ICES Identification Leaflets for Plankton

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LEAFLET NO. 179

Potentially Toxic Phytoplankton
1. Haptophyceae (Prymnesiophyceae)

by

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Haptophyceae (Prymnesiophyceae)

Introduction

While some members of the Haptophyceae, e.g., *Chrysochromulina*, have only recently been recognized as potentially toxic or harmful members of the marine plankton, others, like *Prymnesium*, are well-known fishkillers, the effects of which have been described repeatedly in the literature since the beginning of this century. The harmful effects of haptophytes are diverse, but the harmful potential to ecosystems and to man is very incompletely known. Many species undoubtedly remain undescribed, their structure and autecology are little known, and there are conflicting reports on their toxicity. The toxic principles remain on the whole poorly characterized.

This leaflet gives a brief overview of the haptophytes at present known to be harmful. We expect, however, that all species of *Prymnesium* – a genus comprising some half dozen species – are toxic (only three have been examined so far). The situation is uncertain with respect to *Chrysochromulina*, with only one or two of the many species described (c. 50) known to be toxic. In the genus *Phaeocystis* nearly all information pertains to the species usually known as *P. pouchetii*, but the species concept is at present under debate (two or more species?).

The non-coccolithophorid haptophytes, to which the harmful species belong systematically, comprise c. 20 genera. Many of these remain poorly studied and their toxic potential is unknown.

Description of the class

The Haptophyceae comprise mainly unicellular or colony-forming algae from the marine plankton. The cells are yellow or yellow-brown, the chloroplasts (usually two in number) containing chlorophyll *a* and two or three different chlorophyll *c*'s (Jeffrey, 1990). One of the main structural characteristics of the group is the haptonema, a filiform organelle which occurs together with the (usually) two flagella. The haptonema has not been found in any other group of organisms. It may attain a length of over 100 μm (in *Chrysochromulina camella,* 160 μm, according to Leadbeater, 1972), and the length is a species characteristic. Some species lack a haptonema (many coccolithophorids, including the cosmopolitan *Emiliania huxleyi*), or it is rudimentary. The function of the haptonema has been a source of discussion. It can serve as an attachment organelle; species with a short haptonema are often attached with the tip of the haptonema to the coverslip when examined under the microscope. The haptonema is usually stretched forward in swimming cells, but long haptonemata coil up on contact with other objects. Kawachi *et al.* (1991) have recently shown that *Chrysochromulina hirta* and other species of *Chrysochromulina* use the haptonema as a food uptake organelle. Small eukaryotic algae attach to the haptonema and are collected into small food packets. The haptonema then bends back to deliver the packets at the posterior end of the cell, where they are phagocytized.

The cells of most haptophytes are covered with carbohydrate scales, the structure of which is species specific. The so-called coccoliths are calcified scales of coccolithophorids, a very large group of haptophytes. Coccoliths are sometimes visible in the light microscope, while many uncalcified types of scales are visible only under the electron microscope.

The toxic effect of members of the Haptophyceae will be described under the individual genera and species.

Description of genera

Chrysochromulina Lackey, 1939
[Type species: *Chrysochromulina parva* Lackey, 1939]

This genus comprises about 50 known species, mainly from the marine plankton. Characters used to identify the individual species include cell size, flagellar and haptonema lengths, and the structure of the scales. Until recently only one species, *C. polylepis*, was known to be toxic, but *C. leadbeateri* (Estep *et al.*, 1984) is now believed to be responsible for fishkills in northern Norway in 1991 (Throndsen and Eikrem, 1991).

Chrysochromulina polylepis Manton & Parke, 1962   Fig. 1a–g

Description: Cells somewhat metabolic; generally ovoid but sometimes spheroidal with the flagellar pole obliquely truncate and depressed to form a groove. Cells are 6–12 μm long, 5–9 μm wide (Fig. 1a–d). The two flagella are homodynamic, of equal or subequal length, and 2–3 times the cell length. The haptonema is thinner than the flagella, 1–1.5 times the cell length, and capable of attaching by its distal swollen tip. Each cell has two yellow-brown chloroplasts, and four different types of flat scales (Fig. 1e,f).

