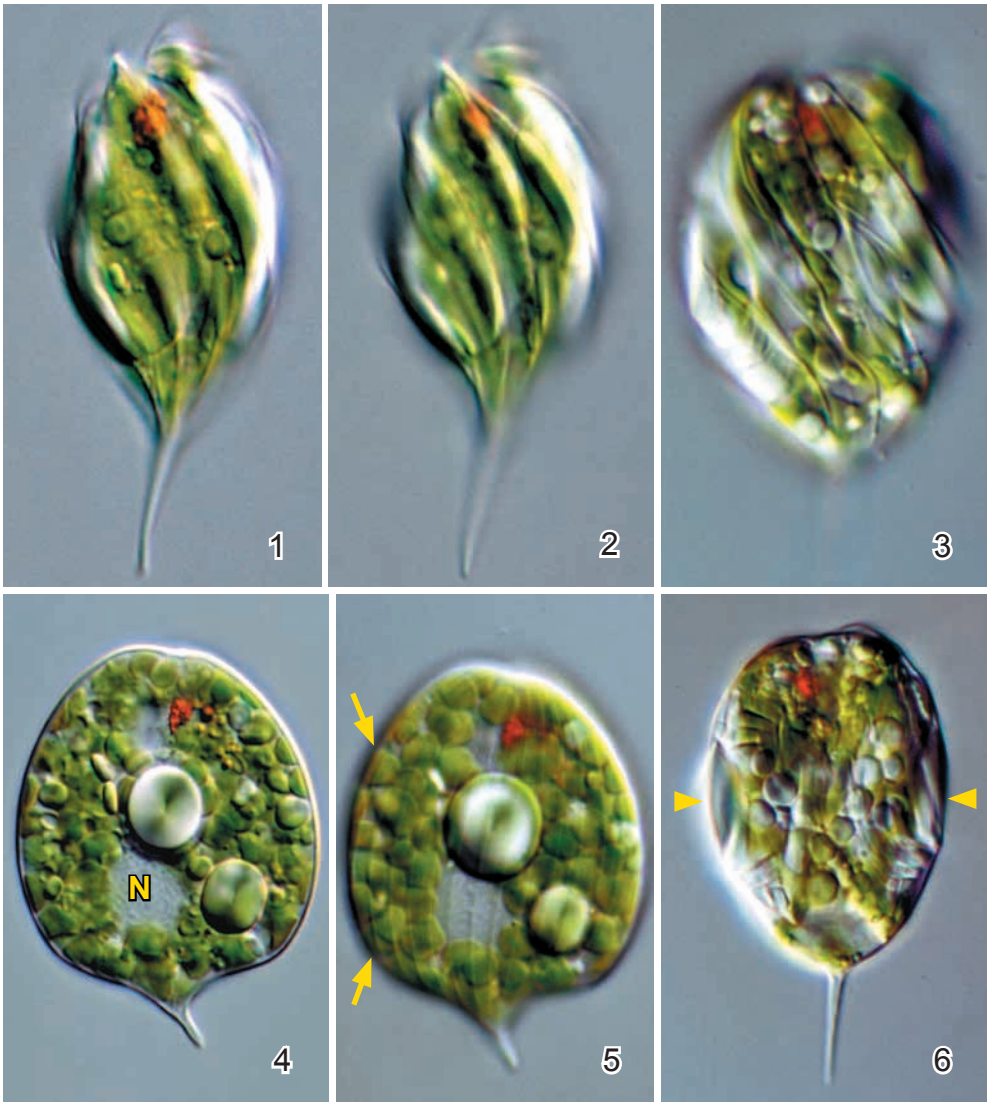


Fig. 1 – 6: Euglenids. 1, 2: *Phacus pyrum* is about 40 µm long and the pyriform body has helical ridges (1). Note the long, acute tail, which gradually forms from trunk end. **3, 6:** *Phacus pseudonordstedtii* is also about 40 µm long and thus similar to *P. pyrum*, but the body is obovate (3) and the straight tail emerges abruptly from the trunk (6). Typically, the paramylon is deposited in two large grains, often rings (arrowheads). **4, 5:** The flat *Phacus acuminatus* is about 40 µm long and broadly rounded posteriorly, where a short, slightly curved tail emerges. In contrast to the two species ahead, the pellicle is longitudinally striated (5). Usually, a large, discoidal paramylon grain occurs in the centre of the cell; often, it is accompanied by a second, smaller grain in more lateral position (4). The chloroplasts of *P. acuminatus* are discoidal and 2–3 µm across (5, arrows). N – nucleus.

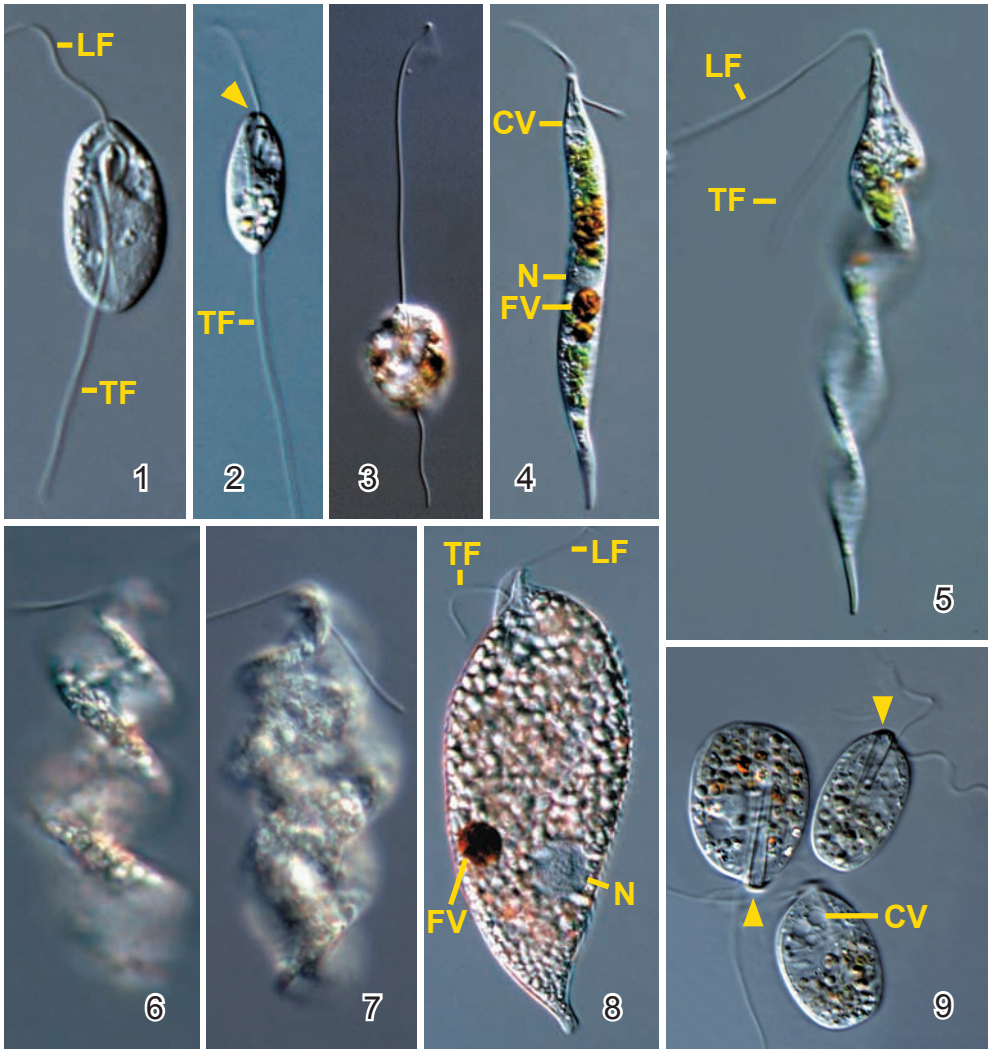


Fig. 1 – 9: Euglenids. *Anisonema*, *Heteronema* and *Entosiphon* are colourless euglenids with two apically emerging flagella. **1, 2:** *Anisonema* has a leading flagellum and a longer, posteriorly directed trailing flagellum. The trailing flagellum of the 11 µm long *A. ovale* is one and a half of body length (1). The trailing flagellum of *Anisonema obliquum* (2), which is about 22 µm long and has an apical depression (2, arrowhead), is five times longer than the body. **3:** Likely, this 34 µm long flagellate is *Heteronema globuliferum* with the leading flagellum longer than the trailing flagellum. **4 – 7:** *Heteronema acus* (4) has a fusiform body, while the 100–130 µm long *H. trispira* is distinctly spiralized (5–7). **8:** *Heteronema mutabilis*, which is 170–250 µm long and highly metabolic, is one of the largest flagellates in Simmelried. Note the trumpet-shaped oral opening from which the flagella emerge. **9:** *Entosiphon sulcatum* is a very common, 20–32 µm long flagellate with a conspicuous, tubular ingestion apparatus (arrowheads). CV – contractile vacuole, FV – food vacuole, LF – leading flagellum, N – nucleus, TF – trailing flagellum.

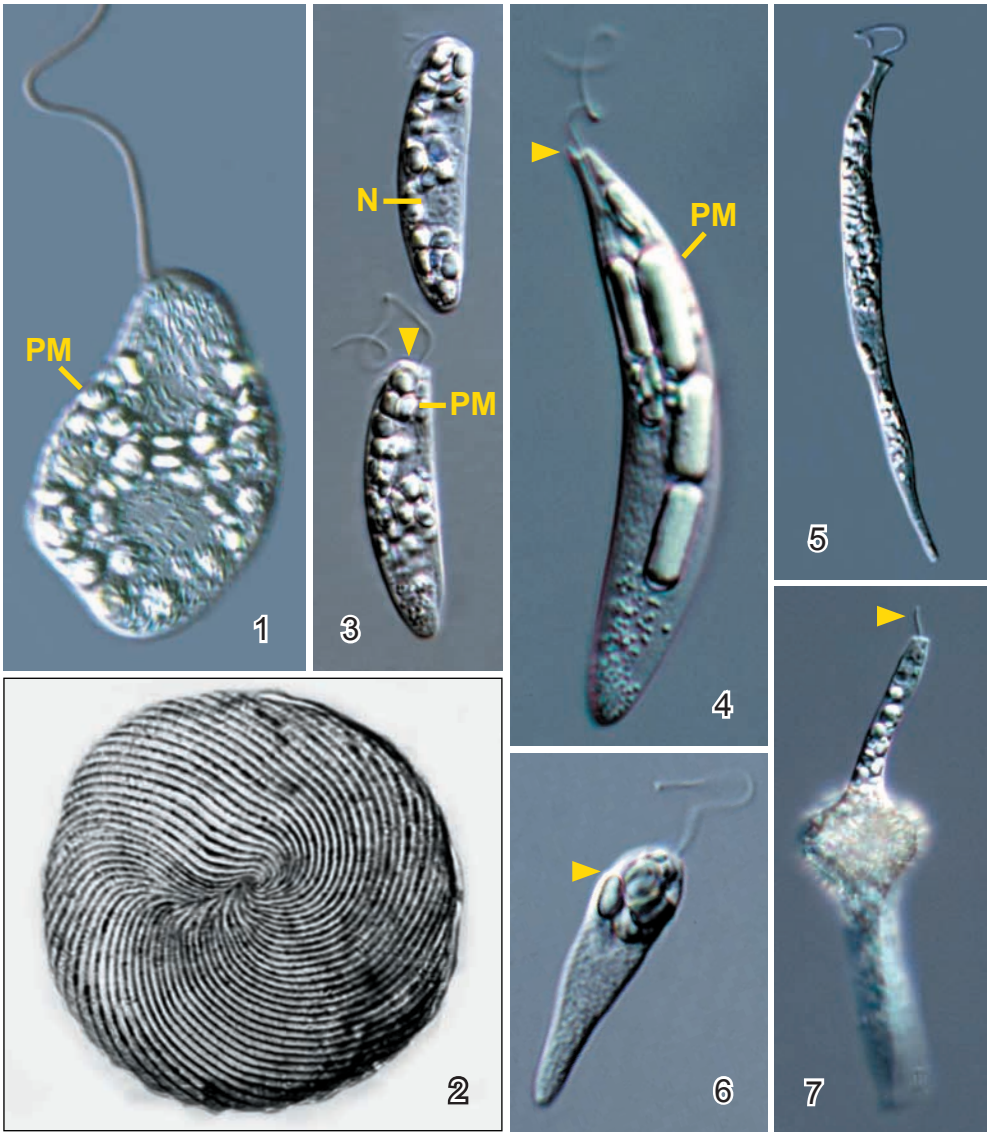


Fig. 1 – 7: Euglenids. These are colourless euglenids with one flagellum. **1, 2:** *Peranema trichophorum* is highly metabolic and has a long, thick flagellum (1). The fine striae of the pellicle become distinct after silver nitrate impregnation. **3:** *Rhabdomonas costata* is 20–30 µm long and is similar to *M. pellucidum*, except of the oblique anterior end (arrowhead). **4:** *Menoidinium pellucidum,* which is 35–40 µm long and rigid, is crescentic and has a typical lip (arrowhead) at the anterior end. **5:** *Astasia harrisii* is 45–65 µm long and has a slightly curved, flexible body with a trumpet-shaped anterior end. **6:** *Astasia kathemerios* lives in the anaerobic mud. The posterior end is bluntly pointed, while the widened anterior portion contains a paramylon grain (arrowhead). **7:** *Astasia breviciliata* can be recognized by the short flagellum (arrowhead) and highly metabolic body, N – nucleus, PM – paramylon grains.

