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Diatoms from the Congo and Zambezi Basins - Methodologies and identification of the genera

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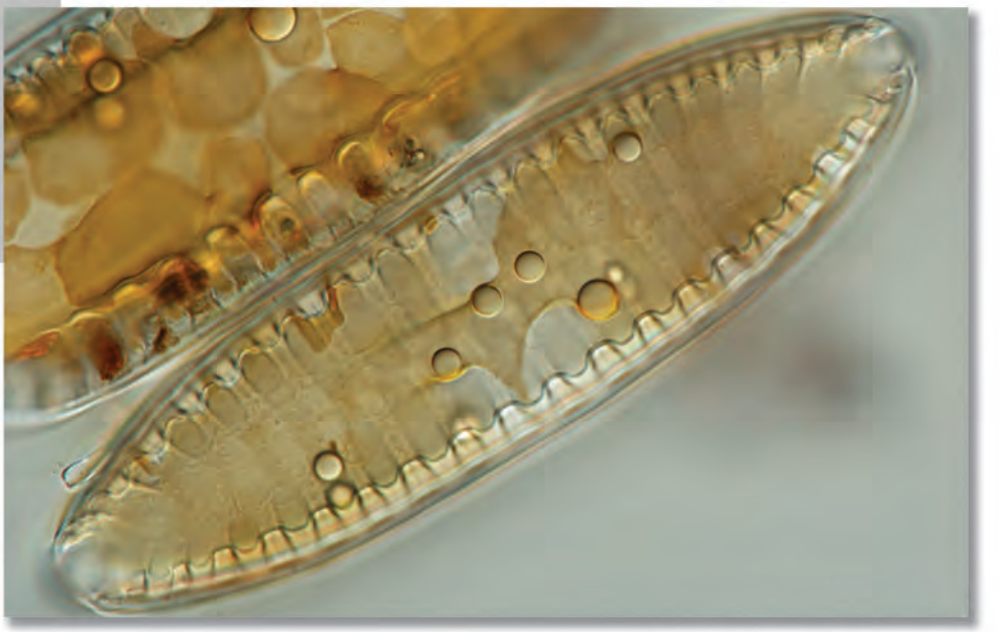

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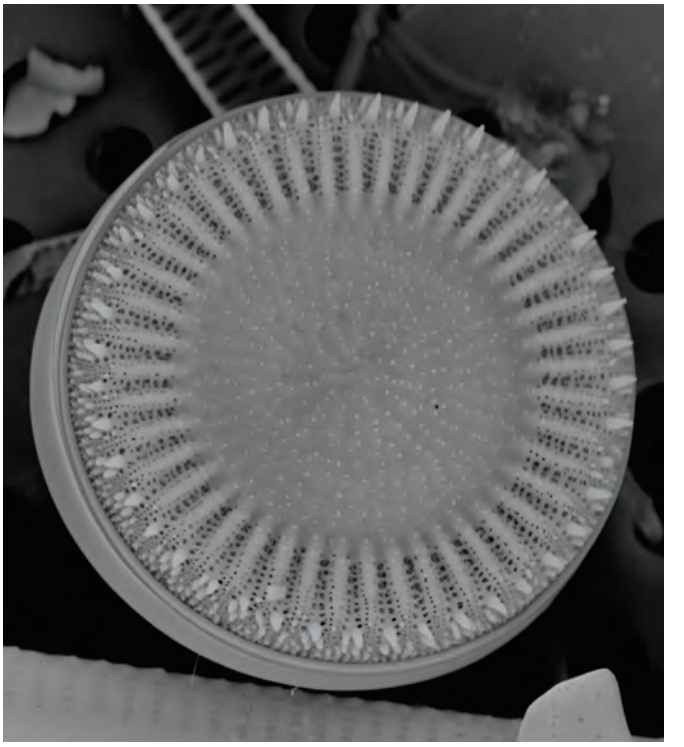

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Front cover: *Surirella* Turpin

Half-title page: *Cyclotella meneghiniana* Kützing

Preface

The Congo river basin is, after the Amazon, the second largest in the world and the Zambezi river is the fourth longest river in Africa. Both rivers and their catchments are of prime importance to millions of people. These human populations continue to increase. For example, the population in the Congo basin (c 777,000 square km^2) experiences an annual increase of c 1.7 million people. This creates rising demands (food, fuel shelter) at a great cost to the forest and to the river itself. As a result, wildlife and fish stocks rapidly decrease, mainly because of the largely uncontrolled trade in bush meat and because of overfishing. Moreover, waters in the catchments are experiencing rapid eutrophication, because of the countless domestic fires that are daily lit to cook food. Ashes are then washed into the water ways by torrential tropical rains. The fires themselves demand massive logging, which causes erosion and further degradation of water quality in these basins.

Measures need to be taken to stop the degradation of tropical river catchments in general, and those of the Congo and Zambezi rivers in particular, and many are already in place. Some of these measures deal with birth control, others impose sustainable hunting and fishing activities. Monitoring of biodiversity and water quality is urgently needed. Most of such interventions demands education, formation and training of local people.

One of the major drawbacks faced by programmes studying the biodiversity of tropical river catchments is the lack of taxonomic knowledge (also called the taxonomic impediment). Yet, estimations of fish stocks, identification of bush meat sold at local markets, the use of aquatic organisms to determine water quality, and many other monitoring activities that could provide scientifically underpinned recommendations to management, largely depend on good taxonomy.

Abc Taxa offers a welcomed forum to disseminate knowledge on a taxon that reveals itself as indicative to water quality: namely diatoms. Over the past decades, water quality monitoring research has produced a long set of (mostly locally applicable) Biotic Indices (BIs) using different biological groups. Such BIs have the advantage that they monitor the health of aquatic communities which are the result of time averaged effects of potential pollution events, that could easily be missed by point measurements of water chemistry, especially in flowing rivers. The first wave of BI largely dealt with fish, macrophytes and macro-invertebrates. Since about 20 years, however, there is an increased use of diatoms in water quality monitoring, mostly (of course) in the northern hemisphere where the taxonomy of these algae is much better known. The present book will remedy the taxonomic impediment of diatoms in the Congo and Zambezi catchments and will allow the start of new monitoring programs and the refinement of running ones.

The editors of Abc Taxa are to be congratulated for the production of this high - level monograph and so are the authors of this highly appreciated volume. May this series see light to many forthcoming issues that will relieve the taxonomic impediment in the Global South.

Koen Martens

Head of Research RBINS

Editor in Chief European Journal of Taxonomy

Abstract

Diatom research has historically been well established in Central Africa but more commonly directed towards the phytoplankton of large bodies of standing water. Recently there has been considerable international research interest on using diatoms as indicators of water quality. Usually attached diatoms originating from rivers and streams are used for this purpose. Diatom taxonomy has undergone considerable changes during the last 3 decades with many new diatom genera being established, these diatom genera are ecologically relevant in terms of establishing water quality conditions. This volume sets out to introduce researchers to the latest concepts in collection and preparation methodology as well as diatom taxonomy and nomenclature. This is achieved by illustrating and discussing methodological concepts, providing a fully illustrated glossary and illustrating, by a variety of means, the most common diatom genera occurring in the Congo and Zambezi catchment region.

Key words - *Bacillariophyta*, morphology, taxonomy, tropical Africa, water quality

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1. Introduction

1.1. Diatom research in Central Africa

The African Great Lakes, Tanganyika, Malawi and Victoria and surrounding regions attracted the interest of several phycologists at the end of the 19th century. The first publication appeared in 1880 written by Dickie who reported on attached algae on the aquatic phanerogams (seed-bearing plants) of Lake Malawi (also called Lake Nyasa or Lake Nyassa): he found a total of 38 taxa of which 31 are diatoms. The research on the diatoms of Lake Malawi/Nyasa and lotic ecosystems in the surroundings was continued by Müller (1897, 1903, 1904, 1905, 1910) resulting in the description of 126 new diatom taxa (species, varieties and forms). Müller also examined material from Lake Victoria from which he described another ten new diatom taxa, and one new variety from Mount Kilimanjaro. West (1907) reported on the algae of the three Great Lakes including a total of 58 diatom taxa, 26 from Lake Malawi, 19 from Lake Victoria and 37 from Lake Tanganyika. The publication included the description of nine new taxa, all from Lake Tanganyika. Several diatoms from this lake, new to science were depicted by Hustedt in Schmidt's atlas of diatoms (Schmidt 1914, 1922, 1925), followed later (Hustedt in Huber-Pestalozzi 1942) by an elaborated description. In addition to the studies of Müller the diatoms from Lake Victoria were studied by Ostenfeld (1908, 1909) who reported 15 and 9 taxa respectively, Schröder (1911) described a new *Rhizosolenia* species (now transferred to the genus *Urosolenia*), Virieux (1913) reported 25 taxa and one new variety, Woloszynska (1914) reported 34 species of which two were new species, one a new variety and one a new forma, and Bachmann (1933) mentioned 18 taxa including one new variety. A first overview of all taxa reported from the Great Lakes was published by Van Meel in 1954, followed by an updated checklist in 1993 (Cocquyt *et al.* 1993). Later the lacustrine and riverine algal diversity in the African Great Lakes area was discussed in Cocquyt (2006). Besides the Great Lakes, diatom investigation in the region was also carried out in rivers, ponds, etc., e.g., Bachmann (1938), Caljon (1987, 1988) and Mpawenayo (1996).

Diatom research in D.R. Congo, formerly the Republic of Zaire (1971-1997) and Belgian Congo (1908-1960) started with Zanon (1938) who studied the diatoms from the region of Lake Kivu. He reported 263 taxa belonging to 33 genera. Seventeen taxa were new to science of which ten were *Pinnularia* species; the others belonging to *Cocconeis*, *Cymbella*, *Eunotia*, *Neidium* and *Synedra*. In the mid-20th century Hustedt (1949) published a treatise on the diatoms of the Albert National Park in Belgian Congo, nowadays the Virunga National Park in D.R. Congo. Among the 55 new taxa, 25 belong to *Nitzschia*, the others are spread over 12 other genera. Some research was also done on the Congo River. In 1948 Kufferath reported 25 taxa in the plankton of the Congo River near Makanza, previously called Nouvelle-Anvers, midway between Kisangani and Kinshasa, including one new *Nitzschia* species (Kufferath 1956a). In 1956 he mentioned eight taxa near the isle of Mateba (Kufferath 1956a) and 44 taxa of which 10 were new

from Banana Beach (Kufferath1956b), both localities are close to the mouth of the Congo River in the Atlantic Ocean (Kufferath1956a) and include marine species. Not only the Congo River but its tributaries including the Lindi River, the Tshopo River and small rivers and ponds in Kisangani were studied by Golama (1996) who found 278 diatom taxa. A new *Gomphonema* was described from the Tshopo River (Compère 1995). Some years earlier a new *Stauroneis* was described from a fish pond in Kinshasa (Compère 1989). Cholnoky (1970) described three new species among the 93 taxa he observed in the Bangweulu swamps. In addition to the papers mentioned, there also exist a limited number of unpublished thesis studies conducted at universities in D.R. Congo.

Diatom research in Zambia started only recently, with exception of studies carried out in the Bangweulu swamps by Cholnoky (1970). Lake Kariba, located on the border of Zambia and Zimbabwe was also the subject of algal investigations. Thomasson (1965) reported ten diatom taxa, *Aulacoseira granulata* being the dominant species. Diatom communities and their seasonal succession were studied by Hancock (1979) as well as the epiphytic diatom community on underwater leaves of *Salvinia molesta* D.S. Mitchell (water fern) (Hancock 1985). Cronberg (1997) mentioned the presence of 155 algal species in Lake Kariba based on a study of 152 plankton samples collected between 1986 and 1990. Among these only thirteen taxa belong to the diatoms, seven are *Aulacoseira* species. A later study in this lake (Muzavazi *et al.* 2008) also reported twelve diatom species, of which only four could be assigned a species name.

1.2. Diatom research related to water quality in Central Africa

Attempts to use diatoms as a tool for water quality of rivers in Central Africa started only recently. Some small rivers and streams south of Gombe Stream National Park, Tanzania (Bellinger *et al.* 2006) have been the subject of such an investigation. A number of indicator species tolerant to eutrophication were found and the Trophic Diatom Index (TDI) (Kelly & Whitton 1995) values showed significantly higher impact in deforested than in forested streams.

Utete *et al.* (2013) studied the impact of aquaculture on the water quality in Lake Kariba based on physical and chemical variables, but not using diatoms. In East Africa some research was done over the last few decades on diatoms in relation to water quality, mainly through PhD theses in Kenya and Ethiopia (e.g., Lung'ayia 2002, Beyene 2010, Beyene *et al.* 2009, 2014).

This is in contrast to South Africa which has a long history of diatom research related to ecological research and water quality (Taylor & Cocquyt in press). Cholnoky can be considered as the founder of diatom studies in South Africa. His intensive and extensive studies on the taxonomy and ecology of the diatoms was also the start of the South African Diatom collection, nowadays owned by the South African Institute for Aquatic Biodiversity and housed at the North-

West University in Potchefstroom, South Africa. Cholnoky had little faith in only the chemical analysis of water quality and stated that "*the chemical and physical characteristics of a water body could be determined more reliably and easily through a study of the diatom associations found living in it*" (Cholnoky 1968). The application by Cholnoky of the Thomasson (1925) community analysis on benthic diatom community composition was a forerunner of modern autecological indices. The method allows comparisons between sites in the same river, or the tracking of changes at a single site, but only one aspect of the water chemistry is chosen. When we consider for example the amount of nitrogenous effluent, the sum of all specimens belonging to the genus *Nitzschia* is calculated as an abundance value relative to the total of the cells enumerated from a particular diatom community.

Why the genus *Nitzschia*? *Nitzschia* is a genus known generally to be nitrogen heterotrophic and be able to utilise organically bound nitrogen. Therefore the relative abundance of this genus in a sample gives a reflection of the amount of nitrogenous pollution at the site studied. A higher percentage indicates a higher degree of impact in terms of nitrogenous effluent. Another example is that a pH gradient can be tracked in a river system by using the abundance values of the diatom genus *Eunotia*. This genus is known to prefer acid environments, to be acidobiontic. Cholnoky (1968) obtained good results using this index. However, the user of the Thomasson analysis method needs to have an in-depth knowledge of the autecology of individual diatom genera and species to be able to draw accurate environmental conclusions based on diatom community composition. Several years later, Archibald (1972) and Schoeman (1976) attempted to develop better approaches using diatoms in water quality monitoring. Their development was parallel to the development in water quality monitoring in Europe. The first proved to be unsuccessful. Schoeman (1976) simplified the community analysis method used by Cholnoky: he divided the diatom associations into four groups, each with their own particular ecological requirements. The table of results is thus shortened compared to the long species tables used by Cholnoky.

Schoeman (1976, 1979) came to the conclusion that these diatom groupings (or associations) could be successfully employed to assess the quality of running waters especially in regard to their trophic status. Unfortunately the investigation of diatoms as indicator species in South African freshwater ecosystems was then interrupted to be restarted at the beginning of the 21st century. Bate *et al.* (2002) attempted to relate a descriptive index, based on a dataset for the environmental tolerances of diatom species found in the Netherlands (van Dam *et al.* 1994), to water quality in South Africa. The "van Dam *et al.* index" includes pH, conductivity, oxygen requirements, trophic status, saprobic status and habitat requirements of a selected number of diatom species found in waters of the Netherlands (van Dam *et al.* 1994). Bate *et al.* (2002) concluded that benthic diatoms could be useful for water quality investigation in South Africa and that they give a time-integrated indication of specific water quality components, but that the particular data set, generated in the Netherlands, could not be transposed directly for use under South African conditions.

Taylor (2004) and Taylor *et al.* (2007a, b) continued this investigation by testing several numerical diatom indices developed in Europe for indicating water quality in some of the most important river systems in South Africa. They concluded that in general these European indices could be used with success in South Africa but that there are, however, some potential problems (Taylor *et al.* 2007b). In particular, the list of taxa included in the indices needs to be adapted to the studied region. Although most European diatom indices may be used in many regions as they are based on the ecology of widely distributed or cosmopolitan taxa, special attention should be paid to taxa occurring in pristine waters and to endemic taxa, absent in the indices reference lists. When these taxa are abundant the inferred water quality may be misinterpreted.

Another problem that arises is the rapid changes in diatom taxonomy, especially at the genus level. Some European indices were erected in the seventies or in the eighties of the last century and have never been revised. The positive result in the study of Taylor *et al.* (2007b) is they demonstrated that many widely distributed diatom species found in South Africa have similar environmental tolerances to those recorded for these species in Europe and elsewhere.

1.3. Aim of the present diatom book

The aim of the present work on diatoms is twofold. On the one hand we want to encourage and facilitate the study of diatoms as a useful tool for water quality monitoring. On the other hand we want to give an overview of the most common diatom genera which can be observed in the Congo and Zambezi basins. Accurate identifications at this level form the basis for further taxonomic studies. Nomenclatural and taxonomic changes and the description of numerous new diatom species and genera during the past decades make the study of diatoms in tropical Africa complex. In the present work the recently accepted diatom taxonomy at genus level is illustrated for the most common genera of tropical Africa using schematic computer generated drawings. On these drawings the typical characteristics, or characteristics important for identification of species, are highlighted in red, often on a duplicate of the drawing. Moreover, light microscopic micrographs are presented from cleaned material, all from the Congo and Zambezi basins, to show the typical valve ornamentations on which identification is based. Where possible light microscopic micrographs from living material are given to show the plastid(s) structure typical for the genera; these micrographs however are mainly from Southern African material. Only if both authors of the present work were completely certain of the species identity the species name is added to the figure captions. For most genera the ultrastructures of the diatom valves are illustrated with photographs taken with a scanning electron microscope; the material used originates from the Congo and Zambezi basins. A scale bar is added to all micrographs to indicate the size of the valves and the ultrastructures. Light and scanning electron microscope investigations were performed at the North-West University, Potchefstroom, South Africa and at the Botanic Garden Meise, Belgium.

2. Definition of a diatom

Diatoms or Bacillariophyta are a major group (phylum) of microscopic eukaryotic algae, unicellular but often forming colonies. The cell wall, called a frustule, is highly differentiated and heavily impregnated with silica (hydrated silicon dioxide) and is composed of two valves connected by girdle bands (Fig. 1). The valves and girdle bands fit together very tightly preventing flux of material across the cell wall, which can only take place through openings (pores and slits) in the frustule. A thin layer of organic material (membrane) is also present on the outside of the cell wall. All diatoms probably secrete polysaccharides; some may diffuse in the surrounding environment while others may remain around the cell as stalks, pads, threads or even capsules. This thin organic layer obscures the details of the silica cell wall ornamentations which are used for identification. For this reason diatom cells must be cleaned (oxidation to remove the organic material) before making permanent light microscopic slides and before making preparations for scanning electron microscopic investigation.

The origin of the diatoms may go back to the early Jurassic period (201.3 Ma) or even before, although well-documented fossil records only extend to the middle Cretaceous (127-89 Ma). The diatoms found in the Upper Cretaceous sediments are all of marine origin; most genera are now extinct. Evidence for the presence of freshwater species is found from the late Eocene (38 Ma) and Miocene (23 Ma) onwards.

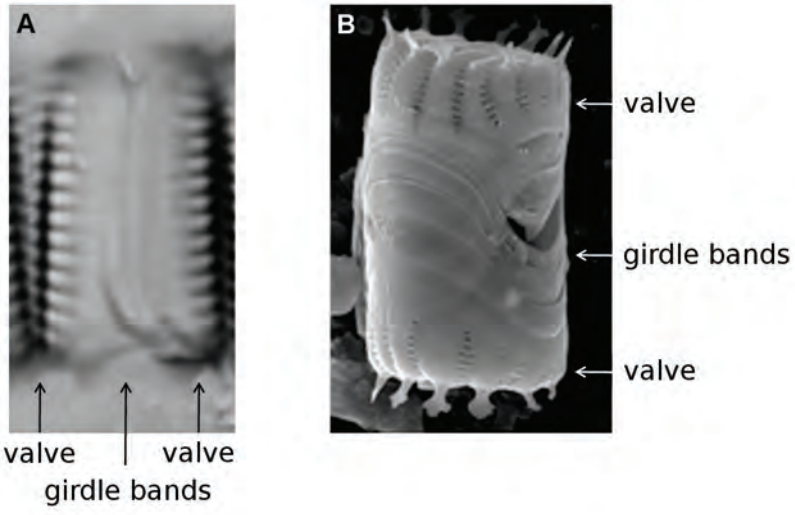


Fig. 1. Diatom frustules, composed of two valves connected by girdle bands. A. Light microcopy (LM). B. Scanning electron microscopy (SEM).

Algae traditionally formed part of botanical studies as they were considered in the past as plants: they are photosynthetic organisms, making their own organic material using sunlight (autotrophs). In the system of the five kingdoms (Whittaker 1969), they are part of the Protista (the other kingdoms are the Plantae, Animalia, Fungi and Monera or Bacteria); later the Monera were divided into the Eubacteria and the Achaebacteria (Woese & Fox 1977). A more recent system (Woese *et al.* 1990) divides all living organisms in three domains: Bacteria, Archaea and Eukarya or Eukaryota. The diatoms are part of the last domain as they possess a true nucleus encapsulated in a nuclear membrane.

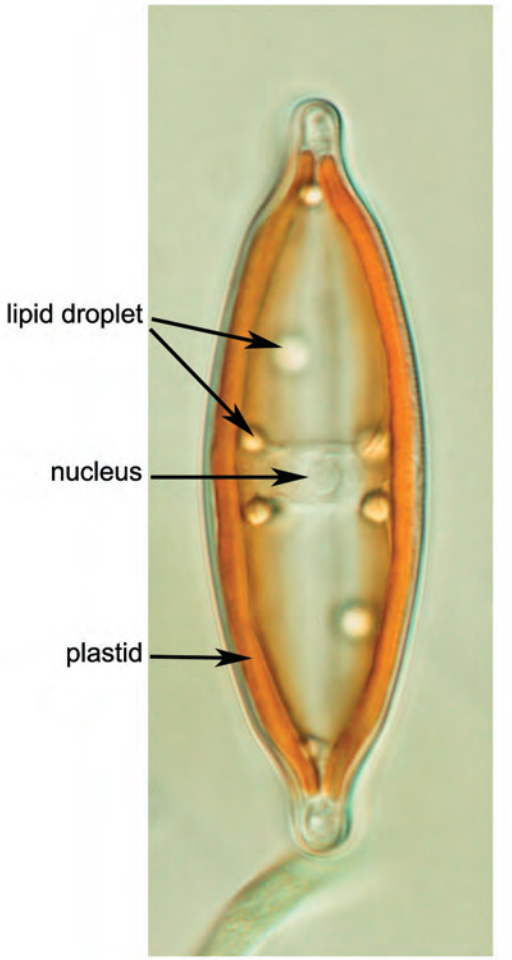


Fig. 2. Living diatom cell showing the plastid, lipid droplets and the nucleus.

3. Living diatoms

Diatoms are a major component of the primary producers in aquatic ecosystems. They can live free in the water column or be attached to a substratum. When they are free living, floating in the water column, they are called planktonic. When the entire life cycle takes place in the water column they are euplanktonic; when they become suspended in the plankton after being detached from the substratum they are known as tychoplanktonic. Tychoplankton occur mostly near-shore in the littoral zone of lakes. In rivers, suspended benthic organisms form part of what is known as the potamoplankton. Species that live on the bottom of a waterbody are called benthos. Benthic species can be attached to the bottom and are then sessile, or they can be motile (or both). The bottom can consist of a hard substratum such as stones, pebbles, boulders, rocks, or of loose sediments such as sand, mud, silt, clay. The term periphyton is used for species attached on submerged substrata; depending on the substratum we can have epiphytic species when they are attached to aquatic plants, epipelic when they are living on sediments and mud, epixylic when they are attached on wood, epilithic when they are living on stones, rocks, boulders, etc., and epipsammic when they are attached to sand grains.

4. Morphology of the diatom cell

Diatoms are unicellular algae with a siliceous cell wall, the frustule. Besides the photosynthetic pigments chlorophyll a and c and fucoxanthin they possess β-carotene, diatoxanthin, diadinoxanthin, violaxanthin, antheraxanthin, and zeaxanthin and storage products (oil/lipid droplets) (Fig. 2, previous page). Two main groups, based on cell symmetry can be distinguished: the radially symmetric or centric diatoms (Fig. 3) and the bilaterally symmetric or pennate diatoms (Fig. 4). In freshwater, the first are commonly found suspended in the water column while the second are more typical of benthic habitats or are temporarily re-suspended in the water column, although several *Nitzschia* (pennate diatom genus) are a typical component of the phytoplankton in tropical African lakes.

Other aquatic organisms can also possess siliceous structures which can be confused with diatoms. The first are structures called spicules, formed by sponges. They are composed of a solid silica body having a central empty canal almost as long as the entire length of the spicule. Several kinds of spicules exist, e.g., gemmasclere, microsclere and megasclere (Fig. 5).

The second type of siliceous structures are phytoliths, silica bodies formed in or between plant cells. Phytoliths are also solid silica structures with a very large diversity of shapes, often genus specific (Fig. 6). The solid silica structure can have ornamentations, such as cones which can be surrounded by smaller, satellite cones.

A third silica structure we can mention are cysts, formed by other algae such as Chrysophyta and Dinophyta. Cysts are characterized by an apical pore and the

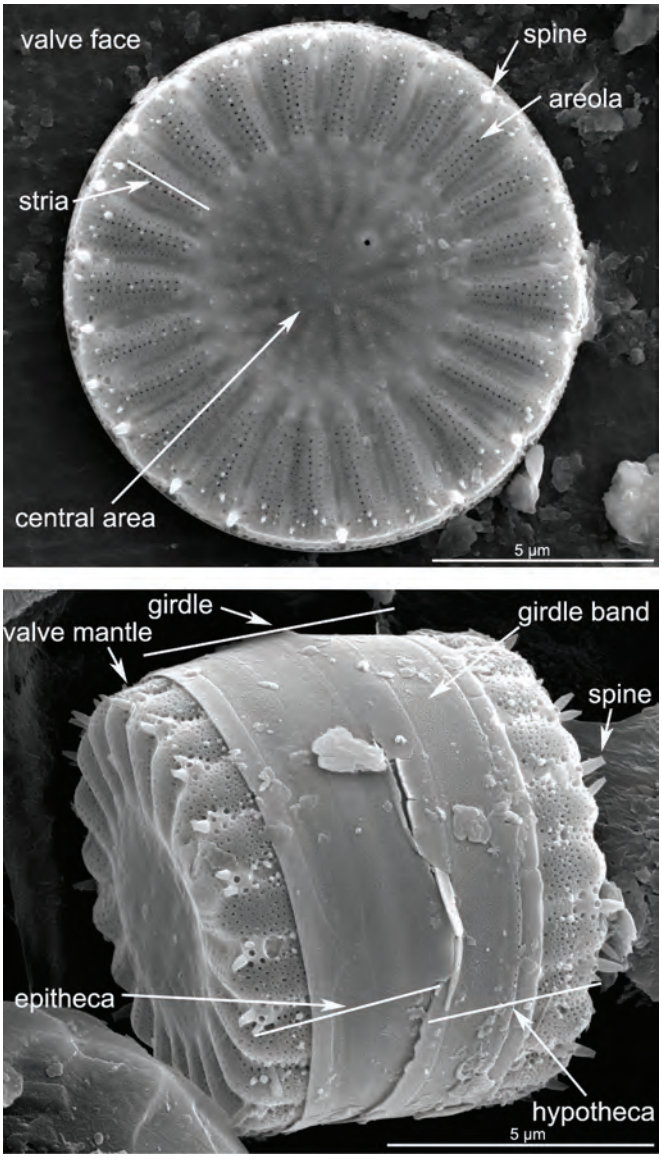


Fig. 3. Centric diatom showing the different structures. SEM. Top: valve view. Below: girdle view of an entire frustule composed of two valves and several girdle bands.

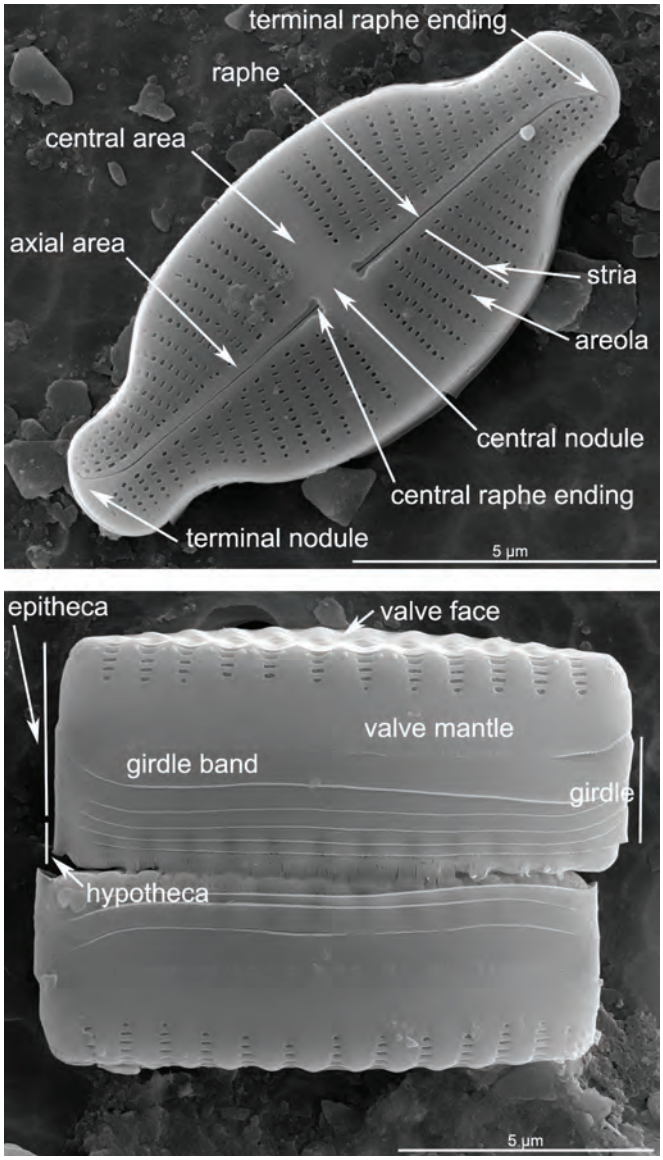


Fig. 4. Pennate diatom showing the different structures. SEM. Top: valve view. Below: girdle view of two entire frustules composed of two valves and several girdle bands.

wall can be smooth or ornamented (spines, verrucae, ridges) (Fig. 7). Another structure that can be confused with a diatom frustule is the lorica, a shell-like protection, of *Trachelomonas,* a genus within the Euglenophyta (Fig. 7). The wall

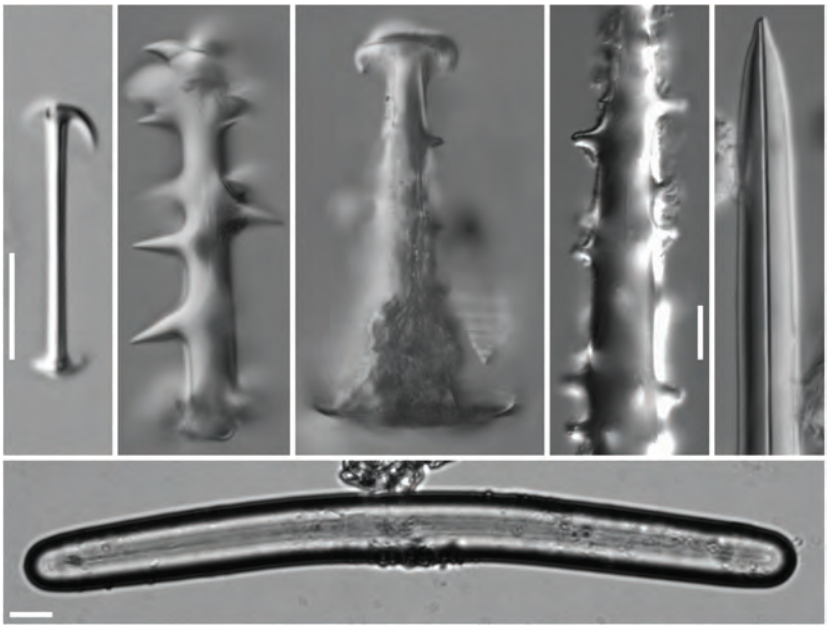


Fig. 5. Sponge spicules, different types. LM. Scale bars = 10 µm.

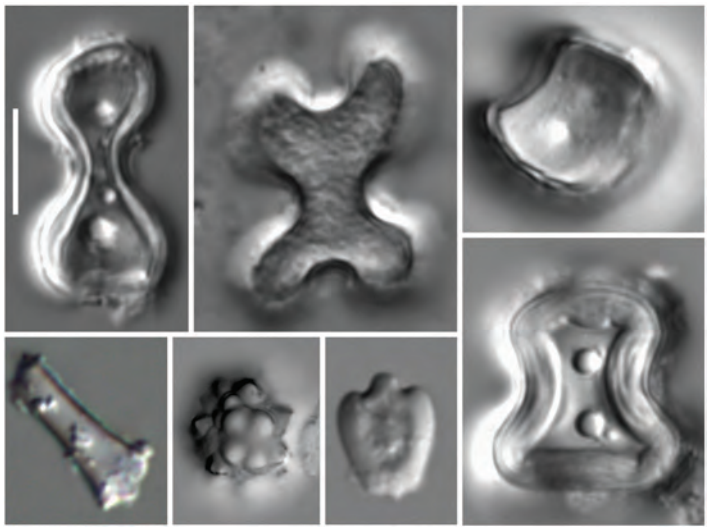


Fig. 6. Phytoliths, different types. LM. Scale bar = 10 µm.

of the lorica, in which silica can be incorporated, can be smooth or ornamented with small spines and is, like the mentioned cysts, characterized by an apical gap from which the flagellum protrudes.

Note that all the pictures presented of these silica bodies (sponges, phytoliths, cysts and lorica) are from material sampled in the Congo and Zambezi basins.

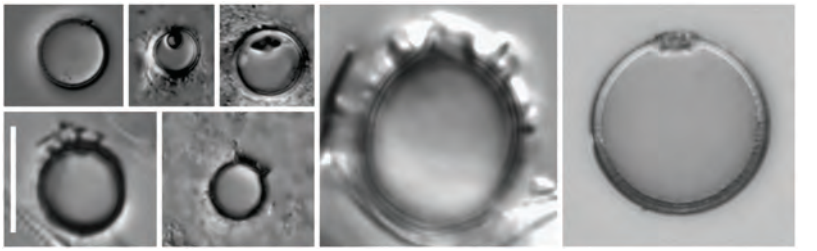


Fig. 7. Different types of Chrysophyte cysts on the left, a Dinophyte cyst in the centre, and the lorica of a *Trachelomonas* (Euglenophyte) on the right. LM. Scale bar = 10 µm.

5. How to recognize diatoms in natural environments

Periphytic (attached) diatom communities may be seen as a thin golden-brown film covering the substrata (Fig. 8). This film can be very thin but can also become thicker and much more obvious during certain times of the year when environmental conditions such as light, temperature and nutrient availability favour diatom growth. The film formed by the diatoms feels slimy or mucilaginous. Attached diatoms grow on all kinds of substrata including solid substrata such as pebbles, boulders and rocks and submerged stems and leaves of aquatic and/or submerged macrophytes (Fig. 8). Man-made objects such as paper, plastic bags and glass may be colonized by diatoms. Diatoms may even be found in soils, with several taxa adapted to survive desiccation. Diatoms form a component of the phytoplankton community where they live in suspension, or attached to other algae. An essential aspect when using diatoms to infer ecological conditions is to sample well colonized substrata. It takes several weeks for an uncolonized substratum to be fully colonized by diatoms. During that time a process of succession in diatom species and abundances can be observed.

The colonization of a substratum by diatoms takes place in various phases and by different diatoms during succession (Bijkerk 2014). Pioneer diatoms, often belonging to small *Achnanthidium* sp. (e.g., *A. minutissimum*), affix themselves to the substratum by small mucilaginous stalks. During succession they are overgrown by other species belonging to among others *Gomphonema*, *Encyonema*, *Rhopalodia* spp. These are attached also to the substratum by mucilaginous stalks but longer ones, or they are attached to the other diatoms or their stalks. The diatom film found

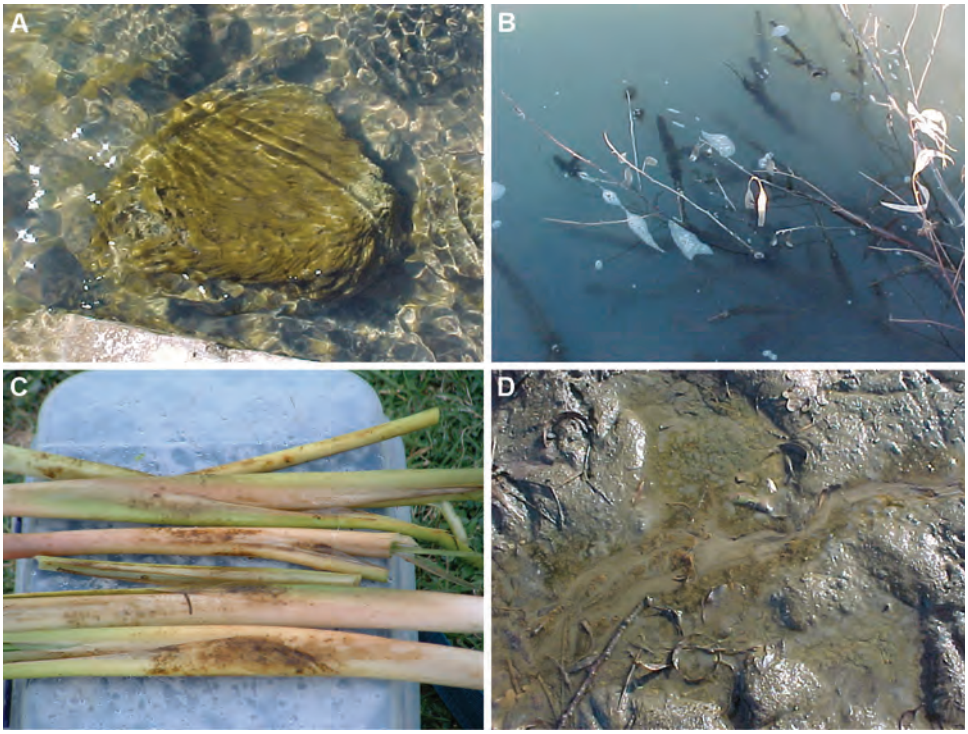


Fig. 8. Periphytic diatom communities on various substrata. A. Thick diatom layer (biofilm) attached to boulders. B. Thick diatom layer on submerged parts of tree branches. C. Thin diatom layer attached to submerged stems of *Phragmites australis* (Cavanilles) Trinius ex Steudel. D. Diatom layer on mud.

on a substratum can thus be compared to a forest with several layers such as the canopy, the understory, the shrub and the ground layer.

Diatoms can be attached in various ways to the substratum: mucilage stalks, mucilage tubes, mucilage pads (Fig. 9). Diatoms often form colonies, in particular this adaption allow planktonic species to remain suspended in the water column. The colonies can have the form of a chain, be stellate or zigzag (Fig. 10).

6. The role of diatoms in aquatic food webs

Diatoms are key organisms in aquatic ecosystems, together with representatives of the other micro-algae. They are autotrophic, making their own organic material from inorganic nutrients and sunlight through photosynthesis. Phosphorus (as dissolved orthophosphate) and nitrogen (as nitrate, nitrite or in the form of ammonium ions) are

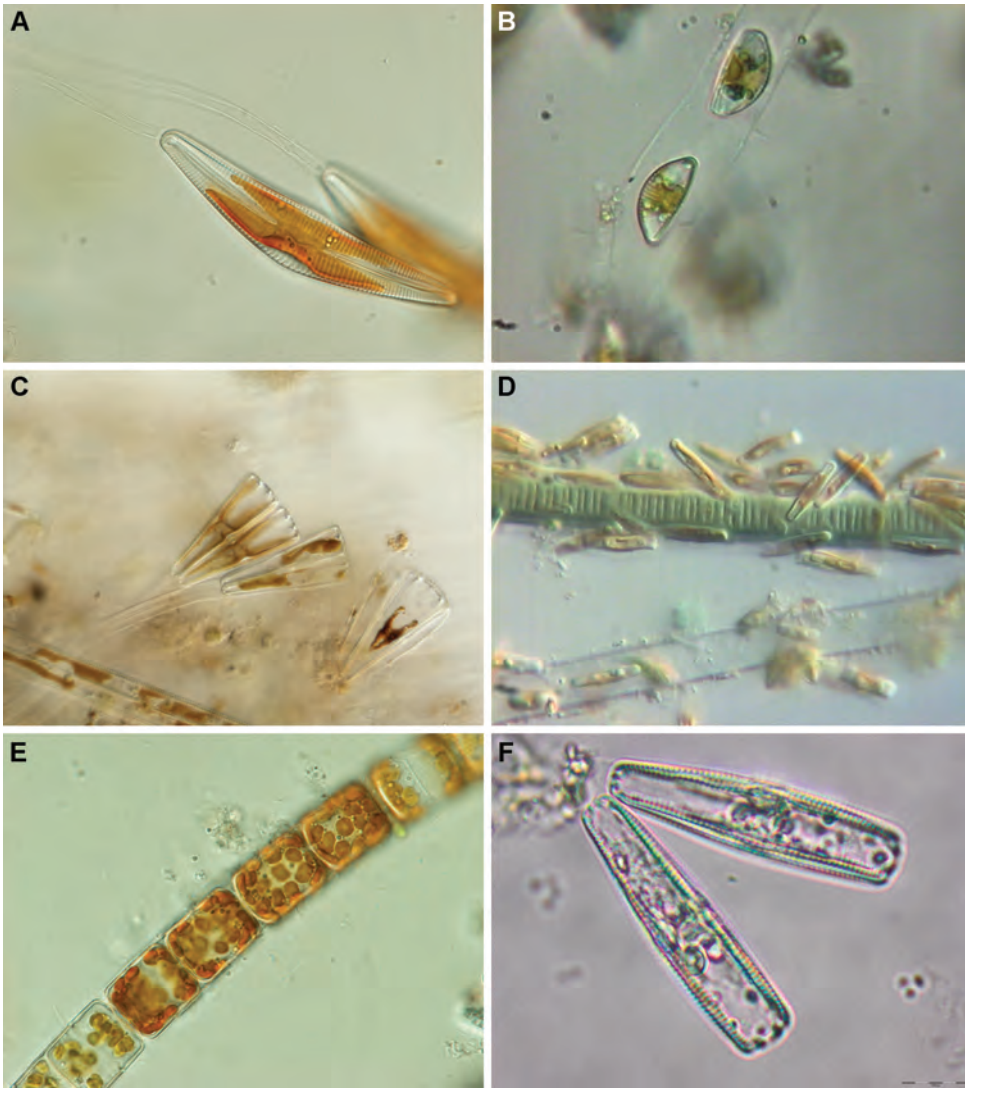


Fig. 9. Living diatom cells. LM. A. *Cymbella* sp. attached to a substratum with a mucilage stalk. B. *Encyonema caespitosum* inhabiting a mucilage tube. C. Cells of *Gomphonema* sp. with dichotomously branching mucilage stalks. D. Cells of *Achnanthidium minutissimum* attached to a *Lyngbya* sp. (filamenteous bluegreen alga) by means of short mucilage stalks. E. Chain forming cells of *Melosira varians* attached to each other by mucilage pads. F. *Afrocymbella barkeri* attached to a substratum with short mucilage stalks.