The cells usually swim rapidly with frequent and sudden changes of direction. They may swim with the flagella and haptonema forwards or backwards. When swimming rapidly, the haptonema is usually coiled.
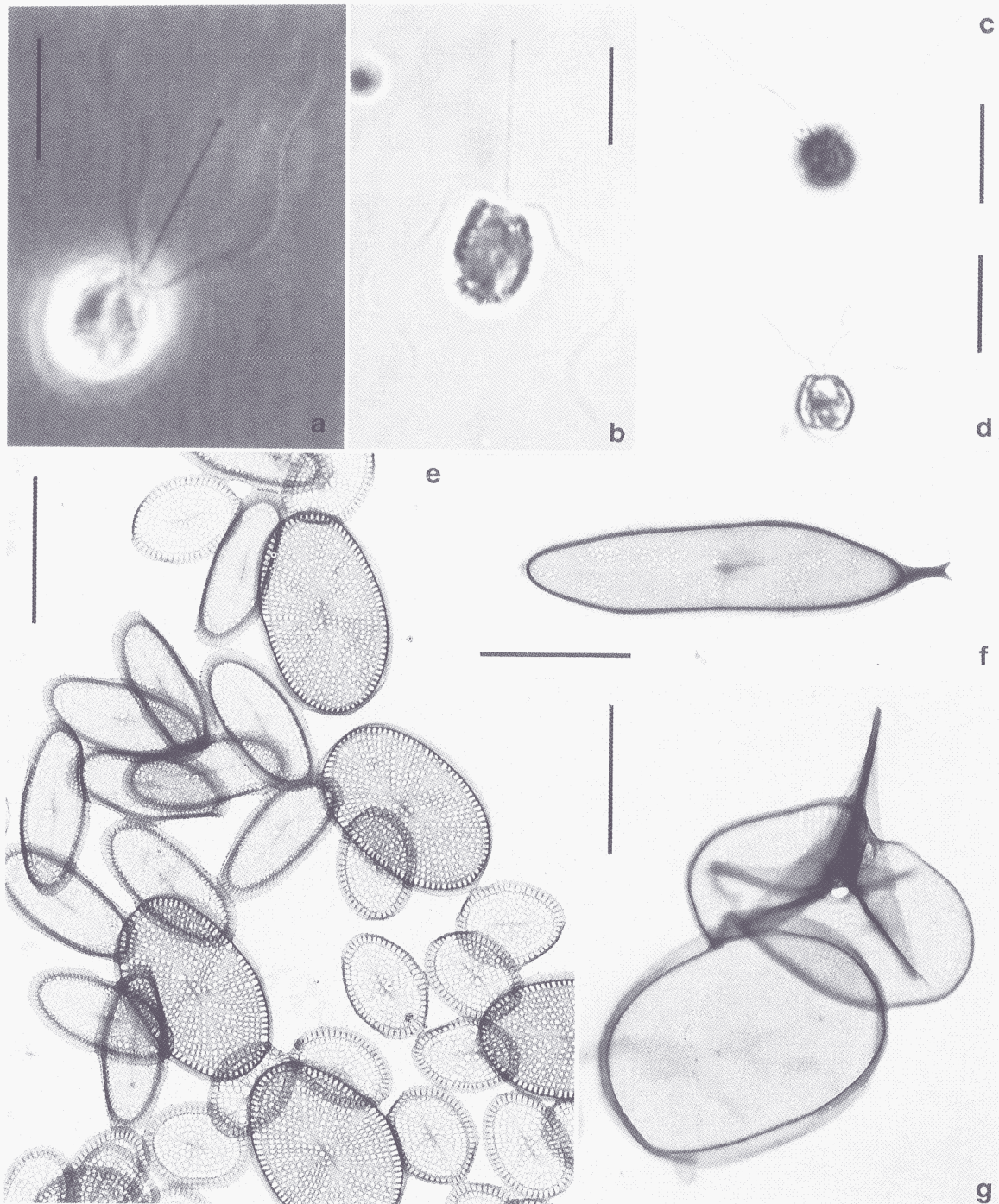
Cysts are unknown.

Figure 1a–g: *Chrysochromulina polylepis*. 1a,b: live cells with extended haptonema; the distal swelling on the haptonema is visible in 1b. Phase contrast (Fig. 1a) and bright field (Fig. 1b); 1c,d: cells fixed in Lugol's iodine, both bright field; 1e–g: electron microscopical wholemounts; 1e: showing three different scale types; 1f: the fourth scale type, which is present in small numbers; 1g: aberrant scale types found in Norwegian material. Figure 1a–f: material from Denmark; Figure 1g: from Norway (Paasche *et al.*, 1990). Scale bars in Figure 1a–d: 10 μm; Figure 1e–g: 1 μm.

Taxonomic remarks: *Chrysochromulina polylepis* is readily distinguished by the structure of the scales. Paasche *et al.* (1990) have recently, however, in material from Norway, found a deviant cell type. The cells are covered with three kinds of scales, one of which has a prominent central spike (Fig. 1g), while the others are flat, as opposed to the four kinds of flat scales in the type material. The flat scales of the deviant form generally resemble the equivalent scales of the type, but some differences were noted in size and in the appearance of the perforations. Cells with both sets of scales were apparently also seen. Edvardsen and Paasche (1992) were unable to grow the two types of cells separately on a permanent basis, and the aberrant type was tentatively interpreted as a stage in the life cycle of *C. polylepis*. The aberrant cell type has not yet been reported elsewhere.