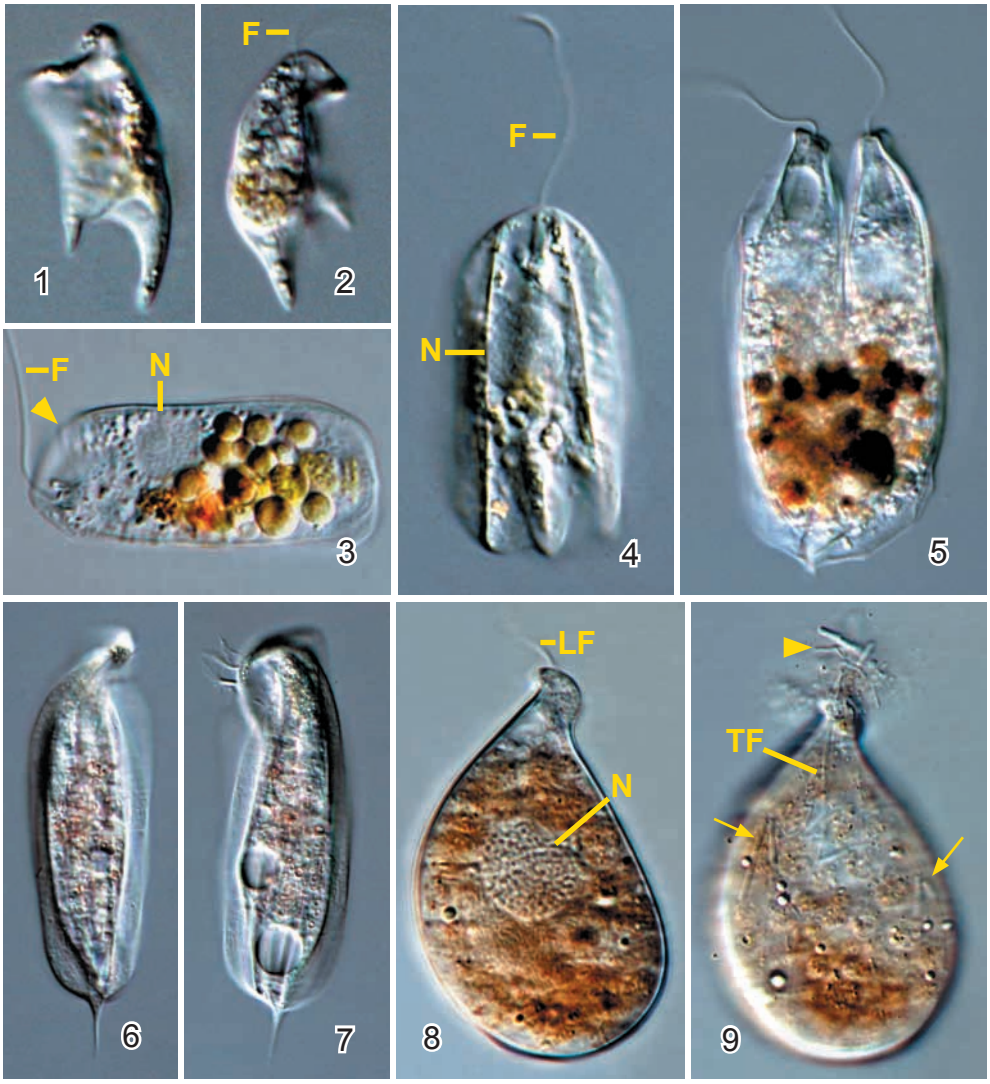


Fig. 1 – 9: Euglenids. The genera *Petalomonas* and *Notosolenus* have a rigid cortex. *Petalomonas* has only the leading flagellum (LF), while *Notosolenus* has also a trailing flagellum (9, TF), which is close to the body. **1, 2:** An undescribed, 40 µm long *Petalomonas* species, which is similar to *P. spinifera,* but has five finger-like, ventrally directed processes shown in ventral (1) und lateral view (2). **3:** *Petalomonas abscissa* var. *pellucida*, which is 15–30 µm long, has an oblique anterior end (arrowhead) and parallel sides. **4:** *Petalomonas mira* var. *truncata* is 25–35 µm long and has three distinct keels extending to the posterior end. **5 – 7:** *Petalomonas praegnans* (65–100 µm) in division (5; lateral view) and in two focal planes (6, 7; ventral and dorsal views). **8, 9:** *Notosolenus lagenos* which is 40–50 µm long, is rounded posteriorly and dorsally, while the ventral side is almost flat. When the focus is on the cortex (9), the trailing flagellum and collected (arrowhead) as well as ingested (arrow) bacteria become visible. F – flagellum, LF – leading flagellum, N – nucleus, TF – trailing flagellum.

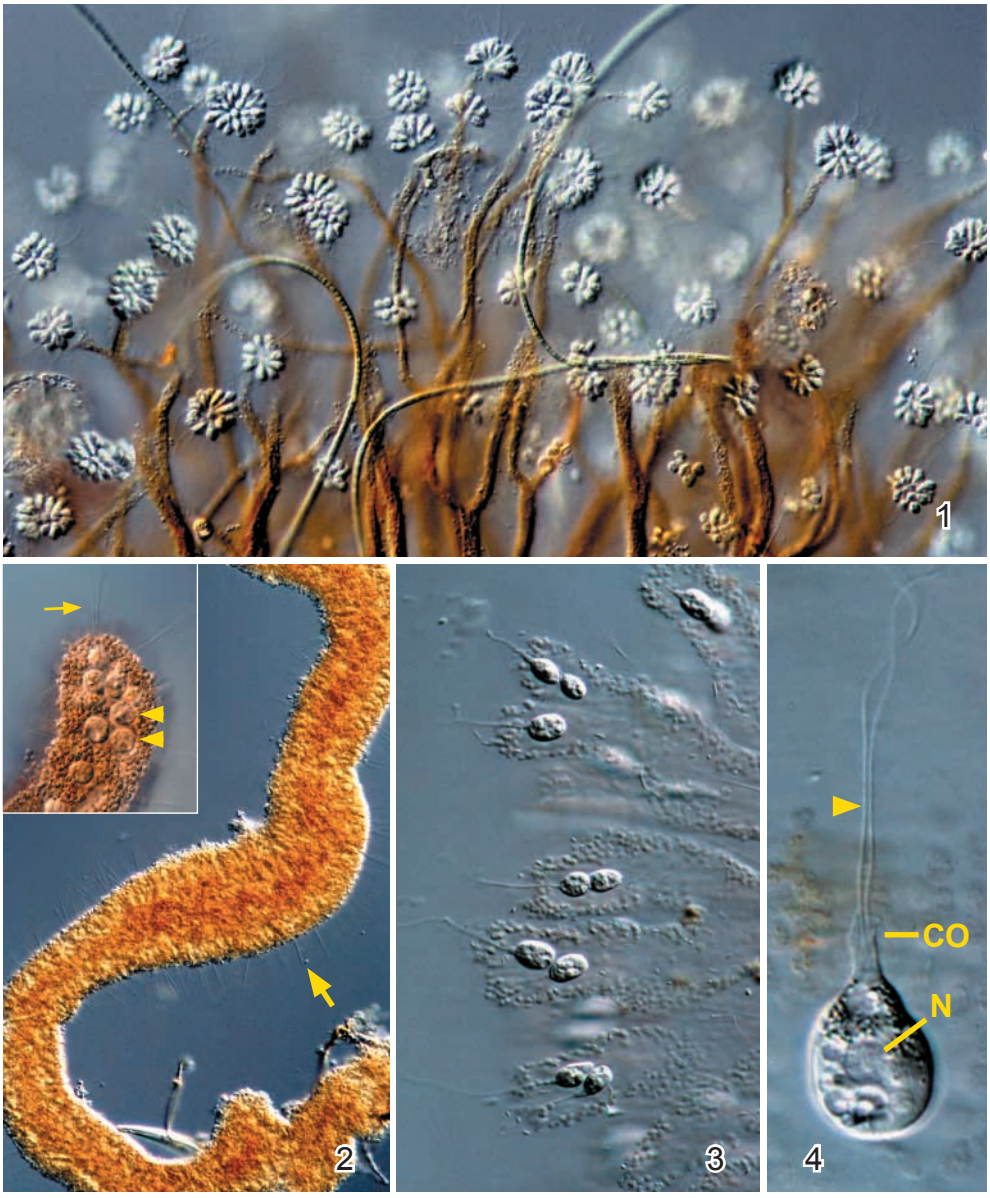
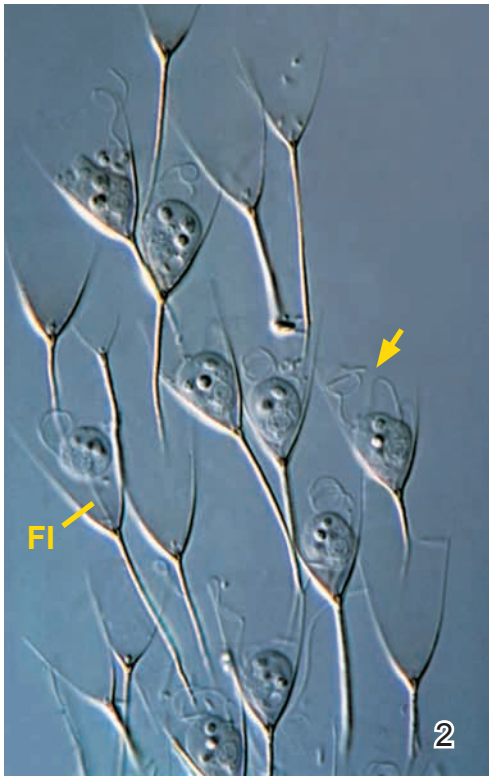


Fig. 1 – 4: Flagellates. 1: *Anthophysa vegetans* forms clusters of 10 – 60 cells on the end of a flexible, brownish stalk. The globular cells are 8–10 µm across and have two flagella of different length. **2:** The vermiform colonies of *Spongomonas intestinum* are up to 3 mm long. The individual flagellates are 10–13 µm in diameter (inset, arrowheads) and are embedded in a gelatinous matrix, which is interspersed with orange or brownish granules. The arrows marks the flagella of a monad. **3, 4:** The hemispherical colonies of *Phalansterium digitatum* form finger-like structures. The solitary cells, which are 13–24 µm long and have a highly characteristic collar (4, CO), have one, rarely two flagella (4, arrowhead). CO – collar, N – nucleus.



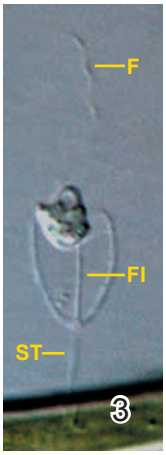


Fig. 1 – 4: Flagellates. 1: *Rhipidodendron huxleyi* is 5–10 µm long and builds fan-like colonies composed of branched bundles of brownish tubes. At the tip of each tube, there is a monad with two flagella of different length (inset). **2 – 4:** Members of the genus *Bicoeca* (syn. *Bicosoeca*) lack a collar around the flagellum and are attached to the lorica with a contractile filament. The treelike colony of *B. petiolata* (2) is composed of 10–20 µm long monads in a champagne glass-shaped lorica. The stalk and bottom of the brownish lorica are thickened. The flagellum is often spiralized (2, arrow). The stalked lorica of *B. exilis* (3) is 20 µm long, while the 10 µm long lorica of *B. lacustris* (4) is pointed posteriorly. F – flagellum, Fl – filament, ST – stalk.