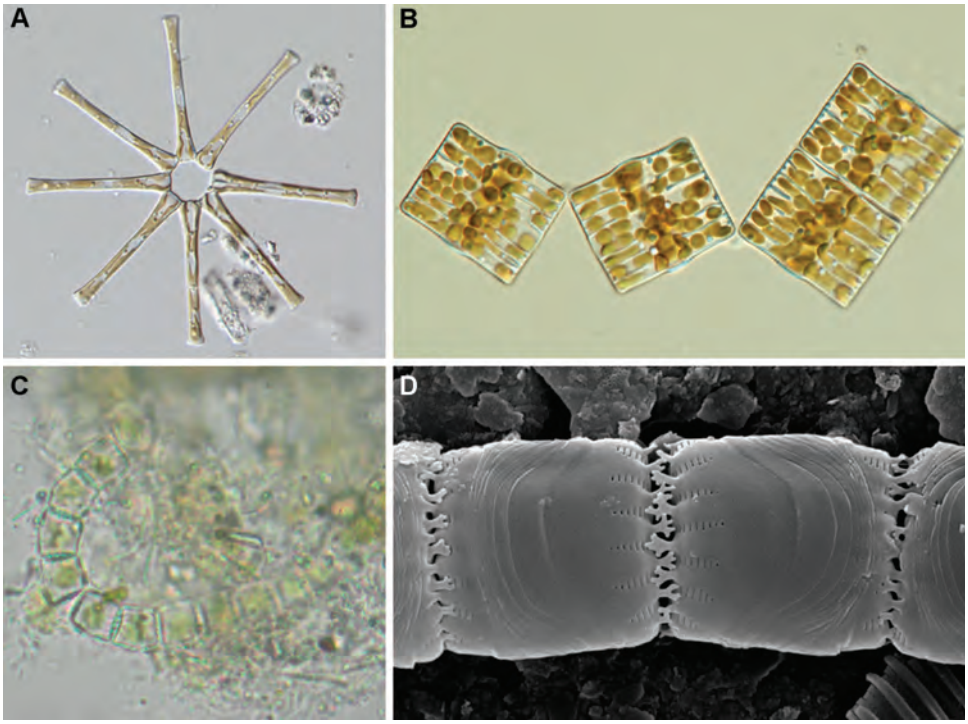


Fig. 10. Various types of colonies formed by diatom cells. A-C: LM, D: SEM. A. *Asterionella formosa* cells forming a stellate colony. B. *Tabellaria flocculosa* cells forming a zigzag colony; cells are attached to each other at the corners by mucilage pads. C. *Staurosirella* sp. cells forming a chain; cells are attached to each other, valve face to valve face, by connecting spines. D. *Staurosira* sp., detail of connecting spines.

among the most important nutrients for diatom growth, iron and other trace elements are also necessary. Being part of primary production they lie at the base of the food web and are consumed by heterotrophic organisms which are secondary producers. The consumers of diatoms range from microscopic ciliates to grazing molluscs and plankton filtering fishes. Changes in the environment will first become apparent at the base of the food web i.e., changes within the algae community including diatoms. For this reason diatoms are often used as bio-indicators in the study of water quality. The advantage of using diatoms in water quality analyses is that, besides the ease of sampling (section 7) they can be preserved for relatively long periods.

Identification of diatoms is based on the morphologic characteristics of the frustule/valve, a rigid structure (cell wall) composed of silica, and for this reason samples can be fixed in situ and stored with little concern that the cell wall will deform or rapidly

degrade. Immediate analysis is not required in contrast to phytoplankton analyses. However it is still worth examining the living communities and noting not only the other micro-algae and their interactions with the diatoms, but also the amount of dead diatoms (empty frustules). In lakes especially more than half of the observed diatoms can be empty frustules and sometimes only a minor portion are in fact living diatom cells.

7. Field collection methodology

7.1. Epilithon

The preferred substratum used for the diatom-based monitoring for water quality assessment in riverine environments comprises cobbles and small boulders or rocks. Most of the diatom indices developed and tested throughout the world can be applied using the diatom communities found on this substratum.

The main advantage with using the epilithon is that cobbles and small boulders are generally widely available throughout the entire length of a river or stream, from the source up to the mouth. Moreover the epilithic diatom community has been studied intensively around the world, their ecology is better known and the performance of the major diatom-based indices on this substratum is well understood at least in the case of Europe, North America and South Africa. In the absence of this substratum alternative man made substrates can be used such as bricks, pieces of concrete, bridge supports, pillars, channel walls, etc., and in the absence of these artificial substrata can be introduced. However, if this is the case sampling should only be done after these artificial substrates have been submerged for at least four weeks, allowing diatoms to colonize them. A disadvantage of this method is that one is not sure if the diatom community has already attained its climax structure after the four weeks and there is also the rather high probability that the substratum is removed by third party or animals before sampling can take place. Sampling from this substratum is achieved as follows. At least five cobbles or pebbles, of a size that can safely be picked up, are removed from the river or stream. The upper surfaces, those exposed to the flow of the river, are then firmly brushed with a small plastic brush such as a tooth or nail brush (or a knife) into a collection tray. All the substrata are pooled together and form a single sample. This sample is then well mixed and placed in a suitable labelled bottle. Other hard substrata which cannot be removed from the river may be sampled *in situ*. This is best achieved by scraping the substrata with a knife, spoon or with a tooth brush. The tooth brush tends to trap the biofilm rather well between its bristles and the brush can then be repeatedly rinsed into the sampling tray or other receptacle until sufficient material has been collected. Preservation in the field is recommended except when the cells are to be examined in their living state. Preservation is achieved using ethanol to a final concentration of 20% by volume. In the absence of ethanol formalin may be used but if unbuffered it is not suitable for long term preservation. After each sampling the apparatus used (tooth brush, knife, collection tray) must be thoroughly cleaned with distilled water before collecting a new sample in order to

avoid contamination. If distilled water cannot be carried into the field, the apparatus should be washed after the sampling event in the stream and then again in the stream at the new sampling site before collecting the sample.

7.2. Epiphyton

Although cobbles and small boulders are generally widely available, this is not the case for many rivers in D.R. Congo among which a prime example is the Congo River. Even if such a substratum is available the depth and velocity of flow of this river make obtaining them dangerous. An alternative is then to sample the diatom community growing on permanently submerged, usually rooted, parts of plants, belonging either to submerged macrophytes such as *Potamogeton* spp., *Ceratophyllum* spp., or emergent macrophytes, such as *Phragmites* spp., *Vossia cuspidata* (Roxburgh) Griffith, *Papyrus* spp. It is also possible to sample from *Eichhornia crassipes* (Martius) Solms and *Pistia stratiotes* Linnaeus but it is better to avoid these as they are floating plants and are easily transported and thus not representative of the sampling locality. In the European Integrated Water Policy *Phragmites* is often used as substratum. *Phragmites* was subjected to intensive studies, among others on the colonization by diatoms (e.g., STOWA 2014). In these studies it was found that maximal diatom growth on *Phragmites* stems was attained after five weeks and species diversity stayed more or less constant after seven weeks (Van Dam in STOWA 2014). Species quantity and composition is also dependent on the place the plant is growing in relation to the river bank. Therefore it is important that different parts of different plants are collected: at least 5 pieces of about 5 cm each on which a layer of diatoms/biofilm is clearly visible. These pieces are put together in a plastic zip bag with as little water as possible from the sampling locality. Close the bag and rub the bag with the plant pieces firmly between your hands so that the attached diatoms come loose from the substratum. A brown-greenish liquid will become visible, containing the diatoms. If the plant material is too dry, add a small amount of distilled water. Put the brown-greenish liquid in a bottle and fix immediately in the field with ethanol or formalin, see comments in section 7.1.

7.3. Epipsammon

Diatoms growing on sand grains, epipsammon, form colonies which are different from the epilithic and epiphytic communities. Sand as substratum is subject to abrasion as a result of movement of the grains where only strongly attached taxa can survive. Some typical taxa are *Cavinula lilandae* Cocquyt, M. de Haan & J.C. Taylor recently described from a stream in D.R. Congo and *Cymbellonitzschia minima* Hustedt, an endemic species of the East African Great Lakes. This habitat is not recommended for studies for biomonitoring, however it may form an important part of biodiversity studies. Sampling may be achieved in several ways. If the visible brownish biofilm is thick enough it can be gently scraped from the surface with a spoon or sucked up using a large pipette or syringe. Alternatively the very top layer of sand can be collected and rinsed to free the diatoms from the grains. Motile diatoms may be sampled by collecting the top layer of sand and returning this wet and unpreserved to

the laboratory. The sand is then placed in a Petri dish and either cover glasses or lens tissue is placed over the moist surface of the sand. The diatoms will migrate towards the light and in so doing stick to either the tissue or the glass. The tissue or glass can then be removed and rinsed in order to collect the diatom cells for examination.

7.4. Phytoplankton

Diatoms are one of the algal groups composing the phytoplankton. They can thus also be studied as part of a phytoplankton investigation. Sampling can be done in a quantitative way or, when only relative composition is needed, in a semi-quantitative way.

The quantitative method is mostly used to study the entire phytoplankton community, not only the diatoms. Depending on the trophic state of the water body the sample can be collected in a bottle which can range in volume from 1 l for oligotrophic waters to 50 ml for eutrophic waters. The preservation is done *in situ* with an alkaline iodine solution (Lugol's). When it is not possible to analyze the samples shortly after sampling (within a few days) formalin should be added to the sample in the field just after the fixation with Lugol's. Samples must be kept in the dark and preferably but not obligatory in a refrigerator or a cool box at around 4°C. Prior to analysis the sample is concentrated by settling for 24 to 48 hours for 1 l. To preserve the phytoplankton sample after analysis, buffered formalin must be added as in an alkaline environment dissolution of the diatom frustules is slowly taking place.

The semi-quantitative method is based on the sampling with a phytoplankton net. Best is to use a net with mesh size of 10 µm. Experience in tropical Africa has demonstrated that the diatom communities are composed of small cells, often smaller than 20 µm and even 10 µm. However, in eutrophic systems the meshes are quickly blocked preventing the water to be filtered; nets with larger mesh size can be used but the mesh size must never exceed 27 µm. One must be aware that the results of analyses based on such samples may not be representative of true algal communities as small organisms are not be retained in such a net sample. The phytoplankton net should be held in the stream of moving waters for a couple of minutes, avoiding suspension of benthic material. The concentrated sample at the bottom of the net should then be put in a storage bottle and fixed with ethanol or buffered formalin. In shallow standing waters the phytoplankton net should be dragged back and forth just below the surface. Again care should be taken that benthic material is not disturbed and included in the sample. For standing waters deeper than 10 m, such as lakes and dams, where vertical stratification can occur in the water column, a vertical haul with the phytoplankton net must be taken. The depth of the haul depends on the depth of the photic zone (up to where light penetration is sufficient for algal growth). In oligotrophic lakes such as Lake Tanganyika, the vertical haul may be up to 40 m depth; in other small oligotrophic deep crater lakes a haul of up to 25 m is recommended.

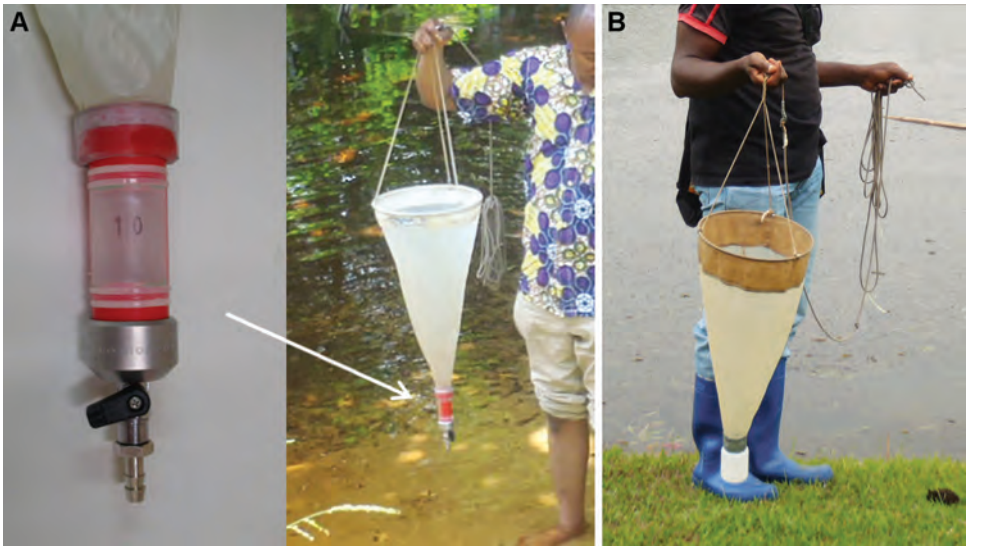


Fig. 11. Phytoplankton net. A. Commercial net (Hydrobios) with removable net bucket with a mesh screen which aids in concentration of the sample and a small tap at the bottom to decant the sample. B. Self-made net with screw thread adapted to a particular plastic bottle, in the depicted case a polyethylene bottle of 100 ml.

In order to aid the passage of water through the net it may be moved gently back and forth but care should be taken that none of the water is lost from the net.

The phytoplankton net is composed of a supporting ring made of stainless steel to which a conical net bag is attached. Usually the ring has a diameter of 25 cm and the bag is around 50 cm long. The sample is concentrated in a removable container or bucket on the end of the net with an opening covered by a mesh screen (Fig. 11 A), the sample is transferred to a bottle by opening a small tap. As the commercial nets (e.g., Hydrobios) are rather expensive, it is also possible to use homemade nets. Special material for phytoplankton nets with mesh size of 10 µm is available from specialized (web)shops. Make sure to use a stainless steel or aluminium ring to avoid corrosion. Instead of a concentration removable net bucket, an adaption piece to screw the bottles used for storing samples can be made (Fig. 11 B).

7.5. Terrestrial or soil diatoms

Soil diatoms, also called aerophilic diatoms, are a special group with many adaptations for the microclimate they live in which can be relatively arid compared to the permanently wet condition of aquatic environments.

Collecting can be done from moist sub-aerial, aerial and arid aerial habitats. It is recommended that six sub-samples of about 5 cm² should be taken within a radius

of 10 m to cover the local variability. To sample arid or dry soils remove carefully any detritus and other material covering the surface of the soil using a knife or a spoon. Collect the soil with a knife or spoon to a depth of about 1 cm. The six sub-samples thus collected should be placed in a paper envelope and not in a plastic bottle, this is to lessen the chances for the growth of bacteria and fungi due to the accumulation of moisture in a bottle. Dry or semi-dry rock faces and seep zones can also be sampled in a similar fashion. The biofilm is scraped from the surface of the rock using a spoon or knife. It is often not possible to cover a 10 m radius and thus several subsamples within the area covered by the biofilm should be collected. Depending on the amount of moisture present the sample can be stored in either paper envelopes or plastic bottles

7.6. Environmental parameters

During sampling, especially for water quality investigation, it is essential to note several characteristics of the water body as well as to measure some environmental parameters.

- Hydrological characteristics: stream velocity
  lake, river or channel depth
  river or cannel width

- Physical variables: water temperature
  turbidity
  sampling depth
  coordinates (collected using a GPS)

- Chemical variables: pH
  electrical conductivity (EC) also called specific electricity
  dissolved oxygen (DO)

- Nutrients: samples for measuring nitrogen:
  nitrates (NO_3-N)
  nitrites (NO_2-N)
  ammonium (NH_4-N)
  phosphorus:
  orthophosphate (PO4-N)
  total phosphate (TP)
  soluble reactive phosphorous (SRP)
  silica, iron, … is recommended if the equipment for measuring these parameters is available.

- Others: sampling site shaded or not

7.7. Annotations

It is essential to take notes during a sample collection trip. Besides the date and time of sampling all information mentioned in the previous section must be noted in the field during or just after the sampling. It is very difficult to remember everything on return back to the laboratory as most of the time collection trips have several sampling occasions and sampling sites.

How to take notes in the field? Do you have to use a field notebook or is it better to use prepared field record forms? Both have their advantages and disadvantages. Field record forms have the advantage that all information needed to be noted in the field is clearly indicated on a A4 sheet and have only to be filled in. It also allows for a standard data set to be collected at each site. The disadvantage is that separate sheets easily get lost. Forms must be clearly and logically composed. An example is given in Fig. 12. This example of a field record form can be adapted to the specific needs and type of sampling that will be conducted.

A notebook has the advantage that all the collected information from different sampling trips remains together. Notebooks are easy to store and must be kept with the relevant sample or slide collection if these are stored in a herbarium, museum, etc. A disadvantage of using a notebook is that one must be careful not to forget to include necessary information on the sample/sampling site, which may be the case for novice collectors; but once sampling becomes a routine, taking notes will also become routine.

7.8. Sample numbering and labeling

The correct numbering and labeling of the samples is also essential during a sampling trip.

Individual labels for each sample should be provided. It is recommended that sample information be written on self-adhesive labels with a pencil to avoid smudging if exposed to water. Once the label has been stuck onto the sampling bottle/vial, transparent tape can then be placed over the label and extend onto the bottle/vial to prevent damage such as abrasion and fading of the label during transport and storage (Fig. 13).

When a routine sampling is planned, labels can be made in advance in the office before starting the field work.

Field annotations in a field notebook or on a field record form together with the corresponding label on the sampling bottle are crucial for successful sampling and sample archiving. A sample without a label and without related field information is scientifically useless.

River: _____ Site: _____
Date: _____ Sample number: _____
Sample collected by: _____

Physical records

Width: _____ Depth: _____

Substrate (record estimated percentage)

bedrock	□	boulders/cobbles	□
pebbles/gravel	□	peat	□
sand	□	silt/clay	□

Estimated percentage of boulders and cobbles covered by:

Filamentous algae □ Other macrophytes □

Shading (record estimated percentage)

Left bank	None □	Broken □	Dense □
Right bank	None □	Broken □	Dense □

Habitat

Pool □ Run □ Riffle □ Slack □

Water clarity

Clear □ Cloudy □ Turbid □

Bed stability

Firm □ Stable □ Unstable □ Soft □

Chemical records

pH:	type of meter used:
Conductivity (μS.cm^{-1}):	type of meter used:
Water temperature (°C):	type of meter used:

Photograph

Facing upstream: Facing downstream:

Remark: It is important to include an immovable structure in a photograph as a reference for future comparison e.g. a bridge

Fig. 12. Example of a field record form to accompany a diatom sampling trip in a river or stream.

Fig. 13. Field collection methodology. A-B. Collecting samples with a phytoplankton net. C-D. Measuring of physical and chemical variables E-F. Taking notes in a field notebook and labeling of a sampling bottle.

8. Laboratory methodology

8.1. Cleaning samples for diatom investigation

Diatom cells are covered on the outside of their silica cell wall by a thin layer of organic material (membrane). This thin layer obscures morphologic features, such as the perforations and the raphe, needed for determination of the diatom species. The sample will also contain detritus, protists, bacteria and soft-bodied algae which are the usual components of a biofilm; this material will also obscure the structures of the diatom cell when viewed at high magnification. Therefore the organic material, not only in and around the diatom cell itself but also other organic material present in the sample, must be removed to obtain cleaned material for making permanent diatom slides. After such cleaning process all that remains are the resistant silica cell walls of the diatoms and occasionally other siliceous structures such as sponge spicules or phytoliths.

Material needed for the cleaning or oxidation of samples

- Beakers (heat-resistant glass) with a total volume of 100 or 250 ml depending on the sample volume and concentration.
- Watch glasses (heat-resistant).
- Hot plate for heating the material (to be used inside a fume cabinet).
- Bottles/vials (preferably glass).
- Pipettes.
- Safety pipette filler (Propipette) (Fig. 14).
- Reagents: peroxide (H_2O_2) 30 %,
  potassium permanganate ($KMnO_4$) for organic rich samples
  hydrogen chloride (HCl) for samples from environments rich in salts, especially calcareous waters.
- Waste bottles for disposal of hazardous compounds.
- Permanent marker.
- Centrifuge for 10 ml centrifuge tubes and centrifuge tubes (optional).

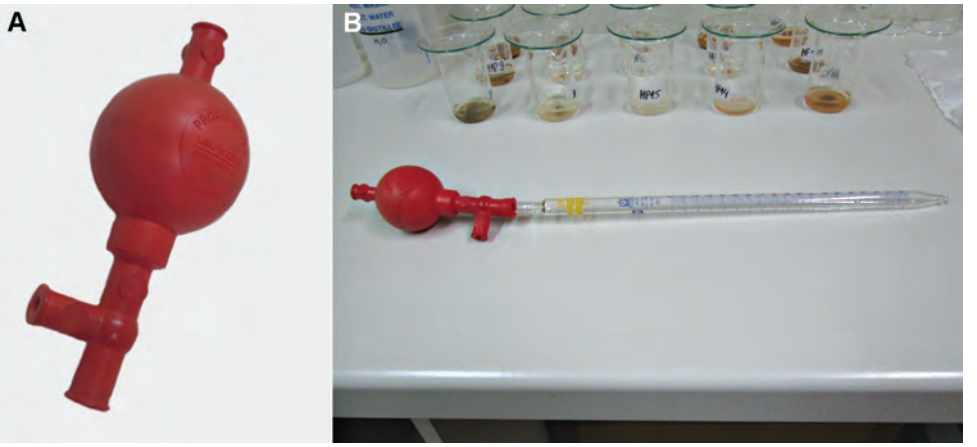


Fig. 14. A. Safety pipette filler. B. Safety pipette filler mounted on a pipette.

Protocol

As with sampling it is important that the final scatter of diatom cells on the slide is representative of the original sample. For this reason it is important to mix or shake the sample well at each stage in the process mentioned below.

- Allow the sample to stand for 24 h in the laboratory to allow the diatoms to settle at the bottom of the bottle. This is best done soon after the field sampling.

- After the period of 24 h to allow for settling, decant the supernatant liquid from the sample bottle (the supernatant liquid must be very clear) taking care not re-suspend any of the settled material which will cause the loss of diatom material. A better method, but more time consuming, is to remove off the supernatant liquid using a pipette provided with a safety pipette filler (follow the instructions in the product operating manual).

- Shake the remaining thick suspension well in the sample bottle to homogenize the material containing the concentrated diatoms and pour a part of the suspension (about 5 to 10 ml of the concentrated sample depending on the concentration of the material and the present organic material) into a heat-resistant beaker.

- Cover the heat-resistant beaker with a watch glass (heat-resistant) to prevent cross-contamination between the samples.

- Mark the heat-resistant beaker in several places with the sample number using a permanent marker.

- Add 10 to 20 ml H_2O_2 (30 %) to the concentrated sample in the heat-resistant beaker.

- Put the heat-resistant beaker with the material on the hot plate inside a fume cabinet at about 90-100°C for 2 to 3 h; the samples should be regularly observed to prevent boiling-over or drying out. The heat-resistant beaker should always be covered with a heat-resistant watch glass to prevent contamination between the beakers. Contamination can happen not only due to splashing of material if boiling becomes too vigorous but also due to diatoms present in the steam of the boiling material. (Fig. 15)

- When the material is very rich in organic material, add some drops of potassium permanganate ($KMnO_4$) to complete the oxidation process. The number of $KMnO_4$ drops needed depends on concentration of organic material in the sample: drops must be added until the suspension clears leaving a straw coloured supernatant and a precipitate ranging in colour from brown to grey to white depending of the geology of the sample site.

- Leave the cleaned solution in the heat-resistant beaker to cool down.

- Rinse the sample with distilled water. This can be done by centrifugation or by allowing the material to settle out for 24 h. For centrifugation the cleaned material must be transferred to 10 ml centrifuge tubes. Before pouring the cleaned solution from the beakers, the beakers must be vigorously swirled to re-suspend the diatoms: heavier particles such as sand grains particles will fall to the bottom of the beaker. Centrifugation is done for 10 min at a rotation speed of 3000 rpm (rotations per minute). After centrifugation the supernatant is decanted or pipetted off using a pipette provided with a safety pipette filler. This washing or rinsing is repeated 4 times; the pH of the final sample should be more or less circumneutral. When the preparation of permanent diatoms slides is not urgent, or when a centrifuge is not available, the material can be rinsed be leaving the material in the beaker or in a centrifuge tube to settle during for 24 h before removing the supernatant by decantation or by pipetting off. Again washing should be repeated 4 times.

The above protocol is only one of many that exist. Additional methodologies can be found in the literature, e.g. STOWA 2014, Taylor *et al.* 2007c.

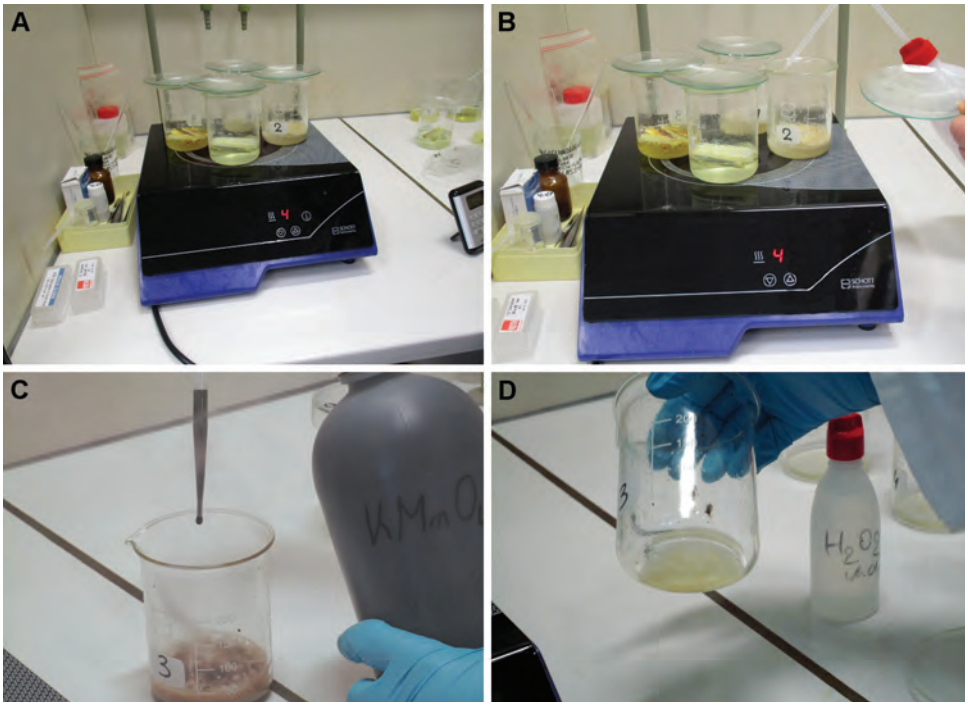


Fig. 15. Removing organic material in a diatom sample: part of the material is placed in a heat-resistant beaker, covered with a heat-resistant watch glass to prevent contamination between the beakers, and placed on a hot plate inside a fume cabinet at about 90-100°C for 2 to 3 hours. For material rich in organic material some drops of $KMnO_4$ are added to complete the oxidation process.

8.2. Permanent diatom slide preparation

Material needed for making permanent diatom slides

- Pasteur pipettes or automatic micro-pipette when quantitative slides are needed (Fig. 16).
- Diatom specific mounting media/mountant with high refraction index (RI ≥ 1.7), for example Naphrax (RI 1.73) or Pleurax (RI 1.73).
- Hot plate
- Microscope slides
- Cover slips (example: 20 x 20 mm, 22 x 22 mm, 22 x 40 mm)

Slide preparation

There are a number of slide preparation methods. The method chosen is less important than the final result. Diatom slides used for ecological and taxonomical studies are most often of the type known as 'strewn mounts'. These mounts represent as closely as possible the structure of the diatom community as collected in the original sample. In order to count or photograph cells on the slide it is important that they do not lie over each other and thus obscure each other (high concentration of material). It is also important that the sample is not highly dilute, in this case enumeration of the sample becomes very difficult and time consuming. A good rule of thumb is that a diatom strewn mount should have 5 – 50 cells visible in the field of the microscope at 1000 x magnification. This of course may not always be possible, especially if the sample has a high sediment content but it can be accepted as a general best practice guideline.

Take an aliquot of the cleaned sample and place in a test tube or other suitable vessel. Add one drop of ammonium chloride 10% solution to the tube and mix with the diatom material.

Put a drop of cleaned sample on a cover slip (about 0.5 - 2 ml depending on the size of the cover slip). If necessary concentrate the cleaned sample or dilute a part of the cleaned sample to a slightly cloudy solution. This is the most important step, if too little material is used the concentration of diatoms on the slide will be too low and making enumeration difficult, if too much material is used the diatom cells will lie over each other and it becomes impossible to identify individual cells. There is also no hard and fast rule for the dilution step, it will depend on the ratio of diatom cells to fine sediment, the initial concentration of diatoms in the field sample etc. This step requires practice and with experience it will be possible to successfully estimate the required concentration.

The volume of liquid placed on the cover slip is also of importance. The surface of the cover slip should only just be covered with liquid, if too much of the liquid (sample) is placed on the cover slip it will lead to unusual drying patterns – most often with the majority of the cells being deposited at the centre of the cover slip.

Let dry the sample on the cover slip. This can be done by two ways:

- air-dry, takes approximately 24 h, best to cover to prevent dust settling on the sample;

- hot plate dry, takes about 1-2 h, very slight warming around 40-50 °C, to avoid the material drying in rings, or leave under a 60 W incandescent lamp - there is less chance with overheating with this method.

At this stage the cover slip can be placed (still with the diatom facing up) on a microscope slide and viewed at low magnification under a light microscope. This is in order to determine of the appropriate concentration of diatom cells is present. If so then the slide can be made into a permanent mount as described below.

Mount in a high resolution mountant. The following mounting media are generally used: Naphrax (RI 1.73) or Pleurax (RI 1.73).

Perform the following procedures out doors or in a fume cabinet. Do not inhale gasses or fumes.

Naphrax: (Fig. 16)

- Put a drop of the mounting media on the microscope slide.
- Put the cover slip with the dried samples at a 90-degree angle on the microscope slide alongside the drop of Naphrax.
- Carefully lower the cover slip.
- Put the microscope slide with the cover slip on the hot plate at ~100 °C.
- Allow to 'boil' for 2 min (to remove the toluene – the solvent).
- Remove the microscope slide from the hot plate and let it cool down.

Pleurax:

- Place the cover slip, diatoms upward, onto the hot plate.
- Put a drop or two (depending on size of the cover slip) of the mounting media on the cover slip.
- Heat the sample until smoke starts to rise from the mounting media, allow this to continue for about 30 to 45 sec. The Pleurax burns easily so be careful not to overheat it at this stage.
- Carefully invert a clean microscope slide onto the cover slip, do not force the slide onto the Pleurax as this will cause it to be squeezed out of the edges. The cover slip should just be 'caught' by the slide.
- Turn the slide over and heat until the mounting media gently bubbles (~ 90 °C).
- Heat the slide until all air bubbles have been driven out.
- Remove the microscope slide from the hot plate and let it cool down.
- Once completely cool try to chip a small portion of the mountant at the edge of the cover slip. If the mountant is brittle the slide is cured. If viscous return to the hotplate and heat for another minute and test again.

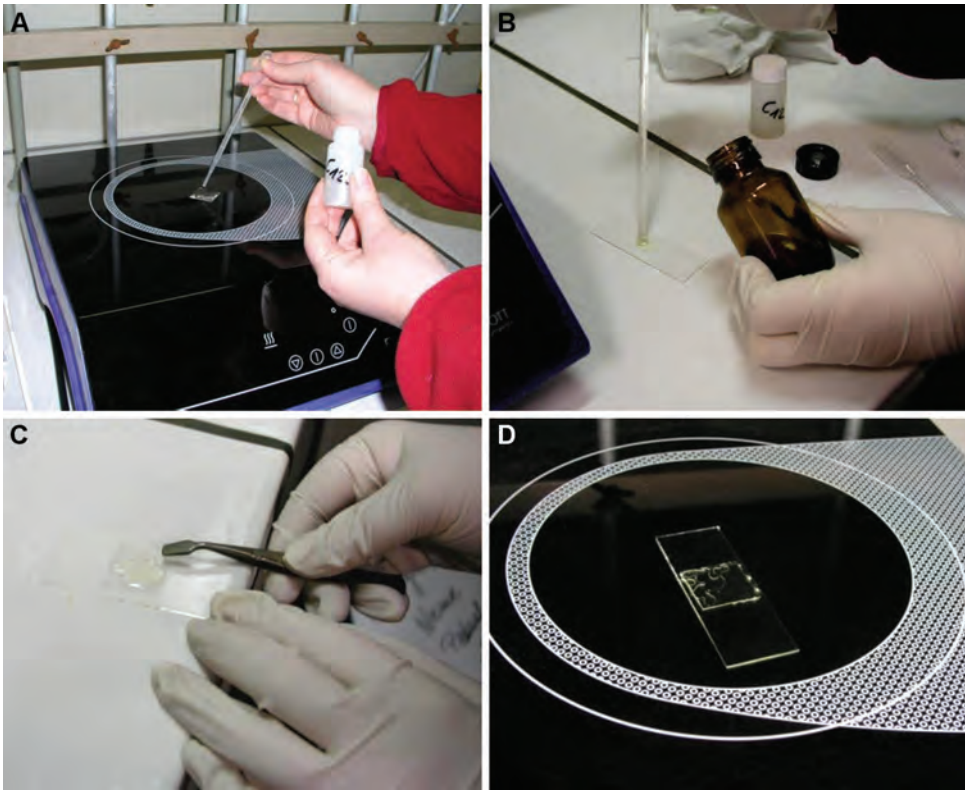


Fig. 16. Making a permanent diatom slide from cleaned diatom material. A. A drop of cleaned sample is placed on a cover slip and dried on a hot plate. B. A drop of the mounting media is placed on the microscope slide. C. The cover slip with the dried samples is held at a 90-degree angle on the microscope slide alongside the drop of mounting media and is carefully lowered. D. The microscope slide with the cover slip is placed on the hot plate at ~100 °C to boil.

8.3. Preparation for Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) is used in diatom taxonomy to study the ultrastructure of the diatom frustules (valves and girdle bands). The valve and girdle ornamentations and perforations are often not fully discernible in light microscopy and can only be studied in detail using SEM. During SEM investigations a three dimensional impression of the structure of the diatom silica cell wall is gained but on the other hand it is not possible to look through the valve as can be easily done with LM. Diatoms with their silica cell wall do not require extra cleaning steps for SEM examinations, other than those explained in section 8.1. in contrast to other, soft-bodied algae which may require critical point drying. However, for water quality monitoring purposes these in-depth investigations using SEM are usually not essential. It should however be taken into account that a large number

of new species have been encountered during water quality studies and in this case it becomes important to document such taxa with SEM if such facilities are available.

Aluminium stubs are used for mounting material for SEM studies as aluminium is a conductive material. Cleaned diatom material can be transferred to these aluminium stubs in several ways:

- a drop of cleaned material can be placed directly on an aluminium stub and air dried;

- a drop of cleaned material can be put on a small cover slip (diameter of 12 mm) and air dried: once the material is totally dry the cover slip is fixed on the aluminium stub with carbon tape or a special conductive glue;

- a drop of cleaned material can be filtered through a Millipore® filter (≤ 2.5 µm); after the filter is totally air dried it is fixed on the aluminium stub with a carbon tape or a special conductive glue.

After mounting the diatoms the stubs are sputter coated with gold or gold palladium. Material is then ready for examination with the scanning electron microscope. Depending on the microscope an acceleration voltage of 10-15 kV is usually adequate for diatom examination, although the new generation of field emission scanning electron microscopes work at low voltages as low as 1 kV.

Stubs with the material must be completely dehydrated before entering in the SEM. Therefore they must be kept under very low humidity conditions. Stubs should always be placed in a dessicator containing silica gel for 24 hours to make sure they are completely dehydrated before SEM examination.

8.4. Storage of samples and permanent diatoms slides

It is always interesting to keep a portion of the original, untreated samples. If a sample is lost during preparation, if there is still a portion of the original material available this can then be used to replace the lost sample. In addition, other researchers may wish to study the material if further investigations are needed using LM or SEM, or especially in case new techniques are developed in the future. The same applies to the cleaned material. Therefore it is essential that the bottle/vials in which the material is preserved are well labelled.

Original uncleaned material is already fixed just after the sampling (formalin of ethanol); the cleaned material on the other hand is not. Therefore ethanol should be added to the bottle/vial to reach a final concentration of 20 % by volume to prevent the growth of micro-organisms such as bacteria, green algae and fungi. Alternatively some thymol crystals (2-isopropyl-5-methylphenol) can be added

to the bottles/vials or the material can simply be allowed to dry out (the bottle should still be kept sealed after drying).

Permanent diatom slides should be well labelled (country, site, locality, river, coordinates, date of collection and name of collector) and stored, preferably in a herbarium or diatom collection to facilitate cross-referencing. Besides their importance for taxonomists diatom slides are, from the point of view of water quality, very important as they provide a permanent historical record of water quality conditions at a site. They should be stored in order to ensure that they can be accessed for future analyses (e.g., hind-casting water quality). Moreover it is recommended that at least two slides are prepared from each sample. One of these should be lodged in the appropriate national herbarium or in another herbarium or institution where its future is assured. A database with all information on the material and on the preparation should be deposited together with the slides.

9. Diatom analysis

9.1. Light microscopic investigation

Diatom taxa in manuals, guides and books are usually depicted as a series of neatly aligned pictures. In the past these pictures were handmade drawings by the authors, e.g., Ehrenberg, Hustedt, Cholnoky. Around the second half of the 20th century the first photographic illustrations appeared. For tropical Africa we can mention here among others Hustedt (1942, 1949) later followed by Gasse (1986) and Cocquyt (1998). The diatom cells are illustrated in valve view showing the morphological characteristics used for determination. Seldom the girdle view is shown, except if it has a typical shape such as in several *Gomphonema* and *Surirella* species. Valve fragments or broken pieces are not or are rarely depicted. The diatom cells observed during investigation are seldom lying in a nice valve view, but are orientated at different angles, obliquely or in girdle view, and may be damaged or in fragments.

Different types of microscopic illumination exist, bright field, dark field, phase contrast, differential interference contrast (DIC), giving slightly different images than those found in the identification guides which use a selection of the best pictures the authors possess. Diatom counts can be easily done with bright field for routine investigation. However for taxonomic purpose more details are often needed which can't be (easily) observed using bright field. Phase contrast and/or differential interference contrast are then recommended (Fig. 17).