Ecology and distribution: *Chrysochromulina polylepis* was originally described from a number of localities in the Irish Sea (Manton and Parke, 1962), and for over twenty years these were the only finds reported in the literature. In 1988, *C. polylepis* occurred unexpectedly in Norwegian, Swedish, and Danish waters (Barth and Nielsen, 1989; Kaas *et al.*, 1992), causing extensive damage to fish, bottom invertebrates, and marine macroalgae. The cells (up to 100 million per litre) were usually present in a very narrow layer (0.5–2 m thick) in the halocline. Single cells are also known from Australia (P. L. Beech and D. Hill, pers. comm.). It is therefore likely that *C. polylepis* occurs worldwide. It is normally rare, but under certain – as yet not fully understood – conditions, it may form extensive blooms which can have a devastating effect on the environment.

Toxicology: The British material examined by Manton and Parke (1962) was tested for toxicity to fish and, like all other known species of *Chrysochromulina*, found to be non-toxic. In the Scandinavian material, Yasumoto *et al.* (1990) found two hemolytic and ichthyotoxic compounds. The major hemolytic factor was the galactolipid, 1-acyl-3-digalacto-glycerol, but small amounts of the polyunsaturated fatty acid, octadecapentaenoic acid, were also present. Very similar toxins were found by these authors in two dinoflagellates, *Gyrodinium aureolum* and *Amphidinium carterae,* of which the former is a well-known cause of mortality in fish and bottom invertebrates.

Prymnesium Massart ex Conrad, 1926
[Type species: *Prymnesium saltans* Massart ex Conrad, 1926]

Prymnesium is closely related to *Chrysochromulina*. The few known species, which all possess a short non-coiling haptonema, can only be reliably distinguished from each other and from species of *Chrysochromulina* by electron microscopy. The relationship between *Chrysochromulina* and *Prymnesium* has been discussed by Green *et al.* (1982) and Moestrup and Thomsen (1986).

Prymnesium parvum N. Carter, 1937   Fig. 2a–e

Description: Cells subspherical to elongate, not or only slightly compressed. The posterior end rounded or tapered, the anterior end obliquely truncate. Cells usually 8–11 μm long and 4–6 μm wide. Two equal or subequal flagella, 12–15 μm long, and a 3–5 μm long, flexible, non-coiling haptonema arising subapically from a depression in the truncate face. Two parietal chloroplasts, which are yellow-green to olive. A large chrysose (chrysolaminarin) vacuole is often visible in the posterior part of the cell.

Body scales of two types, both with a pattern of concentric fibres on the distal surface and radiating fibres on the proximal surface. Scales of the outer layer(s) 0.30–0.43 μm × 0.23–0.30 μm with narrow inflexed rims. Scales of the inner layer(s) 0.29–0.36 μm × 0.26–0.32 μm with a wide rim strongly inflexed over the distal face.

Cysts ovoid, c. 9 × 6 μm with a simple sub-anterior pore; wall composed of scales with electron-dense siliceous material deposited on the distal surface.

When swimming, the cell rotates around its longitudinal axis and the movements of the two flagella are slightly different (heterodynamic).

Taxonomic notes: *Prymnesium parvum* can be distinguished with certainty from other members of the genus only by the structure of the scales. It differs from *P. patelliferum* in the presence of concentric fibres on the distal scale face; *P patelliferum* has radiating fibres on both sides of the scales. Thin sections show that the outer scales of *P. patelliferum* possess upright rims, while the equivalent scales in *P. parvum* have inflexed rims. *Prymnesium calathiferum* has basket-like outer scales. This species, known at present only from New Zealand, is believed to be responsible for fish and shellfish mortalities in New Zealand in 1983 (Chang and Ryan, 1985; Chang, 1985).

Ecology and distribution: *Prymnesium parvum* is a well-known cause of fish mortalities in many temperate and subtropical waters in both hemispheres (Green *et al.*, 1982).