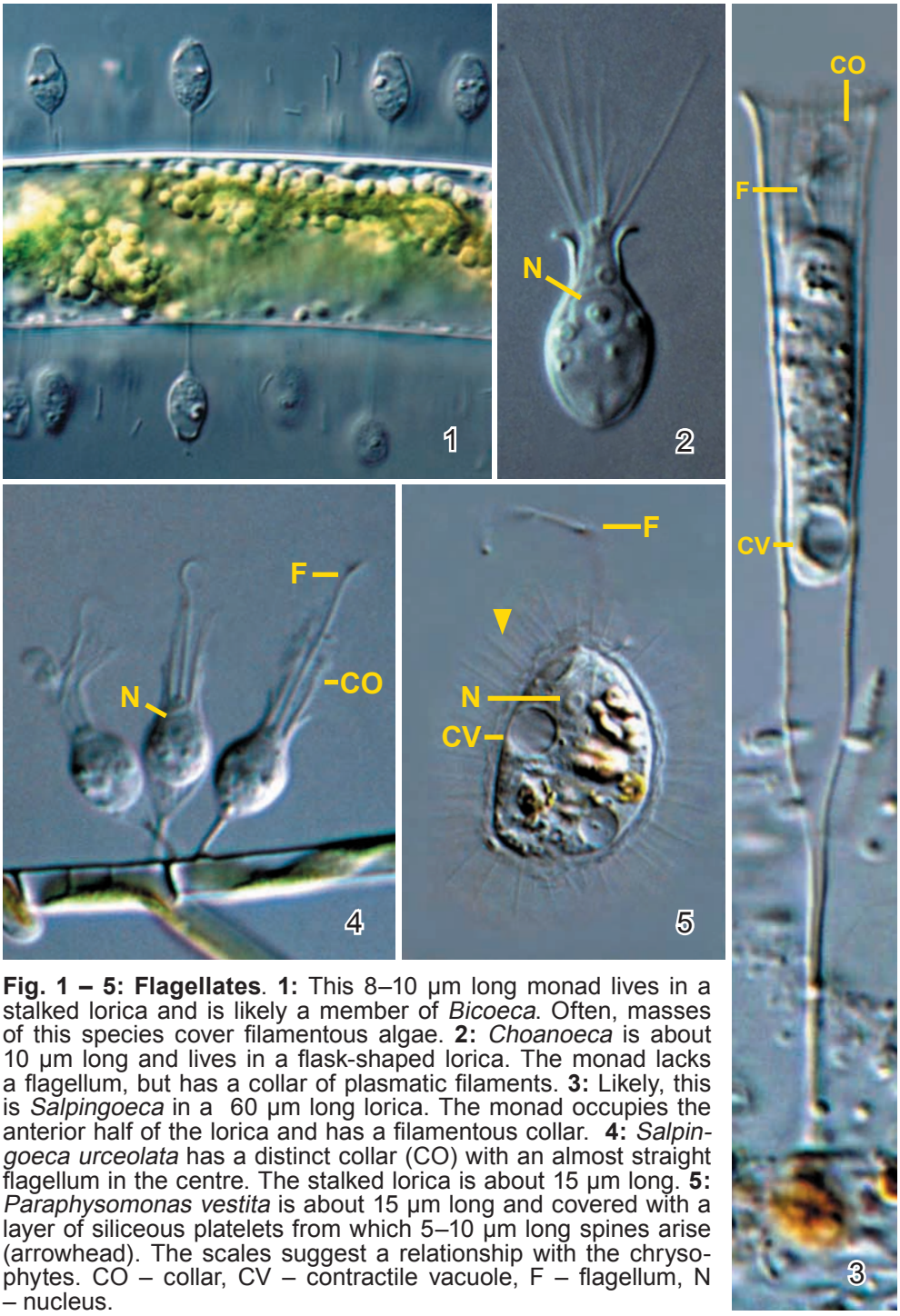


Fig. 1 – 5: Flagellates. **1:** This 8–10 µm long monad lives in a stalked lorica and is likely a member of *Bicoeca*. Often, masses of this species cover filamentous algae. **2:** *Choanoeca* is about 10 µm long and lives in a flask-shaped lorica. The monad lacks a flagellum, but has a collar of plasmatic filaments. **3:** Likely, this is *Salpingoeca* in a 60 µm long lorica. The monad occupies the anterior half of the lorica and has a filamentous collar. **4:** *Salpingoeca urceolata* has a distinct collar (CO) with an almost straight flagellum in the centre. The stalked lorica is about 15 µm long. **5:** *Paraphysomonas vestita* is about 15 µm long and covered with a layer of siliceous platelets from which 5–10 µm long spines arise (arrowhead). The scales suggest a relationship with the chrysophytes. CO – collar, CV – contractile vacuole, F – flagellum, N – nucleus.

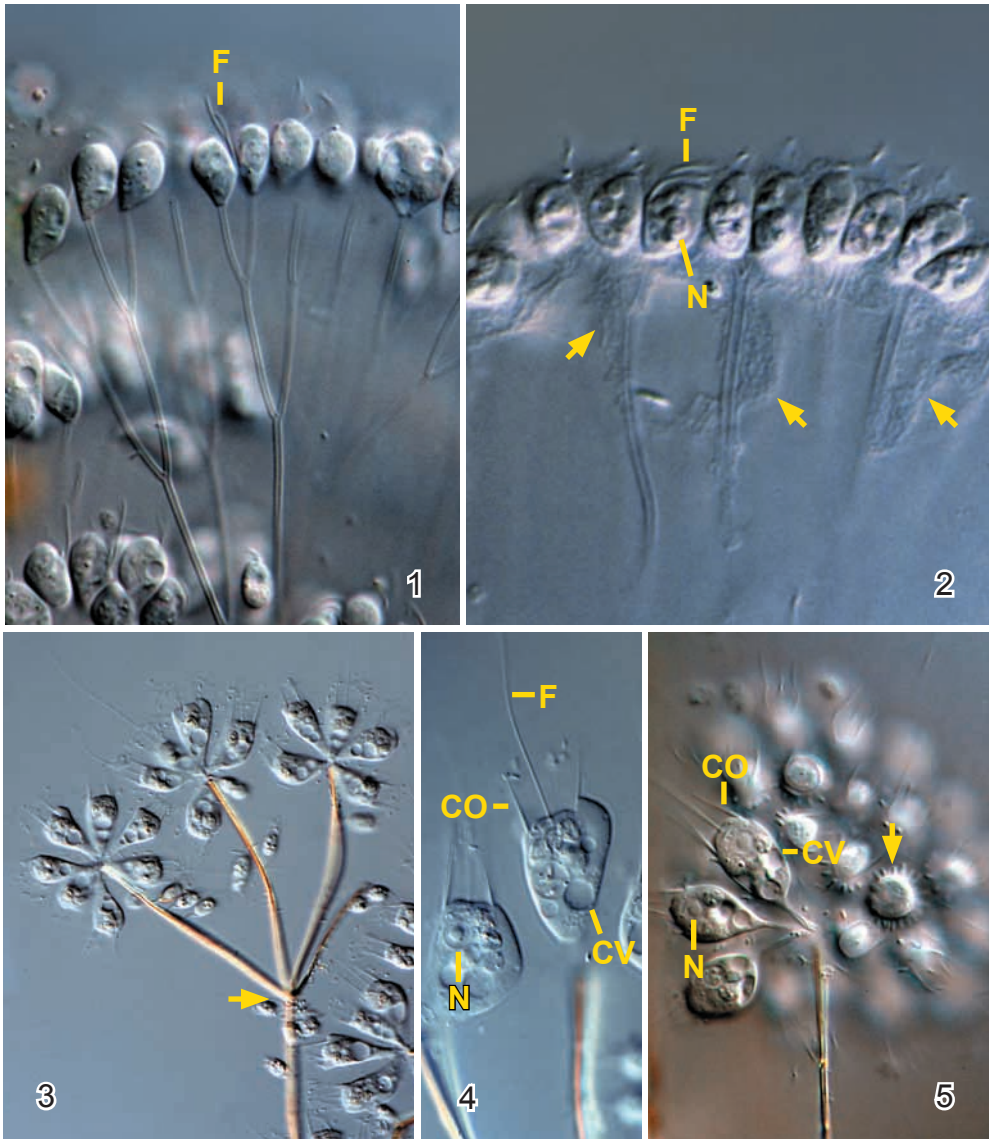


Fig. 1 – 5: Flagellates. Some flagellates are attached to the substrate by stalks. Often, they are colourless and feed on bacteria. **1:** The branched stalks of *Dendromonas virgaria* are thin and hyaline. **2:** *Pseudodendromonas* is 6–10 µm long and has dichotomously branched stalks like *Dendromonas,* but the monads are covered with a delicate mucous sheath (arrows). **3, 4:** The monads of *Codonocladium umbellatum* are 10–15 µm long and sit on a brownish, dendroid stalk (3, arrow). The single flagellum (4, F) is surrounded by a collar (4, CO). **5:** *Codonosiga botrytis* is 15–20 µm long and similar to *C. umbellatum*, but the specimens are attached to an unbranched stalk. The collar consists of minute rods recognizable in cells viewed frontally (arrow). CO – collar, CV – contractile vacuole, F – flagella, N – nucleus.

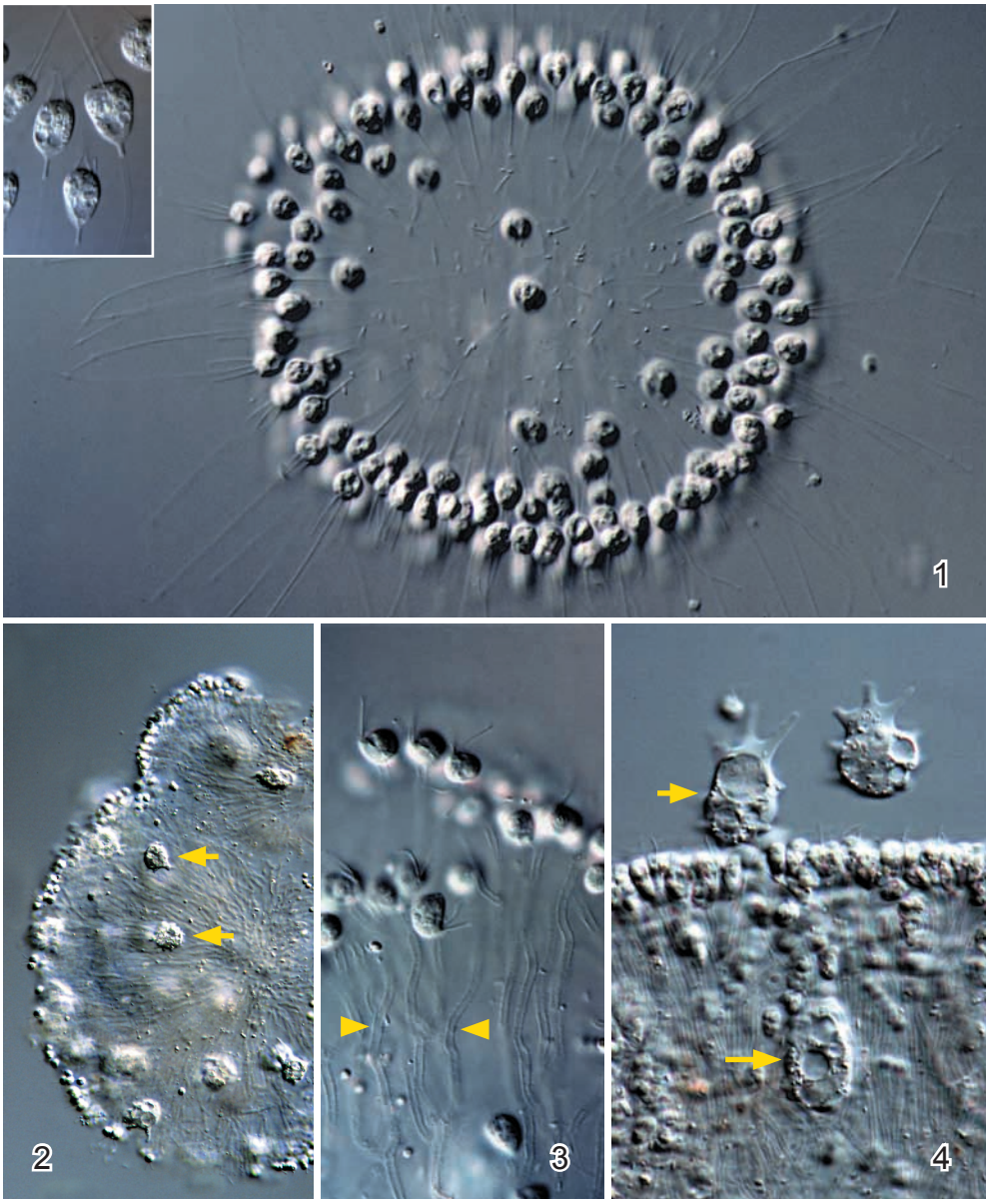


Fig. 1 – 4: Flagellates. Some colourless flagellates from Simmelried. **1:** The mucous colonies of *Sphaeroeca socialis* have 150–300 µm in diameter, and the 10–15 µm long, peripherally arranged monads thrive the colony through the water. The monads are embedded in mucus and have the posterior body end modified to a delicate stalk (inset). **2 – 4:** *Monas lindahlii* forms irregular, 200–400 µm-sized colonies filled with bundles of curved stalks secreted by 6–8 µm long monads (3, arrowheads). Many colonies were attacked by amoebae of the genus *Mayorella* (2, 4, arrows). They leave the colony when squashed (4).