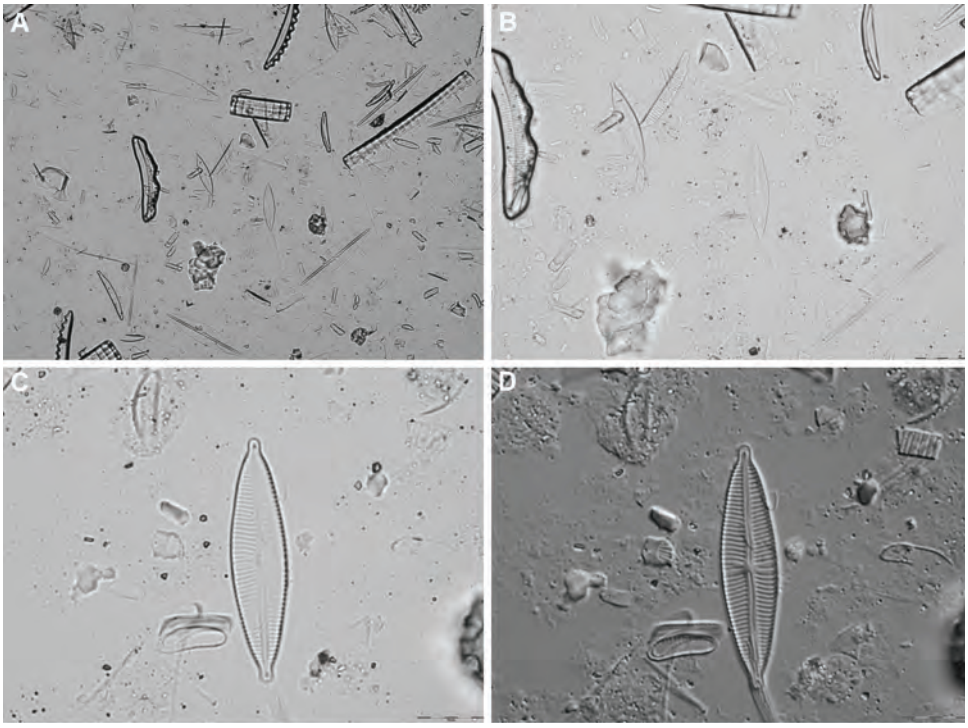


Fig. 17. View of a permanent slide of cleaned diatom cells mounted in Naphrax at different microscopic magnifications and with different illumination. A. Low magnification (200x). B. Medium magnification (400x). C. High magnification (1000x) using bright field. D. High magnification (1000x) using differential interference contrast (DIC).

10. Glossary

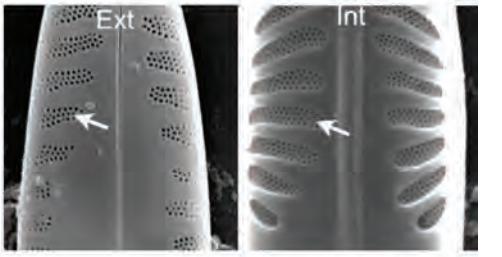
The glossary provides an overview of the most important terms used in diatom taxonomy. All terms indicated in bold in the discussion of the genera, in the present book, are included as well as some outdated terms that are commonly used in the literature, especially in older publications. To make the glossary assessable for French speaking researchers, the English terms are translated into French followed by a short description in French and illustrated using the pictures as in the English glossary (section 10.2). English and French terms are all put in alphabetical order.

10.1. Glossary

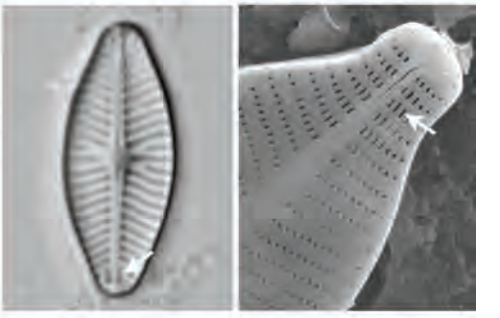
Adnate: cell attached by the raphe bearing valve face to the substratum.

Aerophilic: occurring in well oxygenated habitats such as on mosses, wet stones, moist earth.

Alveolus - alveoli: stria composed of a transversely linear chamber in the valve wall having many small openings to the exterior valve face and one large opening to the interior valve face.



Annulae: structure composed of one to four transapical striae interrupting the typical striae near the apices. Structure present only in the genus *Geissleria.*



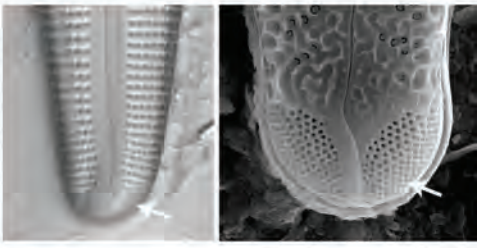
Apex - apices: the extremity of the valve in pennate diatoms, also called pole/poles.

Apical axis: the longitudinal axis of the valve face in pennate diatoms passing through the poles.

Apical nodule: highly silicified part of the diatom valve near the apex, where the raphe furrow ends; also known as the polar nodule.

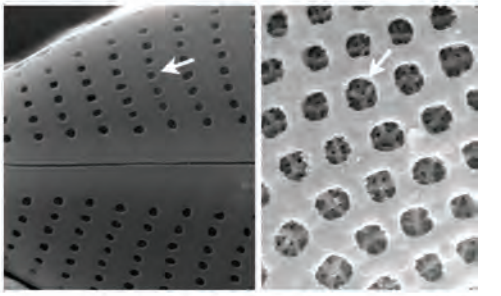
Apical pole: extremity in pennate diatoms

Apical pore field: area with small pores or perforations through the cell wall near one or both valve extremities in pennate diatoms. It is the place where mucopoly-saccharides (mucilage) forming stalks and pads are secreted.



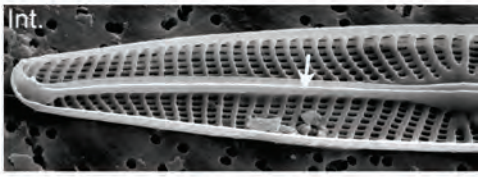
Araphid: pennate diatom valve without raphe slit.

Areola - areolae: round or nearly round perforation in the silica cell wall, also called punctum. The areolae are usually aligned and form striae.

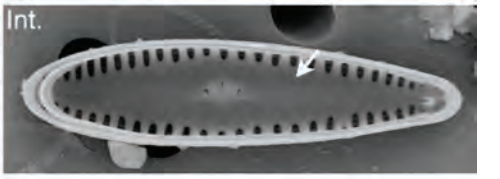


Axial area: hyaline area within the pennate diatoms located on the valve face along the longitudinal axis, between the raphe slit, if present, and the striae.

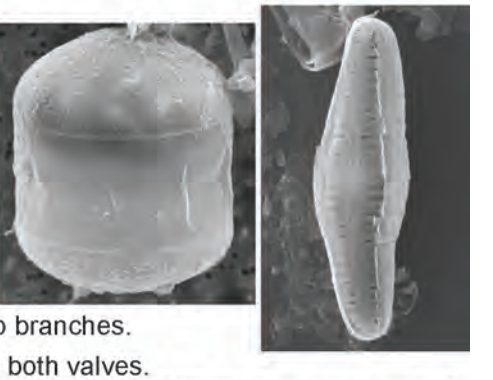
Axial costa: narrow siliceous ridge along the axial area, parallel to and bordering the raphe.



Axial plate: siliceous plate present on the internal part of the valve covering the internal openings of the areolae. The plate is present in some *Gomphoneis* species where its margin is visible as a longitudinal line in light microscopy.



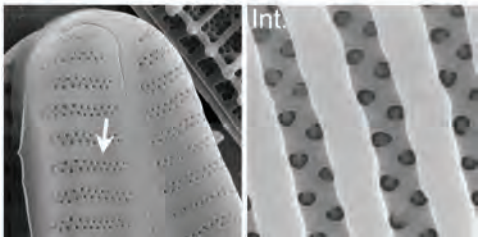
Auxospore: special cell formed during sexual reproduction after the fusion of the gametes. This cell is larger than the daughter cells and the maximum size of the diatom is thus re-established.



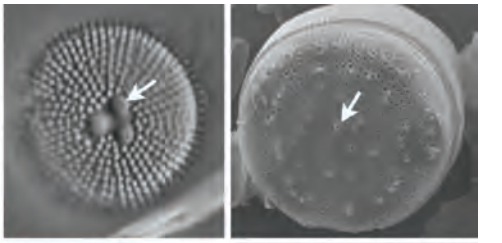
Bifurcate: a structure that is divided in two branches.

Biraphid: pennate diatom with a raphe on both valves.

Biseriate: composed of two parts; a biseriate stria is composed of a double row of areolae.

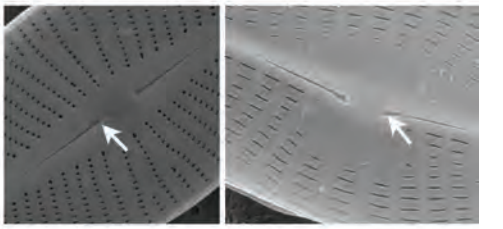


Carinoportula: central process, restricted to the genus *Orthoseira*; the internal openings are simple, the external openings are composed of well-defined collars.

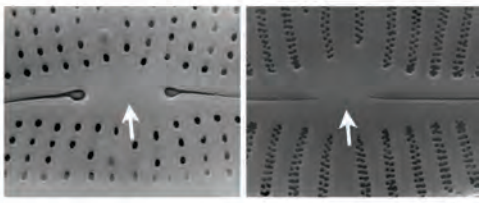


Central area: hyaline area (without areolae) in the middle of the valve face at the position of the central nodule within the pennates. In centric diatoms areolae are present in the central area

Central fissure: central raphe slit ending near the central nodule, may be enlarged or curved.

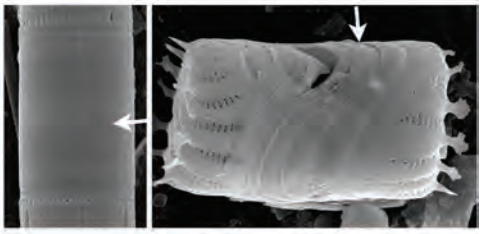


Central nodule: more heavily silicified part of the valve wall in between the central raphe fissures.



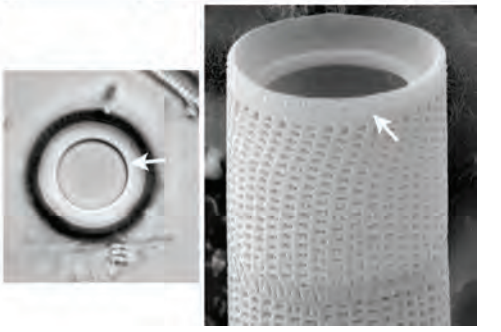
Chrysolaminarin: reserve material, a polysaccharide, present in diatoms and Chrysophytes.

Cingulum - cingula: series of siliceous bands associated with one valve only.

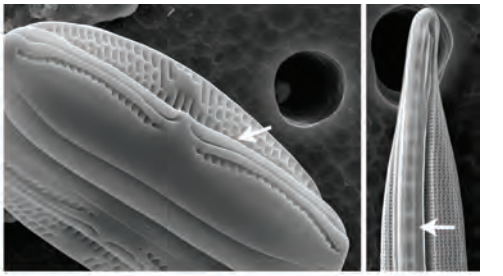


Clavate: club-shaped.

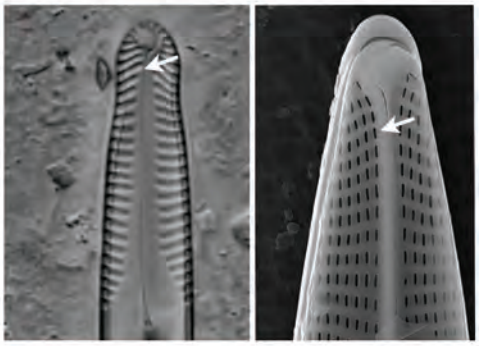
Collum: narrow and hyaline area on the valve mantle within the genus *Aulacoseira*. A small furrow, the sulcus or "Ringleiste" divides the collum from the part of the valve mantle bearing the areolae.



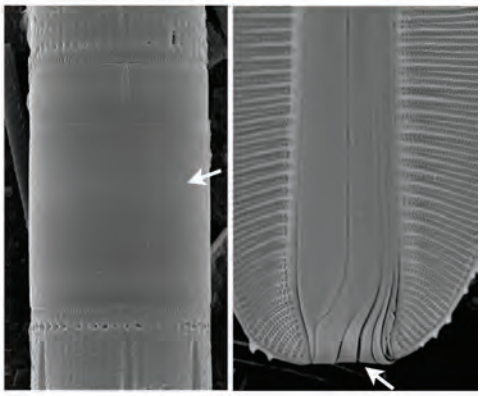
Conopeum - conopea: delicate siliceous flap lying along the apical axis and covering a part of the external valve face; can be slightly to distinctly elevated and partly or totally covering the striae and may extend up to the valve margin.



Convergent: striae are convergent when they are turned away from the central nodule and oriented to the terminal nodule.

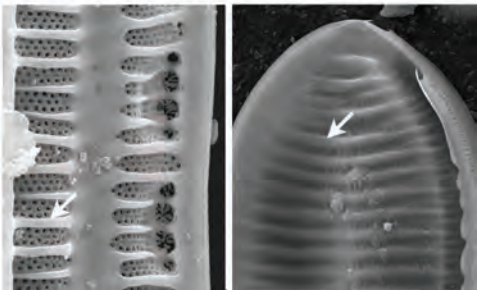


Copula - copulae: siliceous band in between both valves; also called intercalary band or girdle band.



Cosmopolite: occurring everywhere on earth in corresponding habitats.

Costa - costae: rib-like thickenings and non-ornamented part of the valve face parallel to the striae.



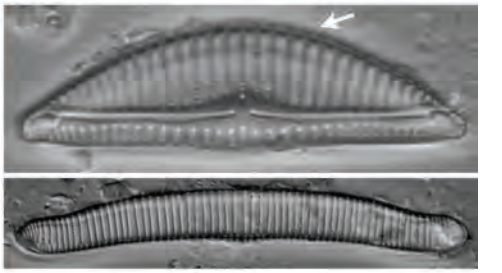
Craticula - craticulae: auxiliary structure on the internal valve face composed of a sternum and strong solid transverse bars, formed under conditions of higher osmotic pressure.

Cribrum - cribra: type of pore occlusion (perforated siliceous plate).

Cruciform: shape of a cross.

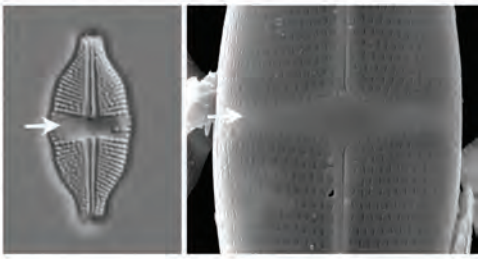
Dorsal side: in diatoms asymmetrical to the apical axis, the side of the valve that is the most convex.

Dorsiventral: valve with distinguishable dorsal and ventral sides.

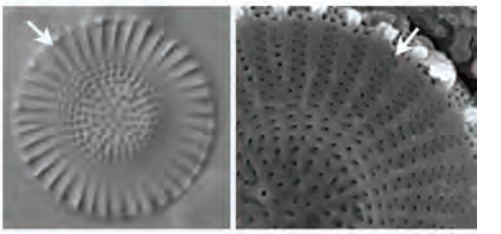


Epitheca: the larger and older of the two valves composing the diatom frustule.

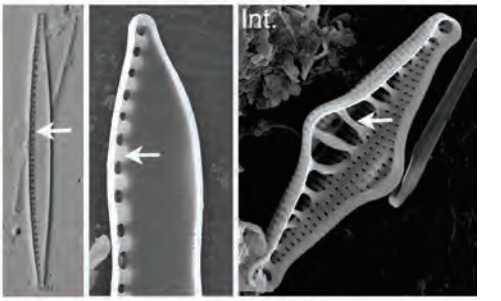
Fascia - fasciae: thick hyaline siliceous area, extending from the central area to the valve marging, in some pennate diatoms, and formed by secondary deposition of silica in depressions of the valve face.



Fascicle: series or bundle of rows of areolae oriented radially in some centric diatoms.



Fibula - fibulae: internal siliceous support of the canal that contains the raphe; also called keel puncta or carinal dot in older literature.

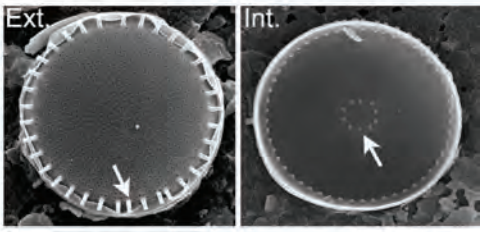


Foot pole: the narrower pole, extremity in heteropolar pennate diatoms.

Foramen - foramina: type of pore occlusion.

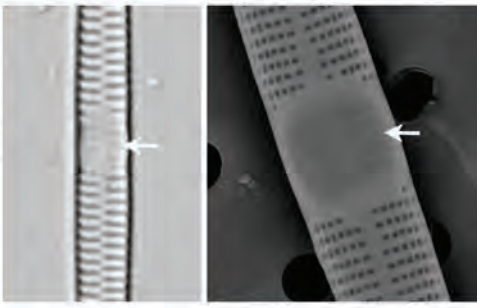
Frustule: diatom cell wall composed of silica, and having two valves and associated girdle bands.

Fultoportula - fultoportulae: or strutted process; tubular process in some centric diatoms, associated with the secretion of β-chitin. The tubular central process is accompanied by two or more satellite pores in internal valve view; a tube or a simple pore in the valve wall in external valve view.



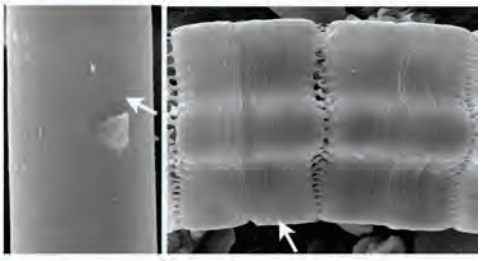
Fusiform: the shape of a spindle with the broadest part mid-valve and tapering to both ends.

Ghost striae: faint striae, composed of areolae that do not perforate the valve wall.



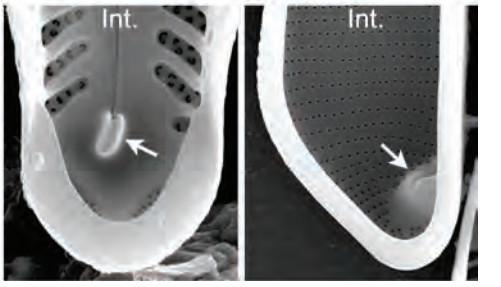
Girdle: series of siliceous bands associated with the valve; also called cingulum.

Girdle band: one of the bands associated with the valve.

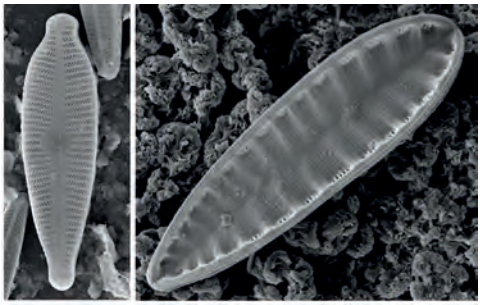


Head pole: the largest pole, extremity in heteropolar pennate diatoms.

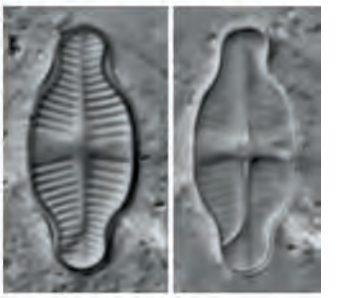
Helictoglossa - helictoglossae: structure with the shape of a pair of lips found at the end of the terminal raphe fissures near the internal ends of the valve in many pennate diatoms bearing a raphe; in the past also called an infundibulum.



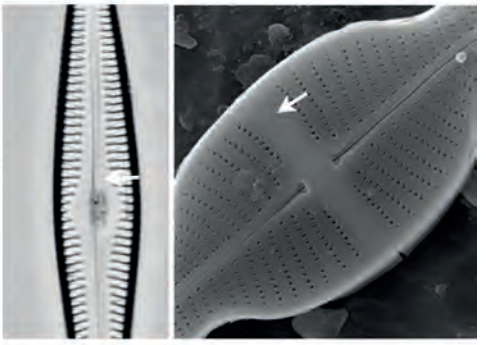
Heteropolar: asymmetric valve; having a different shape of poles or apices.



Heterovalvar: frustule composed of two different valves; difference can be in the presence or absence of a raphe or in the valve ornamentation.

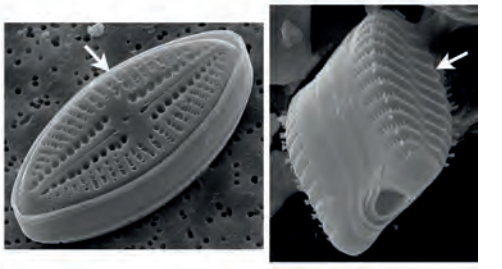


Hyaline area: area on the valve without perforations or ornamentations.



Hymen: type of pore occlusion.

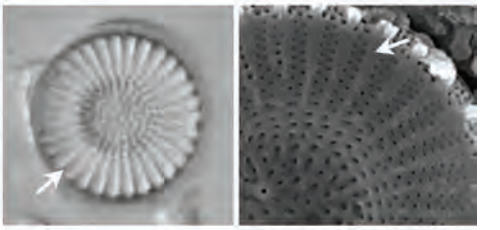
Hypotheca: the smaller and younger valve of the diatom frustule.



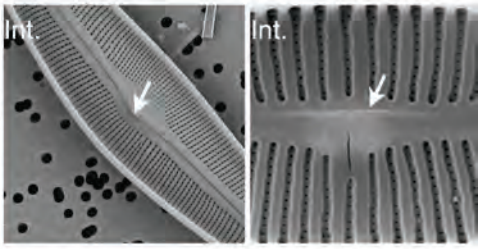
Infundibulum: structure with the shape of a pair of lips found at the end of the terminal raphe fissures near the internal ends of the valve in many pennate diatoms bearing a raphe; former name for a helictoglossa.

Intercalary band: siliceous band in between both valves; also called copula or girdle band.

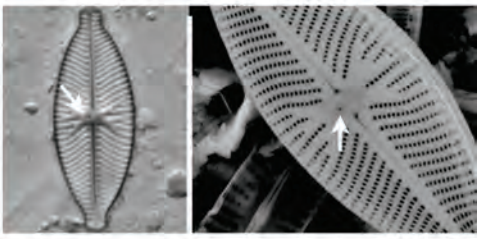
Interfascicle: rib-like thickened and unornamented part of the valve face in centric diatoms running parallel to the striae; also called a costa.



Intermissio: internal slit which connects the central raphe fissures in some cymbelloid taxa; instead of distinct internal central raphe endings, a fissure is present.

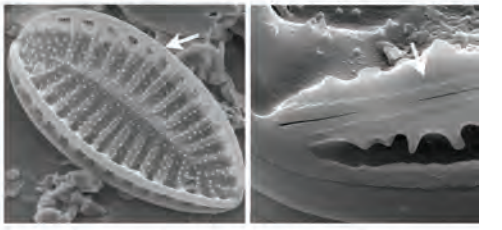


Isolated punctum: round opening in the valve wall in the central area clearly separated from the areolae of the striae. Present in genera such as *Geissleria*, *Placoneis*.



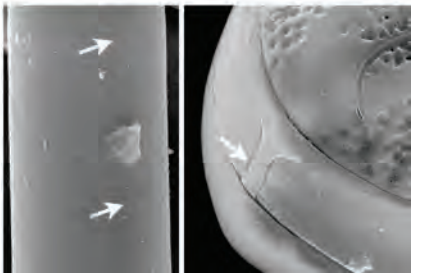
Isopolar: valve symmetric; both apices having the same shape and size.

Keel: elevated ridge bearing the raphe, formed by a folding of the valve wall. Present in genera such as *Nitzschia*, *Surirella*, *Cymatopleura*, *Campylodiscus*.

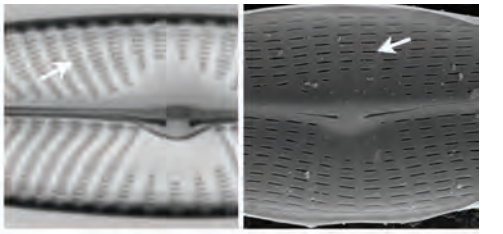


Keel puncta: internal siliceous support of the canal that contains the raphe; old name for fibula.

Ligula - ligulae: siliceous projection of a girdle band which fills the gap in the next band.

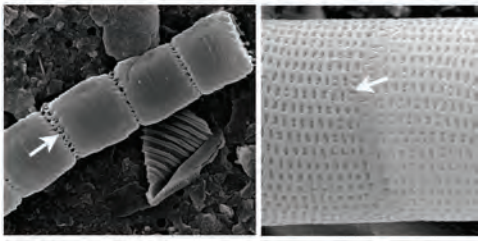


Lineola - lineolae: areola elongated in apical direction.

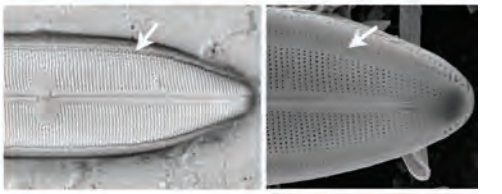


Lineolate stria: stria composed of areolae elongated in apical direction.

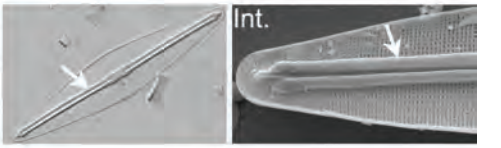
Linking spine: spine, silica extension of the valve, joining frustules together to form a chain.



Longitudinal canal: Chamber with the shape of a tube in the internal valve, oriented along the apical axis. Present in the genus *Neidium*.

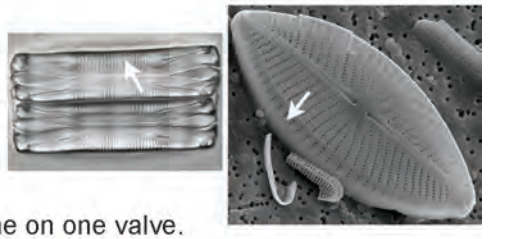


Longitudinal rib: longitudinal silica structure present on the valve face at each side of the raphe and crossing the striae.



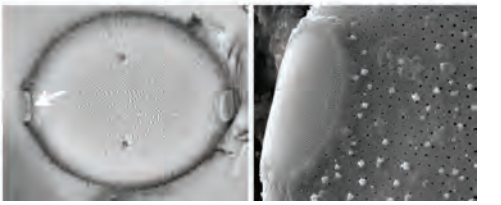
Lunate: shape of a crescent moon.

Mantle: vertical part of the valve, surrounding the valve face at usually 90°.

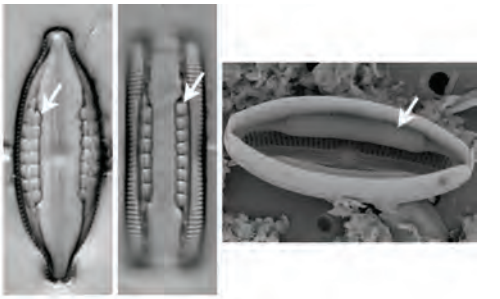


Monoraphid: pennate diatom with a raphe on one valve.

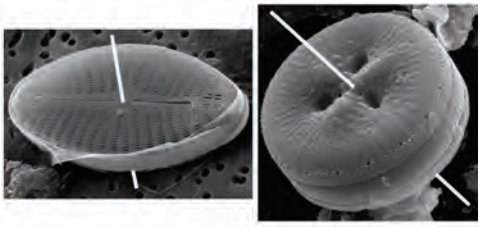
Ocellus - ocelli: eye-like structure composed of small pores surrounded by a shallow rim of silica. Present on the junction of the valve face and valve mantle in the genus *Pleurosira*. Secretes mucopolysaccharide pads that join the cells together.



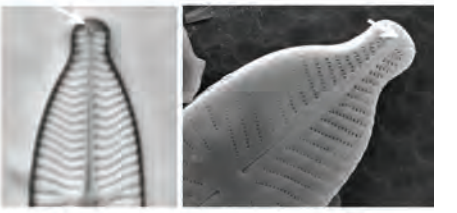
Partectum - partecta: bulbous chamber on the inside of the valvocopula, only present in *Mastogloia*. These chambers are usually arranged in a row along each side of the valvocopula, forming together the partectal ring.



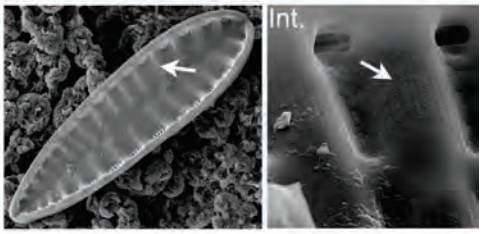
Pervalvar axis: the axis of the valve which is perpendicular to the center of the valve face; in pennate diatoms it is the point where the apical and the trans-apical axes meet; in the centric diatoms it is the point where the striae come together.



Polar nodule: more silicified part of the diatom valve near the apex, where the raphe furrow ends; also known as the apical nodule.

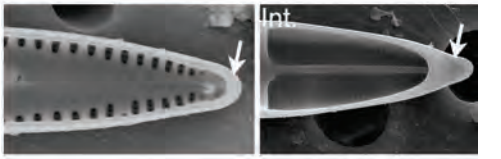


Porca - porcae: transapical undulation of the valve face in the genus *Surirella*; also called a corrugation ridge.



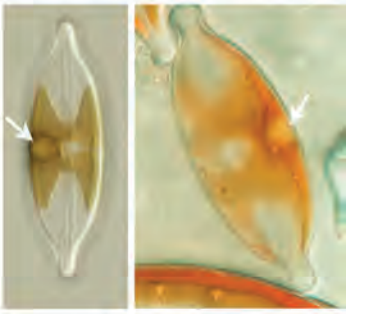
Primary side: the side of the valve formed from the initial branches of the raphe sternum during valve formation in raphid diatoms.

Pseudoseptum - pseudosepta: silica plate in the internal cell extending from the wall of the valve.

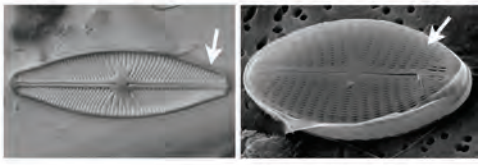


Punctum: round or ovate perforation in the silica cell wall, also called an areola.

Pyrenoid: structure present in the chloroplast of algae which is responsible for the CO_2 fixation and not for the production of starch as proposed in the past; it is often surrounded with starch granules.

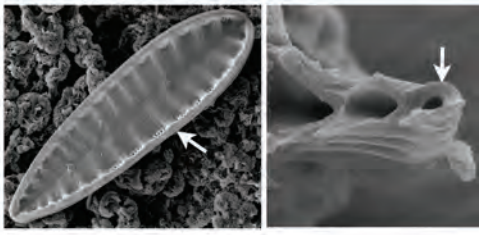


Radiate: striae are radiate when they are orientated away from the central nodule.



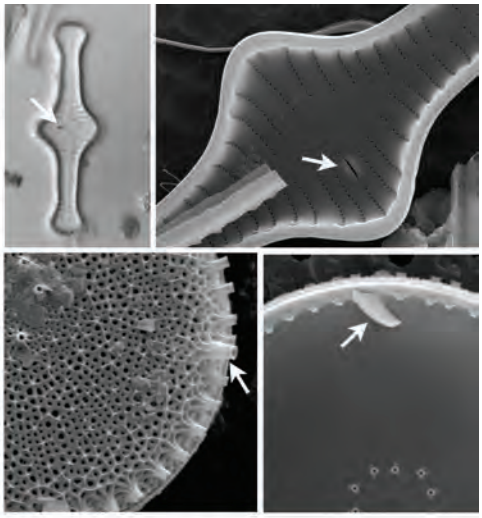
Raphe: slit or fissure through the valve face in the mono- and biraphids, often located along the apical axis.

Raphe canal: cylindrical structure bearing the raphe and more or less closed on the internal side of the valve.



Raphe keel: well pronounced elevated ridge, formed by folding of the valve wall, on the junction of the valve face and valve mantle. Present in genera such as *Nitzschia*, *Surirella*, *Cymatopleura and Campylodiscus*.

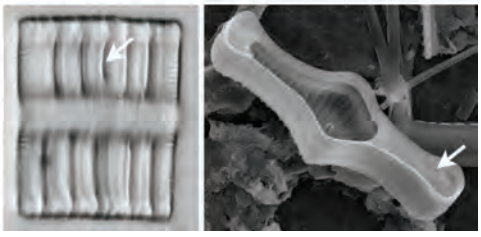
Rimoportula or labiate process: tubular process in some centric and pennate diatoms, associated with the secretion of mucopolysaccharides (mucilage) and other carbon compounds. On the internal valve face the opening of the process has the shape of a pair of lips; on the external valve face the opening is a tube extending out from the valve, or a simple pore in the valve wall.



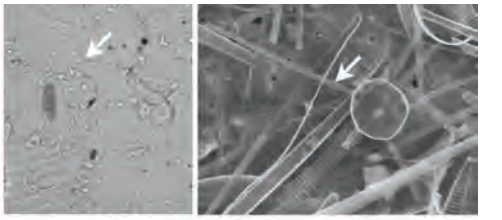
Ringleiste: small silica ledge dividing the collum from the part of the valve mantle bearing the areolae. Only present in the genus *Aulacoseira*.

Secondary side: the side of the valve formed after the primary side by fusion of the silica branches extending from the centre and the extremities of the raphe sternum during valve formation in the raphid diatoms. Junction where fusion takes place is known as the Voight discordance.

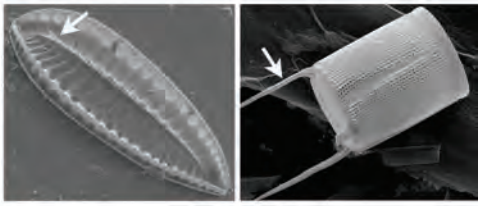
Septum - septa: silica plate in the internal cell extending from the wall of a girdle band.



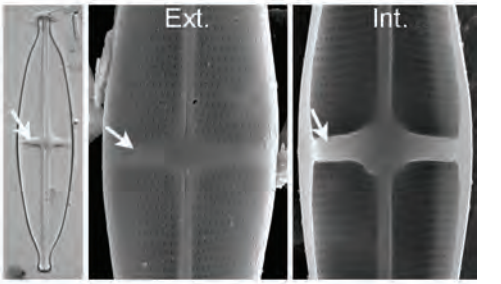
Seta - setae: simple or robust silica extension of the valve, longer than a spine. Present in the genus *Chaetoceros*. The setae join the cells together allowing them to form chains.



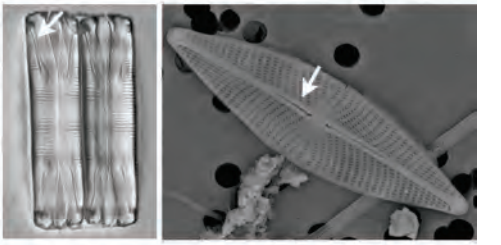
Spine: sharp pointed silica extension of the valve, solid or hollow, very long or tiny, arising at different places on the external valve face in different taxa.



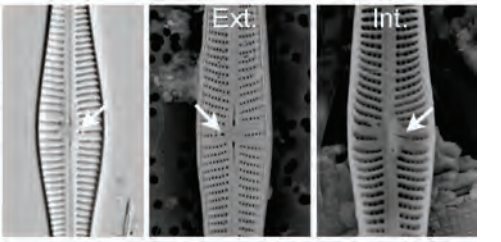
Stauros: hyaline thickening in the central area; in the cell ontogeny formed differently from a fascia; present only in the genus *Stauroneis*.



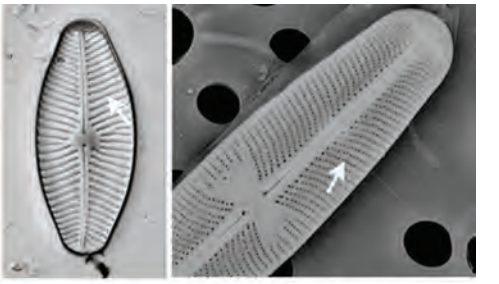
Sternum - sterna: thick siliceous structure of the valve face along the apical axis in pennate diatoms; it is the ontogenic center of the pennates. The sternum often contains the raphe, and may be positioned centrally as in *Navicula*, or marginally as in *Eunotia*.



Stigma - stigmata: opening in the valve wall in the central area distinct in structure from an areola; externally a round or elongate opening, internally it has the shape of a slit or a more complex structure.

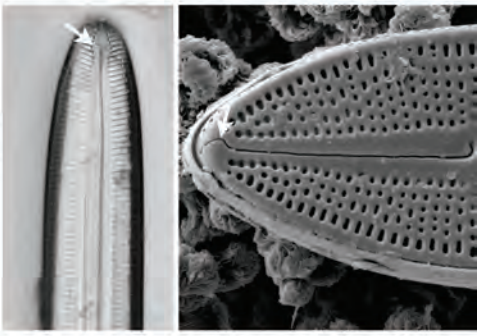


Stria - striae: a row of pores, areolae on the valve.



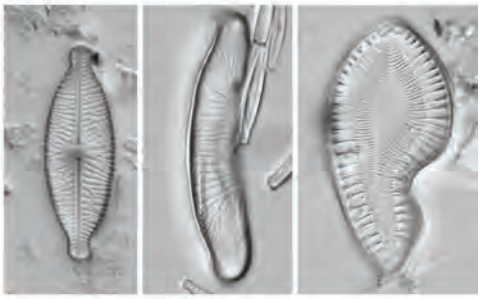
Stria density: number of striae present on the valve, expressed as number in 10 µm. In centric diatoms, it is the number of striae in 10 µm measured at the circumference.

Terminal fissure: terminal raphe slit ending near the pole/terminal nodule, may be expanded or curved.



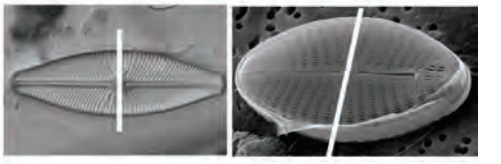
Terminal nodule: more heavily silicified part of the valve wall near a pole and a terminal raphe slit; the polar or apical nodule.

Teratologic form: deformations and abnormalities in the valve ornamentation.



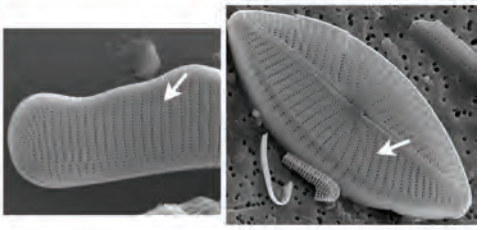
Theca: part of the frustule composed of a valve and its corresponding girdle bands.

Transapical axis: the short axis of a pennate diatom valve, crossing the middle of the valve face; axis perpendicular to the apical axis.



Ubiquitous: occurring everywhere on earth.

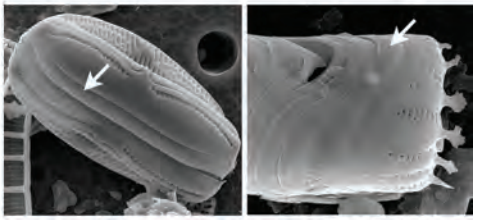
Uniseriate: stria composed of a single row of areolae.



Valve: part of a frustule, composed of a flat part, the valve face, and an extension, usually at 90°, the valve mantle.

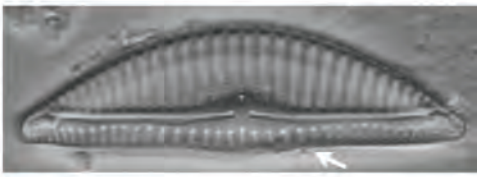
Valve view: view of the frustule turned so that the valve face is visible.

Valvocopula: the girdle band in contact with the valve; the first girdle band.

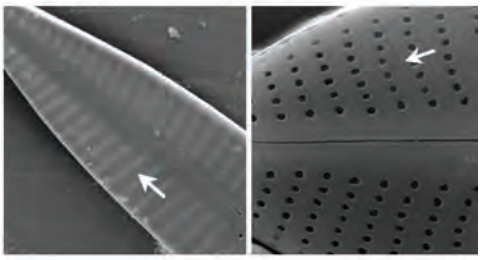


Velum: type of pore occlusion.

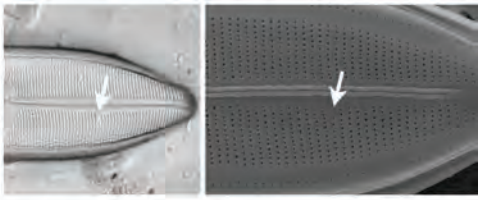
Ventral side: in diatoms asymmetrical to the apical axis, the side of the valve that is straight to slightly convex or concave.



Virga - virgae: solid siliceous rib between regularly aligned areolae, also called interstria/interstriae.



Voigt fault or Voigt discordance: discontinuity in the striae on the secondary side of the valve at the point where the two branches are joined to each other during valve formation.



Vola - volae: type of pore occlusion.