Padilla (1970), who studied an Israeli strain, found it to grow and produce toxin at salinities between 1 and 33, but the growth rate increased considerably at salinities below 10. These findings agree with observations from nature; blooms occur typically in brackish water.
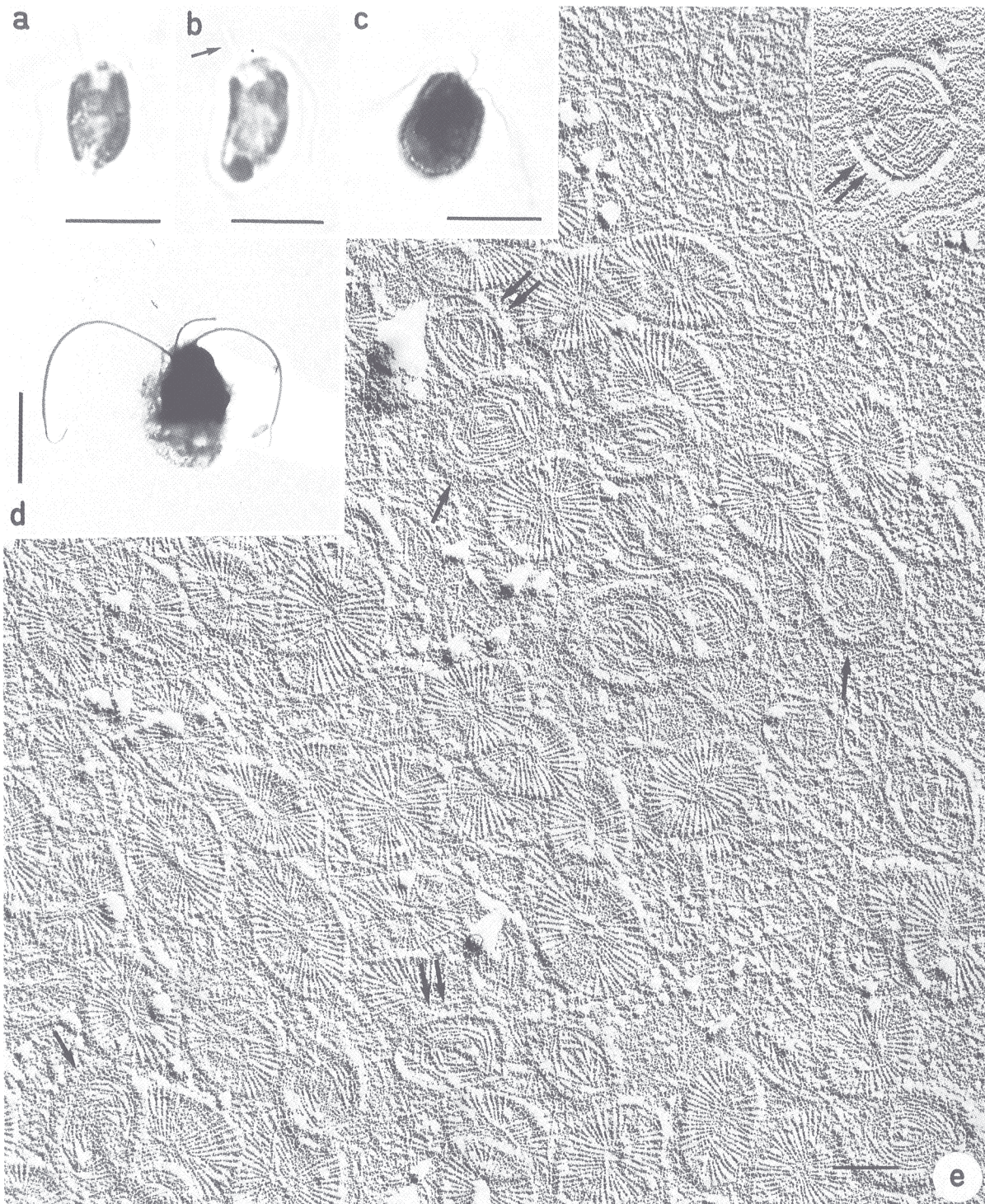
Figure 2a–e: *Prymnesium parvum*. 2a,b: live cells. The haptonema (arrow) is visible in both cells, bright field; 2c: cell fixed in iodine, bright field; 2d,e: electron microscopical wholemounts; 2d: shadowcast whole cell showing all three appendages; 2e: field of detached scales, to show the two types. The distal face of the scales has concentric fibres. One scale type has a wide rim (single arrows), the other a very narrow rim (double arrows). The proximal face has a system of radiating lines in both scale types. Material from Denmark. Scale bars in Figure 2a–c: 10 μm; Figure 2d: 5 μm; Figure 2e: 0.2 μm.

Toxicology: The toxic principles of *P. parvum* are acidic polar phosphoproteolipids (Shilo, 1981). They act on biological membranes, increasing their permeability and causing leakage. There is a strong effect on gill-breathing animals, such as fish and bottom invertebrates. Tadpoles are susceptible to the toxins, but the frogs are not affected. The toxic effect is enhanced by Ca^{2+} and Mg^{2+}, but reduced by Na^+. In closed systems, blooms of *Prymnesium* may be controlled by adding aqueous ammonia (or, e.g., ammonium sulphate) to the water. The protonated ammonia ion is taken up by the cells, and the increased osmotic pressure of the cell causes water to diffuse into the cells, which subsequently lyse.