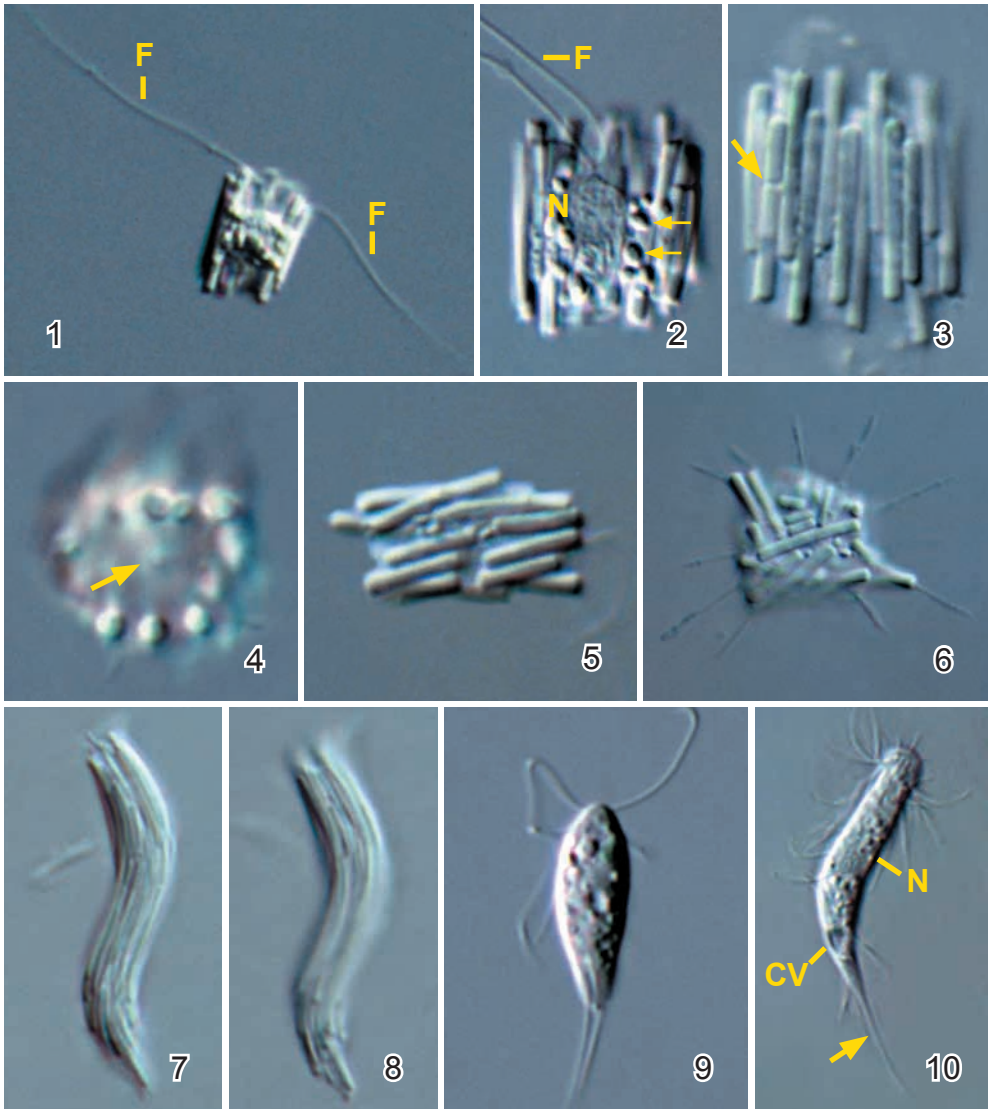


Fig. 1 – 10: Flagellates. Freely motile flagellates, some of which are undescribed, from the Simmelried. **1 – 6:** This undescribed, curious flagellate, which is 12–16 µm long and has two 32–38 µm long flagella, is covered with a palisade-like layer of 9–12 µm long bacteria (1). **2:** The flagella emerge from a cone on the nucleus (N). Arrows mark some refractive grains. **3:** Division of a palisade bacterium (arrow). **4:** Apical view on a palisade composed of 12–25 bacteria. The arrow marks the centrally located cone described in figure (2). **5, 6:** Likely a commencing division (5) and an amoeboid stage in the life cycle (6). **7, 8:** This sigmoid flagellate is 26 µm long and likely belongs to the genus *Pelosigma.* The cell contains a bundle of rods, possibly bacteria. **9:** This flagellate is likely a member of *Hexamitus*. **10:** *Stereonema geiseri*, which is 20–30 µm long, has a distinct tail (arrow) and about 24 cilia-like flagella arranged in two rows. CV – contractile vacuole, F – flagella, N – nucleus.

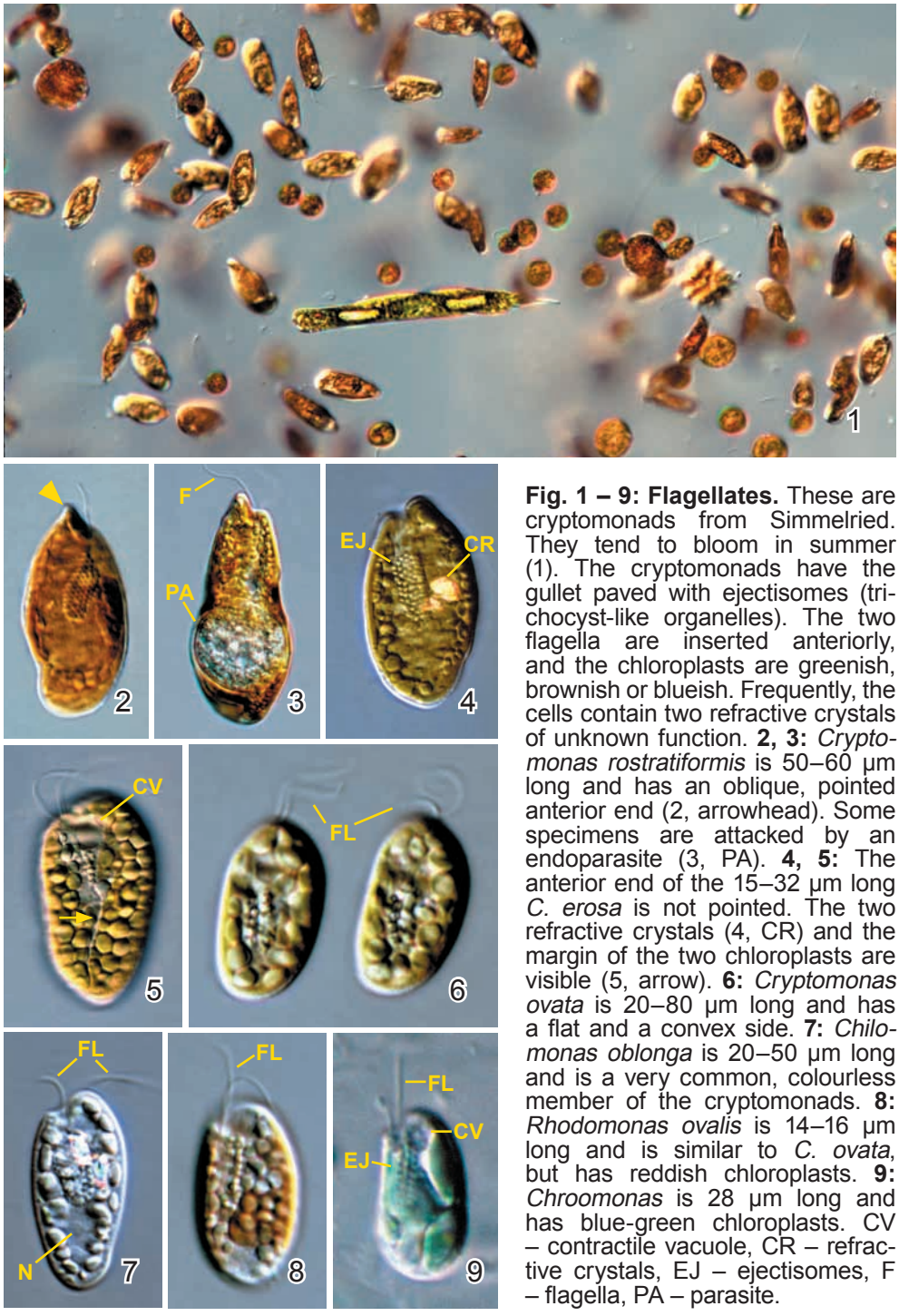


Fig. 1 – 9: Flagellates. These are cryptomonads from Simmelried. They tend to bloom in summer (1). The cryptomonads have the gullet paved with ejectisomes (trichocyst-like organelles). The two flagella are inserted anteriorly, and the chloroplasts are greenish, brownish or blueish. Frequently, the cells contain two refractive crystals of unknown function. **2, 3:** *Cryptomonas rostratiformis* is 50–60 µm long and has an oblique, pointed anterior end (2, arrowhead). Some specimens are attacked by an endoparasite (3, PA). **4, 5:** The anterior end of the 15–32 µm long *C. erosa* is not pointed. The two refractive crystals (4, CR) and the margin of the two chloroplasts are visible (5, arrow). **6:** *Cryptomonas ovata* is 20–80 µm long and has a flat and a convex side. **7:** *Chilomonas oblonga* is 20–50 µm long and is a very common, colourless member of the cryptomonads. **8:** *Rhodomonas ovalis* is 14–16 µm long and is similar to *C. ovata*, but has reddish chloroplasts. **9:** *Chroomonas* is 28 µm long and has blue-green chloroplasts. CV – contractile vacuole, CR – refractive crystals, EJ – ejectisomes, F – flagella, PA – parasite.

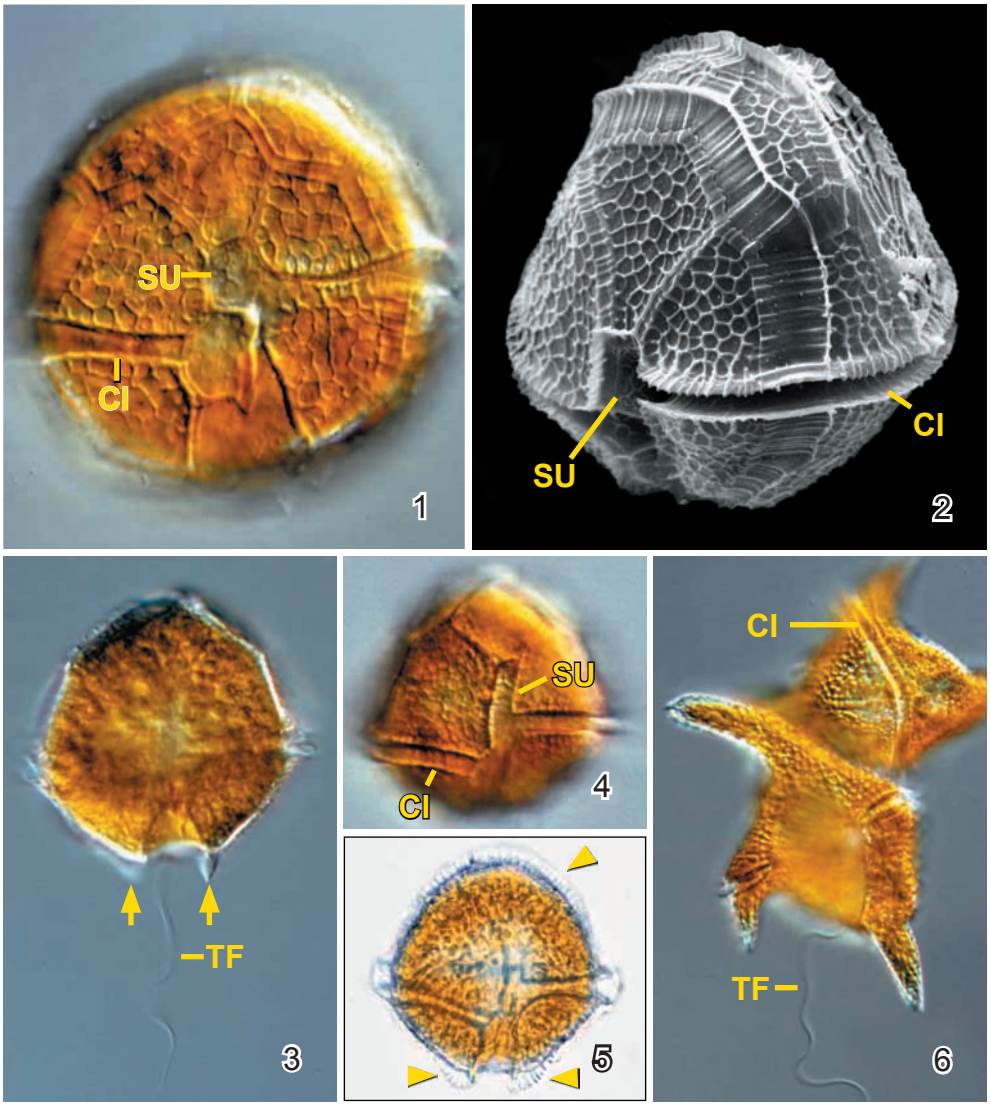


Fig. 1 – 6: Flagellates. *Peridinium* and *Ceratium* are dinoflagellates with a theca of cellulose plates separated by deep grooves containing the flagella. One of the flagella is in the equatorial cingulum (CI), while the other extends in the longitudinal sulcus (SU). The colour of the chloroplasts varies, depending on the ratio of chlorophyll and xanthophyll. **1, 2:** The reticulate theca of *Peridinium* in the light (1, ventral) and scanning electron microscope (2, lateroventral). **3, 4:** *Peridinium bipes* is 40–95 µm long and has two posterior spines (arrows). The ventral surface view shows the distinct sulcus (4). **5:** The anterior and posterior plates of *P. willei* (40–60 µm) have hyaline keels (arrowheads). **6:** *Ceratium cornutum,* which is 100–150 µm long and has three horn-shaped plates, is the only member of the genus in Simmelried. CI – cingulum, SU – sulcus, TF – trailing flagellum.