10.2. Translation of English terms into French

alveolus: alvéole
annulae: annulae
apex: apex
apical axis: axe apical
apical nodule: nodule apical
apical pole: pôle apical
apical pore field: champs de pores apicaux.
araphid: araphide
areola: aréole
axial area: aire axiale
axial costa: côte axiale
axial plate: plaque axiale
auxospore: auxospore
bifurcate: bifurqué
biraphid: biraphide
biseriate: bisérié
carinoportula: carinoportule
central area: aire centrale
central fissure: fissure centrale
central nodule: nodule central
chrysolaminarin: chrysolaminarine
cingulum: cingulum
clavate: allongé
collum: collet
conopeum: conopeum
convergent: convergente
copula: bande intercalaire
cosmopolite: cosmopolite
costa: côte
craticula: craticule
cribrum: cribrum
cruciform: cruciforme
dorsal side: côté dorsal
epitheca: épithèque
fascia: fascia
fascicle: fascicule
fibula: fibule
foot pole: apex/pôle podal
foramen: foramen
frustule: frustule
fultoportula: fultoportule
fusiform: fusiforme
ghost striae: stries fantômes
girdle: ceinture
girdle band: bande de ceinture
head pole: pôle apical
helictoglossa: hélictoglosse
heteropolar: hétéropolaire
heterovalvar: hétérovalvaire
hyaline area: aire hyaline
hymen: hymen
hypotheca: hypothèque
infundibulum: infundibulum
intercalary band: bande intercalaire
interfascicle: côte
intermissio: intermission
isolated punctum: point isolé
isopolar: isopolaire
keel: carène
keel puncta: fibule
ligula: ligule
lineola: linéole
lineolate stria: strie linéolée
linking spine: épine de jonction
longitudinal canal: canal longitudinal
longitudinal rib: côte longitudinale
lunate: luniforme
mantle: manteau
monoraphid: monoraphide
ocellus: ocellus
partectum: locule
pervalvar axis: axe pervalvaire
polar nodule: nodule polaire
porca: porca
primary side: côté primaire
pseudoseptum: pseudoseptum
punctum: point
pyrenoid: pyrénoïde
radiate: radiaire
raphe: raphé
raphe canal: canal raphéen
raphe keel: carène du raphé
rimoportula: rimoportule
Ringleiste: Ringleiste

secondary side: côté secondaire
septum: septum
seta: seta
spine: épine
stauros: stauros
sternum: sternum
stigma: stigma
stria: strie
stria density: densité des stries
terminal fissure: fissure terminale
terminal nodule: nodule terminal
teratologic form: forme tératologique
theca: thèque
transapical axis: axe transversal
ubiquitous: ubiquiste
uniseriate: unisérié
valve: valve
valvocopula: valvocopula
velum: vélum
ventral side: côté ventral
Voigt fault / Voigt discordance: défaut de Voigt
vola: vola

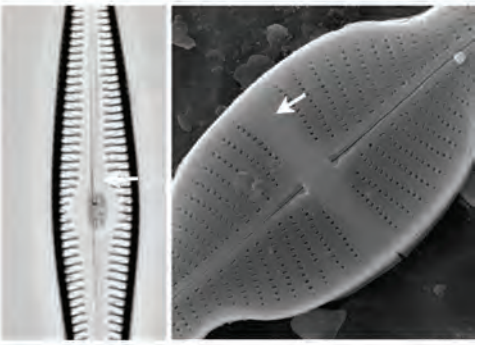
10.3. Glossaire

Adné: attaché au substrat par la surface de la valve à raphé.

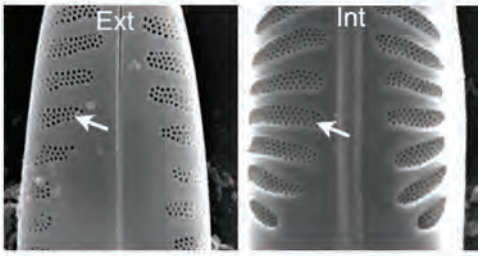
Aire axiale: espace hyalin sur la surface valvaire le long de l'axe longitudinal, entre le raphé, si présent, et les stries chez les diatomées pennées.

Aire centrale: espace hyalin au centre de la valve à hauteur du nodule central si présent, dépourvue d'aréoles.

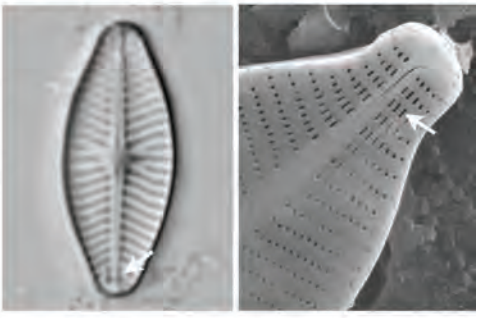
Aire hyaline: zone de la valve sans perforation ni ornementation.



Alvéole: strie composée d'une chambre transversalement linéaire dans la paroi de la valve avec de petites ouvertures multiples à la face extérieure et de grandes ouvertures à la face intérieure de la valve.



Annulae: structure composée d'une à quatre stries transapicales (perpendicu-laires) interrompant les stries typiques vers les apices. Structure restreinte au genre *Geissleria*.



Apex - apices: chez les diatomées pennées extrémité de la valve, aussi appelée pôle.

Apex apical: chez les diatomées pennées hétéropolaires extrémité de la valve la plus large, aussi appelée pôle apical.

Apex podal: chez les diatomées pennées hétéropolaires extrémité de la valve la plus fine, aussi appelée pôle podal ou pôle basal.

Araphide: diatomée pennée sans fissure raphéenne sur les deux valves.

Aréole: ou point, perforation ronde ou presque ronde de la paroi en silice. Les aréoles sont généralement alignées formant une strie.

Axe apical: axe longitudinal de la face valvaire des diatomées pennées reliant les apices.

Axe pervalvaire: axe de la valve qui est perpendiculaire vers le centre de la surface de la valve; dans les diatomées pennées c'est le point de rencontre entre les axes apical et transversal; dans les diatomées centriques c'est le point de rencontre des stries.

Axe transversal: axe de la valve le plus court, passant le centre de la surface de la valve; axe perpendiculaire à l'axe apical.

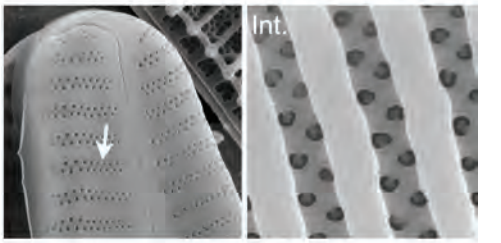
Auxospore: cellule spéciale formée dans la reproduction sexuelle après la fusion des gamètes ; la cellule formée est plus grande que les cellules filles et la taille maximale de la diatomée est rétablie.

Bande de ceinture ou bande intercalaire: une des bandes siliceuses associées à la valve.

Bifurqué: structure qui est divisée en deux parties.

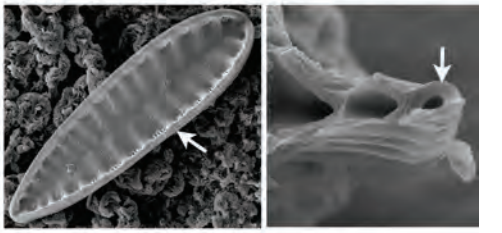
Biraphide: diatomée pennée qui porte un raphé sur chaque valve.

Bisérié: composé de deux parties; les stries bisériées portent deux lignes d'aréoles.

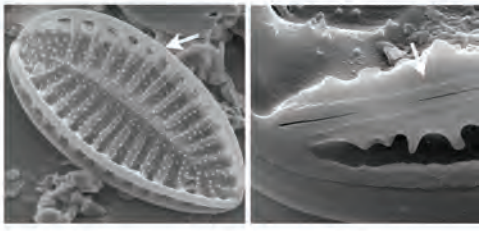


Canal longitudinal: chambre en forme de tube dans la valve interne orientée le long de l'axe apical. Présent dans le genre *Neidium*.

Canal raphéen: structure cylindrique plus ou moins fermée à l'intérieur de la valve, portant le raphé.

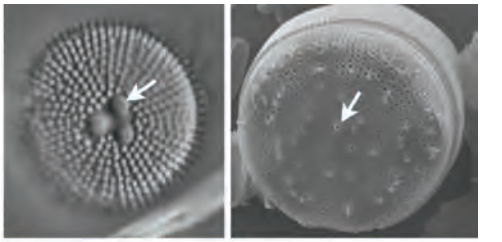


Carène: côte élevée qui contient le raphé, formée par un pli de la paroi de la valve. Présent dans des genres comme *Nitzschia*, *Surirella*, *Cymatopleura*, *Campylodiscus*.

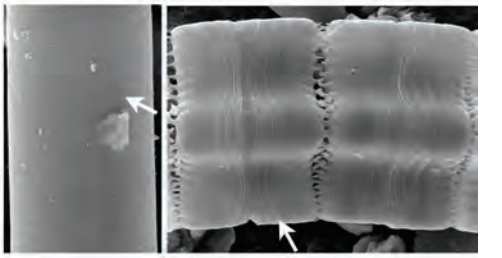


Carène du raphé: structure ressemblant à une crête très distincte au bord de la valve où passe le raphé, formé par un pli de la paroi de la valve. Présent dans des genres comme *Nitzschia*, *Surirella*, *Cymatopleura*, *Campylodiscus*.

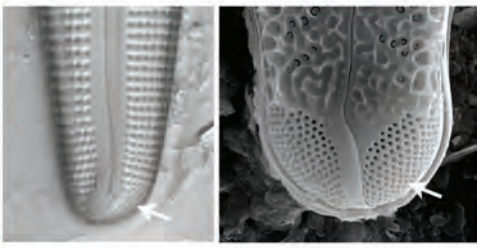
Carinoportule: processus central restreint au genre *Orthoseira*; les ouvertures internes sont simples, les ouvertures externes sont composées des cols bien définis.



Ceinture: série de bandes associées à la valve; aussi appelée cingulum.

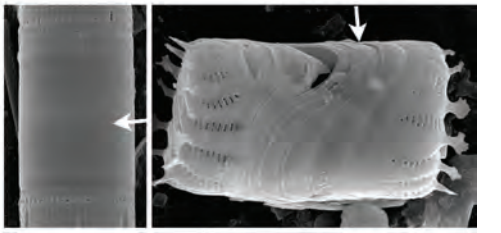


Champs de pores apicaux: zone de pores ou perforations très fines à travers la paroi près d'une ou des deux extrémités de la valve des diatomées pennées. C'est la zone où des mucopolysaccharides qui forment des tiges sont.



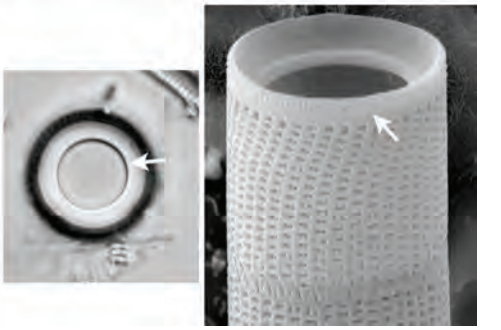
Chrysolaminarine: un polysaccharide de réserve chez les diatomées et les Chrysophytes.

Cingulum: série de bandes siliceuses associées à une valve.

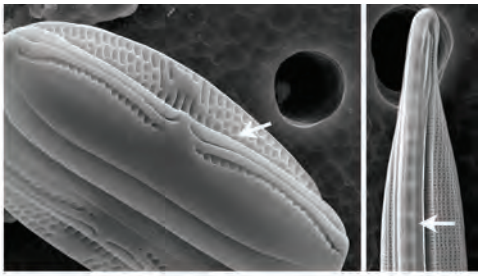


Clavé: en forme d'une massue.

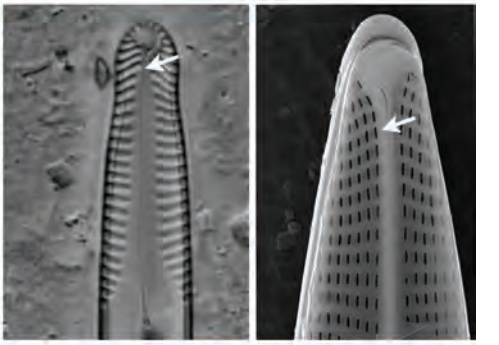
Collet: aire étroite et hyaline du manteau de la valve chez les *Aulacoseira*.



Conopeum: fine couverture siliceuse sur la surface externe de la valve le long de l'axe apical; peut être légèrement à distinctement élevé et couvrir partiellement ou totalement les stries et être étendu jusqu'au bord de la valve.

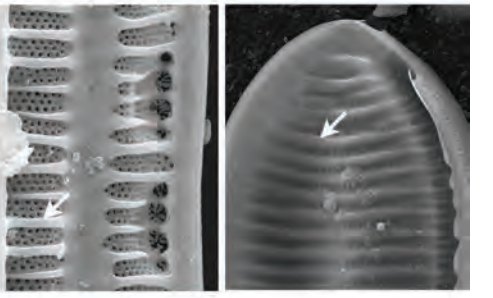


Convergente: les stries sont convergentes quand elles sont détournées du nodule central et orientées vers le nodule terminal.

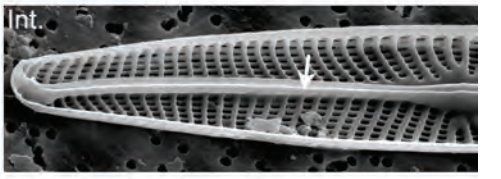


Cosmopolite: présent partout au monde dans les mêmes habitats.

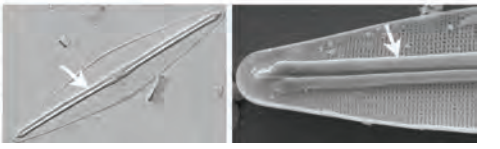
Côte: partie de la valve plus épaisse et non ornementée parallèle aux stries.



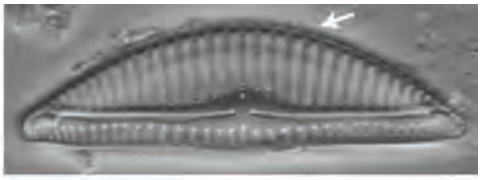
Côte axiale: bord siliceux étroit le long de l'aire axiale, parallèle au et encadrant le raphé.



Côte longitudinale: structure siliceuse longitudinale sur la surface de la valve à de chaque côte du raphé en croissant les stries.

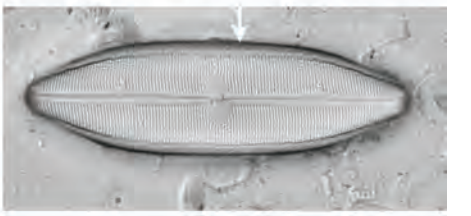


Côté dorsal: dans les diatomées asymétriques en vue de l'axe apical, le côté de la valve le plus convexe.

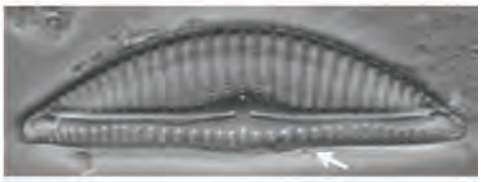


Côté primaire: côté de la valve formé par les branches initiales du sternum raphéen dans l'ontogénie des diatomées à raphé.

Côté secondaire: côté formé après le côté primaire par la fusion des branches de silice allongeant du centre et des extrémités du sternum raphéen dans l'ontogénie des diatomées à raphé.



Côté ventral: dans les diatomées asymétriques en vue de l'axe apical, le côté de la valve qui est droit, faiblement convexe ou concave.

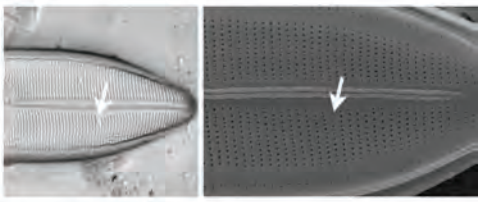


Craticule: structure en surplus de la surface interne d'une valve composée d'un sternum et des barres transversales solides, formée sous des conditions de haute pression osmotique.

Cribum: type de couverture d'un pore.

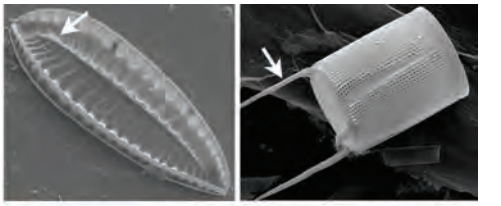
Cruciforme: en forme de croix

Défaut de Voigt: discontinuité dans les stries dans le côté secondaire à l'endroit où les deux branches se fusionnent lors de l'ontogénie des diatomées à raphé.

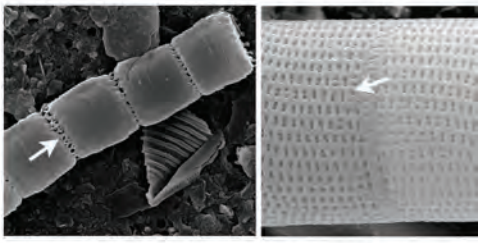


Densité des stries: nombre de stries sur la valve, exprimé en nombre par 10 µm. Pour les diatomées centriques le nombre de stries sur 10 µm de la circonférence.

Épine: prolongement aigu siliceux de la valve, massif ou creux, très long ou minuscule, qui apparait dans les différents taxons à différents endroits sur la surface externe de la valve.

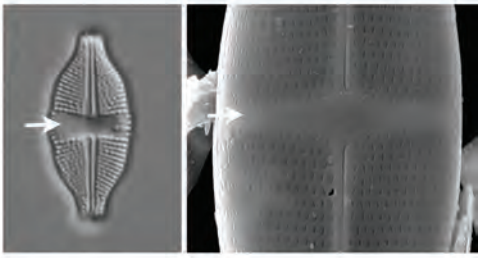


Épine de jonction: épine, prolongement aigu siliceuxse de la valve, qui réunitunie des frustules en une chaîne.

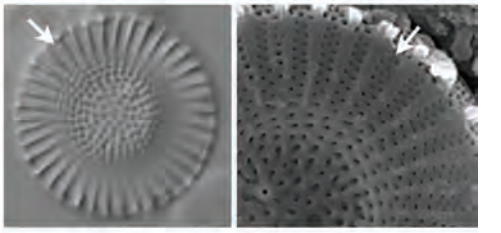


Épithèque: valve la plus large et la plus vieille des deux valves d'une frustule de diatomée.

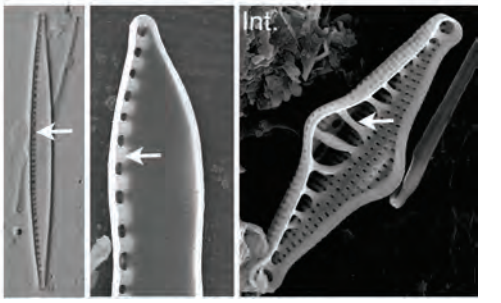
Fascia: aire hyaline épaisse siliceuse, étendue de l'aire centrale vers les bords de la valve chez quelques diatomées pennées, formée par dépôt secondaire de silice dans des dépressions dans la surface de la valve.



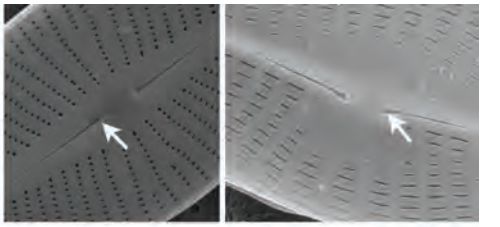
Fascicule: série ou groupe d'aréoles orientées radialement chez certaines diatomées centriques.



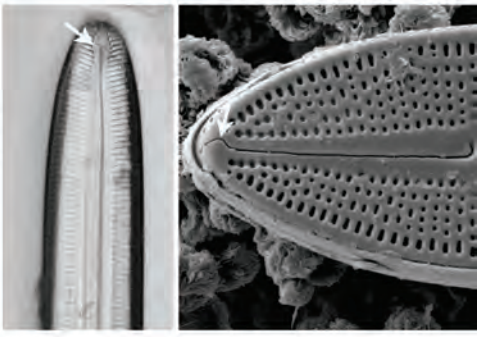
Fibule: support siliceux interne du canal qui contient le raphé.



Fissure centrale: extrémité de la fente raphéenne près du nodule central; peut être élargie ou courbée.

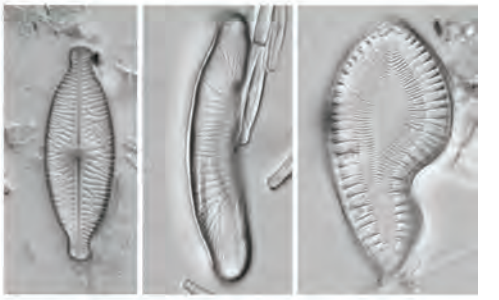


Fissure terminale: extrémité de la fente raphéenne près du nodule terminal; peut être élargie ou courbée.



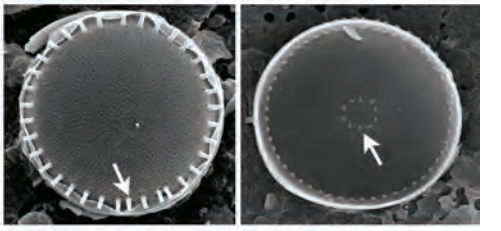
Foramen: type de couverture d'un pore.

Forme tératologique: déformations et anormalités dans les ornementations de la valve.



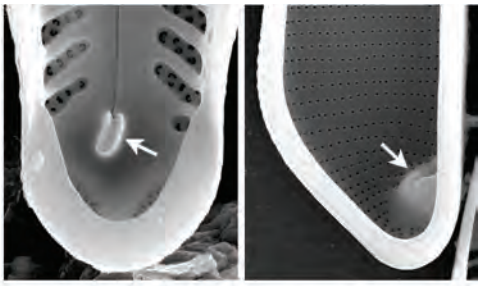
Frustule: cellule d'une diatomée composée de silice, et de deux valves et les bandes connectives associées.

Fultoportule: processus tubulaire chez certaines diatomées centriques, associé à la sécrétion de β-chitine. En vue intérieure de la valve le processus central est entouré de deux ou plusieurs pores satellites; en vue extérieure un tube ou un pore simple dans la paroi de la valve.

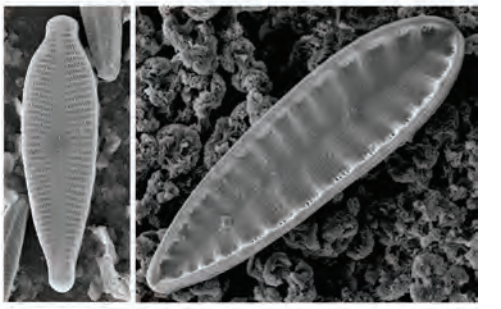


Fusiform: comme un fuseau, avec la partie plus large au centre et devenant plus étroite vers les extrémités.

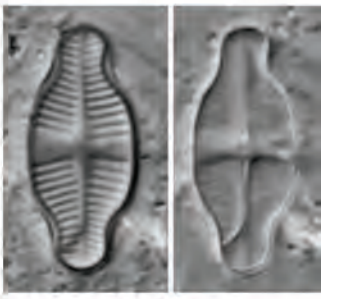
Hélictoglosse: structure en forme de lèvres à l'extrémité de la fissure terminale du raphé vers les extrémités internes de la valve dans beaucoup de diatomées pennées à raphé; autrefois désigné comme infundibulum.



Hétéropolaire: valve asymétrique; présentant une différence dans la forme des pôles ou de l' axe apical.

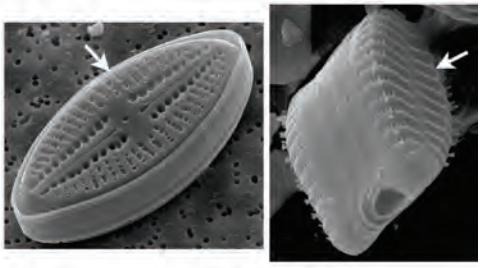


Hétérovalvaire: frustule composée de deux valves différentes; la différence peut être dans la présence ou l'absence d'un raphé ou dans l'ornementation de la surface des valves.



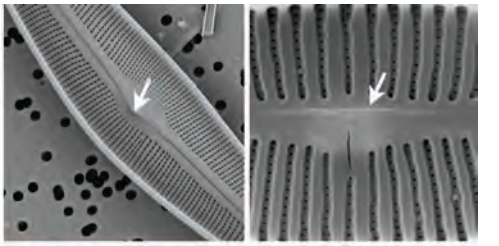
Hymen: type de couverture d'un pore.

Hypothèque: Valve la plus petite et la plus jeune d'une frustule.



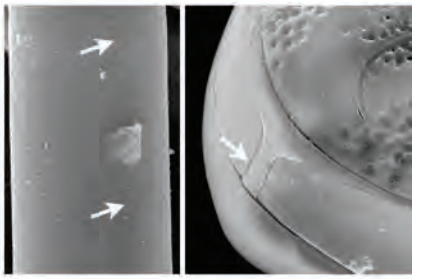
Infundibulum: structure en forme de lèvres à l'extrémité de la fissure terminale du raphé vers les extrémités internes de la valve dans beaucoup de diatomées pennées à raphé : ancien nom pour hélictoglosse.

Intermission: fissure interne qui lie les fissures centrales chez quelques taxons cymbelloides.

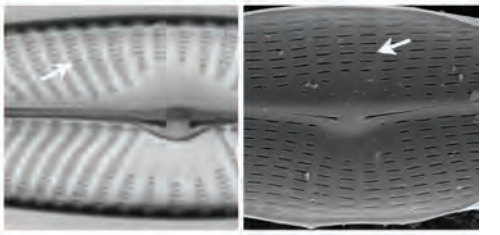


Isopolaire: valve qui a une forme identique de chaque côté de l'axe transapical; les deux extrémités ont la même forme et taille.

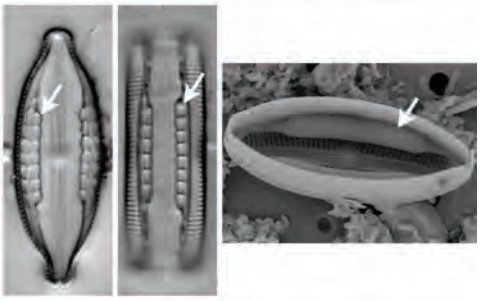
Ligule: expansion siliceuse d'une bande connective qui remplit le sillon, causée par une faille dans la bande, de la bande connective suivante.



Linéole: aréole allongée en direction apicale.

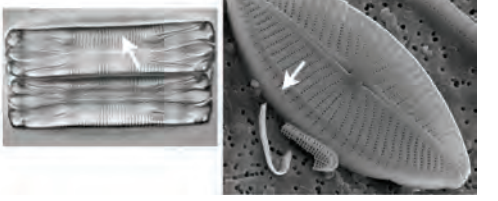


Locule ou partectum: chambre globulaire à l'intérieur de la valvocopula, présente uniquement dans le genre Mastogloia. Les chambres sont rangées sur une ligne le long de chaque côté de la valvocopula en formant un anneau partectal.



Luniforme: en forme de lune, de croissant.

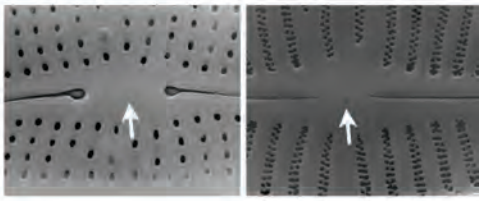
Manteau: hauteur d'une valve, partie dressée de valve qui entoure la face de la valve.



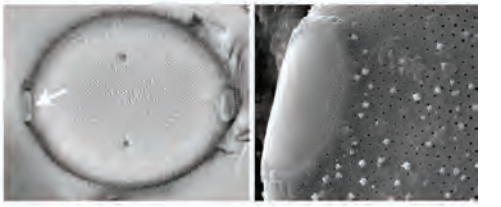
Monoraphide: diatomée pennée qui porte un raphé sur une des deux valves.

Nodule apical, polaire ou terminal: partie de la valve plus épaisse, située près d'un pôle où la fente raphéenne se termine.

Nodule central: partie de la valve plus épaisse entre les fissures centrales du raphé.

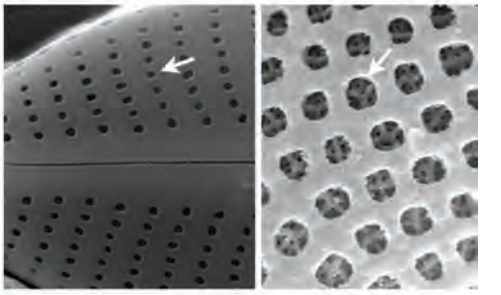


Ocellus: structure en forme d'œil, composée de petits pores entourés d'une côte siliceuse peu profonde. Présente à la transition de la surface de la valve et le manteau dans le genre *Pleurosira*. Responsable de la sécrétion de polysaccharides qui unissent les cellules.

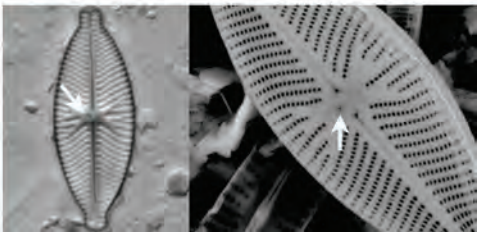


Plaque axiale: plaque siliceuse qui se trouve dans la partie interne d'une valve et qui couvre les ouvertures internes des aréoles. La plaque existe chez quelques représentants du genre *Gomphoneis* où le bord est visible au microscope optique comme une ligne longitudinale.

Point: ou aréole, perforation ronde ou ovale de la paroi en silice.



Point isolé: perforation ronde de la paroi en silice à hauteur de l'aire centrale, nettement séparé des aréoles des stries.



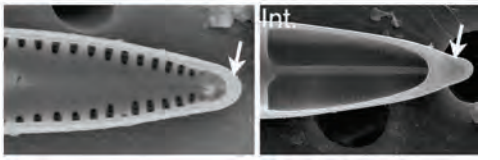
Pôle: chez les diatomées pennées, extrémité de la valve, aussi appelée apex.

Pôle apical: chez les diatomées pennées hétéropolaires, extrémité de la valve la plus large.

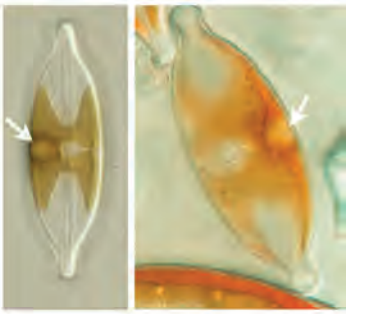
Pôle basal ou pôle podal: chez les diatomées pennées hétéropolaires, extrémité de la valve la plus fine, aussi appelée apex podal.

Porca: ondulation transapicale de la surface de la valve dans le genre *Surirella*.

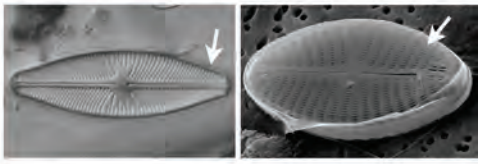
Pseudoseptum: plaque de silice avancée à l'intérieur de la cellule étendue de la valve.



Pyrénoïde: structure chez les algues dans le chloroplaste qui est responsable de la fixation de CO_2, et pas de la production de l'amidon comme supposé autrefois; elle est souvent enveloppée des grains ou d'une gaine d'amidon.

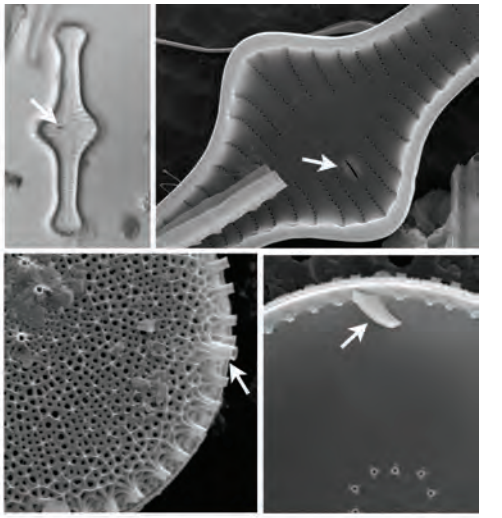


Radiaire: les stries sont radiaires quand elles sont rayonnantes à partir du nodule central.

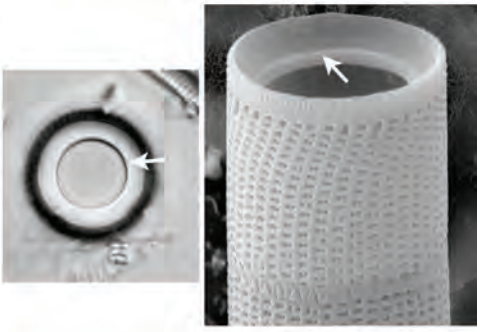


Raphé: fente dans la surface de la valve chez les mono- et biraphides, souvent localisée le long de l'axe apical.

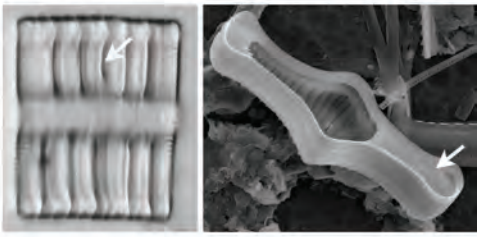
Rimoportule ou processus labié: processus tubulaire de quelques diatomées centriques et pennées, associé à la sécrétion de polysaccharides et d'autres substances contenant du carbone. En vue intérieure de la valve le processus se voit comme une ouverture en forme de lèvres; en vue extérieure un tube



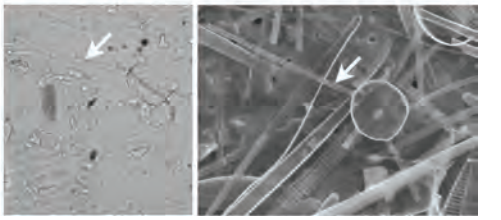
Ringleiste: petit rebord qui sépare le collet de la partie du manteau à aréoles chez le genre Aulacoseira.



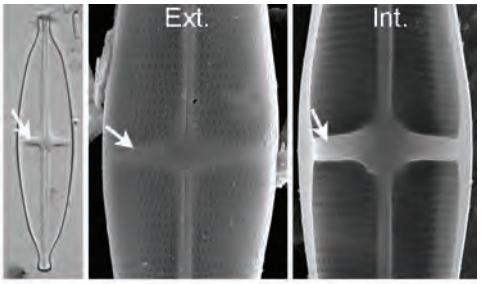
Septum: plaque de silice avancée à l'intérieur de la cellule étendue d'une bande connective.



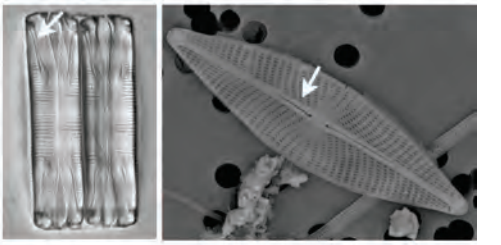
Seta: prolongement simple ou robuste de la valve, plus allongé qu'une épine. Présent dans le genre *Chaetoceros*. Les setae connectent les cellules pour former des chaînes.



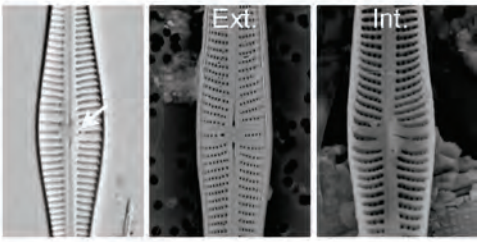
Stauros: partie hyaline épaisse présente dans l'aire centrale, formée différemment d'un fascia dans l'ontogénie de la cellule. Uniquement présent dans le genre *Stauroneis*.



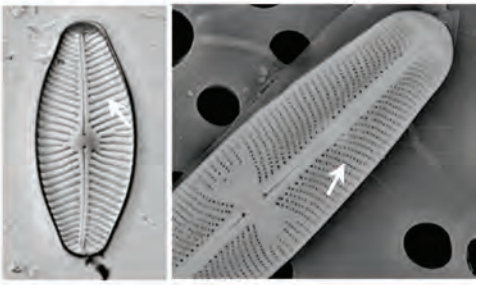
Sternum: structure épaisse siliceuse allongée le long de l'axe apical chez les diatomées pennées; c'est le centre ontogénique des pennées. Le sternum contient souvent le raphé, et peut se trouver au centre, comme chez *Navicula*, ou marginal comme chez *Eunotia*.



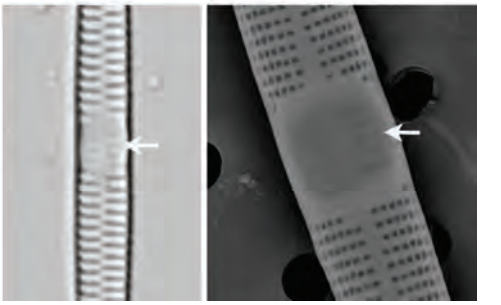
Stigma: perforation de la paroi en silice à hauteur de l'aire centrale, différente d'une aréole; ouverture ronde à l'extérieur et une fente à l'intérieur, ou structure très complexe.



Strie: rangée de pores, d'aréoles sur la valve.



Stries fantômes: stries floues, composées d'aréoles ne perforant pas la paroi de la valve.

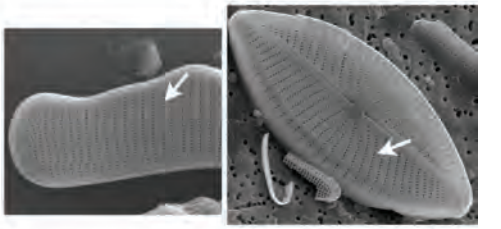


Strie lineolée: strie composée de linéoles (aréoles allongées en direction apicale)

Thèque: partie d'une frustule composée de la valve est des bandes intercalaires associées à cette valve.

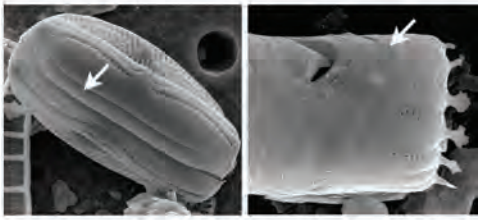
Ubiquiste: présent partout dans le monde.

Unisérié: les stries unisériées portent une seul ligne d'aréoles



Valve: partie d'une frustule, composée d'une partie aplatie, la surface de la valve, et d'une partie dressée, le manteau.

Valvocopula: bande connective en contact avec la valve; c'est la première bande de la ceinture.



Vélum: type de couverture d'un pore.

Vue valvaire: vue de la frustule quand la face de la valve est visible.

Vola: type de couverture d'un pore.

11. Classification of the diatoms

In the present work ninety-one diatom genera are illustrated, covering most of the genera which can be observed in tropical Africa. The classification used is after Round *et al.* (1990) with some modifications when it concerns genera described after 1990. This classification is more complex than the before used “centrics” and “pennates”. We will cite here only the genera discussed in the taxonomic part of the present book.

The divisions given are: class (-phyceae), subclass (-phycidae), order (-ales), family (-aceae) and genus. Note that the names are written in italics from genus level on. Taxa lower than genus most often used in diatom taxonomy are: species, variety and forma.