Prymnesium patelliferum Green, Hibberd & Pienaar, 1982
Fig. 3a–d

Description: Cells mostly subspherical to elongate with more or less parallel sides and rounded posterior end. Anterior end obliquely truncate. Cells 6–12 μm long and 3.5–8.0 μm wide. Two equal or subequal flagella, 10–14.5 μm long, and a 3–5 μm-long flexible haptonema arising subapically from a depression in the truncate face. Two lateral parietal chloroplasts, yellow-green to olive. Storage material (probably chrysose) located in a posterior vacuole.

Body scales of two types, in several layers. Both types measure 0.36–0.37 μm × 0.25–0.27 μm. Scales of the inner layers with a narrow inflexed rim on the distal face, a central thickening, and radial fibrillar pattern on both faces. Scales of the outer layers similar but with relatively tall upright rims.

Cysts as in *P. parvum*.

Taxonomic notes: see *P. parvum*.

Ecology and distribution: *Prymnesium patelliferum* is known from temperate waters in both hemispheres (Green *et al.*, 1982; Larsen and Moestrup, 1989). There are no published data on salinity preferences, but preliminary experiments (Arlstad and Moestrup, unpubl.)

Figure 3a–d: *Prymnesium patelliferum*. 3a,b: live cells, haptonema indicated by an arrow; 3c: cell fixed in Lugol's iodine, haptonema marked with an arrow; 3d: electron microscopical wholemount. Field of detached scales showing a system of radiating lines on both surfaces of the two scale types. Scales of the outer layer have relatively tall upright rims (double arrow), while scales of the inner layer possess a narrow inflexed rim (single arrows). Material from Wilson's Promontory, Australia. Scale bars in Figure 3a–c: 10 μm; Figure 3d: 0.2 μm.

showed excellent growth at all salinities tested (10–41), using a strain from Wilson's Promontory, Australia.

Toxicology: The toxicological potential of *P. patelliferum* is unknown. As pointed out by Green *et al.* (1982), however, two micrographs published by Valkanov (1964) (as *P. parvum*) suggest that the organisms responsible for a sudden mass fish mortality in the Varna Lakes, Bulgaria (salinity 1 and 10–12), may have been *P. patelliferum*.

Phaeocystis Lagerheim, 1893

Species of this genus are morphologically polymorphic. Several previously described species were until recently considered morphological varieties of a single species, *P. pouchetii*. The old discussion regarding the number of species has now been reopened (see below). The discussion suffers particularly from lack of knowledge about the life cycle.

Phaeocystis cf. *pouchetii* (Hariot) Lagerheim, 1893   Figs. 4, 5a–f, 6d

Description: A hypothetical life cycle of *P.* cf. *pouchetii* is shown in Figure 4. At least two different stages occur. The colony-forming stage is the most conspicuous, and the yellow-green colonies may attain a size of several millimetres. The cells are embedded in mucilage, forming a monolayer at the periphery of the colony. The shape of the colony varies from spherical to irregular.

Individual cells are 4–8 μm long and usually contain two (1–4) chloroplasts. They lack flagella and haptonema. Scales are also absent (Chang, 1984).

The motile stage is unicellular, 3–8 μm long, biflagellate, with a very short haptonema which is difficult to see in the light microscope. The cells usually contain two chloroplasts. The surface is covered with submicroscopical flat scales of two kinds (Fig. 5e). Cells of some clones contain trichocyst-like structures which appear as pentagonal stars after discharge from the cell (Fig. 6d). Other clones lack this material (Parke *et al.*, 1971). Several types of motile cells have been described (Kornmann, 1955; Veldhuis, 1987) and at least some of these are capable of self-replication. The colonies probably form from single cells, often seen attached to the spines of the diatom *Chaetoceros* (Fig. 5 a,d). The origin of these cells is uncertain, but they appear to represent flagellates, which have settled and resorbed the flagella and haptonema. The single cells divide and eventually form colonies. Free-floating colonies may divide by fragmentation.