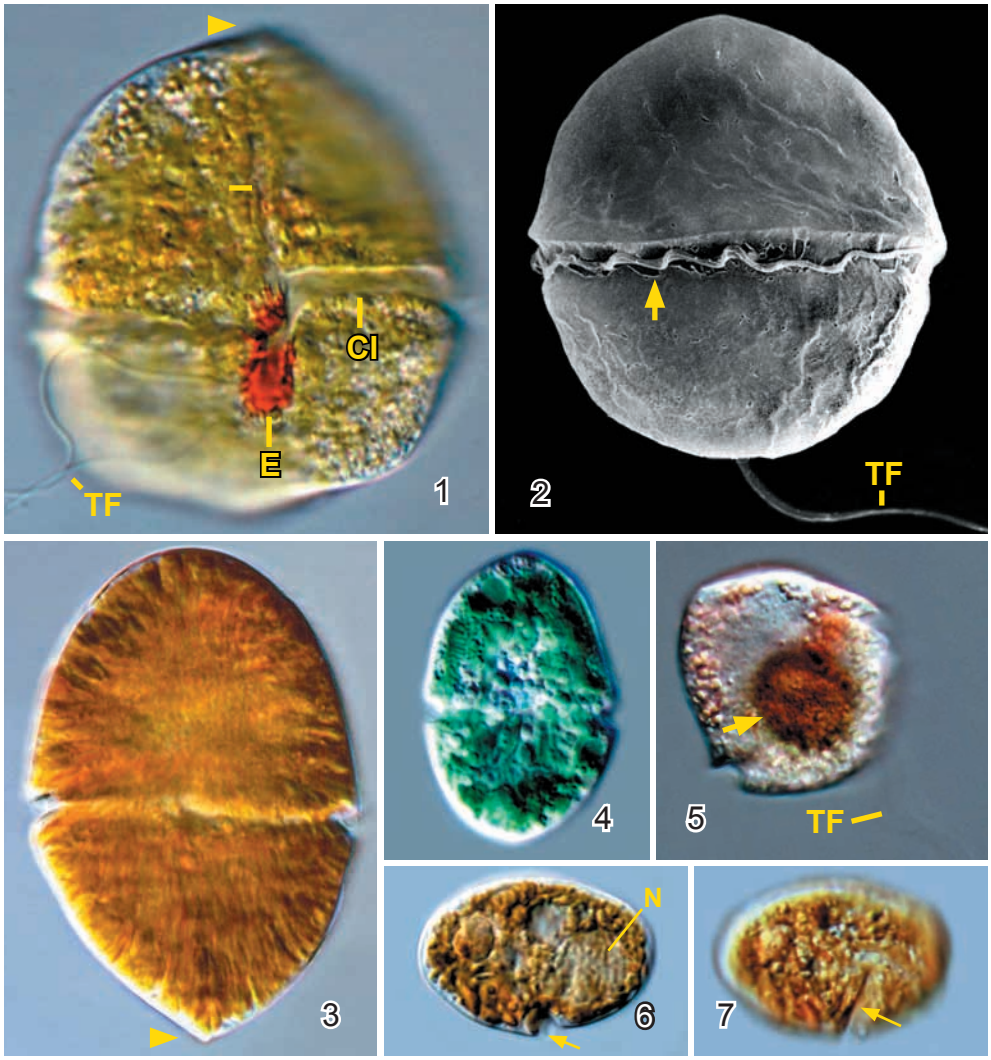


Fig. 1 – 7: Flagellates. *Glenodinium*, *Gymnodinium* and *Hemidinium* are dinoflagellates with a smooth theca. These genera/species are brownish, yellowish or bluegreen by the chloroplasts; rarely, chloroplasts are lacking. **1:** Ventral view of *Glenodinium gymnodinium* which is about 40 µm long and has a conspicuous bipartite eyespot (E). The apical end is slightly pointed (arrowhead). **2:** Dorsal view of *Gymnodinium* spec. in the scanning electron microscope. Both the transverse (arrow) and the trailing flagellum are visible. **3:** *Gymnodinium fuscum* is 80–100 µm long and can be recognized by the pointed posterior end (arrowhead). **4:** *Gymnodinium aeruginosum* is 20–35 µm long and has bluegreen chloroplasts; the cysts are embedded in a mucous coat. **5:** *Glenodinium edax,* which is about 35 µm long, lacks chloroplasts, but is coloured by ingested volvocids and dinoflagellates (arrow). **6, 7:** *Hemidinium nasutum* is 25–30 µm long and has a rather distinct bulge (6, arrow) above the reduced cingulum (7, arrow). Cl – cingulum, N – nucleus, SU – sulcus, TF – trailing flagellum.

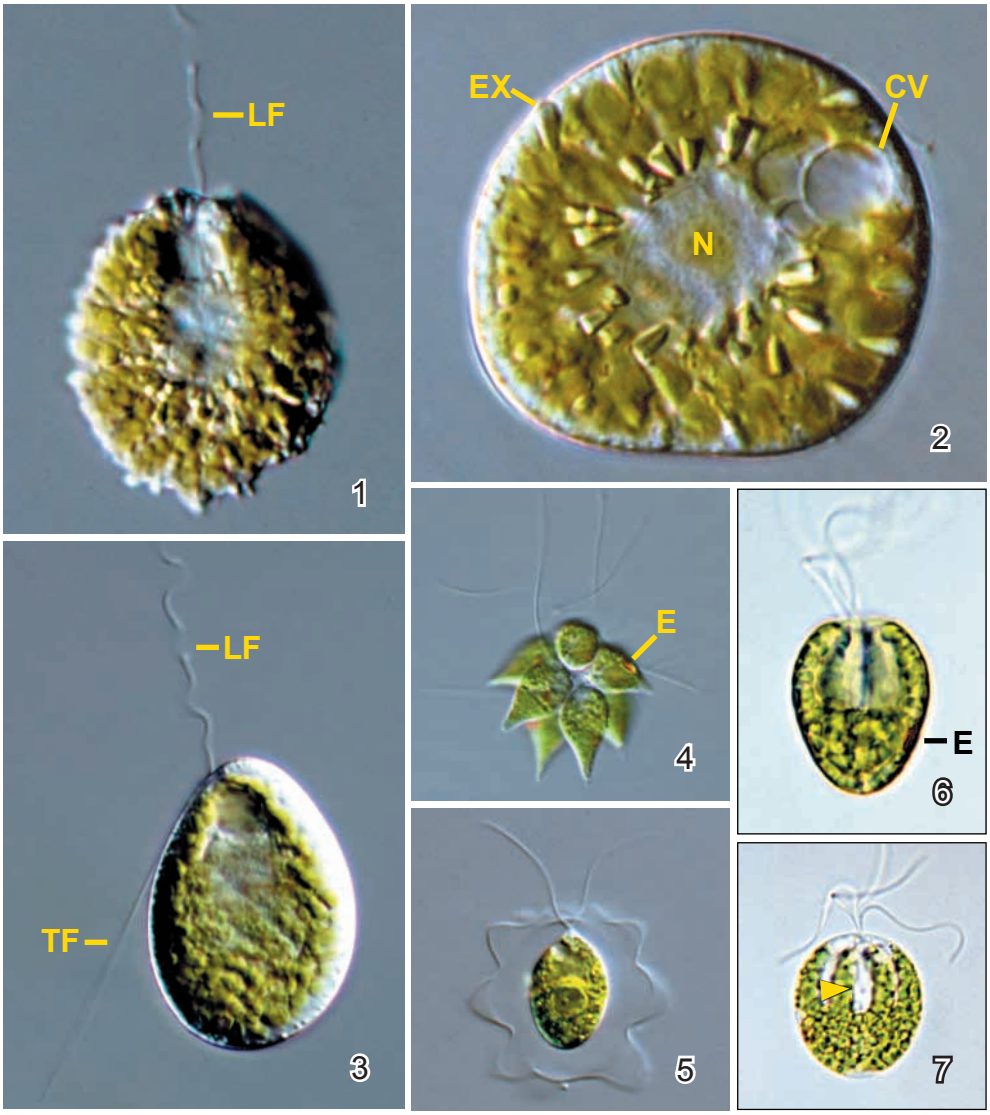


Fig. 1 – 7: Flagellates. These are green, chloroplast-bearing flagellates from the plankton of Simmelried. **1, 2:** *Gonyostomum latum*, which is about 40 µm long, has two flagella (posteriorly directed flagellum not visible) and conical extrusomes (EX) peripherally and around the nucleus (N). **3:** *Vacuolaria virescens* is 30–85 µm long and is related to *Gonyostomum,* but lacks extrusomes. However, there are spherical mucocysts which can secrete mucus around the cell. **4 – 7:** These are members of the order Volvocida with two or four flagella. **4:** *Spondylomorum caudatum* builds 30–45 µm-sized colonies with eight pyriform cells. **5:** *Lobomonas ampla* is 15–22 µm long and is covered by a gelatinous envelope with conical lobes. **6, 7:** *Pyramidomonas tetrarhynchus*, which is 20–28 µm long, has four flagella and a notched chloroplast (7, arrow). CV – contractile vacuole, E – eyespot, EX – extrusomes, LF – leading flagellum, TF – trailing flagellum.

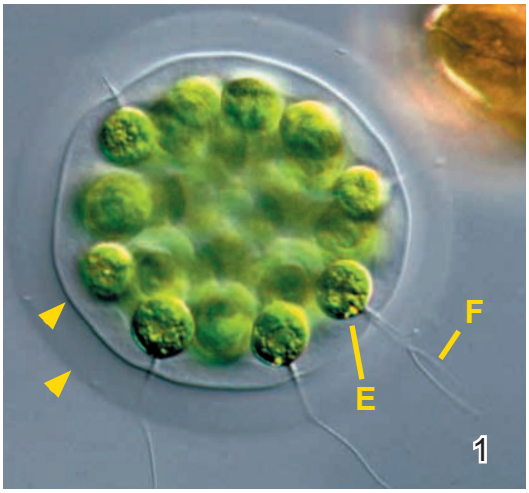
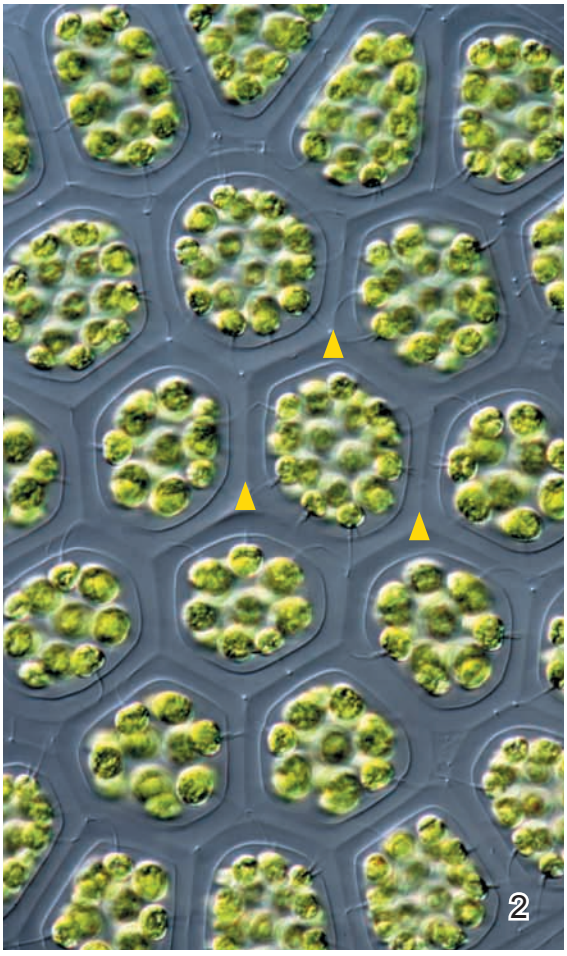
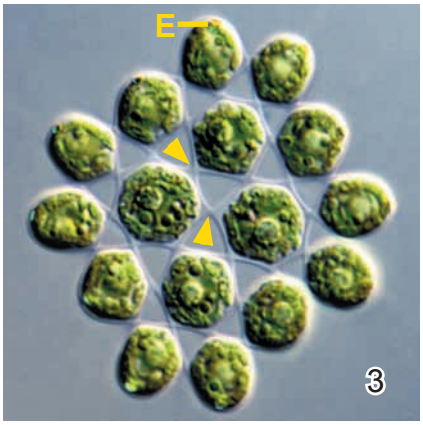
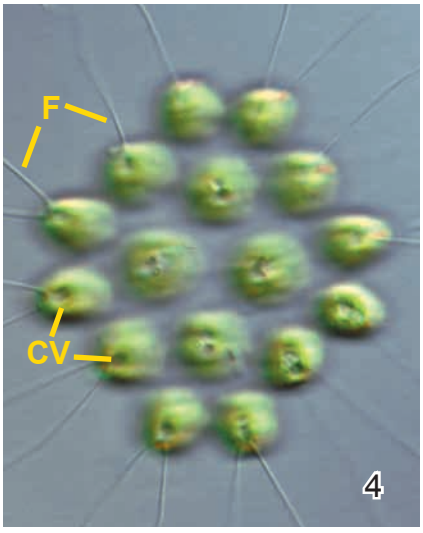


Fig. 1 – 4: Flagellates. These biflagellated members of the volvocides form swimming colonies of 16–128 cells. **1, 2:** *Eudorina elegans* builds spherical colonies of 16–128 cells within a two-layered envelope (1, arrowheads). For asexual reproduction, each cell can build a daugther colony (2, arrowheads). **3, 4:** The plane colonies of *Gonium pectorale* consist of 4–16 cells connected by gelatinous bridges (arrowheads). The two flagella (F) of the cells, which are 5–14 µm across, and the contractile vacuole become visible in a slightly varied focal plane. CV – contractile vacuole, E – eyespot, F – flagella.