Division Bacillariophyta

Class: Coscinodiscophyceae Round & R.M. Crawford
- Subclass: Thalassiosirophycidae Round & R.M. Crawford
  - Order: Thassiosirales Glezer & Makarova
    - Family: Thalassiosiraceae Lebour
      - Genus: *Thalassiosira* Cleve
    - Family: Stephanodiscaceae Glezer & Makarova
      - Genus: *Cycostephanos* Round
      - *Cyclotella* Kützing ex Brébisson
      - *Discostella* Houk & Klee
      - *Pantocsekiella* Kiss & Ács
      - *Stephanodiscus* Ehrenberg
- Subclass: Coscinodiscohycidae Round & R.M. Crawford
  - Order: Melosirales R.M. Crawford
    - Family: Melosiraceae Kützing
      - Genus: *Melosira* C. Agardh
  - Order: Aulacoseirales R. M. Crawford
    - Family: Aulacoseiraceae R.M. Crawford
      - Genus: *Aulacoseira* Thwaites
  - Order: Orthoseirales R. M. Crawford
    - Family: Orthoseiraceae R.M. Crawford
      - Genus: *Orthoseira* Thwaites
- Subclass: Biddulphiophycidae Round & R.M. Crawford
  - Order: Triceratiales Round & R.M. Crawford
    - Family: Triceratiaceae (Schütt) Lemmermann

Genus: *Pleurosira* (Meneghini) Trevisan

Subclass: Rhizosoleniophycidae Round & R.M. Crawford

Order: Rhizosoleniales Silva

Family: Rhizosoleniaceae De Toni

Genus: *Urosolenia* Round & R.M. Crawford

Class: Fragilariophyceae Round

Subclass: Fragilariophycidae Round

Order: Fragilariales Silva

Family: Fragilariaceae Greville

Genus: *Asterionella* Hassall

Ctenophora Grunow ex D.M. Williams & Round

Diatoma Bory

Fragilaria Lyngbye

Fragilariforma D. M. Williams & Round

Meridion C. Agardh

Pseudostaurosira D.M. Williams & Round

Staurosira Ehrenberg

Staurosirella D.M. Williams & Round

Tabularia Kützing ex D.M. Williams & Round

Ulnaria (Kützing) Compère

Order: Tabellariales Round

Family: Tabellariaceae Kützing

Genus: *Tabellaria* (Ehrenberg) Kütizng

Class: Bacillariophyceae Haeckel

Subclass: Eunotiophycidae D.G. Mann

Order: Eunotiales Silva

Family: Eunotiaceae Kützing

Genus: *Actinella* F.W. Lewis

Actinellopsis J.C. Taylor, B. Karthick & Kociolek

Desmogonium Ehrenberg

Eunotia Ehrenberg

Subclass: Bacillariophycidae D.G. Mann
Order: Mastogloiales D.G. Mann
Family: Mastogloiaceae Mereschkowsky
Genus: *Mastogloia* Thwaites ex W. Smith
Order: Cymbellales D.G. Mann
Family: Rhoicospheniaceae Chen & Zhu
Genus: *Rhoicosphenia* Grunow
Family: Anomoeoneidaceae D.G. Mann
Genus: *Anomoeoneis* Pfitzer
Family: Cymbellaceae Greville
Genus: *Afrocymbella* Krammer
Cymbella C. Agardh
Cymbopleura (Krammer) Krammer
Encyonema Kützing
Encyonopsis Krammer
Placoneis Mereschkowsky
Family: Gomphonemataceae Kützing
Genus: *Gomphonema* Ehrenberg
Gomphosphenia Lange-Bertalot
Order: Achnanthales Silva
Family: Achnanthaceae Kützing
Genus: *Achnanthes* Bory
Lemnicola Round and Basson
Psammothidium Bukhtiyarova & Round
Family: Cocconeidaceae Kützing
Genus: *Anorthoneis* Grunow
Cocconeis Ehrenberg
Family: Achnanthidiaceae D.G. Mann
Genus: *Achnanthidium* Kützing
Planothidium Round & Bukhtiyarova
Order: Naviculales Bessey
Family: Cavinulaceae D.G. Mann
Genus: *Cavinula* D.G. Mann & Stickle
Family: Diadesmidaceae D.G. Mann
Genus: *Diadesmis* Kützing
Humidophila R.L. Lowe, Kociolek, J.R. Johansen, Van de Vijver, Lange-

Bertalot & Kopalová
Luticola D.G. Mann
Family: Amphipleuraceae Grunow
Genus: *Amphipleura* Kützing
Frustulia Rabenhorst
Family: Brachysiraceae D.G. Mann
Genus: *Brachysira* Kützing
Family: Neidiaceae Mereschkowsky
Genus: *Neidium* Pfitzer
Family: Sellaphoraceae Mereschkowsky
Genus: *Fallacia* Stickle
Pseudofallacia Y. Liu, Kociolek & Q.X. Wang
Sellaphora Mereschkowsky
Family: Pinnulariaceae D. G. Mann
Genus: *Caloneis* Cleve
Pinnularia Ehrenberg
Family: Diploneidaceae D.G. Mann
Genus: *Diploneis* (Ehrenberg) Cleve
Family: Naviculaceae Kützing
Genus: *Adlafia* Gerd Moser, Lange-Bertalot & Metzeltin
Capartogramma Kufferath
Eolimna Lange-Bertalot & W. Schiller
Fistulifera Lange-Bertalot
Geissleria Lange-Bertalot & Metzeltin
Hippodonta Lange-Bertalot, Metzeltin & Witkowski
Kobayasiella Lange-Bertalot
Mayamaea Lange-Bertalot
Navicula Bory
Nupela Vyverman & Compère
Seminavis D.G. Mann
Family: Pleurosigmataceae Mereschkowsky
Genus: *Gyrosigma* Hassall
Pleurosigma W. Smith

Family: Stauroneidaceae D.G. Mann
Genus: *Craticula* Grunow
Stauroneis Ehrenberg
Family: incertae sedis
Genus: *Envekadea* Van de Vijver, Gligora, Hinz, Kralj & Cocquyt
Order: Thalassiophysales D.G. Mann
Family: Catenulaceae Mereschkowsky
Genus: *Amphora* Ehrenberg ex Kützing
Halamphora (Cleve) Levkov
Order: Bacillariales Hendey
Family: Bacillariaceae Ehrenberg
Genus: *Bacillaria* J. F. Gmelin
Denticula Kützing
Gomphonitzschia Grunow
Hantzschia Grunow
Nitzschia Hassall
Simonsenia Lange-Bertalot
Tryblionella W. Smith
Order: Rhopalodiales D. G. Mann
Family: Rhopalodiaceae (Karsten) Topachevs'kyj & Oksiyuk
Genus: *Epithemia* Kützing
Rhopalodia O. Müller
Order: Surirellales D. G. Mann
Family: Entomoneidaceae D.G. Mann
Genus: *Crucicostulifera* J.C. Taylor & Lange-Bertalot
Family: Surirellaceae Kützing
Genus: *Campylodiscus* Ehrenberg ex Kützing
Cymatopleura W. Smith
Stenopterobia (Brébisson) Van Heurck
Surirella Turpin

12. Diatom genera

Thalassiosira Cleve 1873

Type species: *Thalassiosira nordenskioeldii* Cleve

SYNONYM:

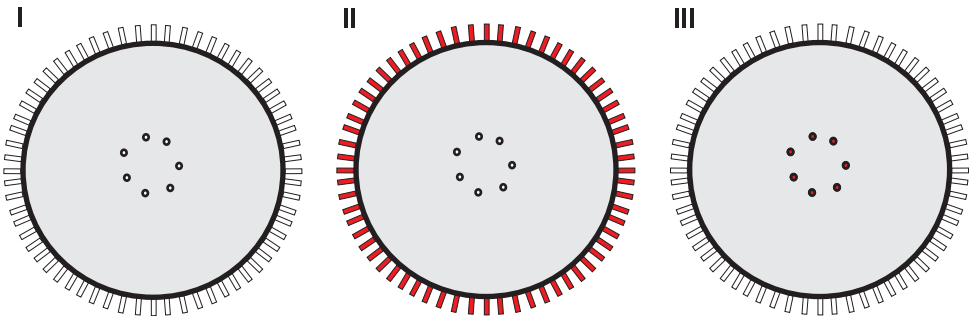
Coscinodiscus Ehrenberg 1839 pro parte

Characteristics – Cells **centric**, striae radiate, not arranged in **fascicles**, areolae may be difficult to discern under LM. A row of prominent **fultoportulae** (strutted processes) present at junction of valve face and mantle (II, Fig. 18: F) which at first glance may resemble spines. Valve face **fultoportulae** (strutted processes) present and usually arranged in a ring in the centre of the valve face (III, Fig. 18: D, G, H). One **rimoportula** present (Fig. 18: I).

Plastid structure – Cells with small discoid plastids (Fig. 18: A-B) and a number of scattered lipid bodies (Fig. 18: A-B).

Identification of species – Cell diameter, size and number of the areolae, placement and structure of the marginal and valve face **fultoportulae**.
Note: Many important cell characteristics can only be observed using SEM.

Ecology – Cells planktonic may become entrained in the benthos. Found in waters with medium to high conductivity and higher trophic levels.



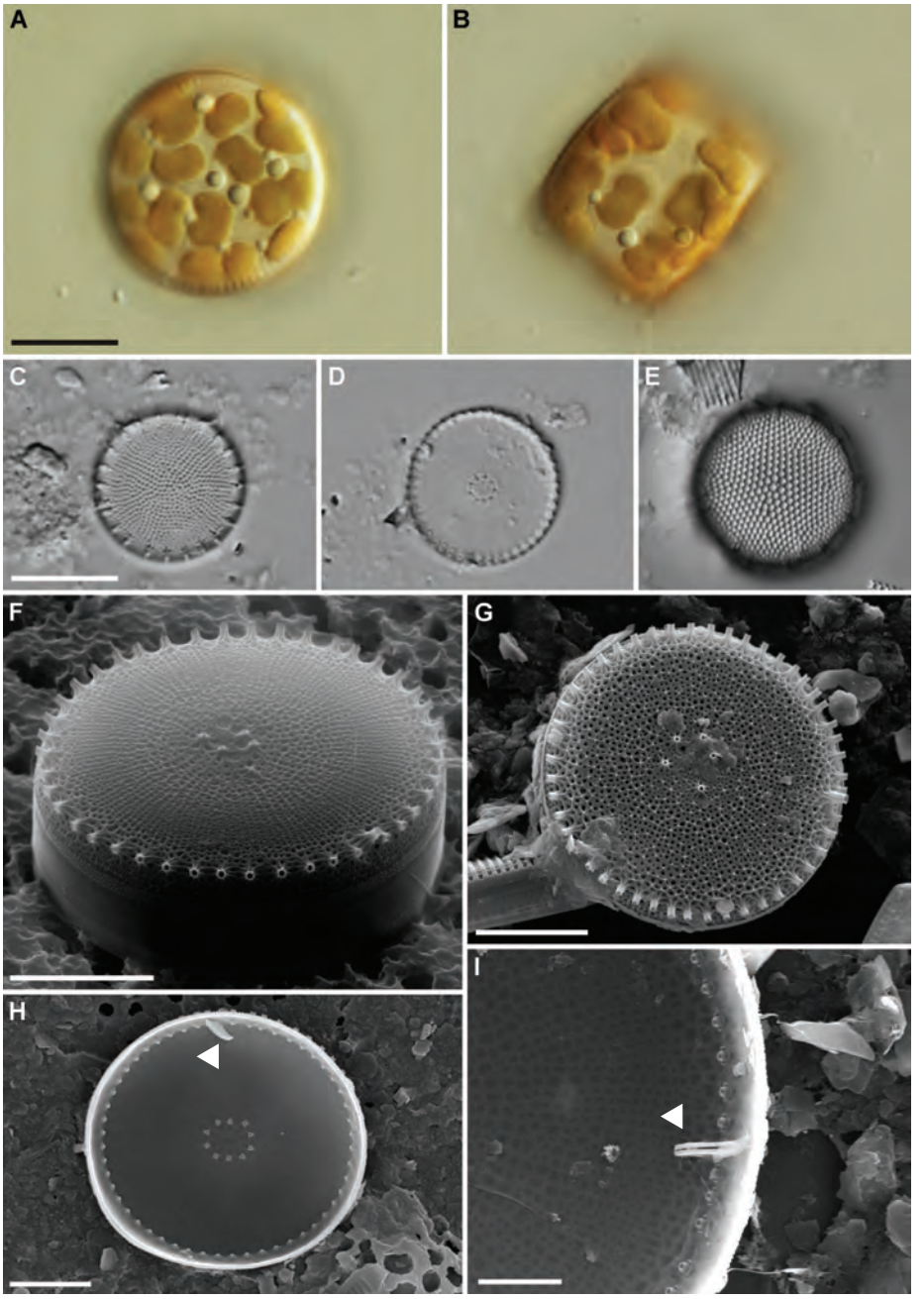


Fig. 18. *Thalassiosira* spp. **A-E**. LM. **A-B.** Living cells of *T. weissflogii*. **A.** Valve view. **B.** Girdle view. **F-I**. SEM, *T. weissflogii*. **F-G.** External view of valve, note central valve face fultoportulae and marginal ring of marginal fultoportula. **H-I.** Internal view of valve, note internal opening of valve face and marginal fultoportula and one rimoportula (arrow).
Scale bars = 10 µm (A-E), 5 µm (F-H), 1µm (I).

Cyclostephanos Round 1988

Type species: *Cyclostephanos novaezeelandiae* (Cleve) Round

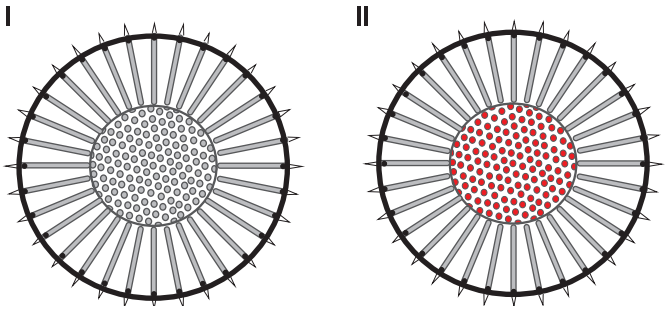
SYNONYM:
Stephanodiscus Ehrenberg 1845 pro parte

Characteristics – Cells **centric** with radiate striae. Striae near the valve margins arranged in bundles (**fasicles**) separated by **interfascicular costae** which extend from the valve margin approximately half way across the valve face where they fuse together. Central area composed of irregularly spaced areolae (II). Spines present at junction of valve face and valve margin at the end of each **costa**. Valve face **fultoportulae** (strutted processes) present on valve face and below the spines on the valve margin. Several **rimoportulae** present near the spines.

Plastid structure – Cells with small discoid plastids.

Identification of species – Cell diameter, number of striae, **fasicles** and **costae** as well as structure of costae. Note: Many important cell characteristics, such as the branching of the striae on the valve mantle, can only be observed using SEM.

Ecology – Cells solitary not forming chains, planktonic may become entrained in the benthos. Found in waters with medium conductivity and ranging from oligotrophic to eutrophic conditions.



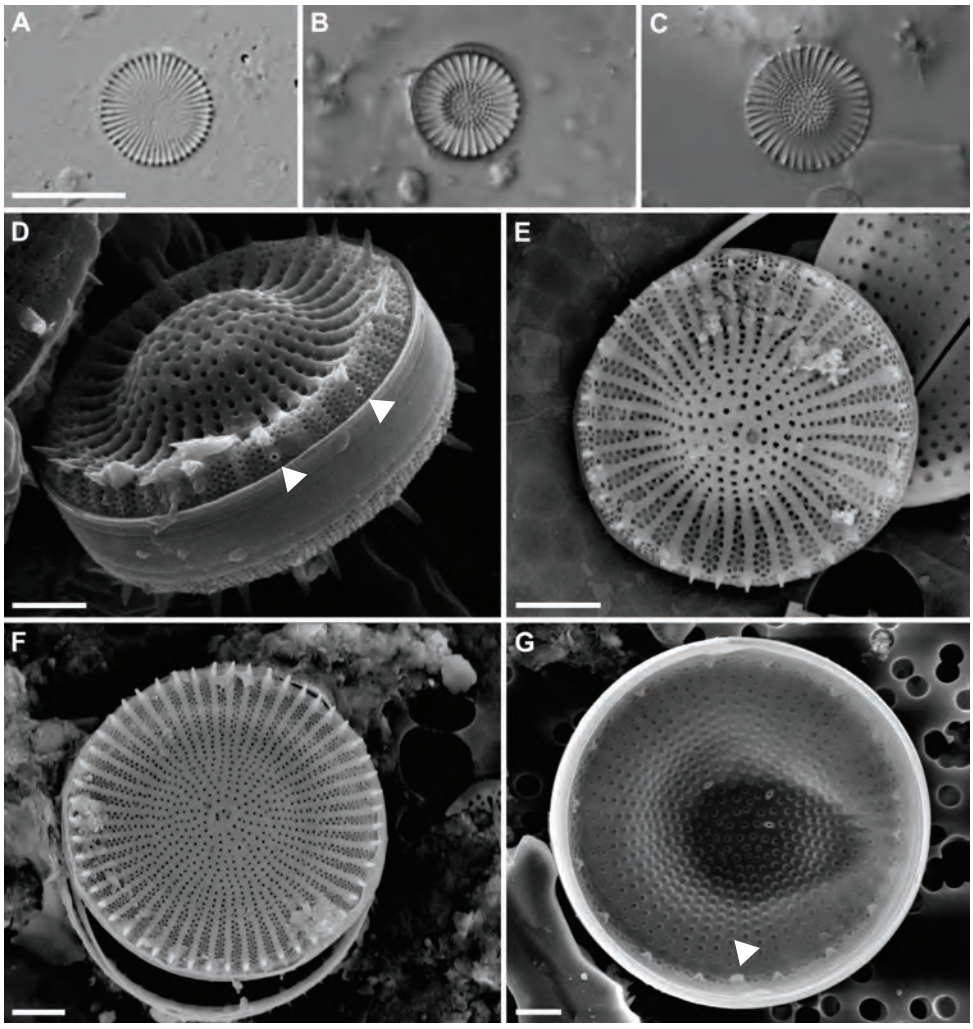


Fig. 19. *Cyclostephanos* spp. **A-C**. LM. **A-C**. Valve views. **D-G**. SEM. **D.** Oblique view showing a ring of spines at the junction of the valve face and mantle, and some fultoportulae on the mantle (arrows). **E-F**. External view of valve. **G.** Internal view of valve showing the internal openings of the valve and marginal fultoportulae and the rimoportula (arrow).
Scale bars = 10 µm (A-C), 2 µm (D-E), 1 µm (F-G).

Cyclotella Kützing ex Brébisson 1838

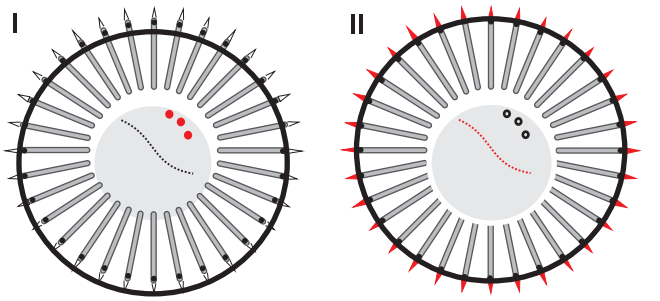
Cyclotella tecta Håkansson & R. Ross

Characteristics – Cells **centric** with radiate striae. Striae separated by robust **interfascicular costae** which extend from approximately half way across the valve face to the valve margin, leaving an open central area which may undulate slightly (II). Spines can be present at junction of valve face and valve mantle at the end of each **costa** (II). Valve face **fultoportulae** (strutted processes) are often present on valve face towards the center (I, Fig. 21: G, H) and below the spines on the valve margin. One **rimoportula** present on the valve mantle.

Plastid structure – Cells with small discoid plastids, scattered lipid bodies (Fig. 20: A).

Identification of species – Cell diameter, number of striae and costae as well as structure of the costae. Presence or absence of valve face **fultoportulae**, number and distribution of marginal **fultoportulae**. Presence or absence of an undulation in the central area. Presence or absence of spines. Note: Many important cell characteristics can only be observed using SEM.

Ecology – Cells, solitary or in pairs but not forming chains, planktonic may become entrained in the benthos. Cells exude chitin threads (Fig. 20: A) from **fultoportulae** allowing them to remain suspended for a longer time in the water column. Found in waters with medium to high conductivity and higher trophic levels.



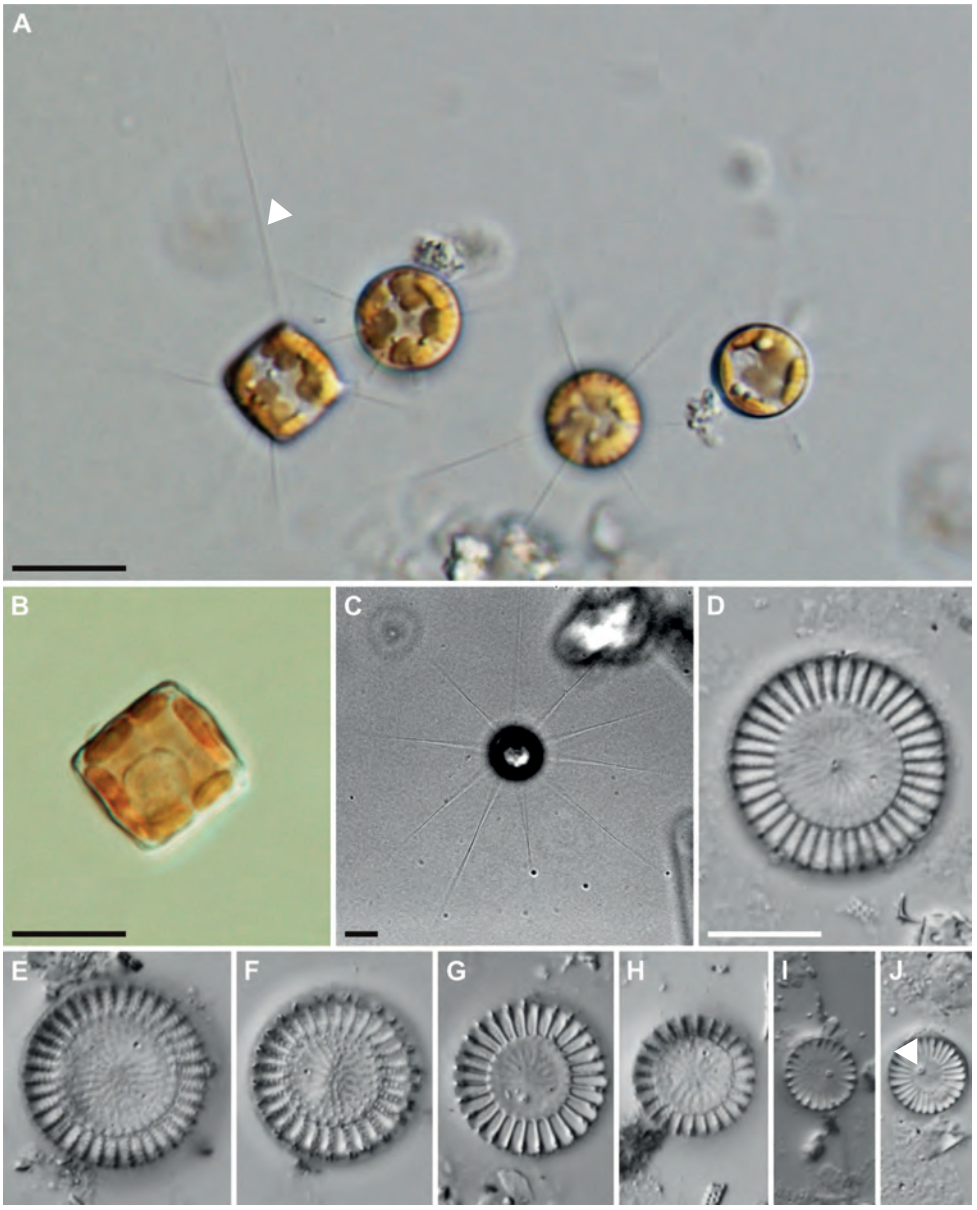


Fig. 20. *Cyclotella* spp. **A-J**. LM. **A**. Living cells, valve and girdle views of *Cyclotella meneghiniana* Kützing, note chitin threads (arrow). **B.** Living cell, girdle view. **C.** Cleaned cell, showing the chitin threads. **D-H**. *C. meneghiniana*, valve views of cleaned cells. **I-J**. *C. atomus* Hustedt, valve views, note rimoportula (arrow).
Scale bars = 10 µm.

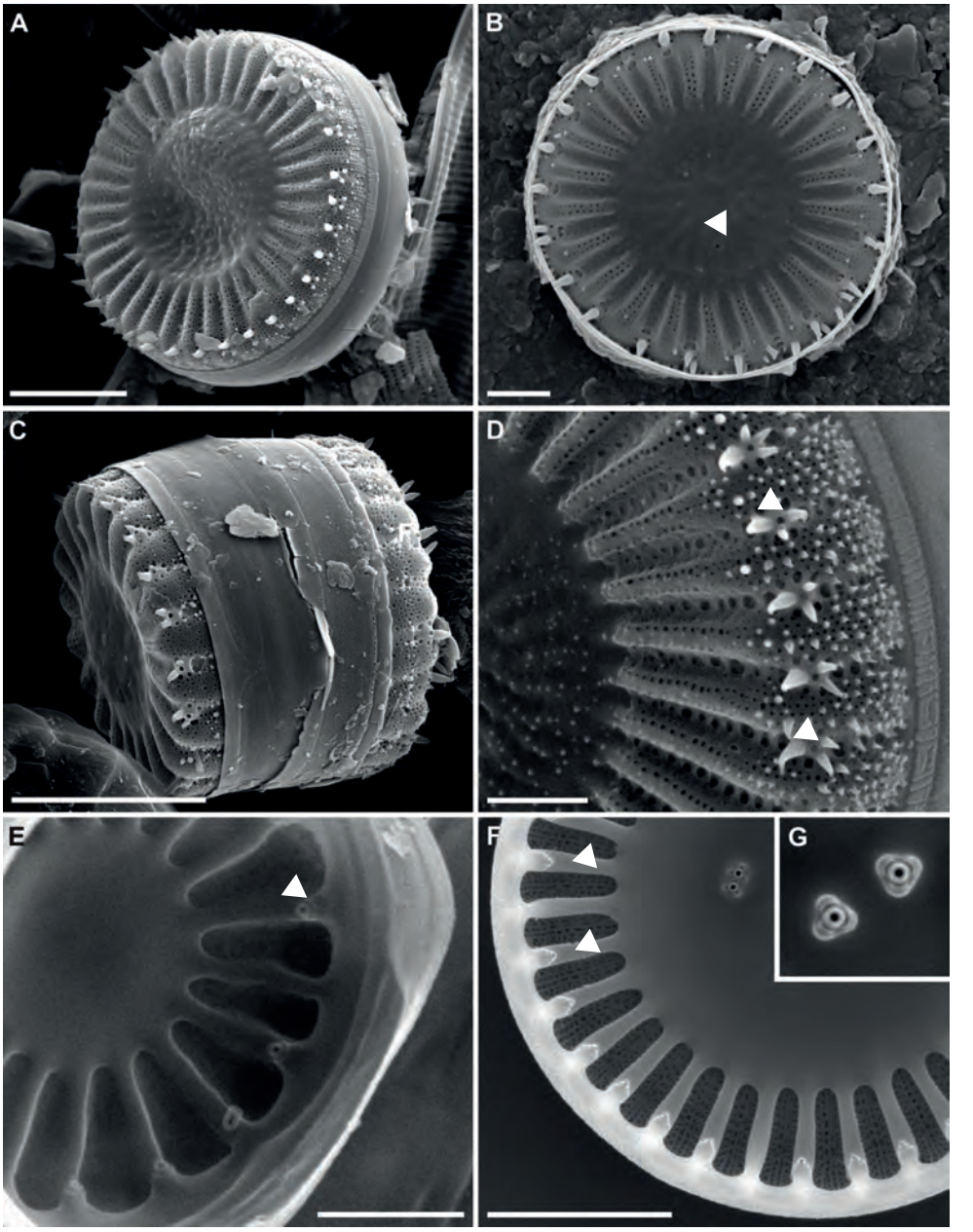


Fig. 21. *Cyclotella* spp. A-F. SEM. **A-D**. *C. meneghiniana*. **A**. Oblique view, note central undulation. **B**. Valve view, note external opening of rimoportula (arrow). **C**. Girdle view. **D**. Detail of the mantle, note the marginal fultoportulae (arrows). **E-G.** Internal view of valve, note internal opening of valve face and marginal fultoportulae (arrows). **G.** Detail of valve face fultoportulae with 3 satellite pores. Scale bars = 5 µm (A-F).

Discostella Houk & Klee 2004

Type species: *Discostella stelligera* (Cleve & Grunow) Houk & Klee

SYNONYM:

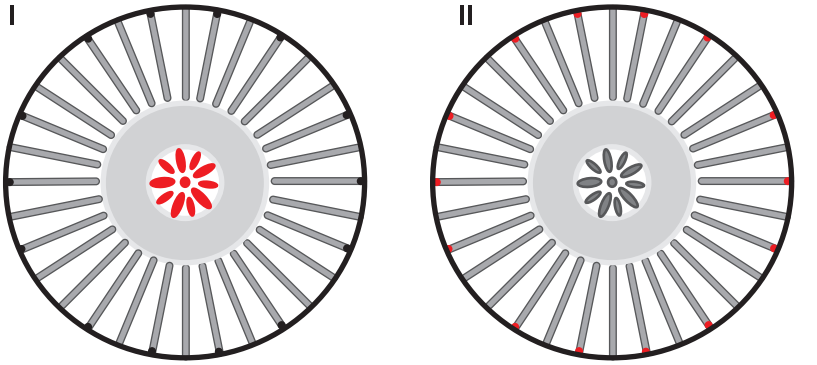
Cyclotella Kützing ex Brébisson 1838 pro parte

Characteristics – Cells **centric,** short striae, separated by robust **costae**, extending from the margin approximately half way across the valve face. Central area thickened silica with large perforations in a more or less stellate pattern (I). Cells lack marginal spines. Marginal **fultoportulae**, only visible with SEM, present at the margin on every second or third costa (II, Fig. 22: J, L, M).

Plastid structure – Cells with small granular plastids.

Identification of species – Species can be identified by cell size and density and structure of the striae. The shape, structure and configuration of the ornamentation of the central area are important.

Ecology – Cells planktonic may become entrained in the benthos. Found in oligotrophic to mesotrophic waters with moderate conductivity.



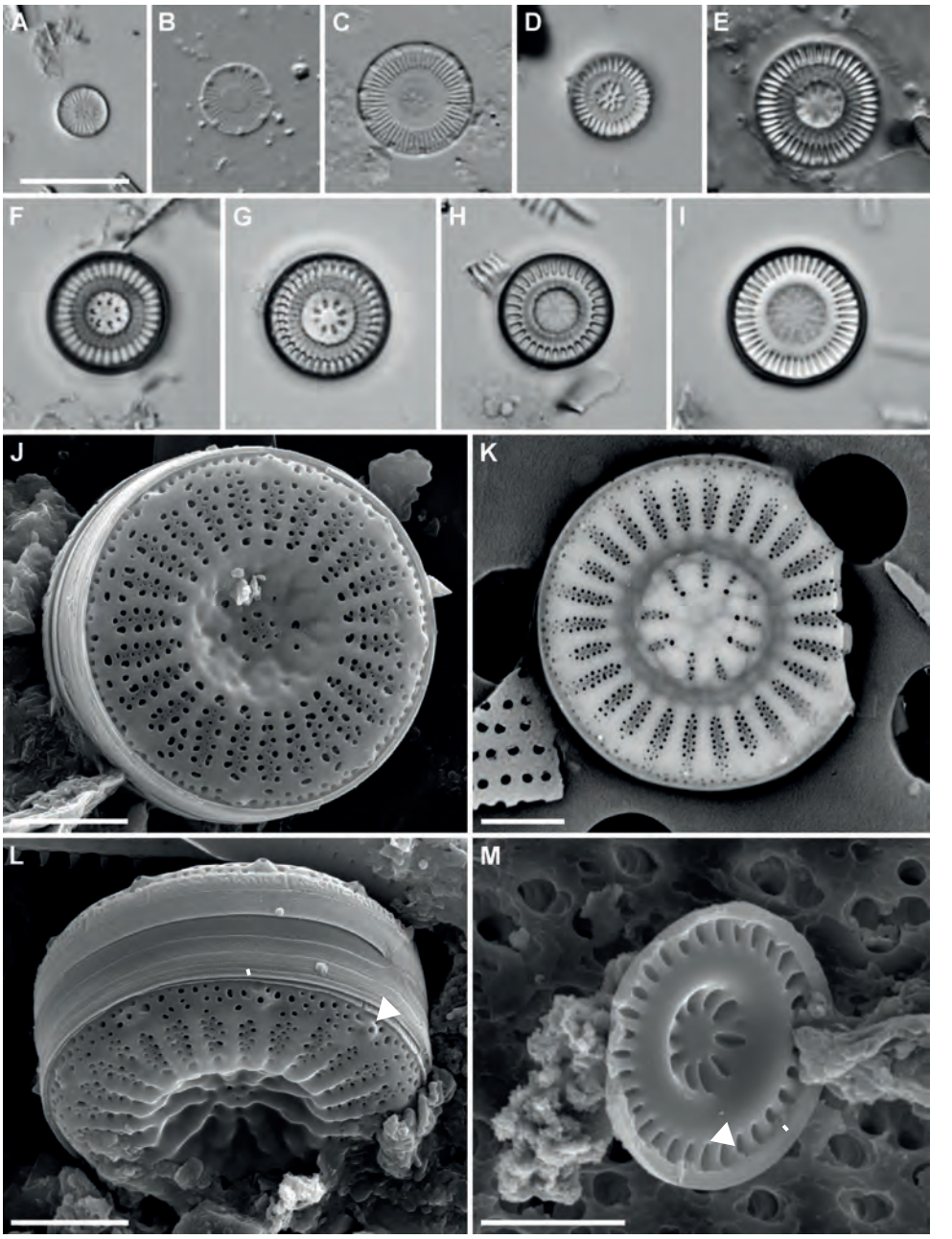


Fig. 22. *Discostella* spp. **A-I**. LM, cleaned material. **A-C**. Valve views of *Discostella woltereckii* (Hustedt) Houk & Klee. **D-I**. Valve views of *D. stelligera*. **J-M**. SEM. **J-K**. External view of valve of *D. stelligera*. **L**. Oblique external view of valve of *D. stelligera*, note external openings of marginal fultoportulae (arrow). **M**. Oblique internal view of valve of *D. stelligera*, note internal openings of marginal fultoportulae (arrow)
Scale bars = 10 µm (A-I), 2 µm (J-L), 5 µm (M).

Pantocsekiella K.T. Kiss & Ács 2016

Pantocsekiella ocellata (Pantocsek) K.T. Kiss & Ács

SYNONYM:

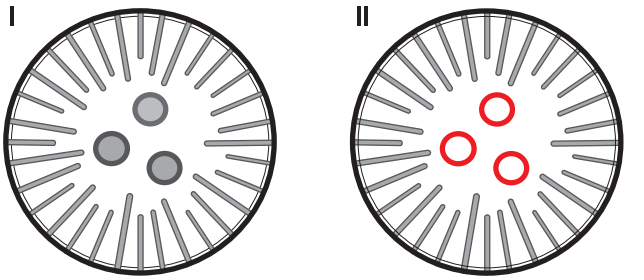
Cyclotella Kützing ex Brébisson 1838 pro parte

Characteristics – Cells **centric** with radiate striae. Striae separated by robust **interfascicular costae** which can differ in length and extend from approximately half way across the valve face to the valve margin, leaving an open central area which has large circular depressions (lacunae) (II, Fig. 23: E, F). Weakly developed spines can be present at junction of valve face and valve mantle at the end of each **costa**. Valve face **fultoportulae** (strutted processes) are often present on valve face towards the center (Fig. 23: E, F) and below the spines on the valve margin. One **rimoportula** present on the valve mantle.

Plastid structure – Cells with small discoid plastids, scattered lipid bodies (see *Cyclotella*).

Identification of species – Cell diameter, number of striae and costae as well as structure of the costae. Number and distribution of circular depressions. Note: Many important cell characteristics can only be observed using SEM.

Ecology – Cells, solitary or in pairs but not forming chains, planktonic may become entrained in the benthos. Found in waters with medium conductivity and higher trophic levels.



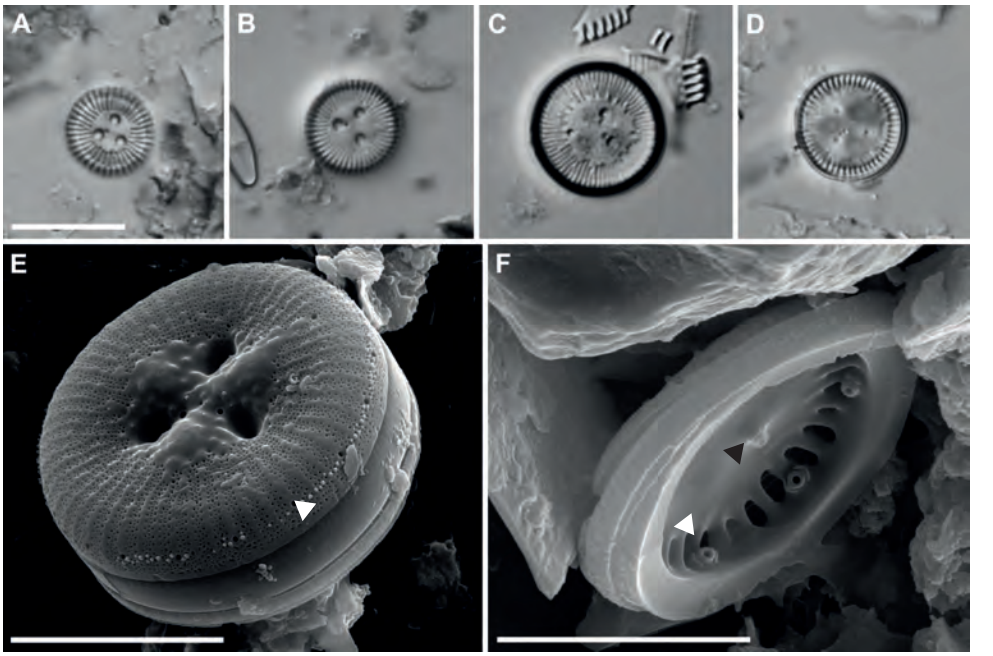


Fig. 23. *Pantocsekiella* **spp. A-D. LM. A-C.** *Pantocsekiella ocellata*, valve views of cleaned cells. **D.** *Pantocsekiella* sp., valve view. **E-F.** SEM. *P. ocellata.* **E.** External oblique view of valve, note external openings of fultoportulae (arrow). **F**. Internal view of valve, note internal opening of valve face (black arrow) and marginal fultoportulae (white arrow). Scale bars = 10 µm (A-D), 5 µm (E), 3 µm (F).

Stephanodiscus Ehrenberg 1845

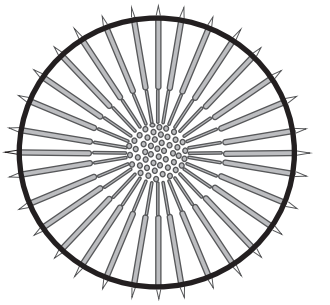
Type species: *Stephanodiscus niagarae Ehrenberg*

Characteristics – Cells **centric** with radiate striae. Valve face flat or concentrically undulate. Striae composed of 2-3 rows of areolae and are combined in **fascicles** (rows of 2-3 areolae) by **interfascicular costae** which extend from the margin of the valve face to the centre of valve face where they fuse together. Spines present at junction of valve face and mantle at the end of each **costa**. Valve face **fultoportulae** (strutted processes) present on valve face and below the spines on the valve mantle. One **rimoportula** present on the valve mantle.

Plastid structure – Cells with small discoid plastids (Fig. 24: A-C).

Identification of species – Cell diameter, number of striae and costae as well as structure of costae. Note: Many important cell characteristics can only be observed using SEM.

Ecology – Cells planktonic may become entrained in the benthos. Chitin threads (Fig. 24: A) exuded from marginal fultoportulae increase surface area, slowing sinking through the water column. Found in waters with medium conductivity and higher trophic levels.



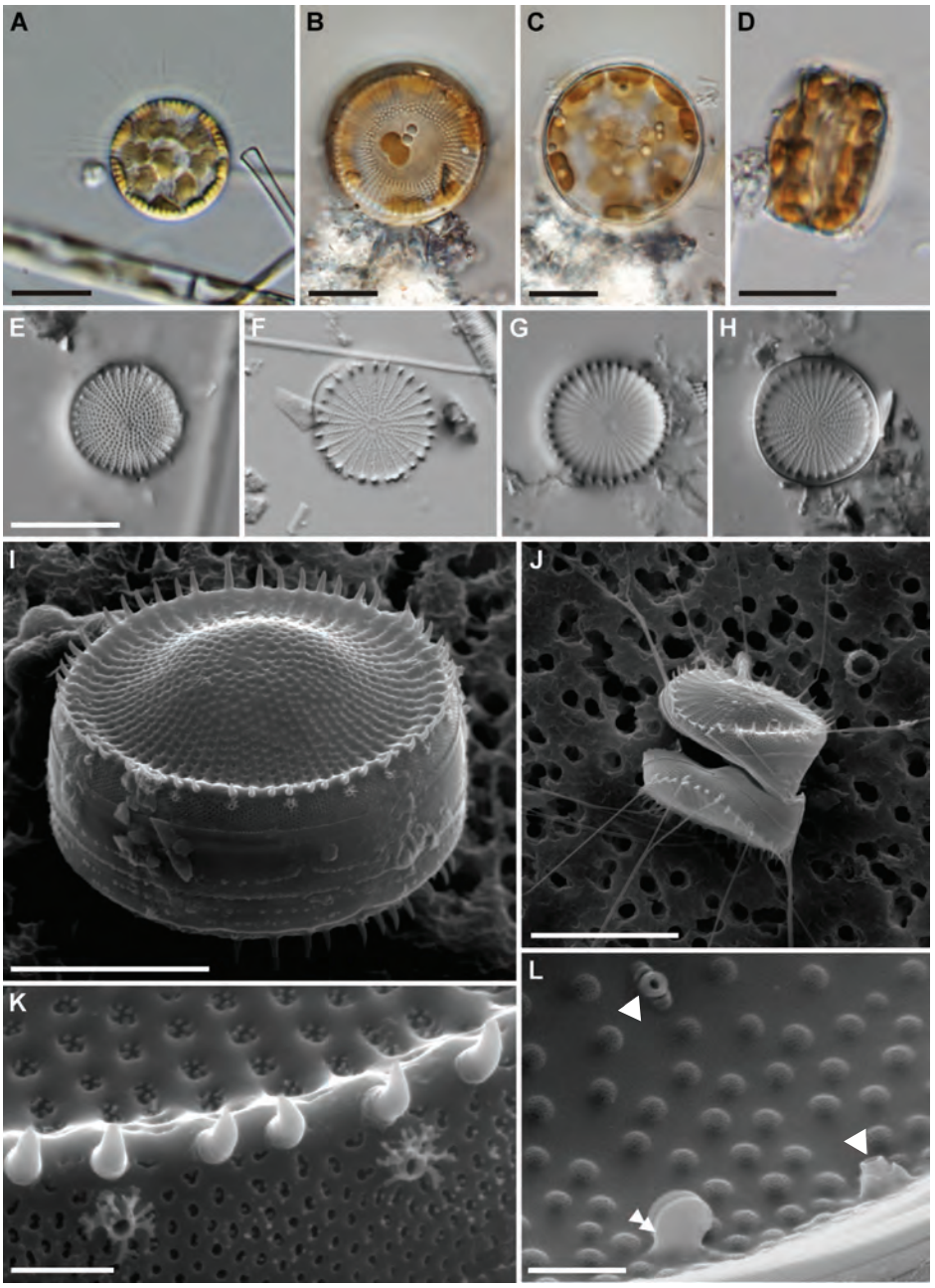


Fig. 24. *Stephanodiscus* spp. **A-H.** LM. **A-D**. Living cells. **E-H**. Cleaned cells. **I-L**. SEM. **I.** Oblique view. **J.** External view of valve, note chitin threads. **K.** External view of valve margine, note marginal spines and marginal fultoportulae. **L.** Internal view of valve, note valve and marginal fultoportulae (arrows) and rimoportula (double arrow).
Scale bars = 10 µm (A-J), 1 µm (K-L).