Taxonomic remarks: Jahnke and Baumann have recently, in a series of articles, re-introduced the old name *Phaeocystis globosa*, claiming that two different species, *P. pouchetii* and *P. globosa,* occur in the North Sea (Jahnke and Baumann, 1986; 1987; Jahnke, 1989). The two species differ in the morphology of the colonies, which are spherical in *P. globosa* and more irregular in *P. pouchetii.* In *P. pouchetii* the cells are arranged in square groups of four, while the cells of *P. globosa* are regularly spaced throughout the colony (Jahnke and
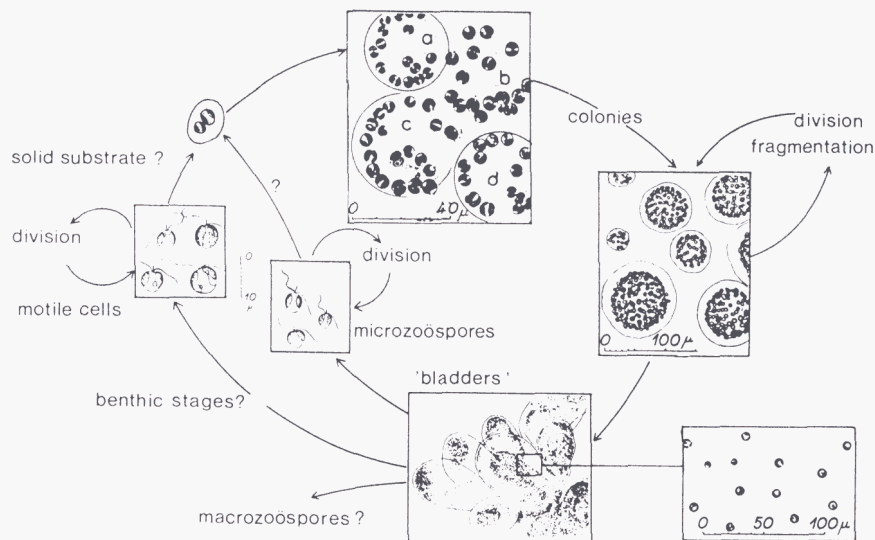

Figure 4: Hypothetical life cycle of *Phaeocystis pouchetii* (after Veldhuis, 1987).
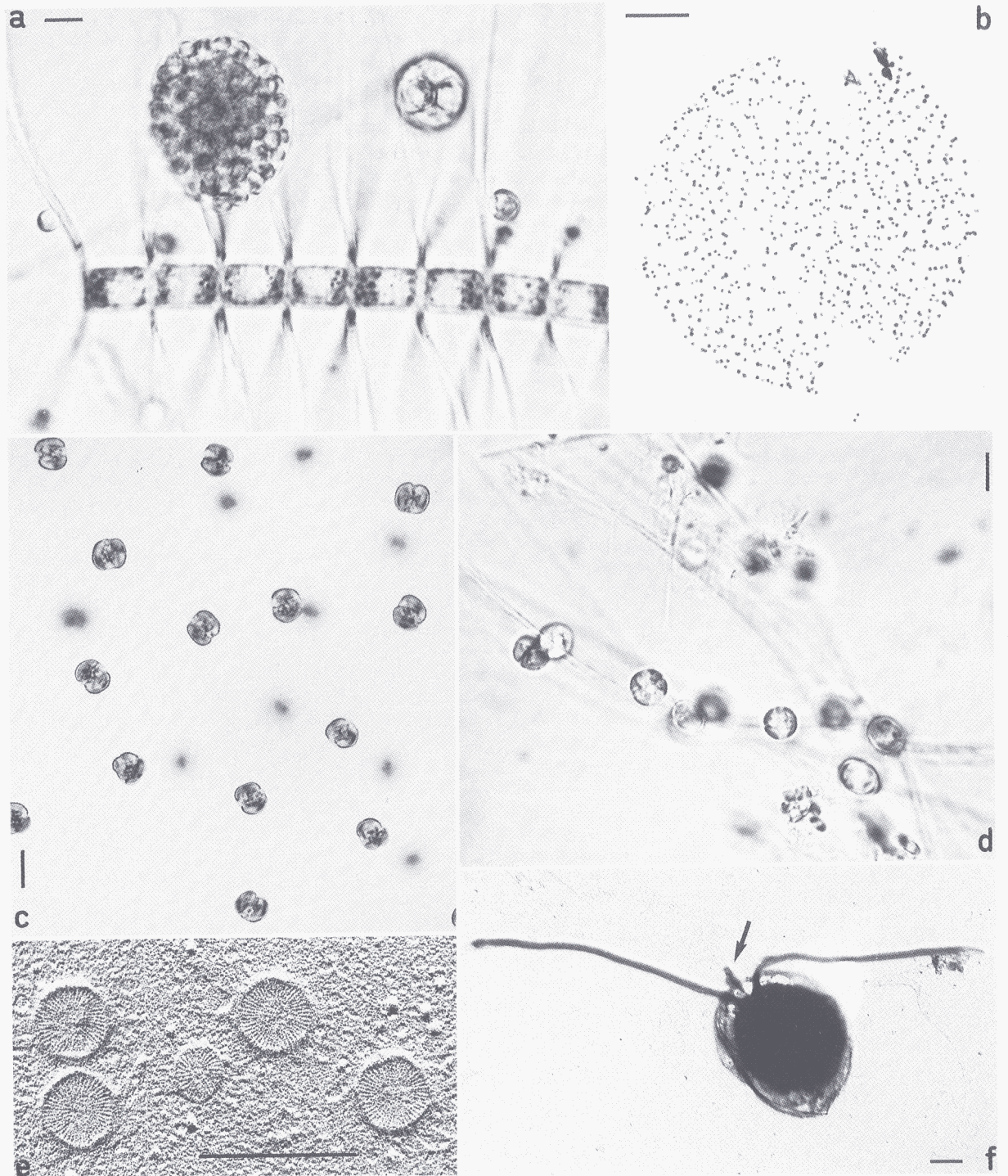
Figure 5a–f: *Phaeocystis* cf. *pouchetii*. 5a,d: single cells and colonies of different sizes attached to the setae of *Chaetoceros*; 5b: colony fixed in Lugol's iodine; 5c: detail of colony. The two chloroplasts are visible in many cells. Figure 5a,c,d: live cells, all bright field; 5e: shadowcast scales of two types. Electron microscopical wholemount; 5f: swarmer showing all three appendages; haptonema indicated by an arrow. Electron microscopical wholemount. Figure 5a–d: material from the Weddell Sea; Figure 5e,f: Danish material. Scale bars in Figure 5a,c,d: 10 μm; Figure 5b: 100 μm; Figure 5e: 0.5 μm; Figure 5f: 1 μm.