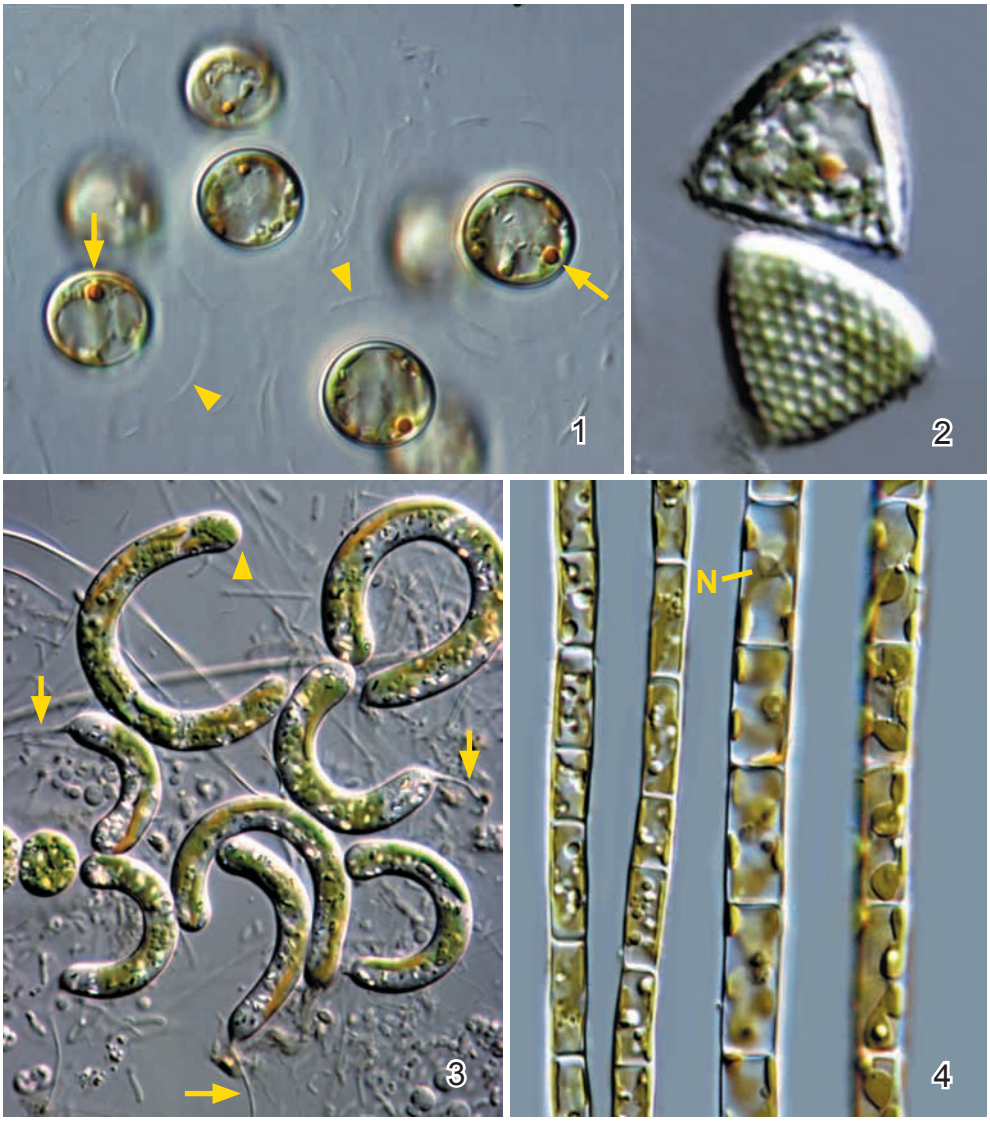
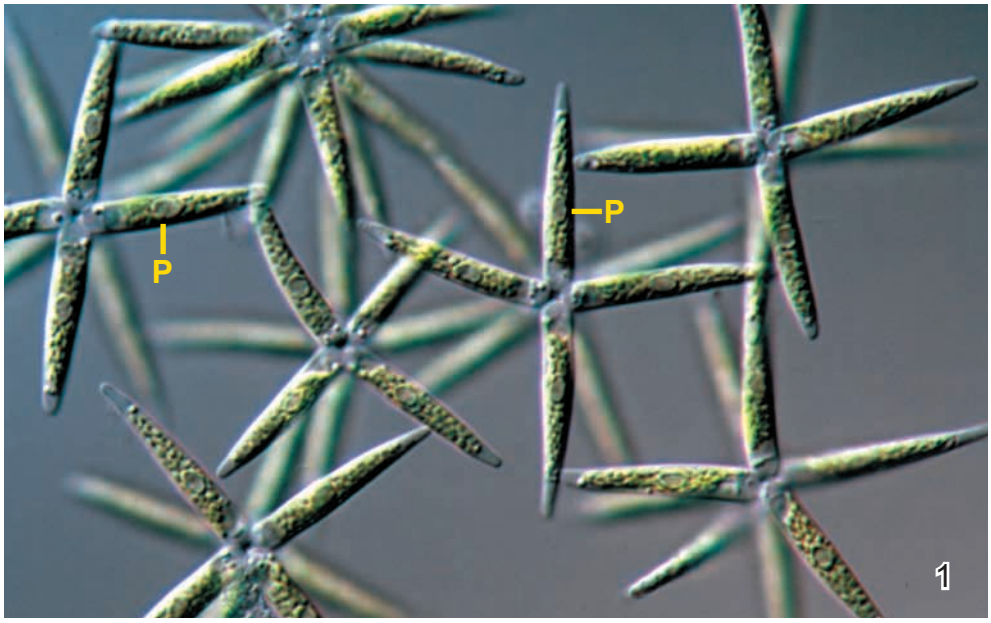


Fig. 1 – 4: Xanthophytes. The photosynthetic pigment of the xanthophytes is chlorophyll (c), in contrast to the chlorophytes which produce chlorophyll (b). A further difference to the chlorophytes is the production of chrysolaminarin instead of starch as carbohydrate reserve. **1:** The spherical cells of *Chlorobotrys polychloris* have a diameter of 18–25 µm and show a lamellated, gelatinous coat (arrowheads). Each cell contains a conspicuous droplet of yellowish or red oil (arrows). **2:** The triangular cells of *Goniochloris sculpta* have a diameter of about 25 µm and a reticulate wall structure. **3:** *Ophiocytium cochleare* has sausage-shaped cells with a tapered stalk at one end (arrows), while the opposite end shows a slight swelling (arrowhead). Although the curved or spiralized cells reach a length of several millimeters, they lack cross walls. **4:** The cells of *Tribonema* are 10–20 µm wide and form long filaments. The yellowish plastids are discoidal or ribbon-shaped. N – nucleus.



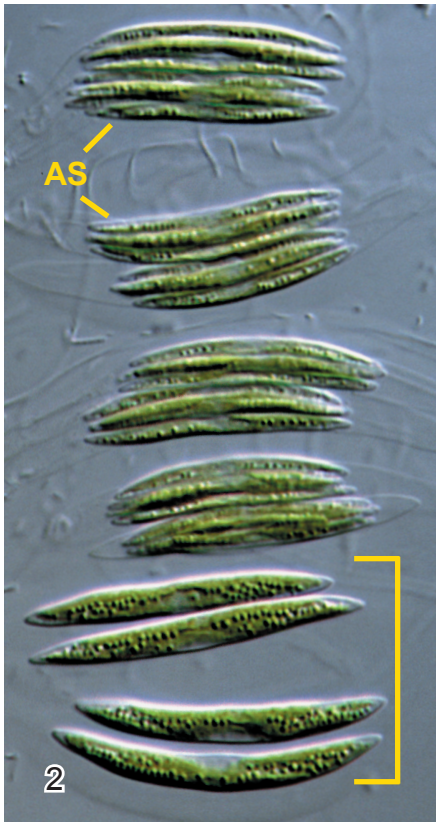
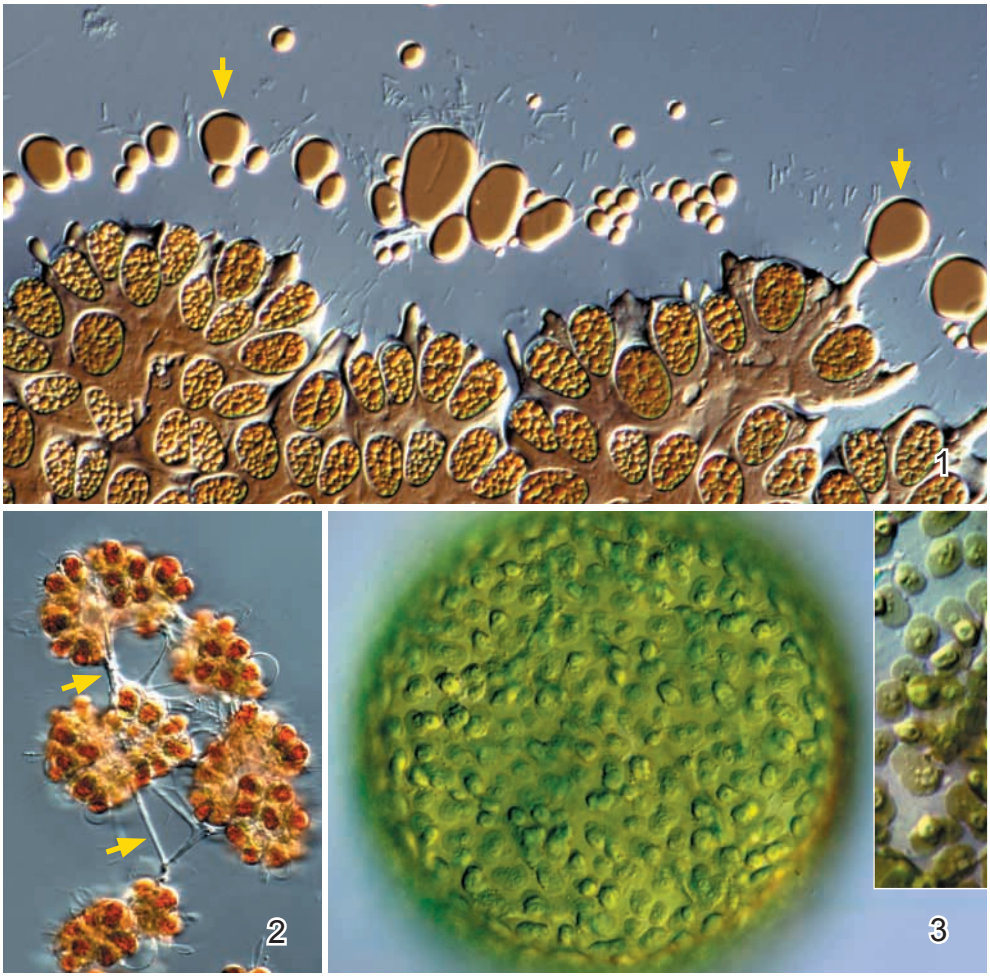


Fig. 1 – 3: Chlorophytes. *Actinastrum hantzschii* has conical, 10–35 µm long cells united to star-like colonies composed of 6–16 specimens. The chloroplast bears a single pyrenoid (P). **2:** *Quadrigula closterioides* builds clusters of four slightly curved cells embedded in a slimy matrix (bracket). For reproduction, a so-called autospore (AS) with four daughter cells is generated within the about 20 µm long parent cell by two division steps. **3:** *Quadrigula chodatii* builds gelatinous colonies with 4–16 fusiform cells each 30–80 µm long. AS – autospores, P – pyrenoid.



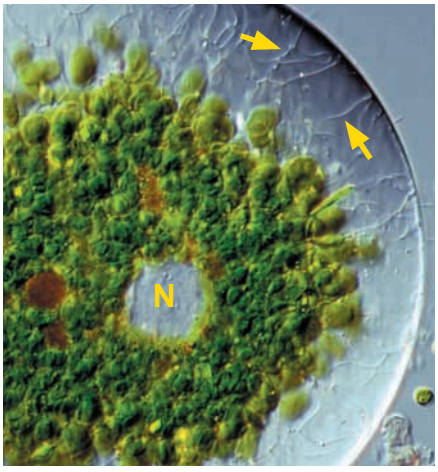
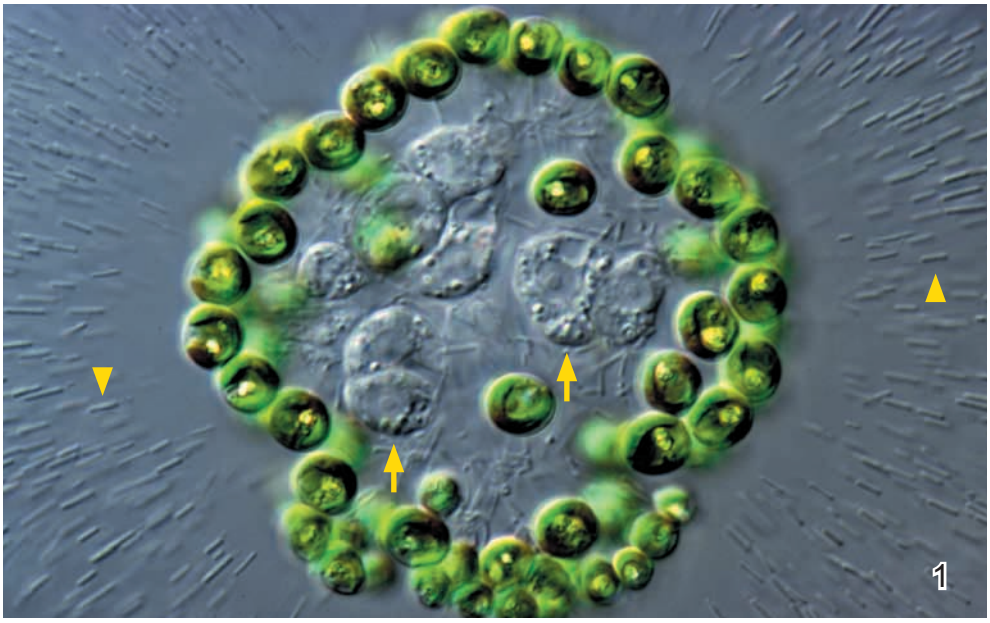
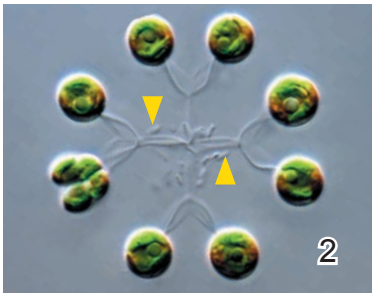


Fig. 1 – 4: Chlorophytes. 1, 2: The irregular colonies of *Botryococcus braunii* contain large amounts of extracellular orange oil which becomes distinct under coverslip pressure (1, arrows). It is believed that paleozoic oil reservoirs derive from hydrocarbon producing algae similar to *Botryococcus*. The ovoid cells are 6–12 µm and are united in botryodial subcolonies connected by slimy filaments (2, arrows). **3, 4:** *Eremosphaera viridis* can be easily recognized by the large, spherical cells 200–800 µm in diameter (3). Hundreds of discoidal chloroplasts are peripherally arranged (3, inset). When exposed to strong light, they can move along filaments (4, arrows) to the centre of the cell, where the nucleus resides (N). N – nucleus.