Melosira C. Agardh 1824

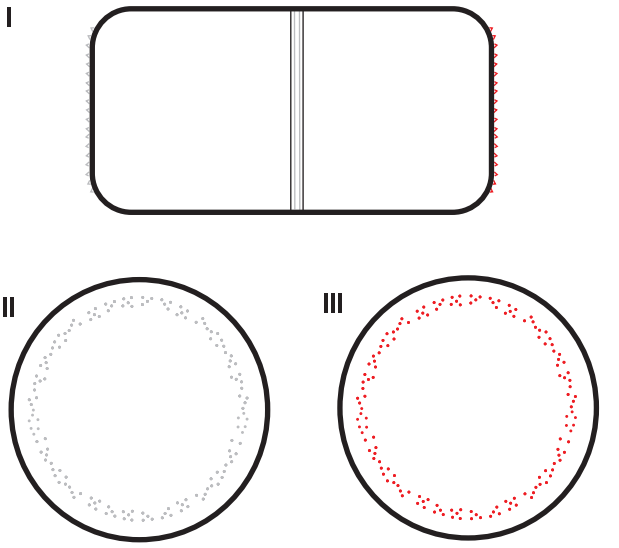
Type species: *Melosira nummuloides* C. Agardh

Characteristics – Cells **centric**, valve mantle is rather deep, cells often observed in girdle view (I). Areolae very small, scattered over the valve face only visible with SEM. **Rimoportulae** small (Fig. 26: C-D, F), scattered over valve face, usually not possible to resolve using LM. Valve face bears a large number of scattered silica granules which can be seen both under LM and SEM (Fig. 25: E-F; Fig. 26:A-B). When seen in valve view under LM a ring of very small spines can be observed around the periphery of the cell close to the valve margin (III; Fig. 25: E-F; Fig. 26: A-B).

Plastid structure – Cells with small plate-like plastids that may be lobed or circular, found around the periphery of the cell (Fig. 25: A-B).

Identification of species – Up till now only one species known from tropical African freshwaters: *Melosira varians* C. Agardh.

Ecology – Cells joined face-to-face by mucilage pads forming long chain like-colonies with the terminal cell attached to the substrate by the same means. Found in the benthos, and may be re-suspended in the plankton, of eutrophic waters with moderate to high conductivities.



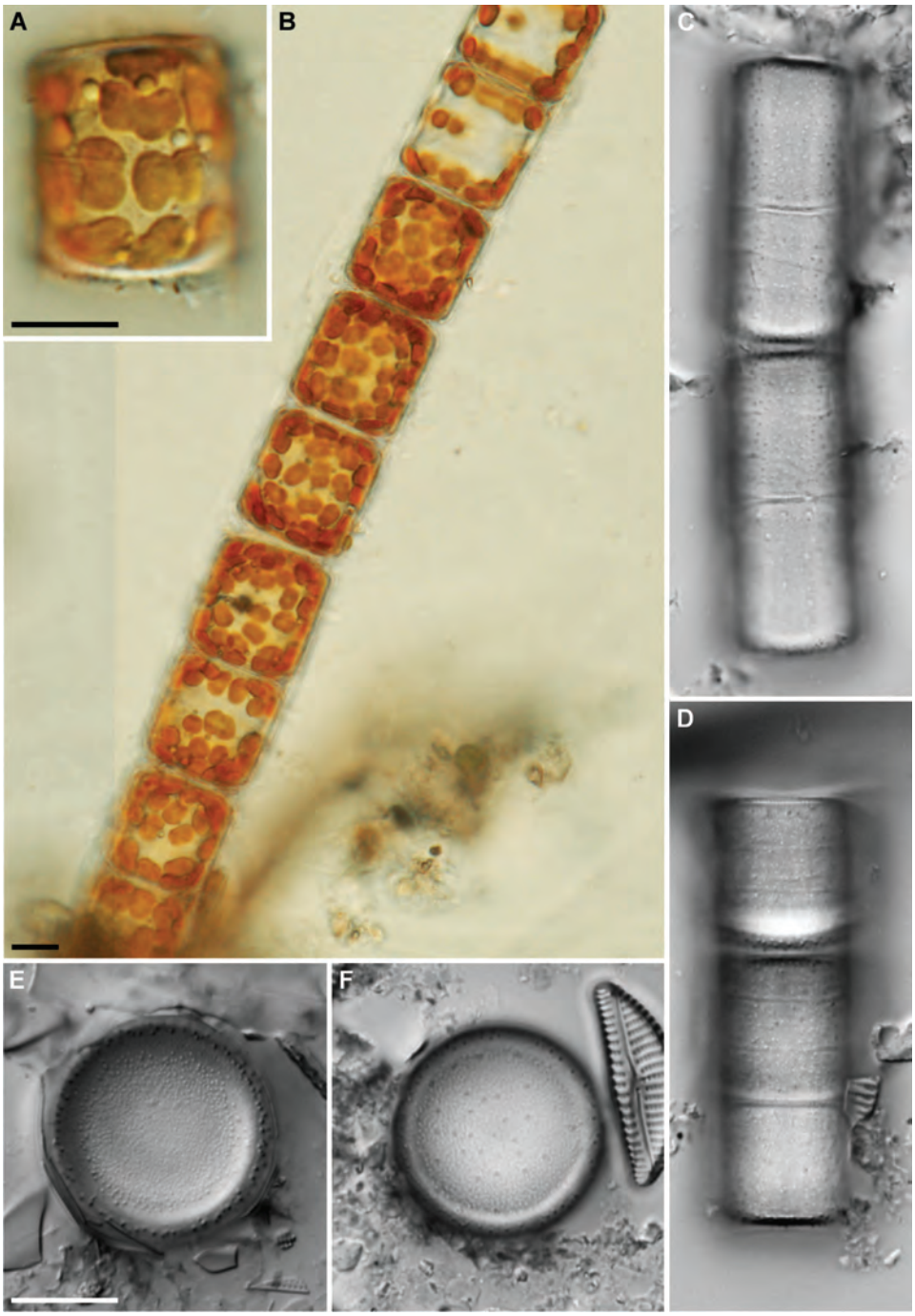


Fig. 25. *Melosira varians*. **A-F.** LM. **A-B.** Living cells, firdle view. **C-F.** Cleaned cells. **C-D.** girdle view. **E-F.** Valve view.
Scale bars = 10 µm.

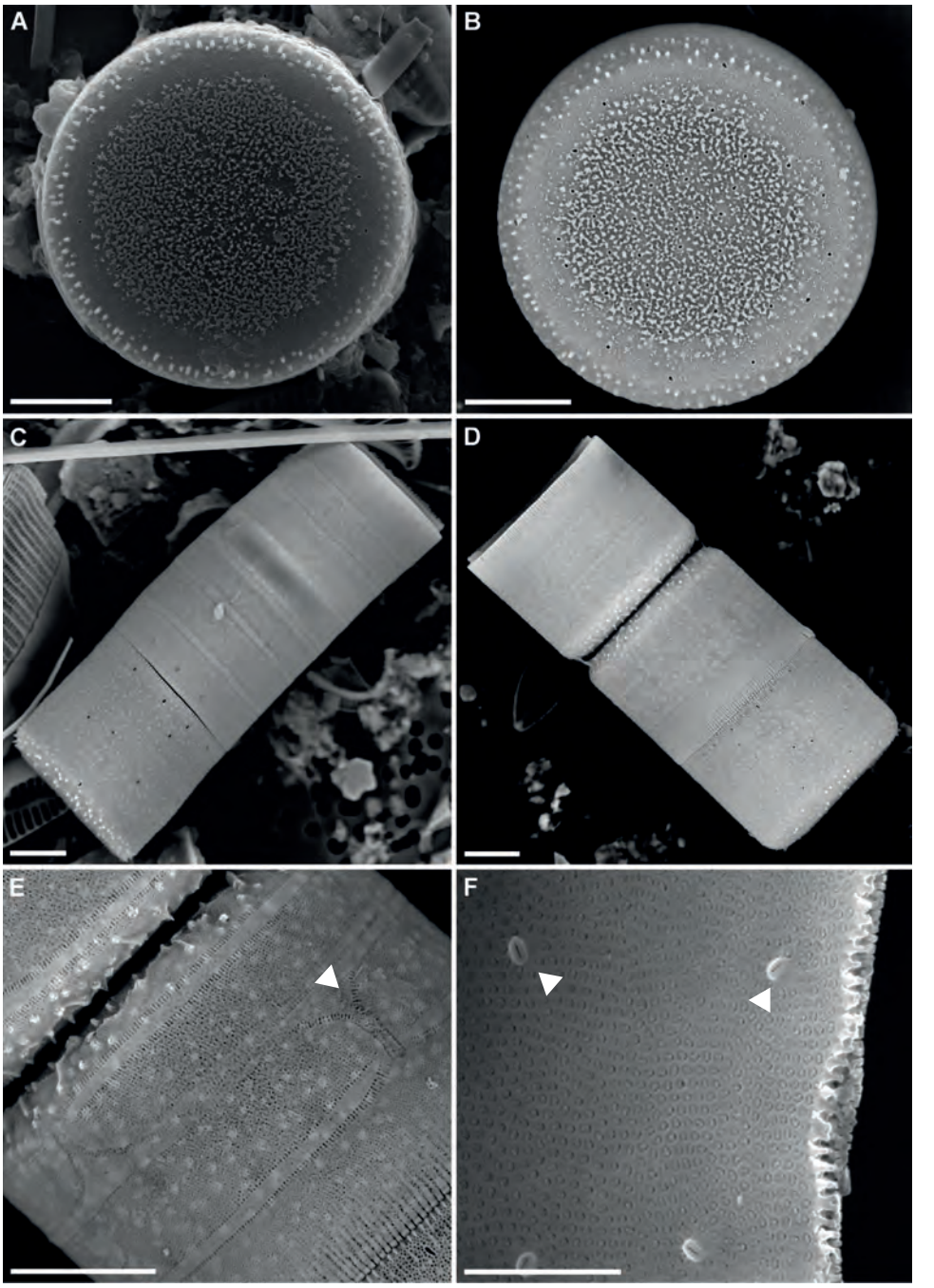


Fig. 26. *Melosira varians*. **A-F.** SEM. **A-B.** External view of valves. **C-D.** Girdle views. **E.** Detail of girdle bands, note ligula (arrow). **F.** Internal view of valve, note rimoportulae (arrows).
Scale bars = 10 µm (A-D), 5 µm (E), 2 µm (F).

Aulacoseira Thwaites 1848

Type species: *Aulacoseira crenulata* (Ehrenberg) Thwaites

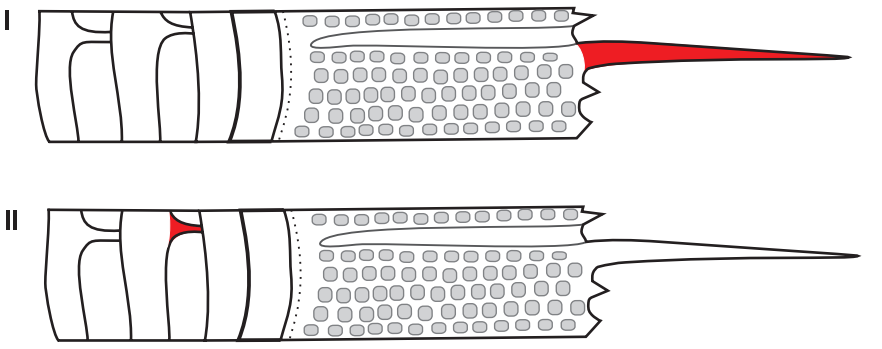
SYNONYM:
Melosira C. Agardh 1824 pro parte

Characteristics – A **centric** diatom genus with the **valve mantle** most often deeper than the diameter of the **valve face**, for this reason cells are mostly seen in girdle view. Areolae usually large and easily discernable in LM but may be rather small in some cases (e.g. *Aulacoseira herzogii* (Lemmermann) Simonsen; Fig. 27: I). Spines are present including long linking spines (I). Girdle composed of both open and closed bands, a **ligula** or tongue-like structure is present (II, Fig. 28: E).

Plastid structure – Many small disc-like plastids (Fig. 27: B-C).

Identification of species – Depth of the valve mantle is very important together with the orientation and dimensions of the striae and type and length of spines present (e.g. *Aulacoseira granulata* (Ehrenberg) Simonsen has long and short linking spines while *Aulacoseira ambigua* (Grunow) Simonsen only has short linking spines and *Aulacoseira herzogii* only has long spines).

Ecology – Cells colonial forming chains, planktonic in a wide range or water qualities. The increased surface area of these chain-like colonies helps to prevent sinking through the water column.



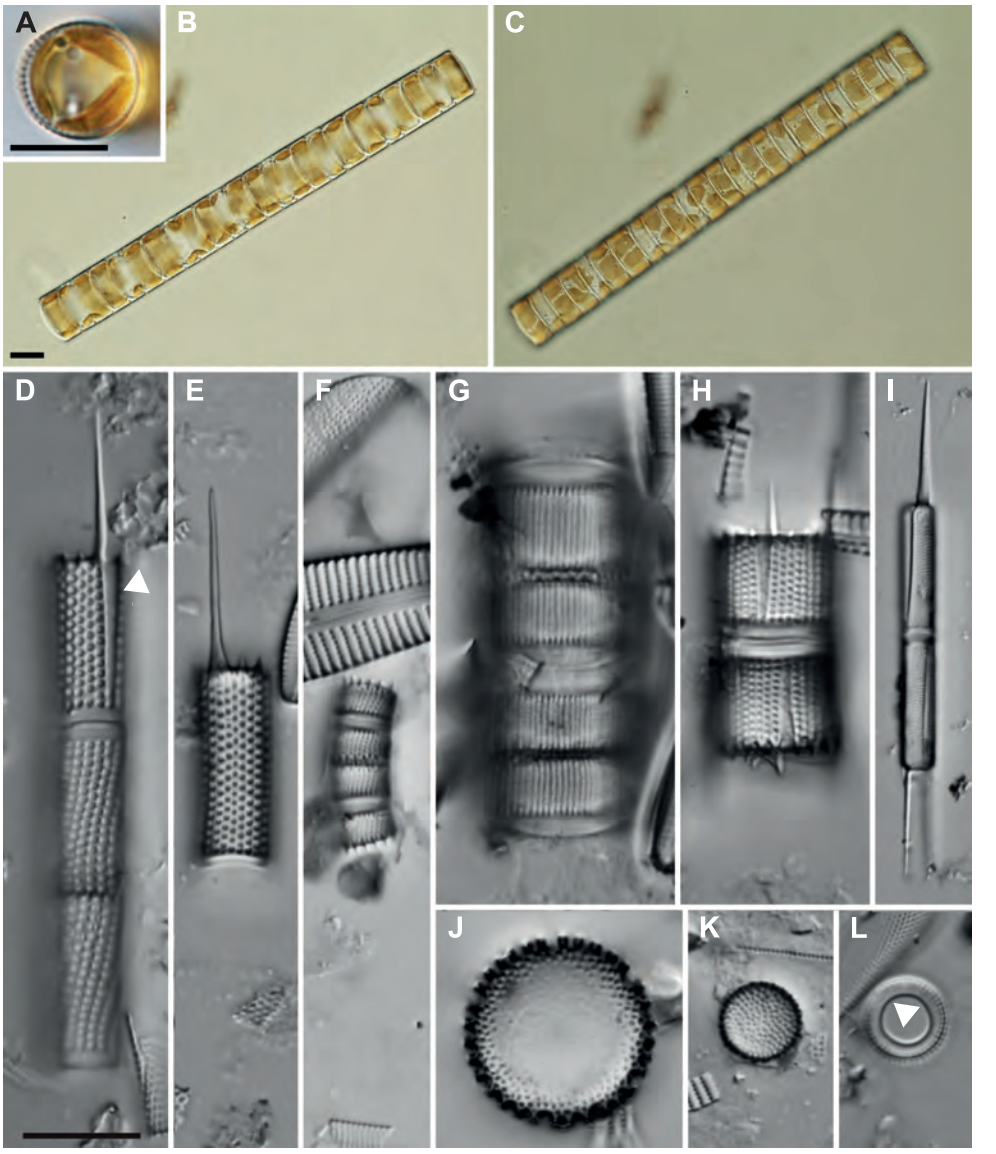


Fig. 27. *Aulacoseira* spp. **A-L**. LM. **A**. Living cell of *Aulacoseira ambigua*, valve view, note position of plastids - appressed to valve mantle. **B-C**. Living cells of *A. ambigua* forming a filamentous colony or chain, different foci of the same filament. **D-E**. Girdle view of *A. granulata*, note long linking spines and associated groove in the mantle (arrow). **F**. Girdle view of *A. subarctica* (O. Müller) E.Y. Haworth. **G.** Girdle view of *Aulacoseira* sp. **H.** Girdle view of *A. muzzanensis* (F. Meister) Krammer, note relatively shorter linking spines as compared with *A. granulata*. **I.** Girdle view of *A. herzogii*. **J-L.** Valve views of various *Aulacoseira* species showing distribution of areolae on valve face and position of the ringleiste (arrow). Scale bars = 10 µm (A-H).

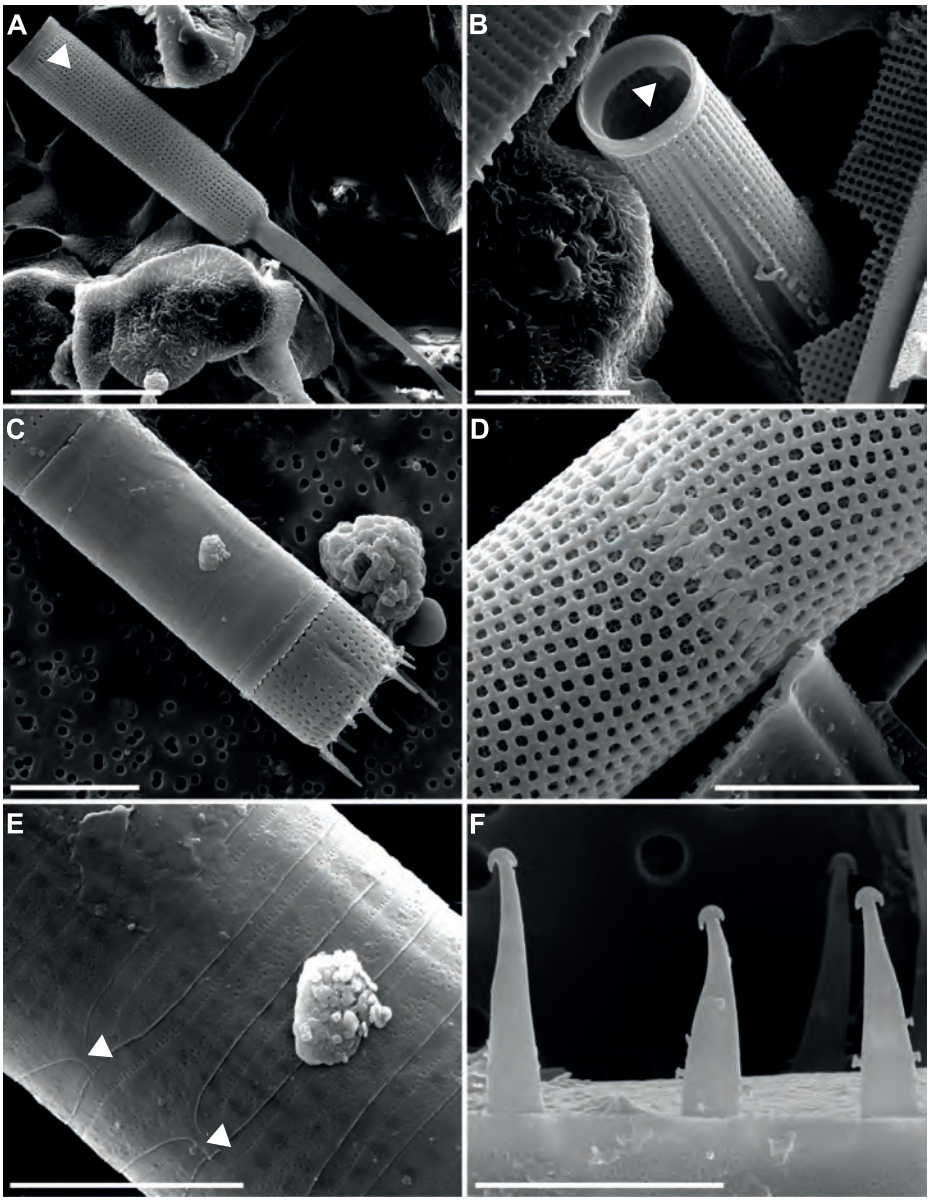


Fig. 28. *Aulacoseira* spp. **A-F**. SEM. **A**. Girdle view of *Aulacoseira herzogii,* note external opening of the rimoportula (arrow). **B**. Oblique view of *A. herzogii* showing groove in the valve mantle occupied by the linking spine, note internal opening of the rimoportula (arrow). **C**. Girdle view of *Aulacoseira* sp. showing valve mantle and associated copulae. **D**. Girdle view of *A. ambigua* showing the structure of the areolae and the short linking spines. **E**. Detail of the structure of the copulae of *Aulacoseira* sp., note the ligulae (arrows). **F**. Detail of the complex structure of the linking spines of *Aulacoseira* sp.
Scale bars = 10 µm (A), 5 µm (B-D), 3 µm (E), 2 µm (F).

Orthoseira Thwaites 1848

Type species: *Orthoseira americana* (Kützing) S.A. Spaulding & Kociolek

SYNONYM:

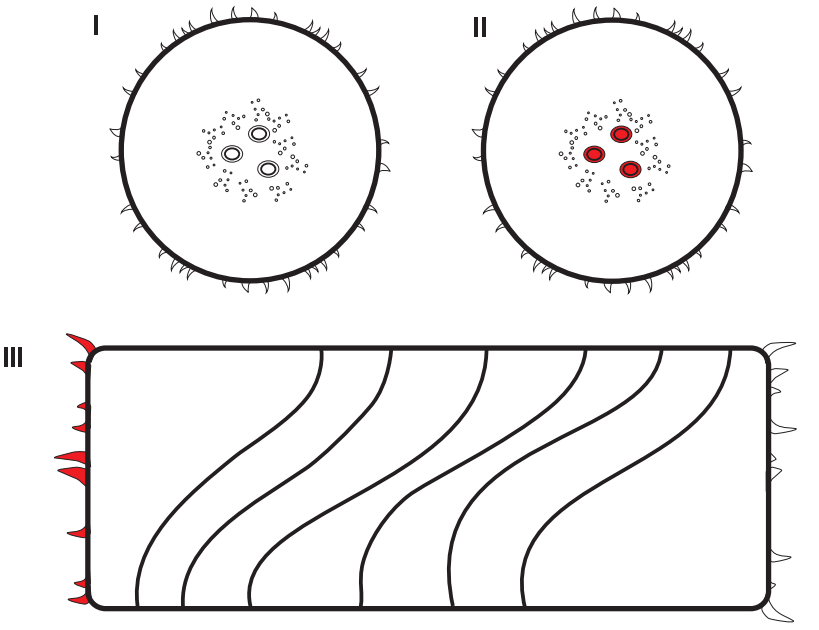
Melosira C. Agardh 1824 pro parte

Characteristics – Cells **centric**, valve mantle is rather deep, cells often observed in girdle view. Girdle composed of multiple bands (**copulae**) (Fig. 30: C, H; Fig. 31: D). Valve face bears unique structures in the centre (II; **carinoportulae**). A ring of spines is found around the periphery of the cell close to the junction of the valve face and mantle (III; Fig. 30: A; Fig. 31: B-C) but may be difficult to observe using LM (Fig. 30 B-F).

Plastid structure – Cells with many small discoid plastids (Fig. 29), found in the peripheral cytoplasm (Fig. 29: A, C) as well as clustered in the cytoplasm surrounding the nucleus (Fig. 29: B).

Identification of species – Based on SEM.

Ecology – Cells linked by spines to form short chains. Generally found in sub-aerial habitats, sometimes washed into rivers, streams and lakes.



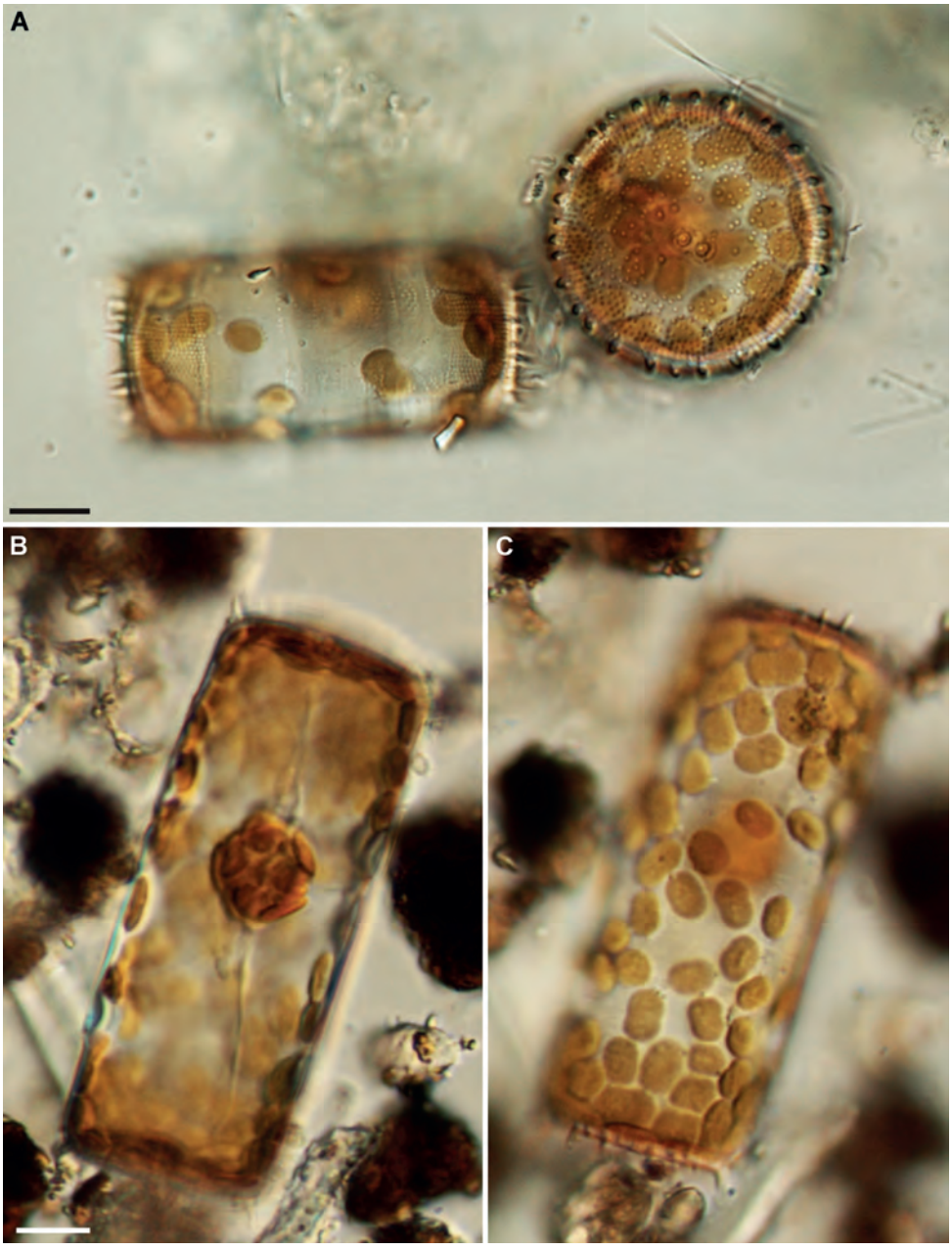


Fig. 29. *Orthoseira* sp. **A-C**. LM, Living cells. **A.** Valve view and girdle view. **B-C.** Girdle view of the same cell at different foci. Scale bars = 10 µm.

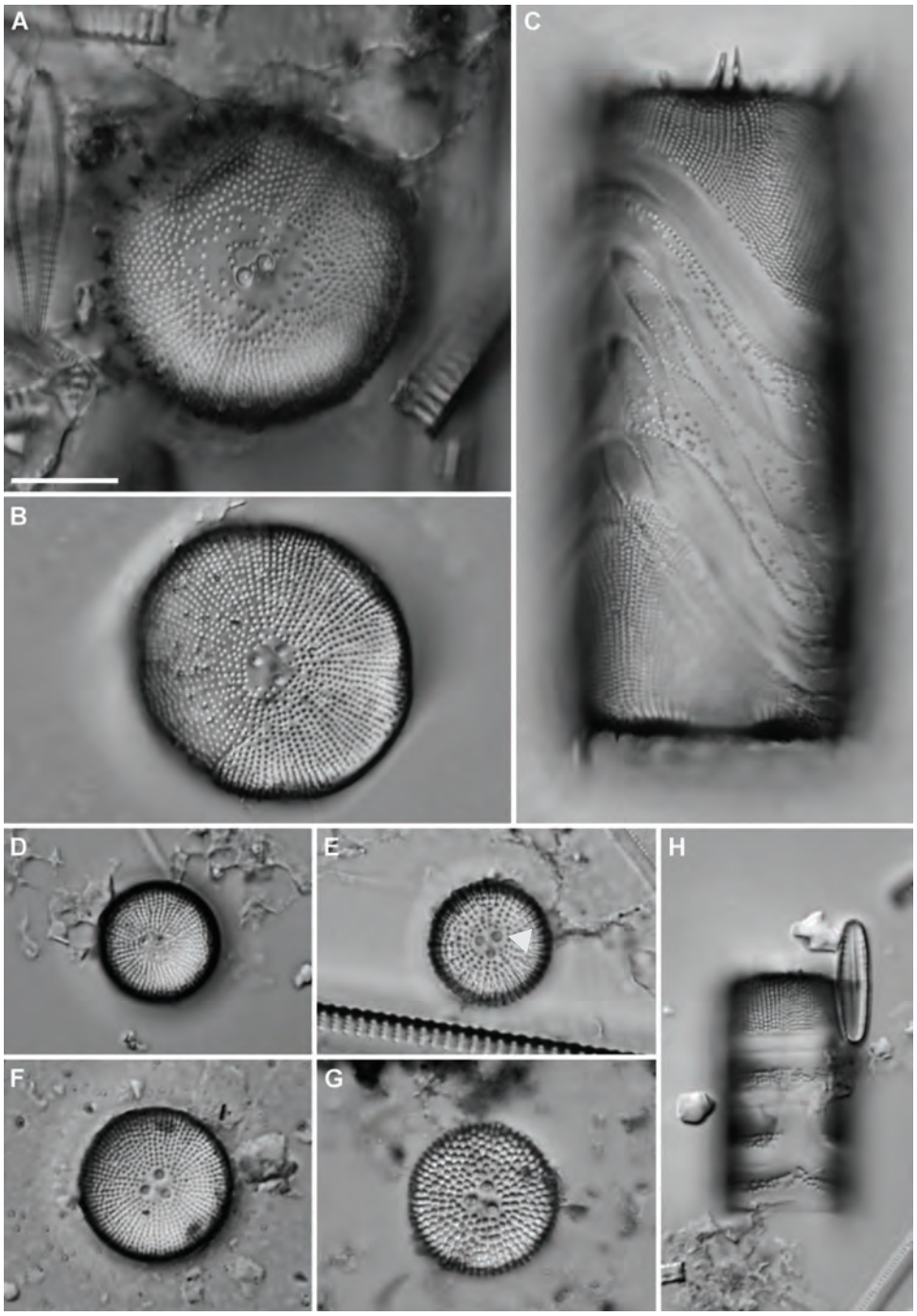


Fig. 30. *Orthoseira* spp. **A-H.** LM, cleaned material. **A-B, D-G.** Valve views, note the carinoportulae (arrow - **E**). **C, H.** Girdle views.
Scale bar = 10 µm.

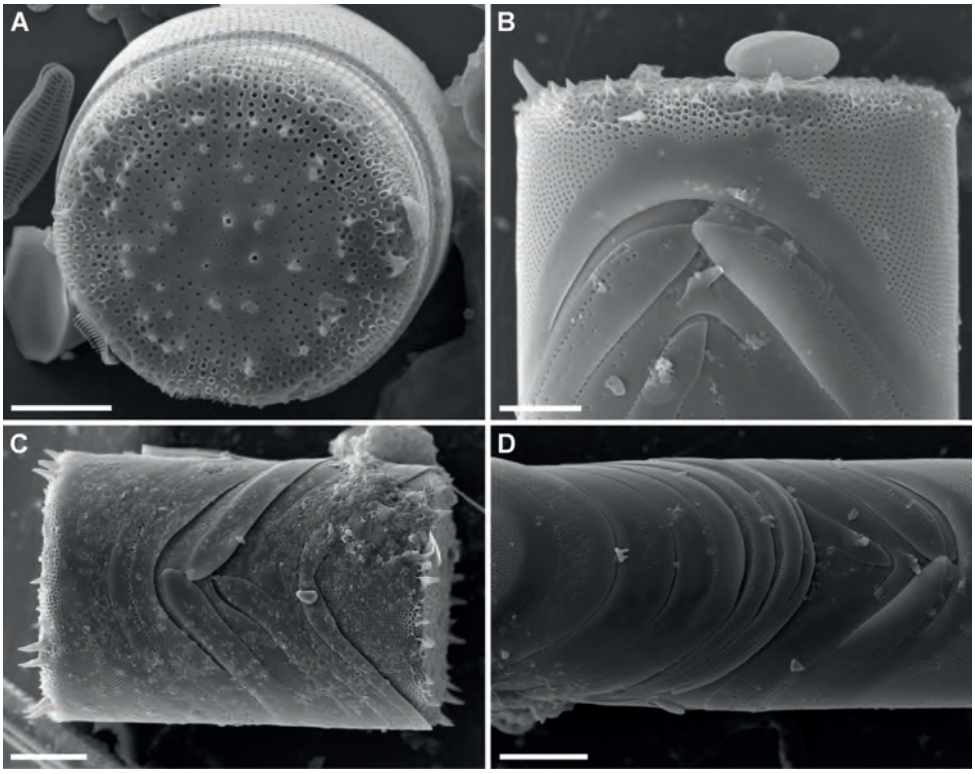


Fig. 31. *Orthoseira* spp. **A-D.** SEM. **A.** External view of valve. **B-C.** Girdle views, note the spines at the junction of the valve face and mantle. **D.** Detail of the girdle bands.
Scale bars = 10 µm (A, C-D), 5 µm (B).

Pleurosira (Meneghini) Trevisan 1848

Type species: *Pleurosira thermalis* Meneghini

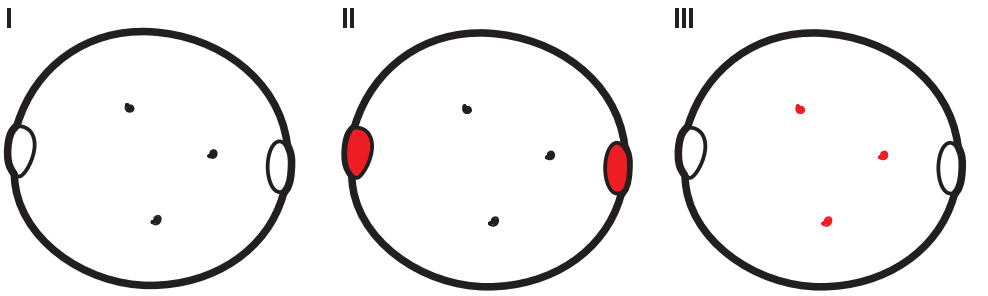
SYNONYM:
Melosira C. Agardh 1824 pro parte
Biddulphia Gray 1821 pro parte

Characteristics – Cells **centric**, oval (**orbicular**) in shape. Valve bears a number of **ocelli** (usually 2) on the valve margin (II). Areolae round, discernable under LM. Short spines and silica granules scattered over the valve face and the valve mantle (III) but may be difficult to observe using LM (Fig. 32: E). A number (1-5) of **rimoportulae** are scattered across the valve face (III; Fig. 32: A-D, E).

Plastid structure – Many small discoid plastids.

Identification of species – Up till now only one species known from tropical Africa: *Pleurosira laevis* (Ehrenberg) Compère.

Ecology – Cells exude mucilage from **ocelli** forming zig-zag chains. Typical of tropical waters with high conductivity and anthropogenically impacted habitats.



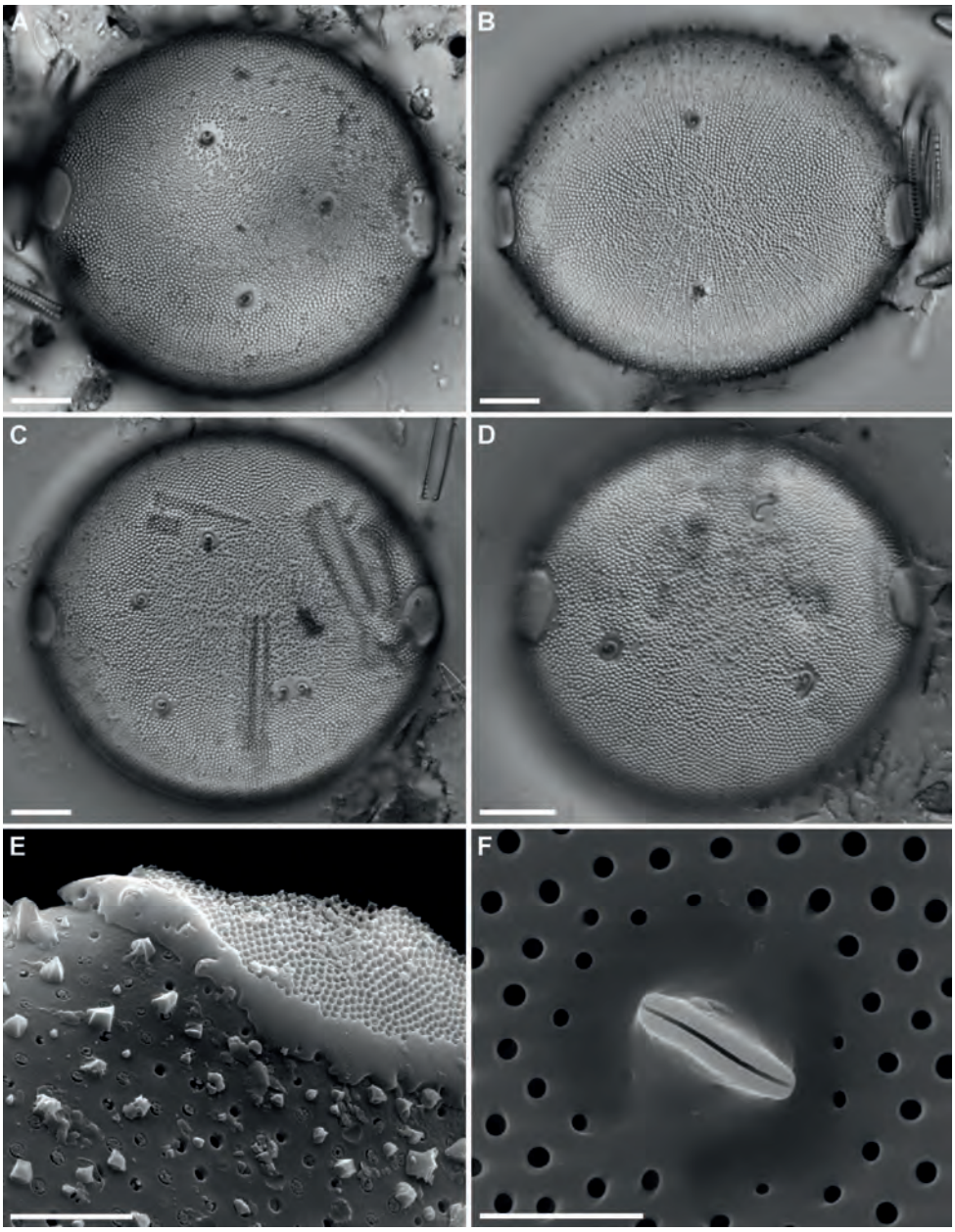


Fig. 32. *Pleurosira* laevis. **A-D.** LM, valve views, note the ocelli. **E-F.** SEM. **E.** External view of valve, detail of an ocellus. **F.** Internal view of valve, detail of a rimoportula.
Scale bars = 10 µm (A-D), 2 µm (E-F).

Urosolenia Round & R.M. Crawford 1990

Type species: *Urosolenia eriensis* (H.L. Smith) Round & R.M. Crawford

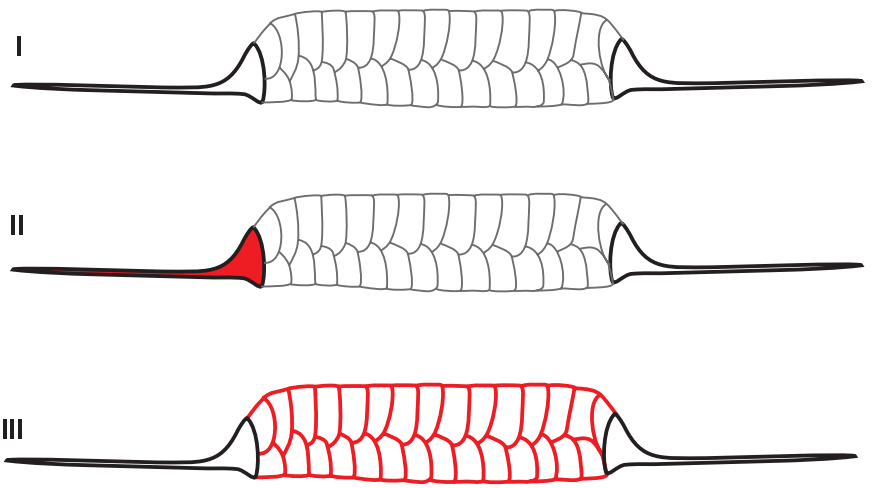
SYNONYM:
Rhizosolenia Brightwell 1858 pro parte

Characteristics – A **centric** diatom genus. Cells **cylindrical** with a small valve and elongate spine (II) on each valve. Frustule very lightly silicified, and the spines may be the only structure remaining after treatment and cleaning of the sample. The valves are joined by scale-like girdle bands (III, Fig. 33: E) (**copulae**), these copulae are rarely discernable under LM.