Baumann, 1987). Single cells of the two species cannot be distinguished from each other in the light microscope (no electron microscopy was performed). A physiological difference between the two species was also noted: *P. pouchetii* grew well between 0 and 14°C and *P. globosa* between 4 and 22°C. *P. pouchetii* was considered to be an Arctic or cold-water species, while *P. globosa* is common in the southern North Sea.

These findings are exciting and indicate the presence of two species. The cells illustrated from the Antarctic by Larsen and Moestrup (1989) appear, however, to combine the features used to separate "globosa" and "pouchetii". The colonies are more or less spherical, though not as regular as illustrated for *P. globosa*. They are collected from cold water like "pouchetii", but the cells are single as in "globosa", not in groups. This material indicates the existence of yet another species of *Phaeocystis*. Pending further information, including electron microscopy of all taxa, we prefer, for the time being, to use the designation *P.* cf. *pouchetii* for all
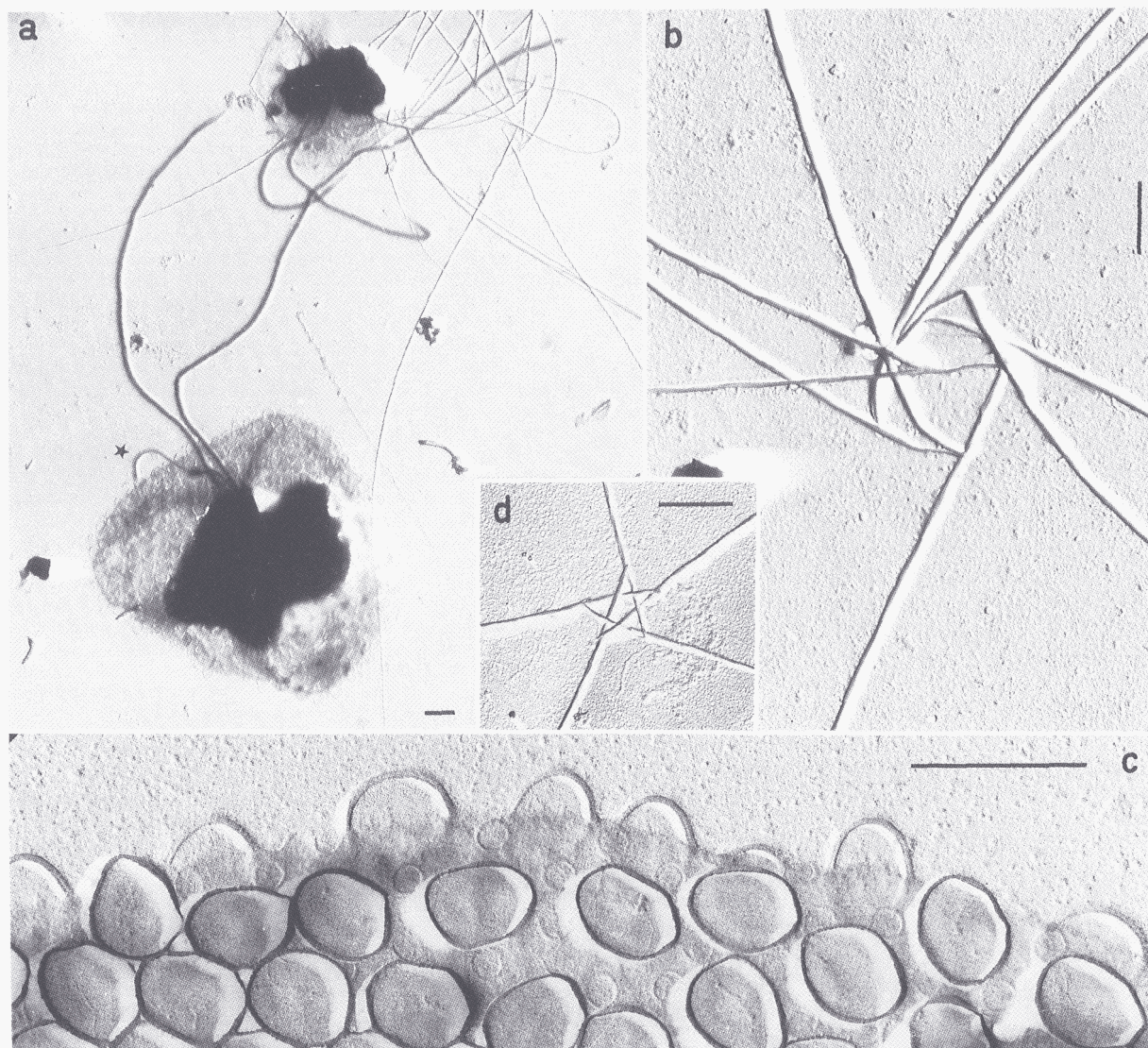