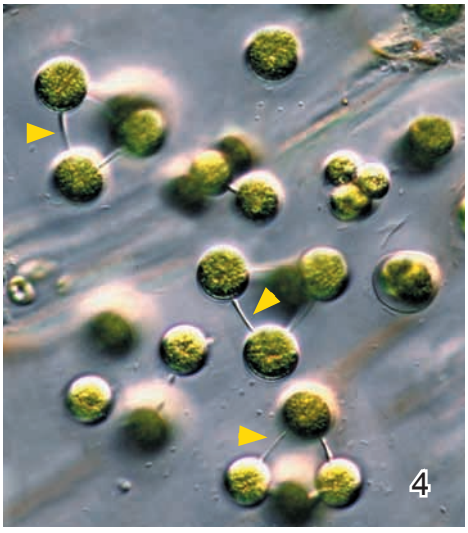
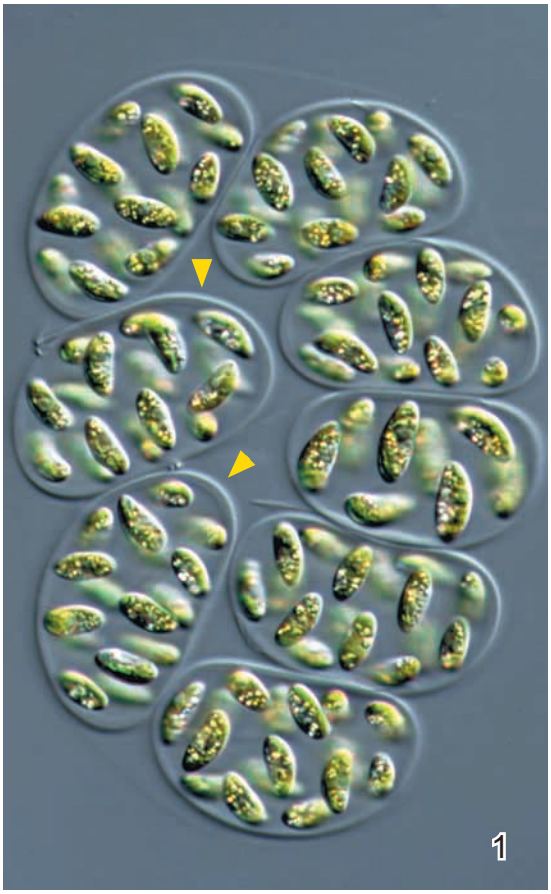


Fig. 1 – 4: Chlorophytes. 1, 2: *Dictyosphaerium pulchellum* builds colonies with globular, peripherally arranged cells 3–10 µm across. From the centre radiate dichotomously branched strands (2, arrowheads) made of wall material from the parent cells. The colonies are surrounded by clear slime often containing bacteria (1, arrowheads). Occasionally, the centre of a colony is inhabitated by a small, unidentified amoeba (1, arrows). **3:** *Dictyosphaerium tetrachotomum* can be distinguished from *D. pulchellum* by the more ovoid cells. Young cells are often irregularly shaped (arrowheads). **4:** *Dictyochlorella globosa* builds tetrahedral clusters composed of 8–13 µm-sized cells connected by slimy strands (arrowheads). The clusters are united to large, slimy colonies.



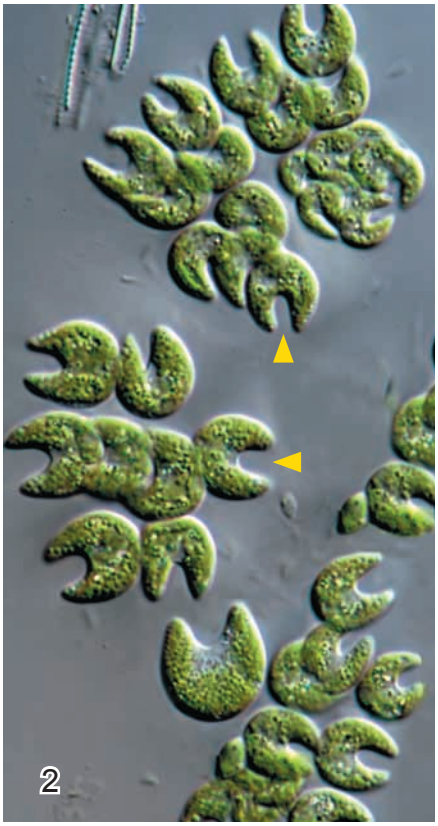


Fig. 1 – 3: Chlorophytes. 1: This large colony of *Nephrocytium* (likely *N. agardhianum*) was generated by the formation of autospores within the parental cells of an originally eight-celled colony. The cell wall of the parent cell gelatinizes and builds the border of the sixteen-celled autospore colonies (arrowheads). After disintegration to separate colonies, the autospores will grow to vegetative cells with a final length of 10–25 µm. **2, 3:** *Kirchneriella obesa* (2) and *K. lunaris* (3) are 6–10 µm long, crescentic cells scattered in a gelatinous sheath. While the inner margin of *K. obesa* is U-shaped (2, arrowheads), that of *K. lunaris* is almost semicircular. Like in *Nephrocytium*, asexual reproduction of *Kirchneriella* occurs by formation of autospores within the parent cells.

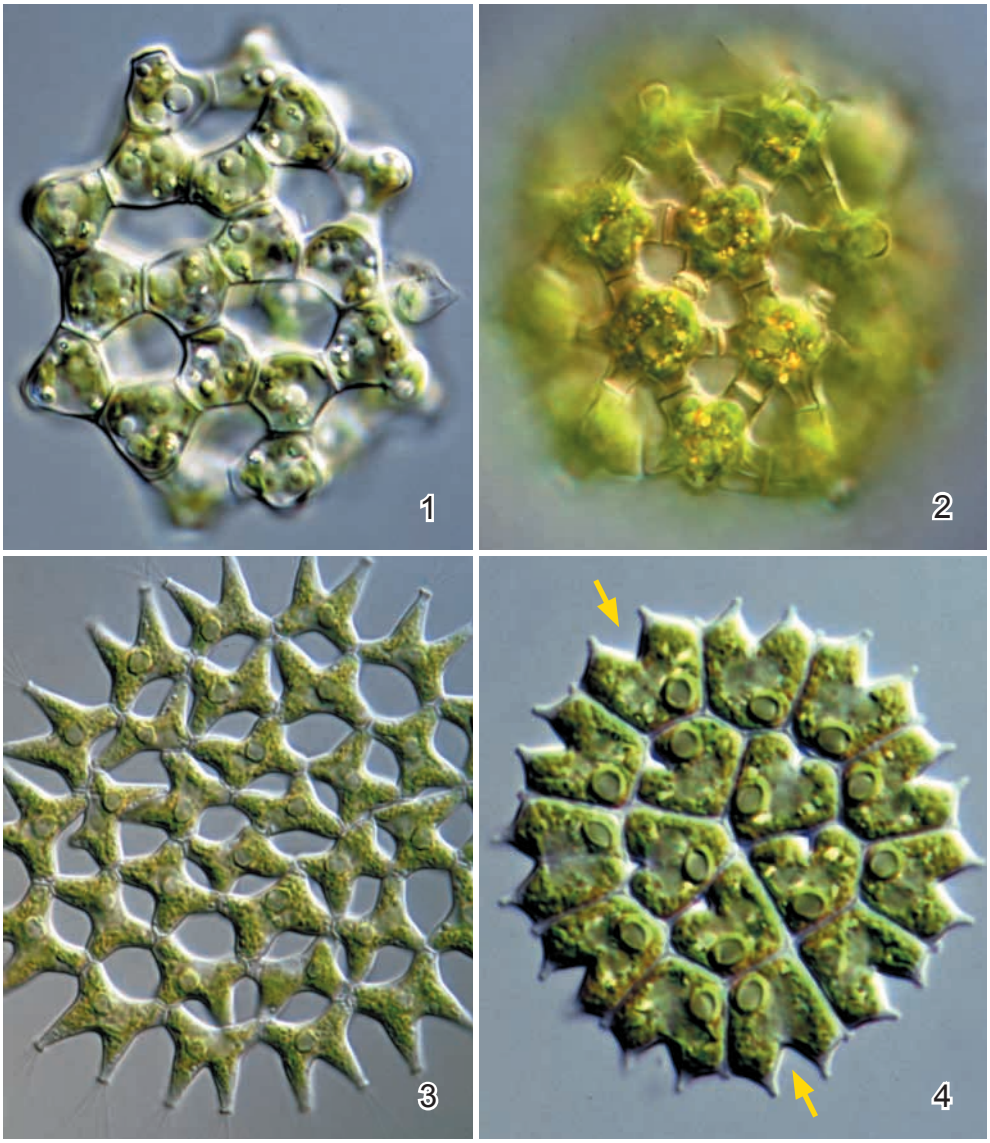


Fig. 1 – 4: Chlorophytes. 1, 2: Members of the genus *Coelastrum* build hollow, polyhedric, 40–80 µm-sized colonies composed of 8–64 cells. While each cell is connected to three neighbours in a colony of *Coelastrum sphaericum* (1), those of *C. reticulatum* (2) are connected to six neighbours. **3, 4:** The genus *Pediastrum* builds stellate colonies 30–300 µm in diameter. The colonies comprise peripheral cells with horn-like projections and inner cells without projections. This shape has been preserved since the Cretaceous, as shown by fossil pediastrums in 140 million years old sediments. The inner cells of *P. duplex* (3) are H-shaped and form a reticulate pattern, while the keystone-shaped cells of *P. tetras* (4) have a V-shaped notch (4, arrows).

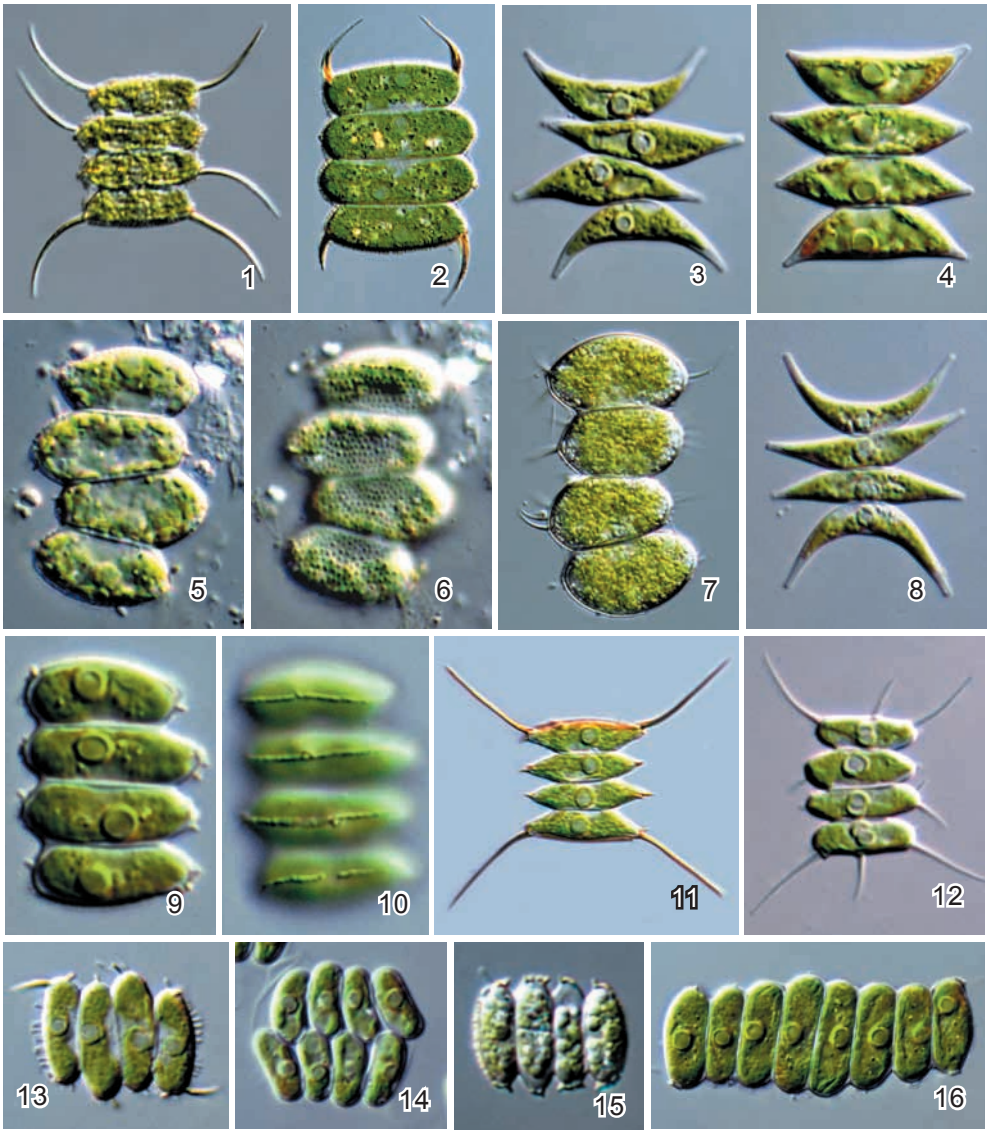


Fig. 1 – 16: Chlorophytes. *Scenedesmus* is a very common and diverse genus in freshwater. Some are model organisms for biochemical, genetic and photo-physiological investigations. The linear colonies comprise 2–16 cells attached side by side. The terminal cells often have spiny processes. The cell wall of some species is granulated or ridged. The typical length of the cells is 5–40 µm. **1:** *Scenedesmus magnus*. **2:** *Scenedesmus quadricauda*. **3:** *Scenedesmus dimorphus*. **4:** *Scenedesmus acutus*. **5, 6:** *Scenedesmus denticulatus* in two focal planes. **7:** *Scenedesmus pecsensis*. **8:** *Scenedesmus acuminatus*. **9, 10:** *Scenedesmus lefevrii* var. *manguinii* in two focal planes. **11:** *Scenedesmus armatus*. **12:** *Scenedesmus spinosus*. **13:** *Scenedesmus semicristatus*. **14:** *Scenedesmus acunae*. **15:** *Scenedesmus brasiliensis*. **16:** *Scenedesmus microspina*.