Plastid structure – Cells with numerous discoid plastids.

Identification of species – Species can be identified by cell size, cell shape and width and the structure of the valve.
Note: Many important cell characteristics can only be observed using SEM.

Ecology –- Cells solitary, planktonic. Found in oligotrophic waters with low to moderate conductivities.



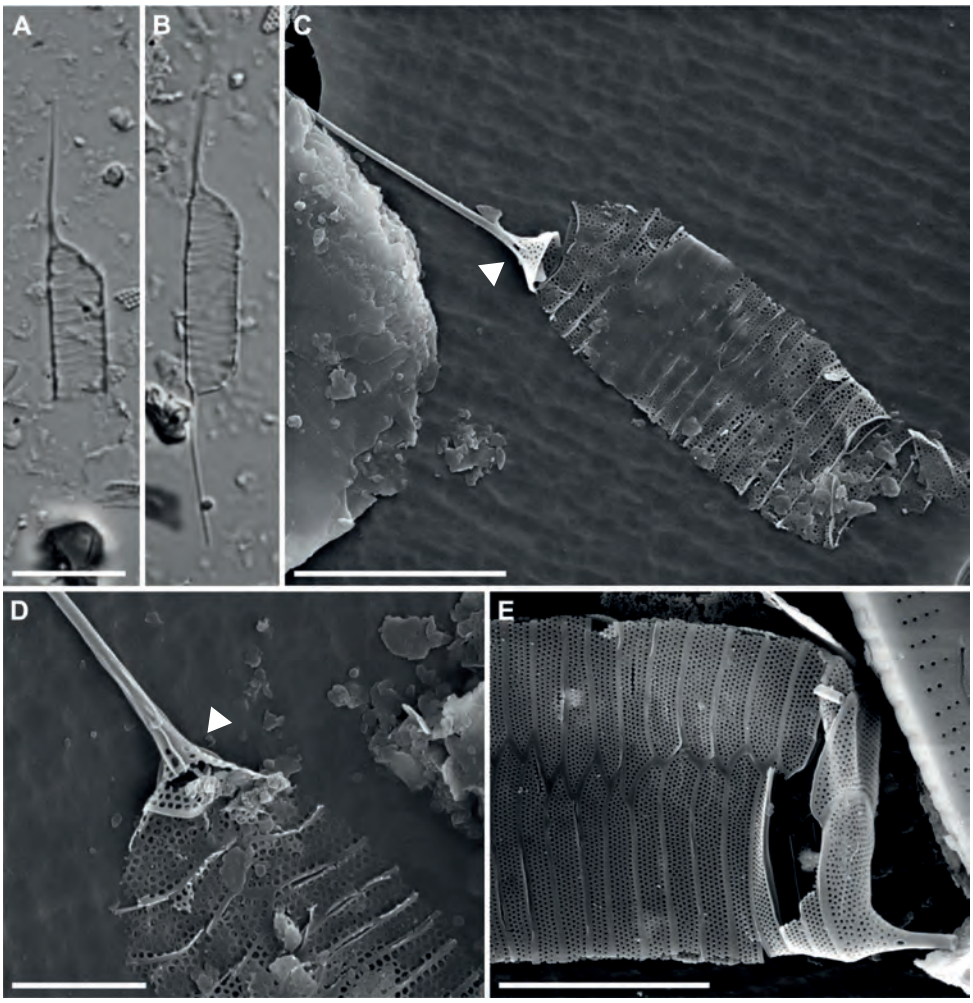


Fig. 33. *Urosolenia* spp. **A-B.** LM, girdle view. **C-E.** SEM. **C-D.** Girdle bands and valve with elongated spine (arrows). **E.** Detail of the scale like girdle bands. Scale bars = 10 µm (A-B), 5 µm (C,E), 2 µm (D).

Asterionella Hassall 1850

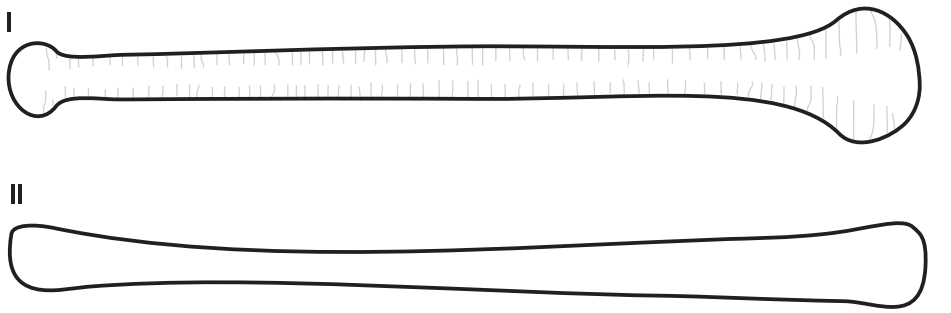
Type species: *Asterionella formosa* Hassall

Characteristics – Cells **araphid**, typically 'bone-shaped' (**heteropolar**) in valve view (I; Fig. 35: A-D) with a larger and smaller pole. Often observed in girdle view (II; Fig. 35: E-G) where one pole is also expanded. Striae are difficult to observe under LM. Spines are present at the junction of the valve face and valve mantle (Fig. 35: F, I). Rimoportulae only visible in SEM (Fig. 35: H).

Plastid structure – Many small plate-like plastids (Fig. 34: A-B).

Identification of species – Up till now only one species occurs commonly in the freshwaters of the tropics: *Asterionella formosa.*

Ecology – Cells colonial, planktonic, suspended in the water column of meso-to eutrophic lakes and impoundments and large rivers. Cells of *Asterionella formosa* secrete mucilage from the pore field of the larger pole and join to form star-like or stellate colonies (Fig. 34: A, C). The increased surface area of these colonies helps to prevent sinking through the water column.



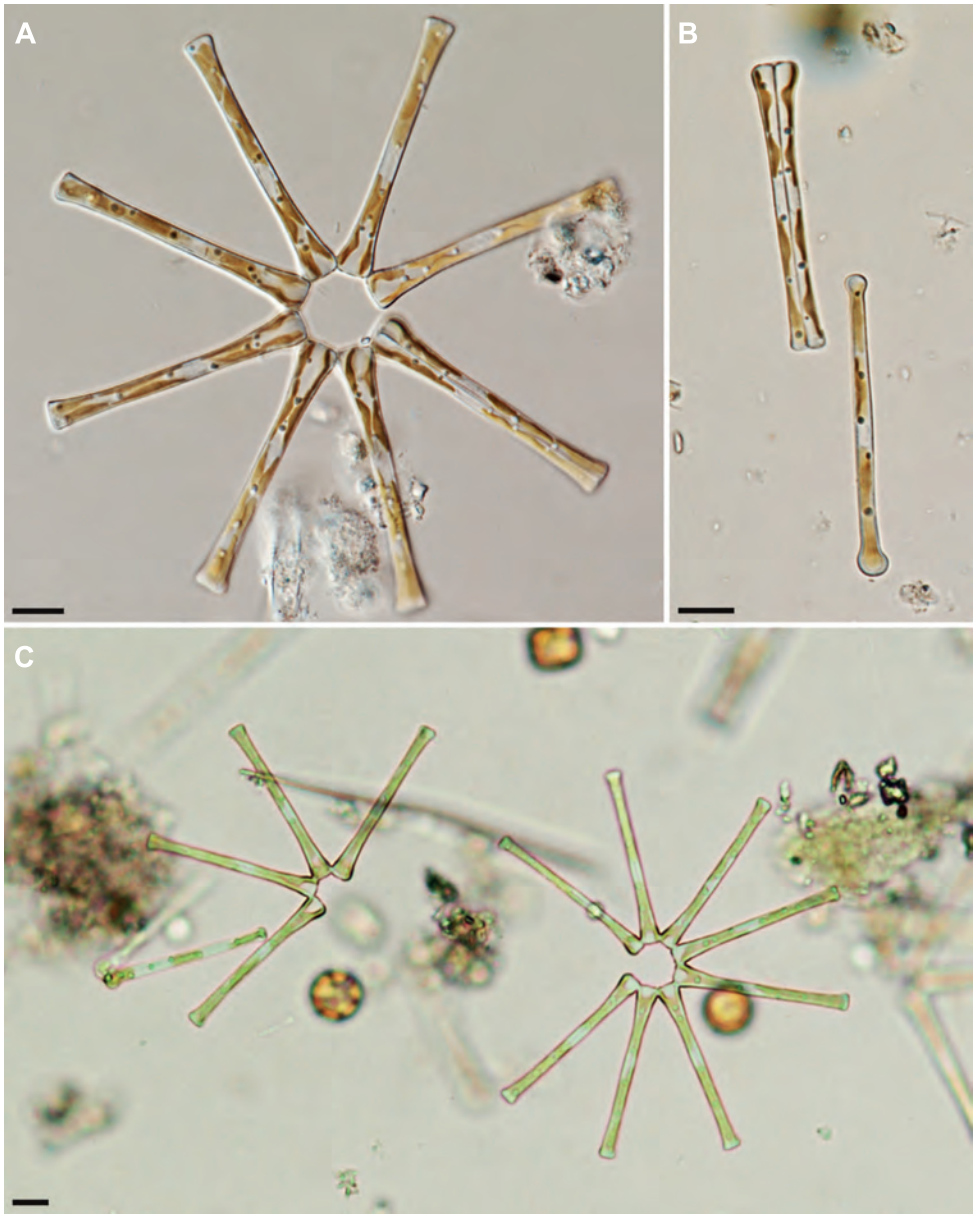


Fig. 34. *Asterionella formosa*. **A-C**. LM. **A**. Living cells, forming typical stellate colony. **B**. Living cells, girdle view, immediately post cell division (left), valve view, note typical 'bone-shape' (right). **C**. Partially formed stellate colonies. Scale bars = 10 µm (A-C).

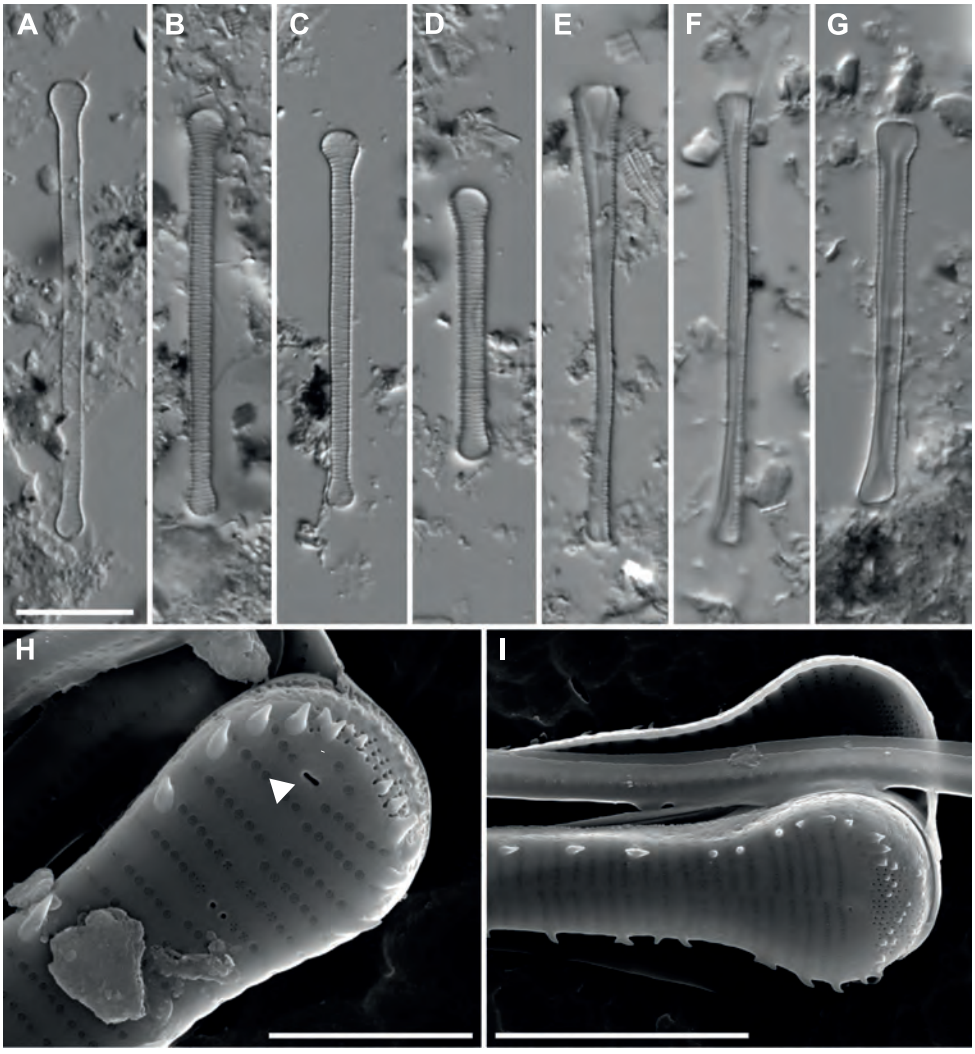


Fig. 35. *Asterionella formosa*. **A-G**. LM. **A-D**. Valve view, note very fient striae and barely visible marginal spines. **H-I**. SEM, cell apices, note apical pore fields, marginal spines and external opening of the rimoportula (arrow).
Scale bars = 10 µm (A-G), 2 µm (H), 5 µm (I).

Ctenophora Grunow ex D.M. Williams & Round 1986

Type species: *Ctenophora pulchella* (Ralfs ex Kützing) D.M. Williams & Round

SYNONYM:

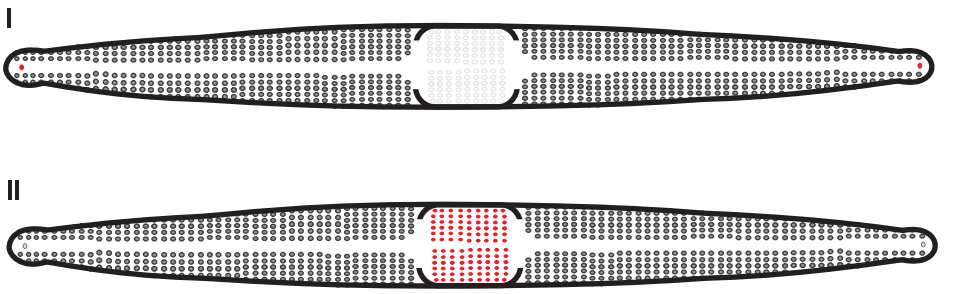
Synedra Ehrenberg 1830 pro parte

Characteristics – Cells **araphid** with parallel striae through the length of the valve, areolae regularly arranged, large and easily observed under LM (Fig. 36: C,D). Areolae with complex structure (Fig. 36: E, F). **Axial area** broad. Central area large (a thickened **fascia**) with **ghost striae** (II, Fig. 36: F, H). **Rimoportula** (labiate or lipped process) present at both apices (I, Fig. 36: E, G).

Plastid structure – Cells with plate-like plastids one lying under each valve face (Fig. 36: A, B).

Identification of species – Up till now only one species known from tropical Africa: *Ctenophora pulchella.*

Ecology – Cells solitary and attached. Found in the benthos of waters with moderate to high conductivity.



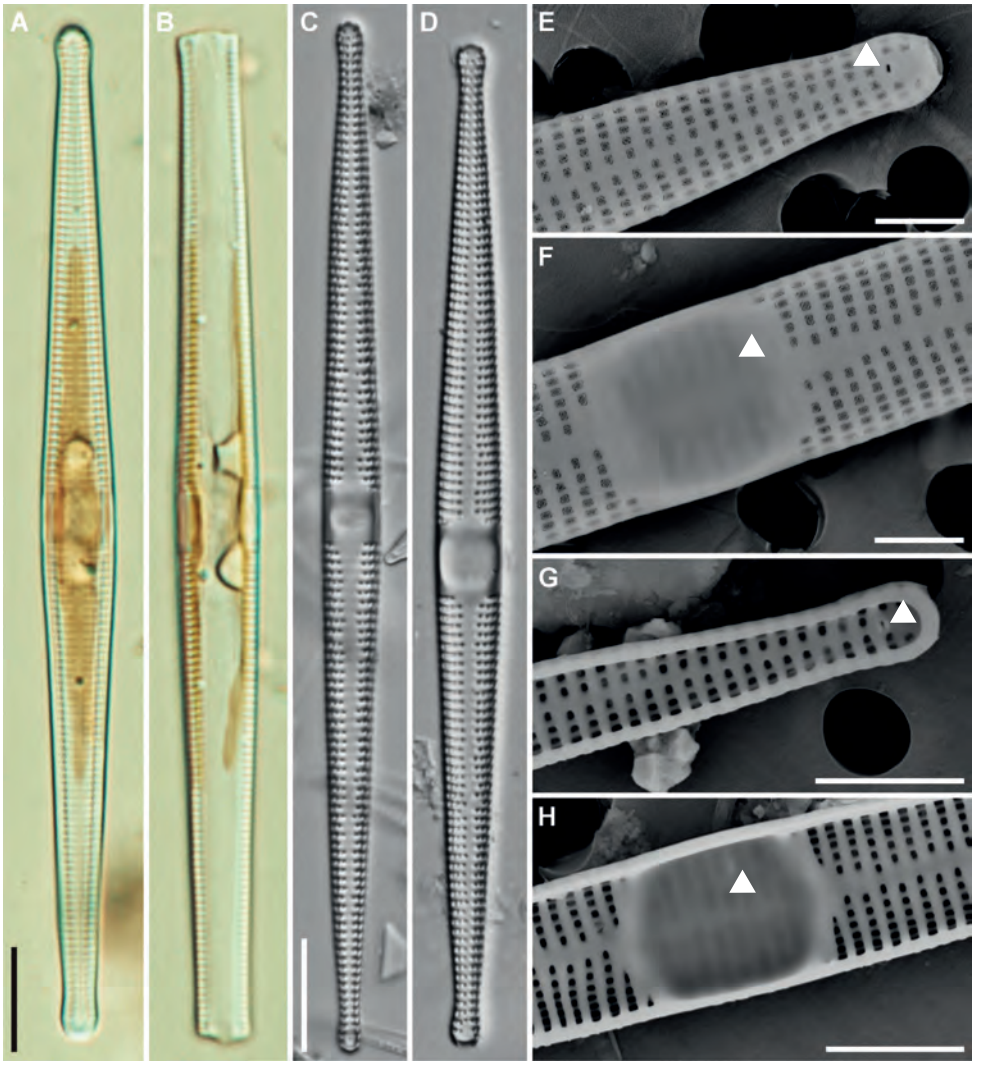


Fig. 36. *Ctenophora pulchella*. **A-D**. LM. **A**. Living cell, valve view. **B**. Living cell, girdle view. **C-D**. Cleaned material, valve view. **E-H**. SEM. **E**. External view of valve, cell apex, note external opening of rimoportula (arrow). **F**. External view of valve, central area, note ghost striae (arrow). **G**. Internal view of valve, cell apex, note internal opening of rimoportula (arrow). **H**. Internal view of valve, central area, note ghost striae (arrow).
Scale bars = 10 µm (A-D), 3 µm (E-F), 5 µm (G-H).

Diatoma Bory 1824

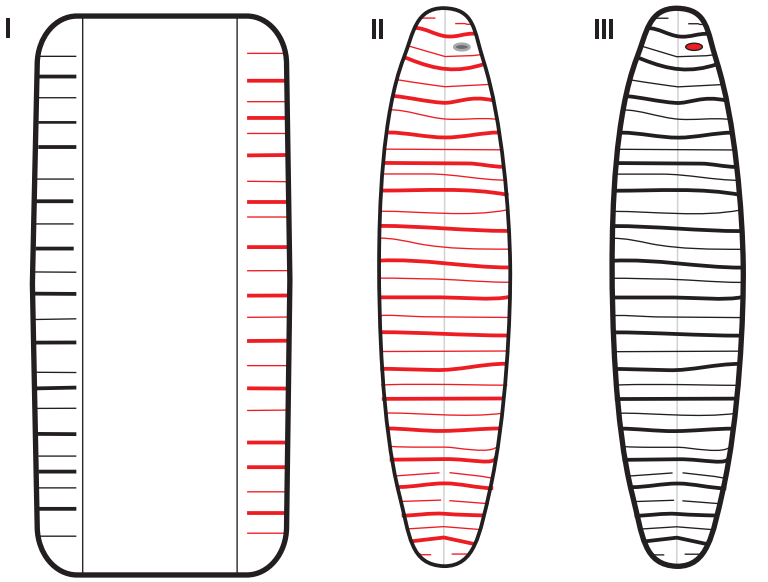
Type species: *Diatoma vulgaris* Bory

Characteristics – Cells **isopolar**, **araphid** with a narrow axial area. Striae composed of very small areolae, difficult to discern in LM. The valve has robust costae which stretch from margin to margin (II, Fig. 37: C, D, F). Costae also visible in girdle view (I, Fig. 37: B). A single rimoportula, sometimes visible in LM, is present near one of the apices (III). **Apical pore fields** at each apex.

Plastid structure – Cells with many small granular plastids (Fig. 37: B).

Identification of species – Up till now only one species known from tropical Africa: *Diatoma vulgaris.*

Ecology – Cells single or in pairs, attached by the corners and non-motile forming colonies. Colonies zig-zag shaped (Fig. 37: B) as cells join corner to corner by a **mucilage pad** exuded from the **apical pore field**. Occur *en-masse* in eutrophic waters forming dense colonies visible to the human eye.



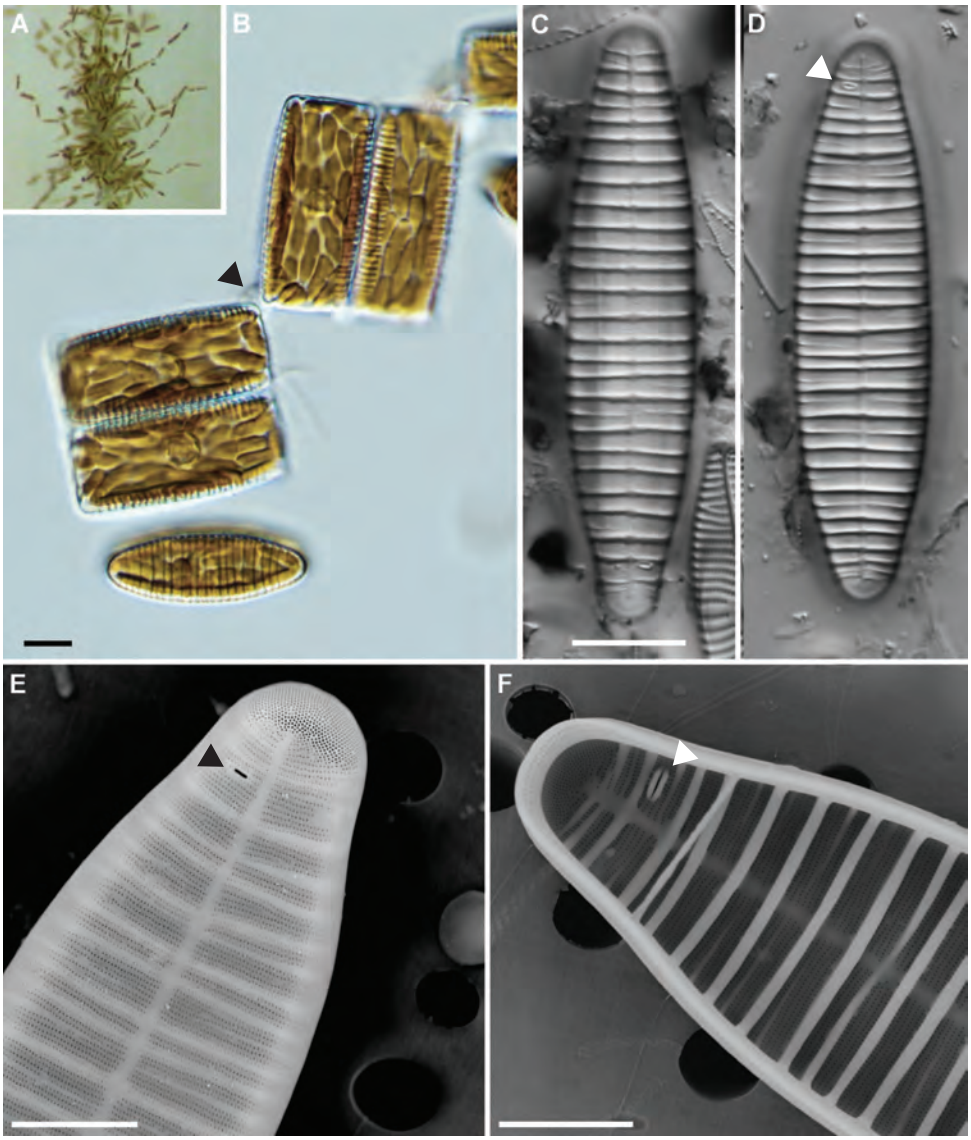


Fig. 37. *Diatoma vulgaris*. **A-D**. LM. **A**. Living cells, colonizing a filament of green algae. **B**. Living cells, girdle and valve views (bottom), note mucilage pads joining cells at the corners (arrow). **C-D**. Valve views of cleaned material, note position of rimoportula (arrow - **D**). **E-F**. SEM. **E**. External view of valve showing external opening of rimoportula (arrow) and apical pore field.
F. Internal view of valve showing the transapical costae and the internal opening of the rimoportula (arrow).
Scale bars = 10 µm (A-D), 5 µm (E-F).

Fragilaria Lyngbye 1819

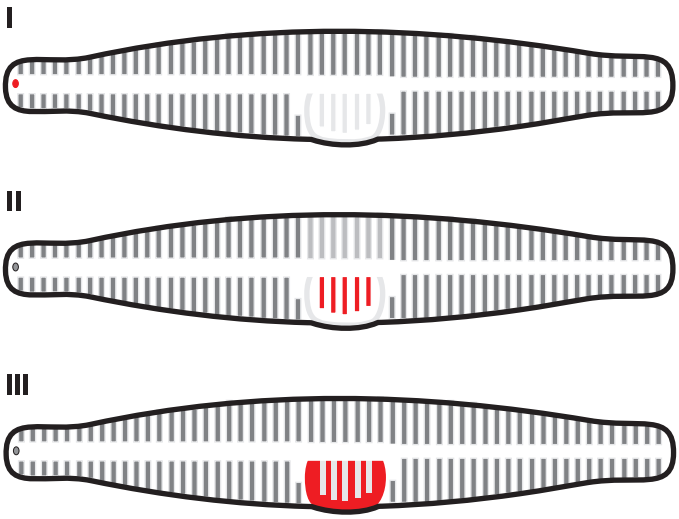
Type species: *Fragilaria pectinalis* (O.F. Müller) Lyngbye

Characteristics – Cells **araphid** with parallel striae through the length of the valve, areolae fine, not easily observed under LM (Fig. 39: A-I). **Axial area** narrow (Fig. 39: E-H) to broad (Fig. 39: D, I). Central area large (a thickened **fascia**; I) with **ghost striae** present (II, Fig. 39: E, F), reaches both valve margins (II, Fig. 39: E, F) or unilaterally expanded (III, Fig. 39: H). **Rimoportula** (labiate or lipped process) (I, Fig. 40: B) present at one apex. Spines at the junction of the valve face and valve mantle.

Plastid structure – Cells with plate-like plastids one lying under each valve face (Fig. 38: A-F).

Identification of species – Species can be identified by cell size, cell shape, structure and density of the striae as well as structure and extent of the axial and central area.

Ecology – Cells colonial, valve face to valve face forming ribbons or basally attached. Found in the benthos of waters with low to moderate conductivity and at a range of trophic levels.



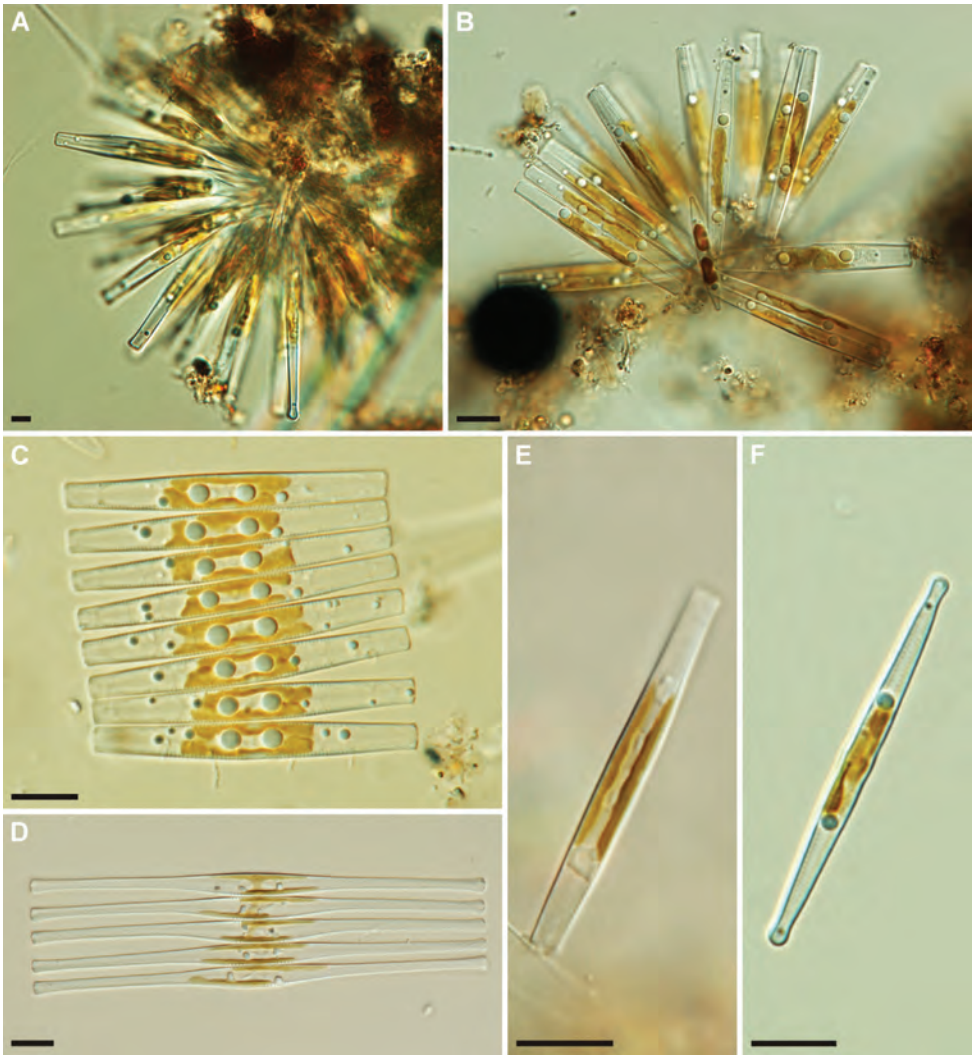


Fig. 38. *Fragilaria* spp. **A-F**. LM, living cells. **A-B**. Cells aggregated into colonies, joined at the base of the cells. **C**. Cells (girdle view) in a ribbon-like colony. **D**. *Fragilaria crotonensis* Kitton, girdle view, ribbon-like colony. **E**. Single cell, girdle view. **F**. Single cell, valve view.
Scale bars = 10 µm (A-F).

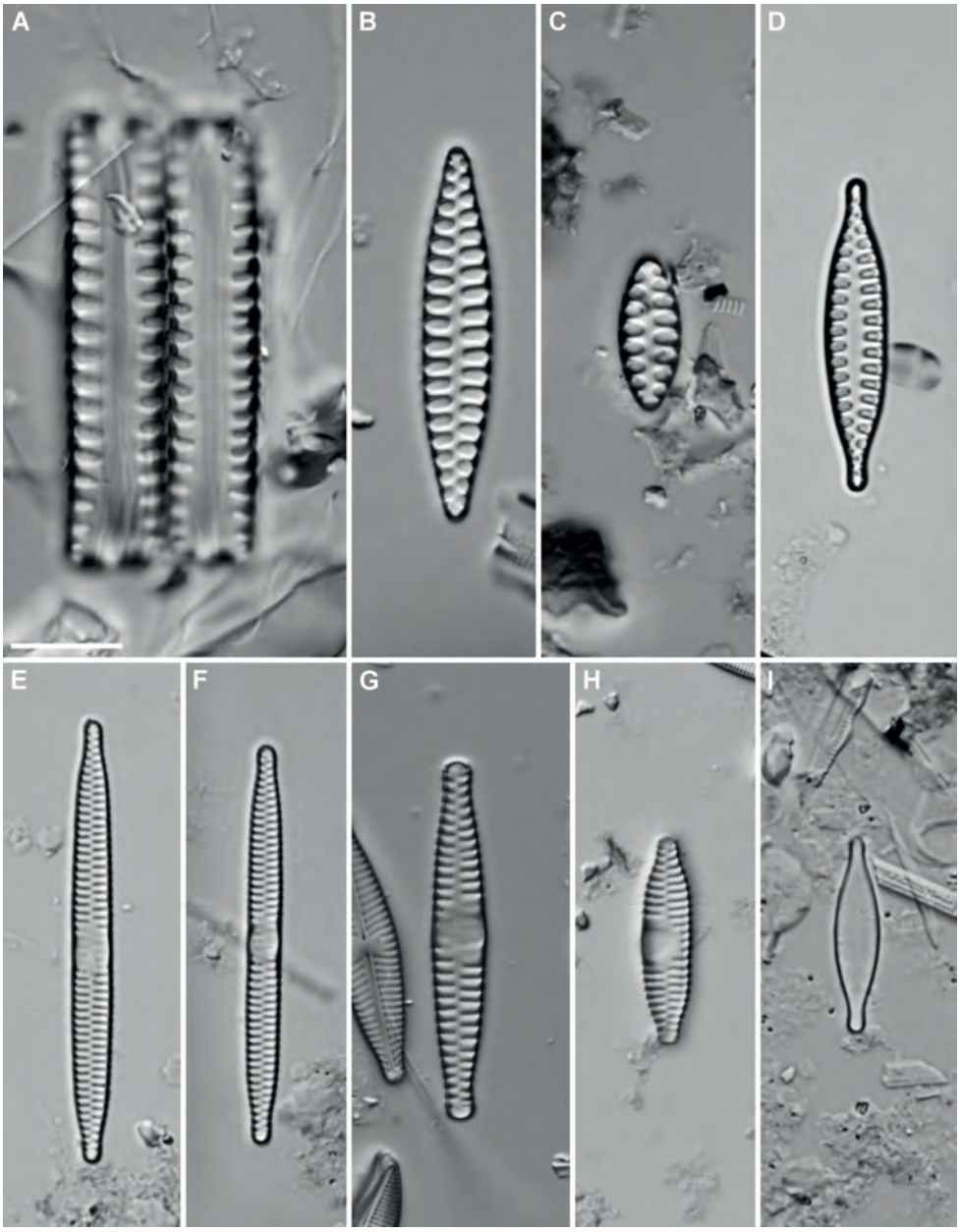


Fig. 39. *Fragilaria* spp. sensu lato. **A-I**. LM. **A**. Girdle view of two cells of *Fragilaria crassa* Metzeltin & Lange-Bertalot. **B-C**. Valve view of *F. crassa*. **D-H**. Valve views of *Fragilaria* spp. **I**. *F. densestriata* Hustedt.
Scale bar = 10 µm (A-H).

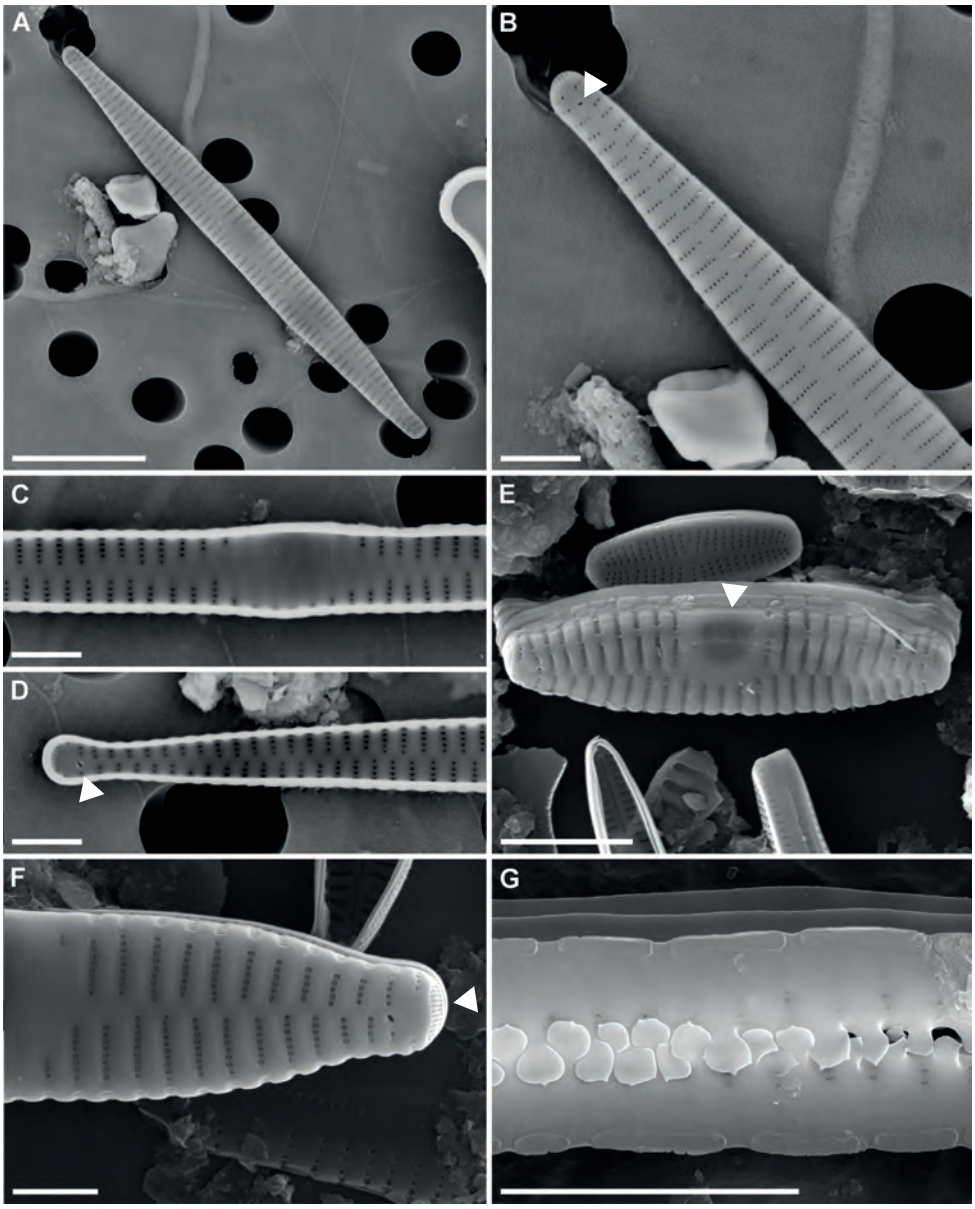


Fig. 40. *Fragilaria* spp. **A-G**. SEM. **A-B**. External view of valve, note external opening of rimoportula (arrow **- B**). **C-D**. Internal view of valves. **C.** Central area. **D**. Apex of cell, note internal opening of rimoportula (arrow). **E**. Oblique view of valve exterior, note thickened fascia (arrow). **F**. External view of cell apex, note apical pore field (arrow). **G**. Girdle view of two valves joined by interlinking spines. Scale bars = 8 µm (A), 2 µm (B-D, F), 5 µm (E, G).

Fragilariforma D.M. Williams & Round 1988

Type species: *Fragilariforma virescens* (Ralfs) D.M. Williams & Round

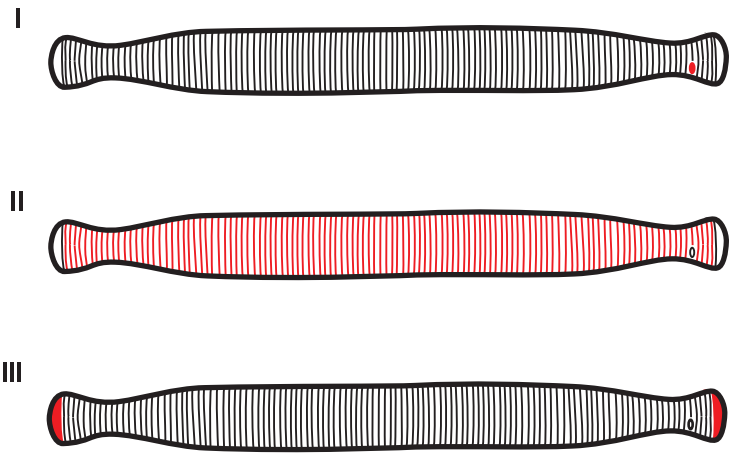
SYNONYM:
Fragilaria Lyngbye 1819 pro parte

Characteristics – Cells **araphid** with parallel striae through the length of the valve (I), areolae fine, not easily observed under LM (Fig. 41). **Rimoportula** (labiate or lipped process) present at one apex (I), difficult to observe under LM. Apical pore fields present at both apices, appearing as unornamented areas under LM (III). **Axial area** very narrow, not possible to observe with LM. Spines at the junction of the valve face and valve mantle (Fig. 42: A-B).

Plastid structure – Unknown from African material.

Identification of species – Up till now only one species known from tropical Africa: *Fragilariforma strangulata* (Zanon) D.M. Williams & Round.