Figure 6a–d. *Phaeocystis scrobiculata* (6a–c) and *P.* cf. *pouchetii* (6d). Shadowcast electron microscopical wholemounts. 6a: whole cell, haptonema indicated with asterisk; 6b: discharged trichocyst-like material showing the nine rays characteristic of *P. scrobiculata;* 6c: the cell surface, showing both cell types; 6d: discharged "trichocyst" of *P.* cf. *pouchetii,* showing the characteristic 5-star. Figure 6a–c: material from New Zealand (6b–c from Moestrup, 1979); Figure 6d: from the Antarctic. Scale bars: 1 μm.

clones whose motile cells agree with the description of Parke *et al.* (1971).

A second species, *P. scrobiculata*, was described from New Zealand waters by Moestrup (1979). It differs in scale structure (Fig. 6c), lengths of the flagella and haptonema (Fig. 6a), and structure of the trichocyst-like material (Fig. 6b). When discharged from the cell (Fig. 6b), it forms a figure of nine rays (four pairs and one single), rather than the pentagonal star of *P.* cf. *pouchetii*. Only flagellates of *P. scrobiculata* are known.

Ecology and distribution: *P.* cf. *pouchetii* is distributed in temperate and cold waters worldwide. When present in large amounts the colonies may cause serious problems for the fishing industry, through the clogging of fishing nets, etc. Such phenomena have given the alga common names such as "brown slime" and "the brown alga" by Danish fishermen (Munk Sørensen, 1990) and "Tasman Bay slime" in New Zealand (Chang, 1983). When blooms of *Phaeocystis* are blown onto the beaches, extensive masses of foam may form, sometimes reaching several metres in thickness (Lancelot *et al.*, 1987). Other effects of the blooms include discolouring of the sea and migration of fish away from affected areas. Some storage of phosphorus is believed to take place in the mucilage of the colonies, enabling the cells to grow in water with low phosphate concentration. The blooms then appear to be controlled by the ambient concentration of nitrogen in the water rather than phosphorus. *Phaeocystis* may also utilize organic phosphorous compounds, for example from decaying diatom blooms.

Cells of *Phaeocystis* are grazed by many other organisms, including copepods, the dinoflagellate *Noctiluca*, and ciliates (Weisse, 1983; Admiraal and Venekamp, 1986; Munk Sørensen, 1990). These organisms may therefore perhaps limit and to some extent control the blooms.

Phaeocystis scrobiculata, first described from New Zealand, was subsequently found in Australia (Hallegraeff, 1983) and in temperate and tropical waters of the North Atlantic (Estep *et al.*, 1984). Studies on its ecology are much needed.

Toxicology: *Phaeocystis* is not known to form toxins that affect fish or bottom invertebrates. It produces acrylic acid (Sieburth, 1960), an antibiotic which kills bacteria in or on the colonies. Sulphur compounds are also produced, including dimethylsulphide (DMS), which is believed to evaporate to the atmosphere and contribute to the acidity of rainwater, perhaps both locally and globally (Lancelot *et al.*, 1987).

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