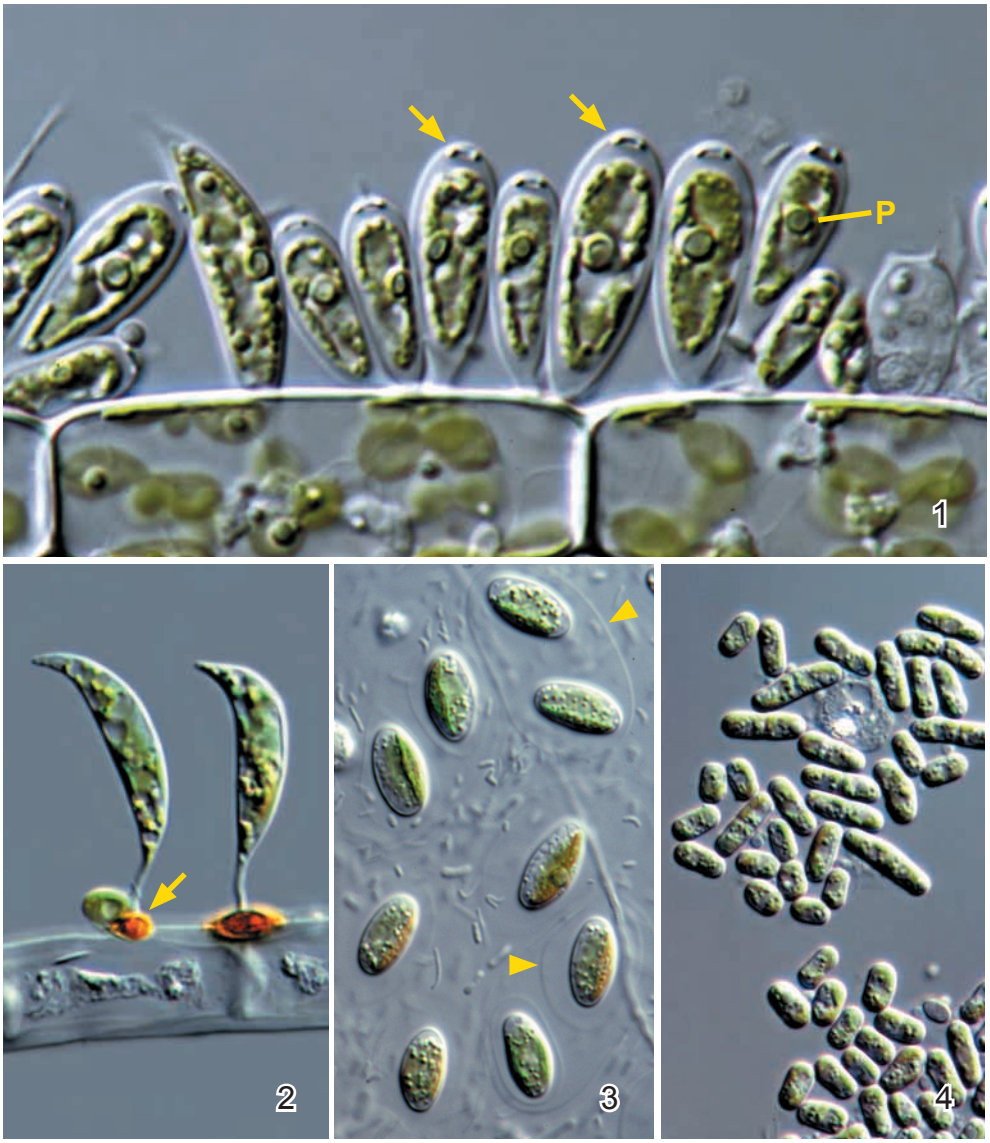


Fig. 1 – 4: Chlorophytes. 1: *Characiellopsis skujae* is an unicellular, 25–60 µm long alga which often covers filamentous algae like *Tribonema* and *Microspora*. The obovate cells can be distinguished from *Characium* by an apical, circular bulge (arrows). **2:** The curved cells of *Characium rostratum* are 25–35 µm long and have a hook-shaped distal end. The stalked cells are attached to the substrate by a brownish disc (arrow). **3:** *Dactylothece braunii* builds large colonies of 3–16 µm long cells covered with a gelatinous sheath (arrowheads). The chloroplasts lack a pyrenoid. **4:** *Stichococcus* has a size of 4–8 µm and is thus one of the smallest chlorophytes. The species can appear in short filaments, but usually the cells are separated showing the oblong shape with rounded ends. P – pyrenoid.

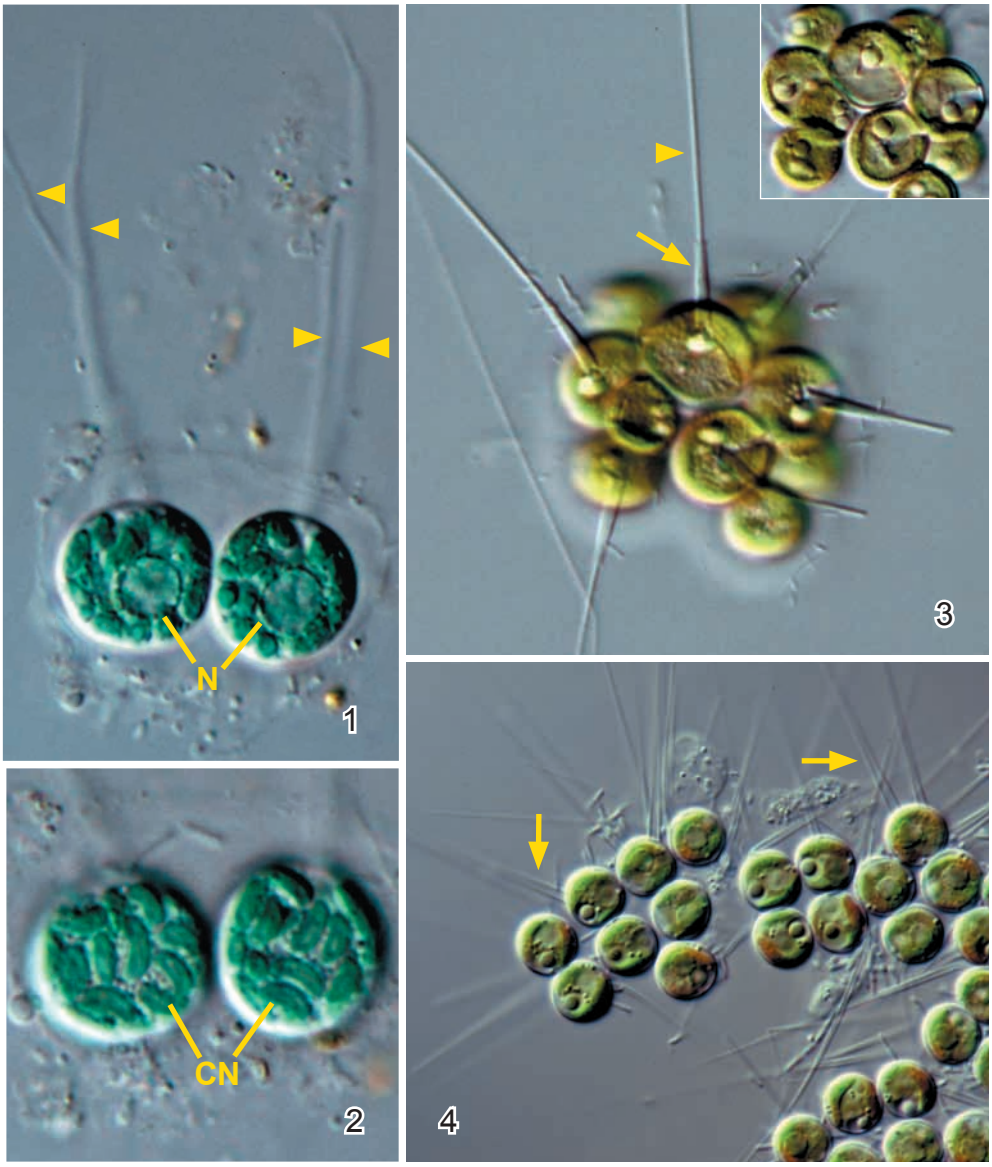


Fig. 1 – 4: Chlorophytes. Some members of the chlorophytes bear thick bristles extending from the cell or from the cell wall. **1, 2:** *Gloeochaete* is rare in Simmelried. The globular cells are about 25 µm across and have two gelatinous bristles (1, arrows). The blue-green colour is caused by symbiotic cyanelles (2), possibly precursors of the chloroplasts. **3:** *Chaetosphaeridium* (likely *C. globosum*) builds small colonies composed of cells with a diameter of 10–15 µm (inset). Each cell bears a cytoplasmic spine (arrowhead), the base of which is covered with a gelatinous sheath (arrow). **4:** *Micractinium pusillum* builds small colonies floating in the plankton. The cells have a diameter of 3–13 µm and bear two or four hollow bristles with a length of 10–60 µm (arrows) to improve buoyancy. CN – cyanelles, N – nucleus.

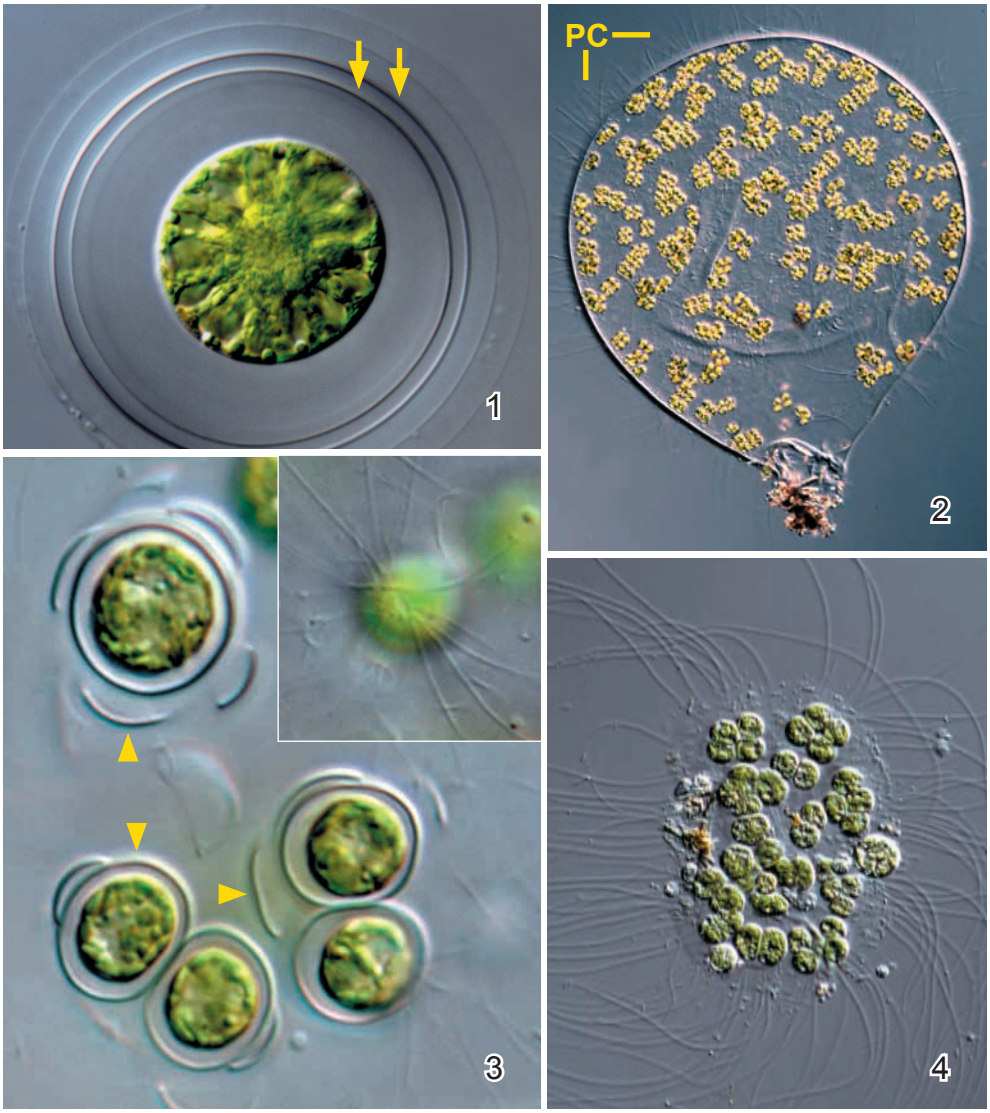


Fig. 1 – 4: Chlorophytes. Members of the order Tetrasporales have cells similar to those of *Chlamydomonas,* that is, they have a contractile vacuole, an eyespot, or/and two flagella. The Tetrasporales build colonies with distinct gelatinous sheaths. **1:** *Asterococcus superbus* occurs in small colonies of 2–8 cells with a diameter of 20–25 µm. Each cell is covered with layers of mucous (arrows) and has a stellate chloroplast. **2:** The pyriform or bursiform colonies of *Apiocystis brauniana* are covered with fine pseudocilia (PC). The spherical cells are 6–8 µm in diameter and arranged in tetrahedral groups in the periphery of the colony. **3:** The cells of *Schizochlamys gelatinosa* are 9–15 µm across and surrounded by scattered remnants of the parent cell wall in the gelatinous matrix (arrowheads). From each cell extend a tuft of filaments (inset). **4:** *Paulschulzia pseudovolvox* has long pseudocilia extending through the sheath of the colony. PC – pseudocilia (= flexible, but non-motile, gelatinous fibres).