Ecology – Cells joined valve face to valve face forming ribbon-like colonies. Found in the benthos of acidic, oligotrophic waters with low conductivity.



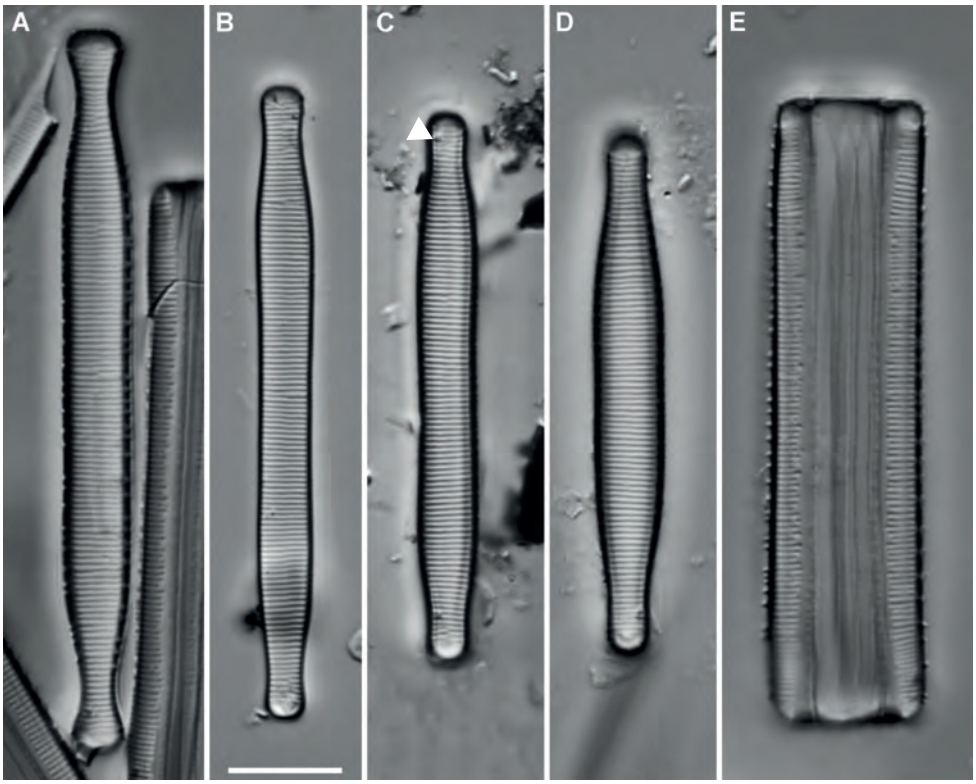


Fig. 41. *Fragilariforma strangulata* (Zanon) D.M. Williams & Round. **A-E.** LM. **A-D.** Valve views, note rimoportula (arrow - **C**). **E.** Girdle view. Scale bar = 10 µm.

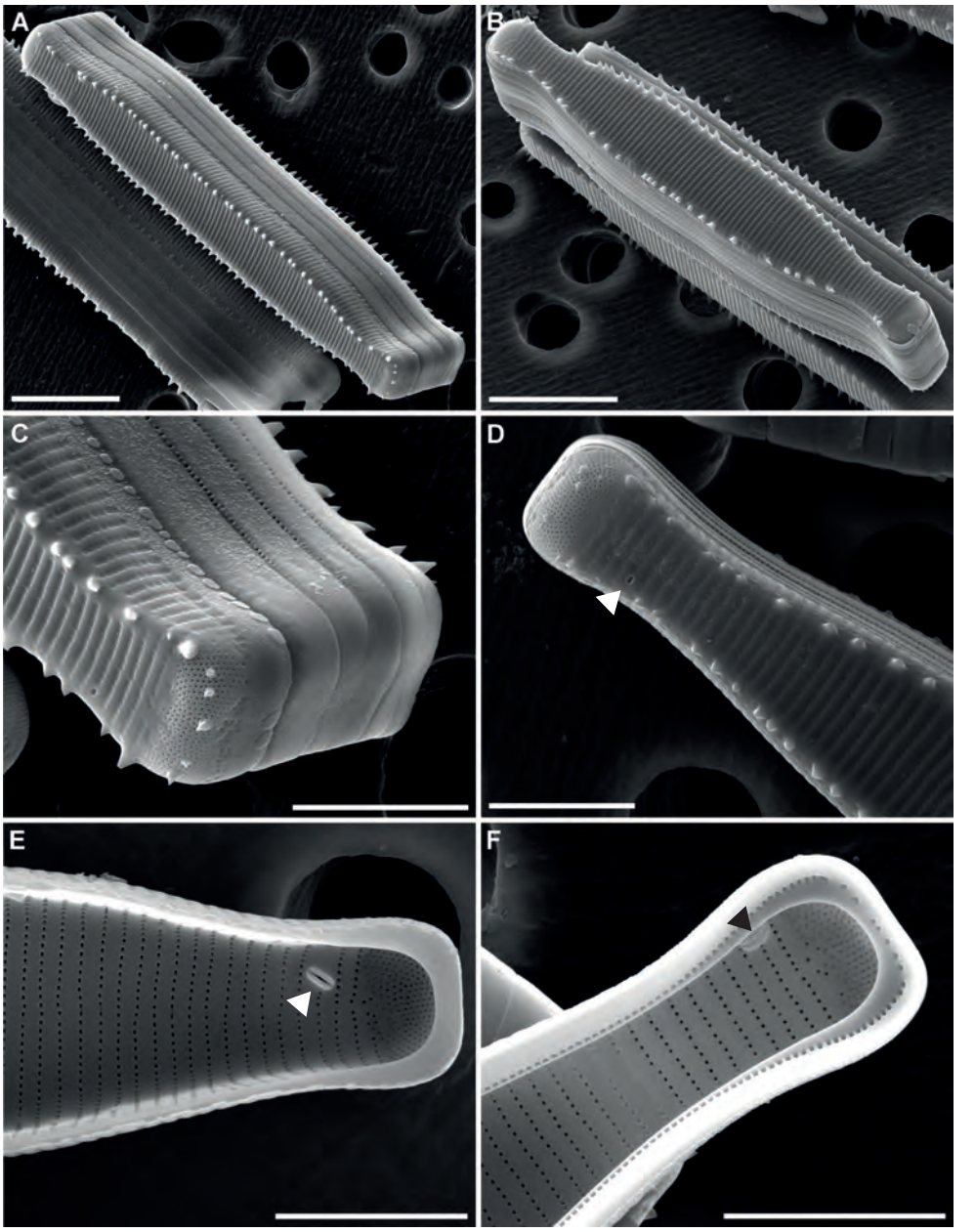


Fig. 42. *Fragilariforma strangulata*. **A-F.** SEM. **A-B.** Oblique external view of valves. **C-D.** External view of apices, showing apical pore field, note external opening of rimoportula (arrow - **D**). **E-F.** Internal view of apices showing variable position of rimoportulae (arrows).
Scale bar = 10 µm (A-B), 5 µm (C-F).

Meridion C. Agardh 1824

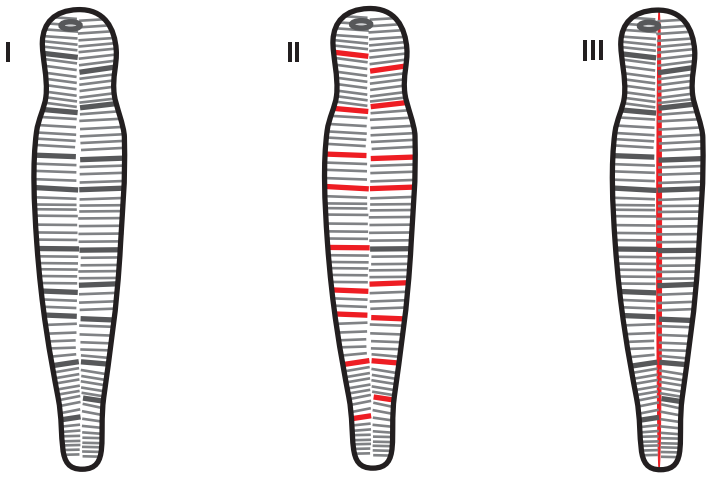
Type species: *Meridion vernale* C. Agardh

Characteristics – Cells **araphid**, **heteropolar** with broadly rounded head pole and narrower foot pole, wedge shaped in girdle view. Valve margin may be constricted just below the head pole. Valve face crossed by transapical striae and costae (II) interrupted in the centre by a narrow axial area (III). Striae are fine, located between the costae and not easily discernable under LM (Fig. 43: A-F). Single **rimoportula** present near the head pole (Fig. 44: A-B).

Plastid structure – Many discoid plastids lying under the valve face.

Identification of species – Up till now only one species known from tropical Africa: *Meridion circulare* (Greville) C. Agardh and *M. circulare* var. *constrictum* (Ralfs) Van Heurck.

Ecology – Cells solitary, or united by the valve faces forming fan-shaped colonies. Found in the benthos of acidic, oligotrophic waters with low conductivities.



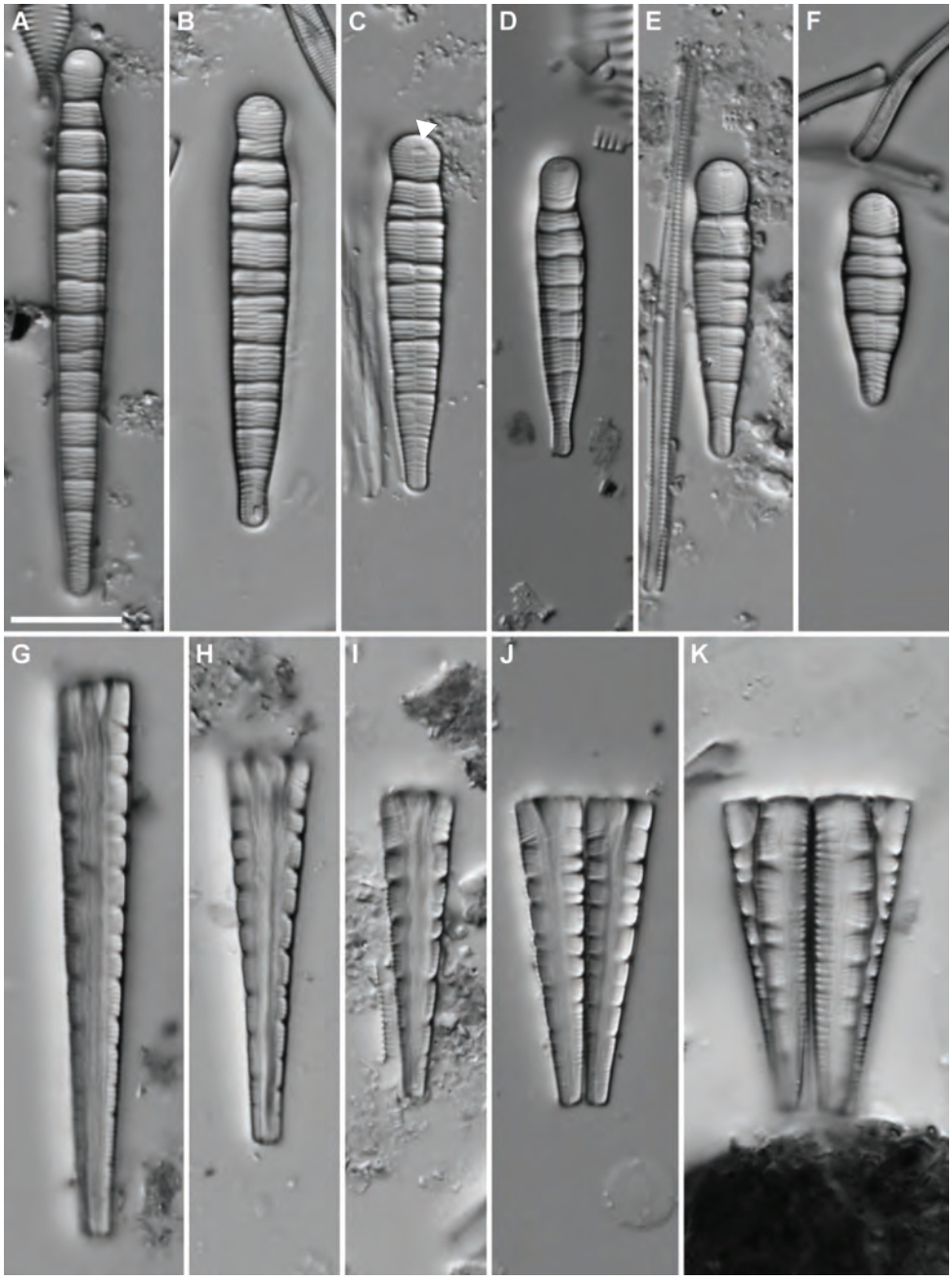


Fig. 43. *Meridion circulare* var. *constrictum*. **A-K**. LM. **A-F** Valve views, note rimoportula (arrow - **C**). **G-K.** Girdle views.
Scale bar = 10 µm .

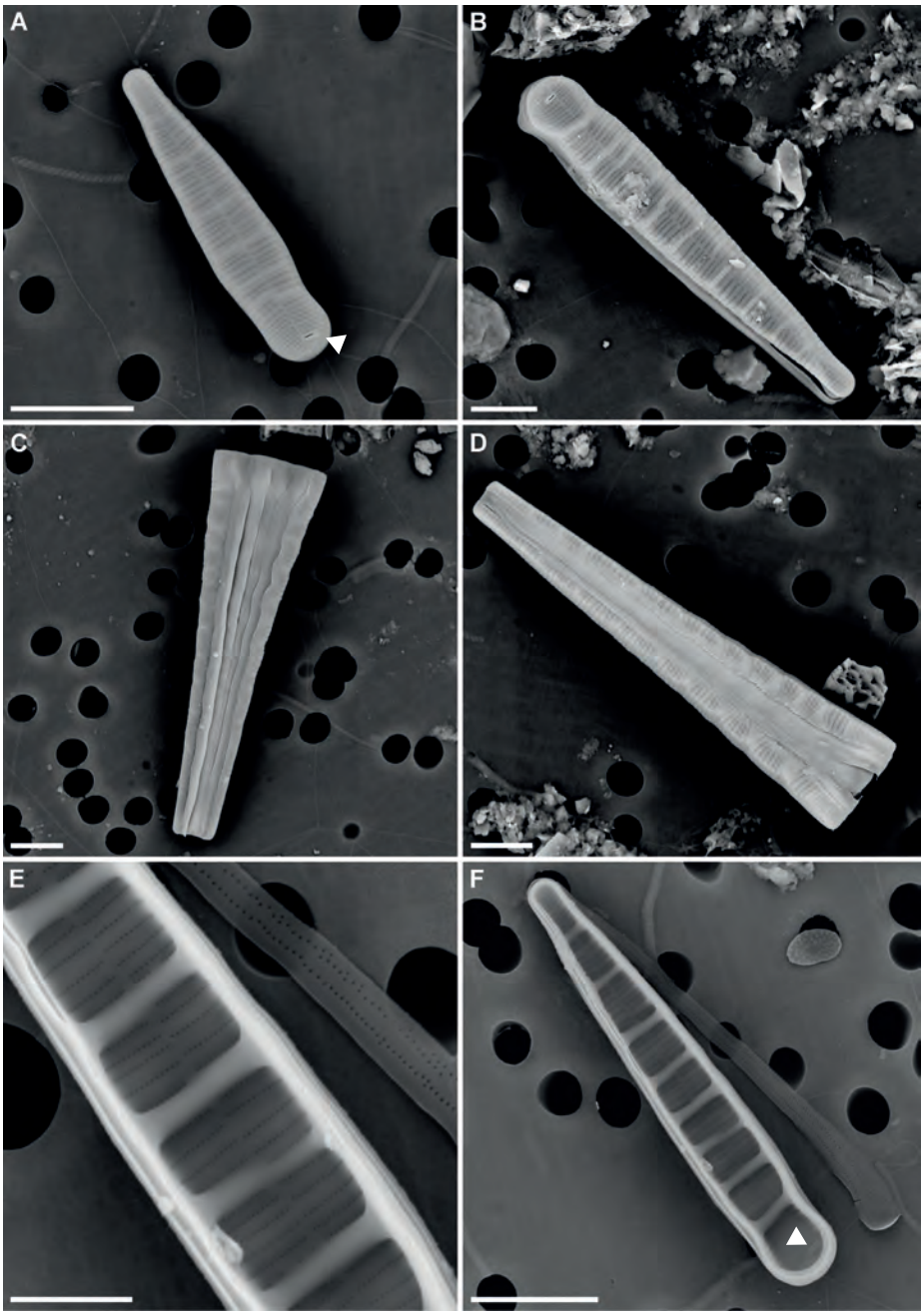


Fig. 44. *Meridion circulare* var. *constrictum*. **A-F**. SEM. **A-B.** External view of valve, note the rimoportula near the head pole apical (arrow **- A**). **C-D.** External view of girdle. **E-F.** Internal view of valve, note the internal opening of the rimoportula (arrow **- F**).
Scale bars = 10 µm (A-D), 3 µm (E), 8 µm (F).

Pseudostaurosira D.M. Williams & Round 1987

Type species: *Pseudostaurosira brevistriata* (Grunow) D.M. Williams & Round

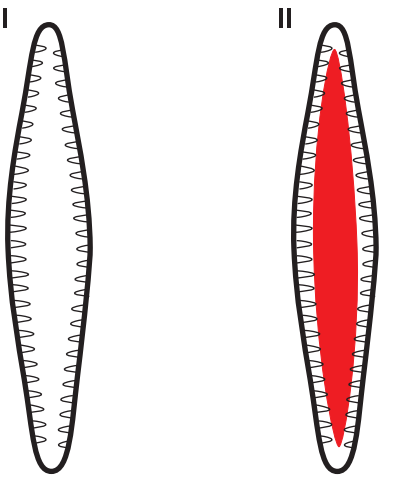
SYNONYM:
Fragilaria Lyngbye 1819 pro parte
Odontella C. Agardh 1832 pro parte

Characteristics – Cells **araphid** with short parallel striae through the length of the valve, areolae fine, not easily observed under LM (Fig. 45). **Axial area** broad, lanceolate. Spines may be present on junction of the valve face and valve mantle. Apical pore field at each pole.

Plastid structure – Cells with plate-like plastids one lying under each valve face (see *Fragilaria*).

Identification of species – Species can be identified by cell size, cell shape, structure and density of the striae as well as structure and extent of the axial area.

Ecology – Cells colonial, valve face to valve face forming ribbons or basally attached. Found in the benthos of waters with low to high conductivity and at a range of trophic levels.



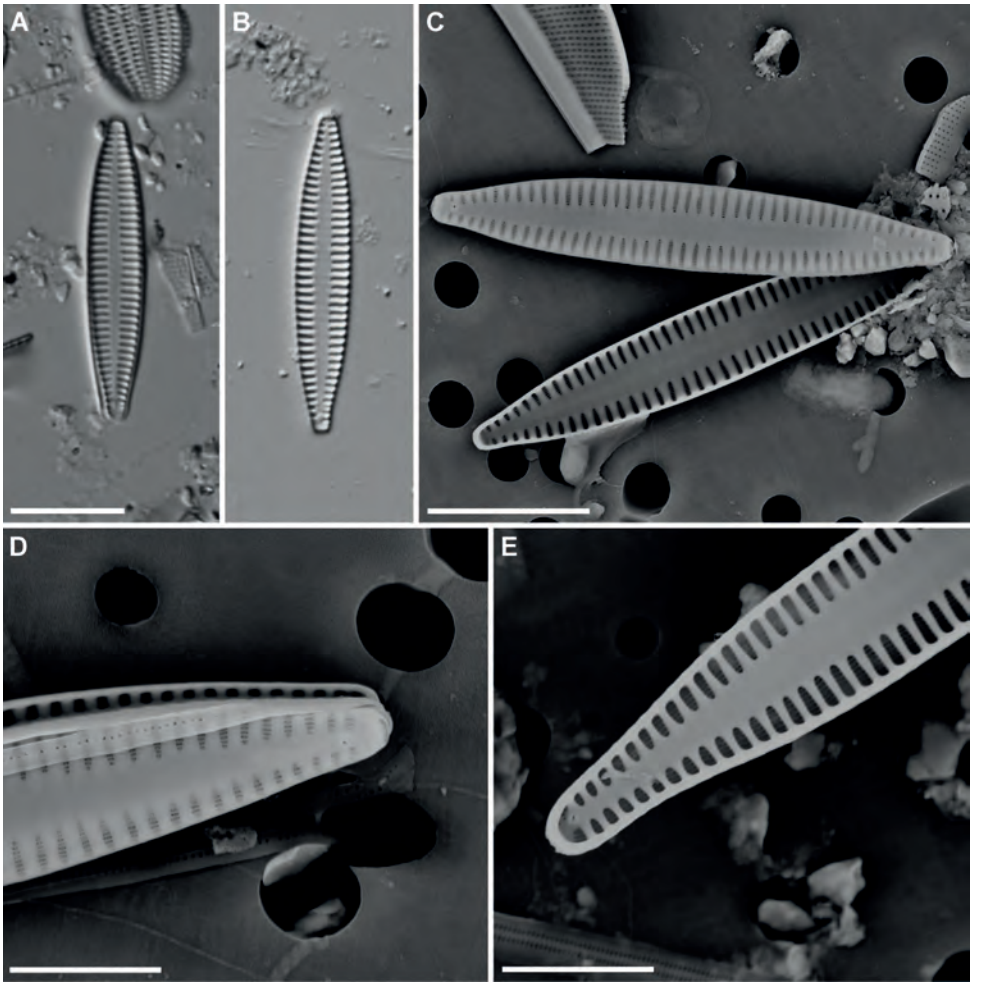


Fig. 45. *Pseudostaurosira brevistriata*. **A-B**. LM, valve view. **C-E.** SEM. **C.** External and internal view of valve. **D.** External view of valve apex. **E.** Internal view of valve apex.
Scale bars = 10 µm (A-C), 3 µm (D), 5 µm (E).

Staurosira Ehrenberg 1843

Type species: *Staurosira construens* Ehrenberg

SYNONYM:

Fragilaria Lyngbye 1819 pro parte

Characteristics – Cells **araphid**, elliptical or cruciform with robust parallel to radiate striae (II) through the length of the valve, areolae round to slightly elongate (Fig. 47: O-P), not easily observed under LM (Fig. 47: A-G, I-N). **Axial area** of variable width. Apical pore fields at one or both apices. Rimoportula absent. Spines present at the junction of the valve face and mantle. Distinguished from *Staurosirella* by the structure of the areolae (rounded).

Plastid structure – Cells with 2 plate-like plastids lying along the girdle (Fig. 46).

Identification of species – Species can be identified by cell size, cell shape, structure and density of the striae as well as structure and extent of the axial area.

Ecology – Cells colonial, linked valve face to valve face by spines forming ribbons (Fig. 46: A-B). Found in the benthos of waters with low to moderate conductivity and at a range of trophic levels.

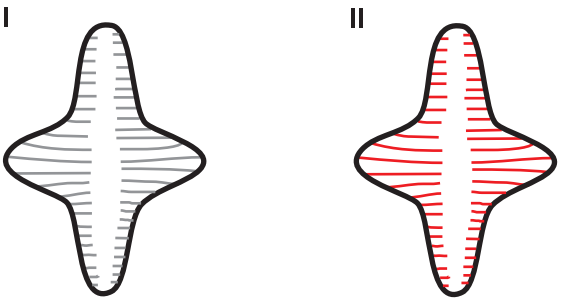


Fig. 46. *Staurosira construens*. **A-D.** LM, living cells. **A-B, D.** Cells linked valve face to valve face forming ribbon colonies. **C.** Valve view (right) and girdle view (above).
Scale bars = 10 µm.

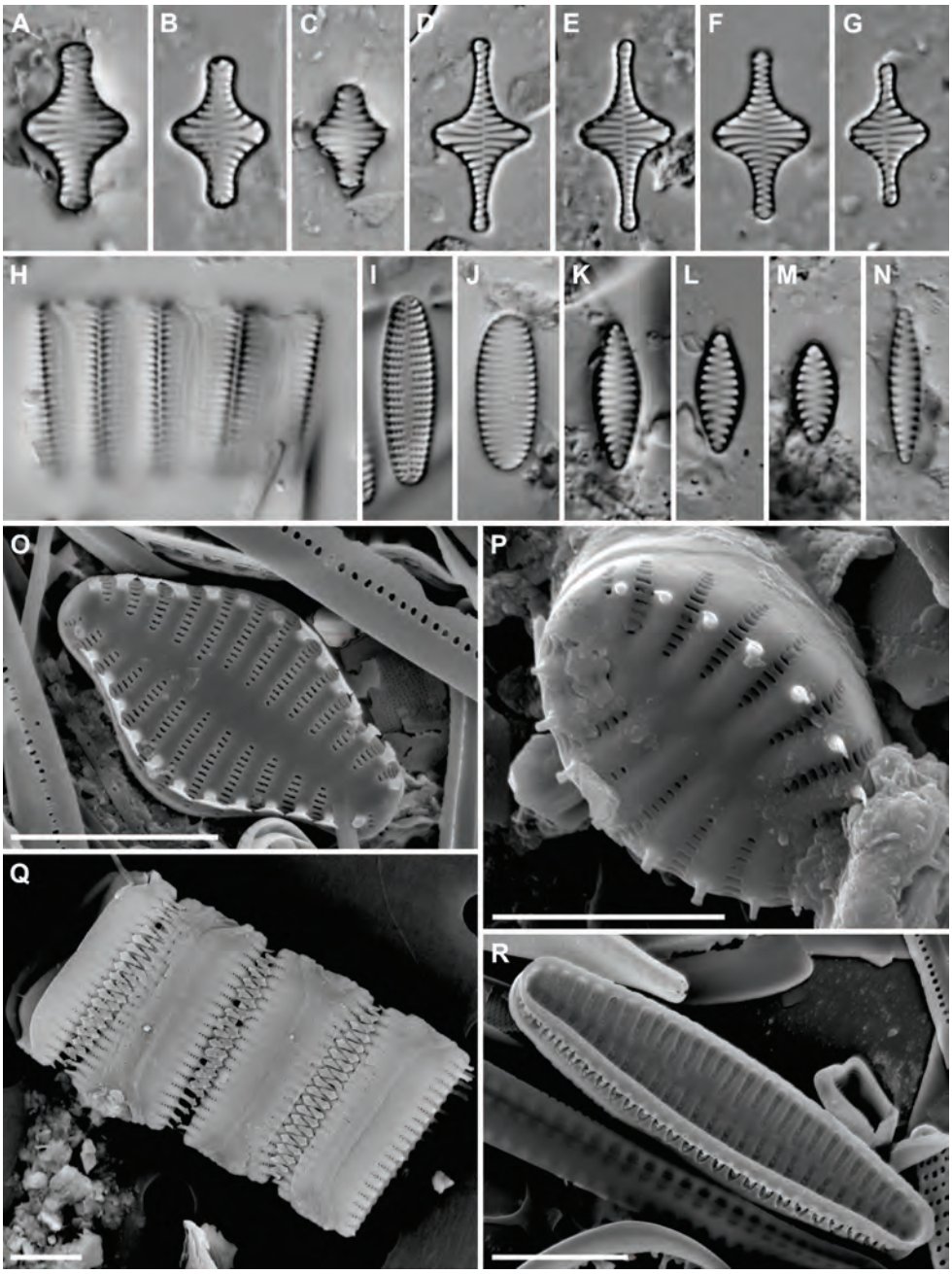


Fig. 47. *Staurosira* spp. **A-N.** LM, cleaned valves. **A-G, I-N.** Valve views. **H.** Girdle view. **O-R.** SEM. **O-P.** External view of valves, note the slightly elongated areolae. **Q.** Girdle view, showing spines at junction of valve face and mantle, forming ribbon colonies. **R.** Internal view of valve.
Scale bars = 10µm (A-N), 5 µm (O), 4µm (P-Q).

Staurosirella D.M. Williams & Round 1987

Type species: *Staurosirella lapponica* (Grunow) D.M. Williams & Round

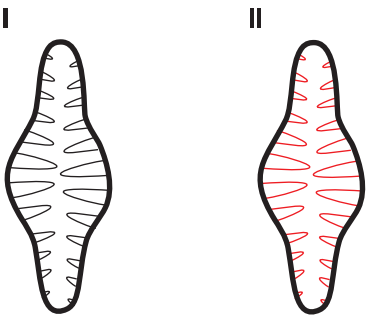
SYNONYM:
Fragilaria Lyngbye 1819 pro parte

Characteristics – Cells **araphid**, elliptical, linear or cruciform with robust parallel striae (II) through the length of the valve, areolae **lineolate** (Fig. 48: K), not easily observed under LM (Fig. 48: A-I). **Axial area** of variable width. Apical pore field at one or both apices. Rimoportula absent. Spines present at the junction of the valve face and mantle. Distinguished from *Staurosira* by the structure of the areolae (elongate).

Plastid structure – Cells with 2 plate-like plastids lying along the girdle (Fig. 48: A).

Identification of species – Species can be identified by cell size, cell shape, structure and density of the striae as well as structure and extent of the axial area.

Ecology – Cells colonial, linked valve face to valve face by spines forming ribbons. Found in the benthos of waters with low to moderate conductivity and at a range of trophic levels.



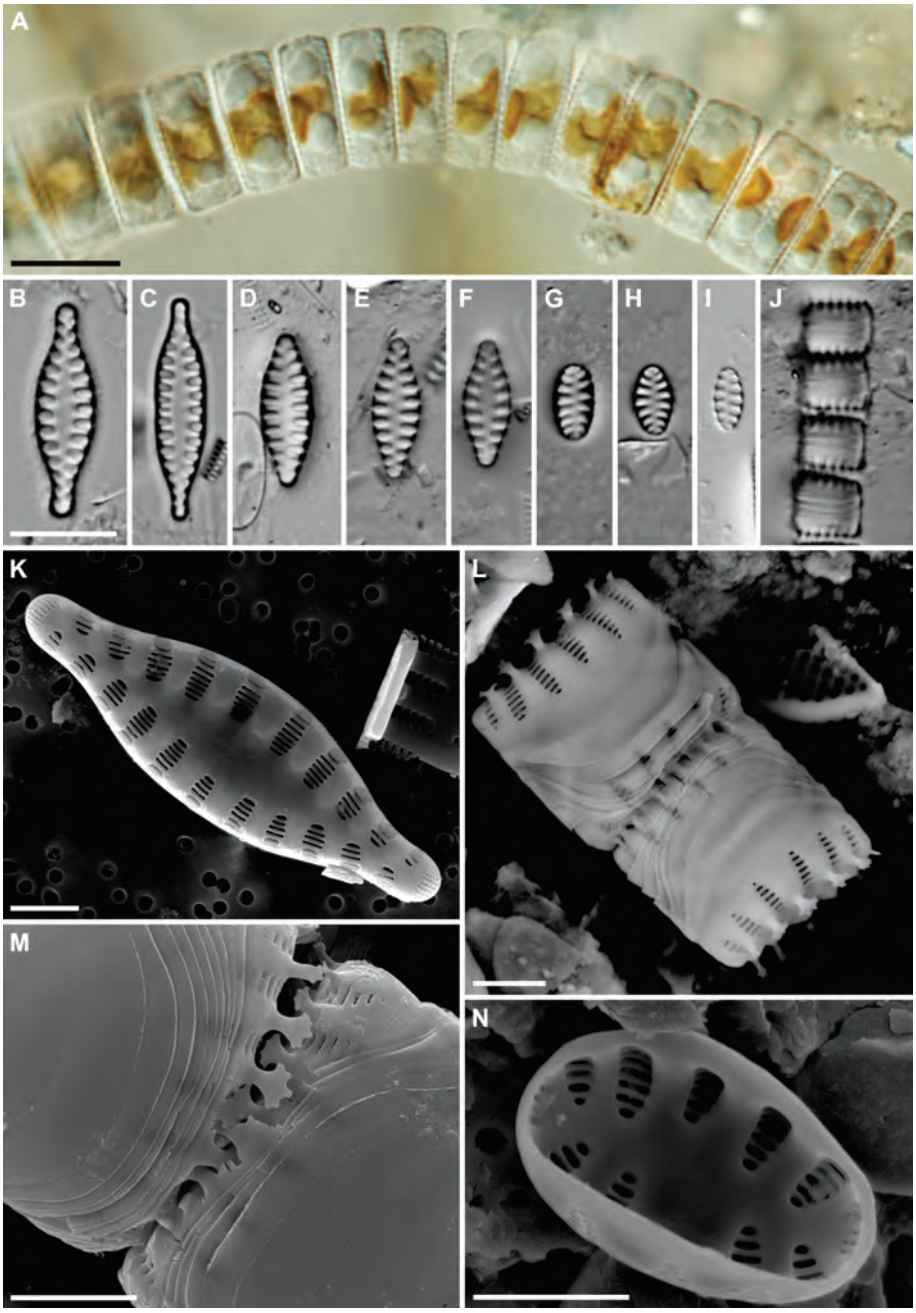


Fig. 48. *Staurosirella* spp. **A-J.** LM. **A.** Living cells. **B-J.** Cleaned valves. **B-I.** Valve views. **J.** *S. pinnata* (Ehrenberg) D.M. Williams & Round, girdle view. **K-N.** SEM. **K.** External view of valve, note the lineolate areolae. **L-M.** Girdle views, note the connecting spines. **N.** Internal view of valve. Scale bars = 10 µm (A-J), 2 µm (K-N).

Tabularia Kützing ex D.M. Williams & Round 1986

Type species: *Tabularia barbatula* (Kützing) D.M. Williams & Round

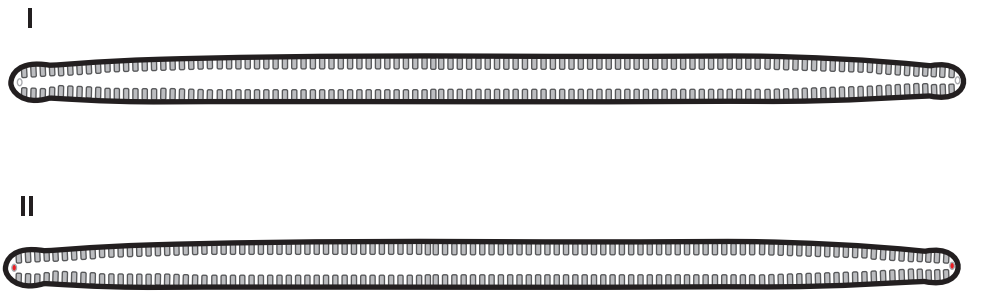
SYNONYM:
Fragilaria Lyngbye 1819 pro parte
Synedra Ehrenberg 1830 pro parte

Characteristics – Cells **araphid**, linear with parallel striae through the length of the valve, areolae fine, not easily observed under LM (Fig. 49: A). **Axial area** broad. **Rimoportula** (labiate or lipped process) present at both apices (II; Fig. 49: B, D). Apical pore field at each pole.

Plastid structure – Cells with plate-like plastids one lying under each valve face (see *Fragilaria*).

Identification of species – Species can be identified by cell size, cell shape, structure and density of the striae as well as structure and extent of the axial and central area.

Ecology – Cells colonial, basally attached. Found in the benthos of waters with moderate to high conductivity and at a range of trophic levels.



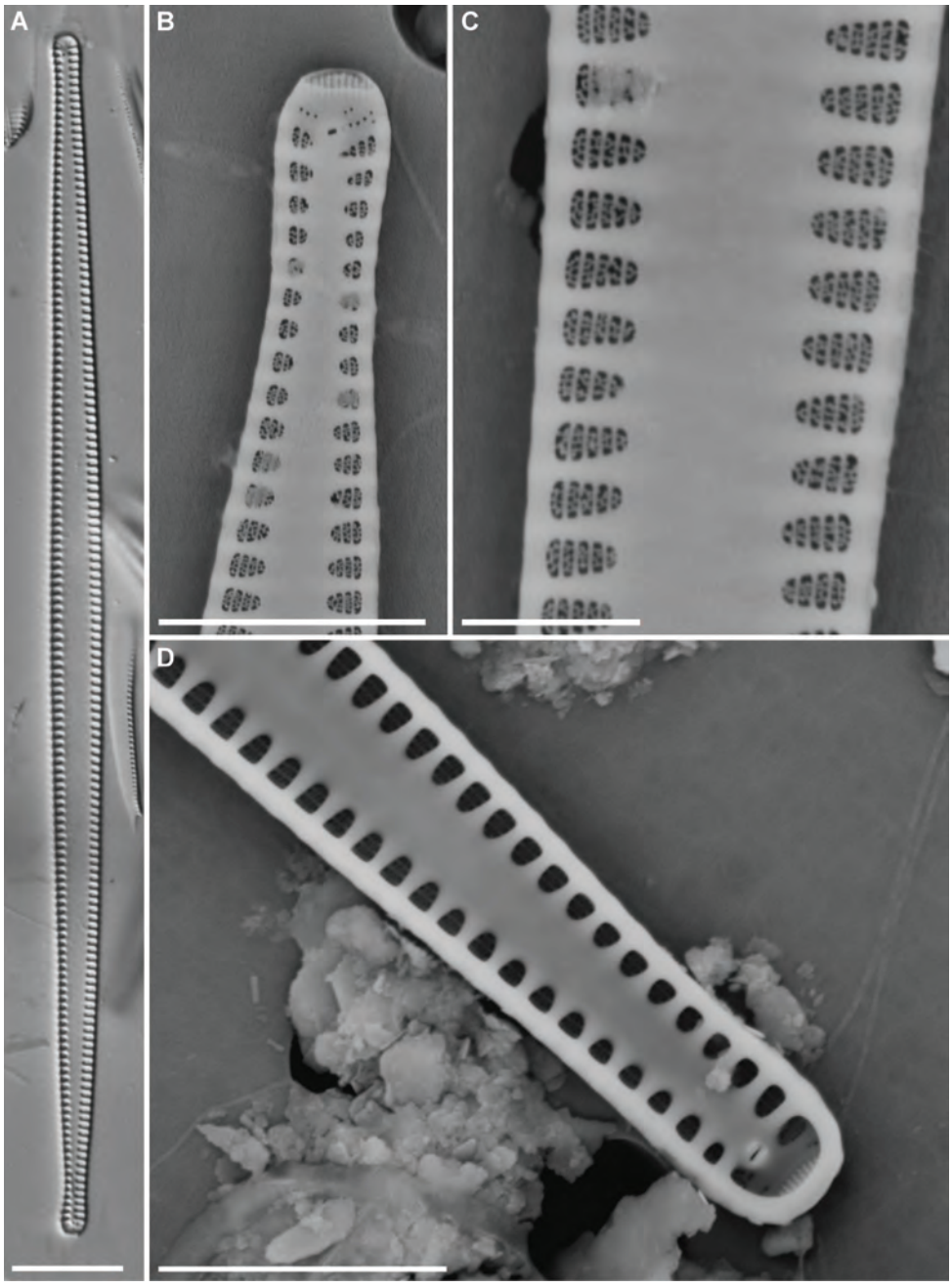


Fig. 49. *Tabularia fasciculata* (C. Agardh) D.M. Williams & Round. **A**. LM. **B-D**. SEM, internal view of valve, note position of internal opening of rimoportula. Scale bars = 10 µm (A), µm 5 µm (B, D), 2 µm (C).

Ulnaria (Kützing) Compère 2001

Type species: *Ulnaria ulna* (Nitzsch) Compère

SYNONYM:

Synedra Ehrenberg 1830 pro parte

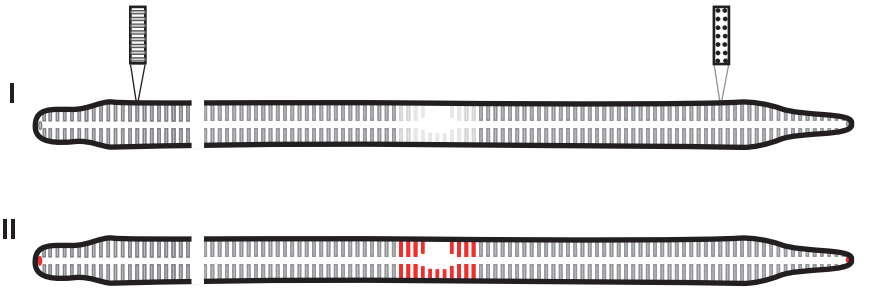
Characteristics – Cells **araphid**, often very long with parallel striae through the length of the valve, areolae fine and often not easily observed under LM (Fig. 52). **Axial area** narrow but clearly discernable. Central area may be present and varies in size (Fig. 52), may reach both valve margins (Fig. 52: B) or be unilaterally expanded (Fig. 52: C-D). Ghost striae may be present (II; Fig. 52: A, D). **Rimoportula** (labiate or lipped process) present at both apices (II). Small apical spines may be present (Fig. 53: A).

Plastid structure – Cells with 2 plate-like plastids lying under the valves (Fig. 51: D).

Identification of species – Species can be identified by cell size, cell shape, structure and shape of the apices, structure and density of the striae as well as structure and extent of the axial and central area.

Ecology – Cells planktonic or colonial, basally attached (Fig. 50). Found in the benthos of waters with low to moderate conductivities and at a range of trophic levels. Thought to be adapted to survive high flow conditions.

Notes – The genus ***Synedra*** sensu lato will often be encountered in older literature. This genus contained number of species common to tropical African waters (e.g. *Synedra nyansae* G.S. West, synonym *S. dorsiventralis* O. Müller). The type of *Synedra* is now considered to be *S. gaillonii* (Bory) Ehrenberg which is a marine species. Most freshwater species from *Synedra* senu lato have now been transferred to *Ulnaria, e.g. Ulnaria nyansae* (G.S. West) D.M. Williams.



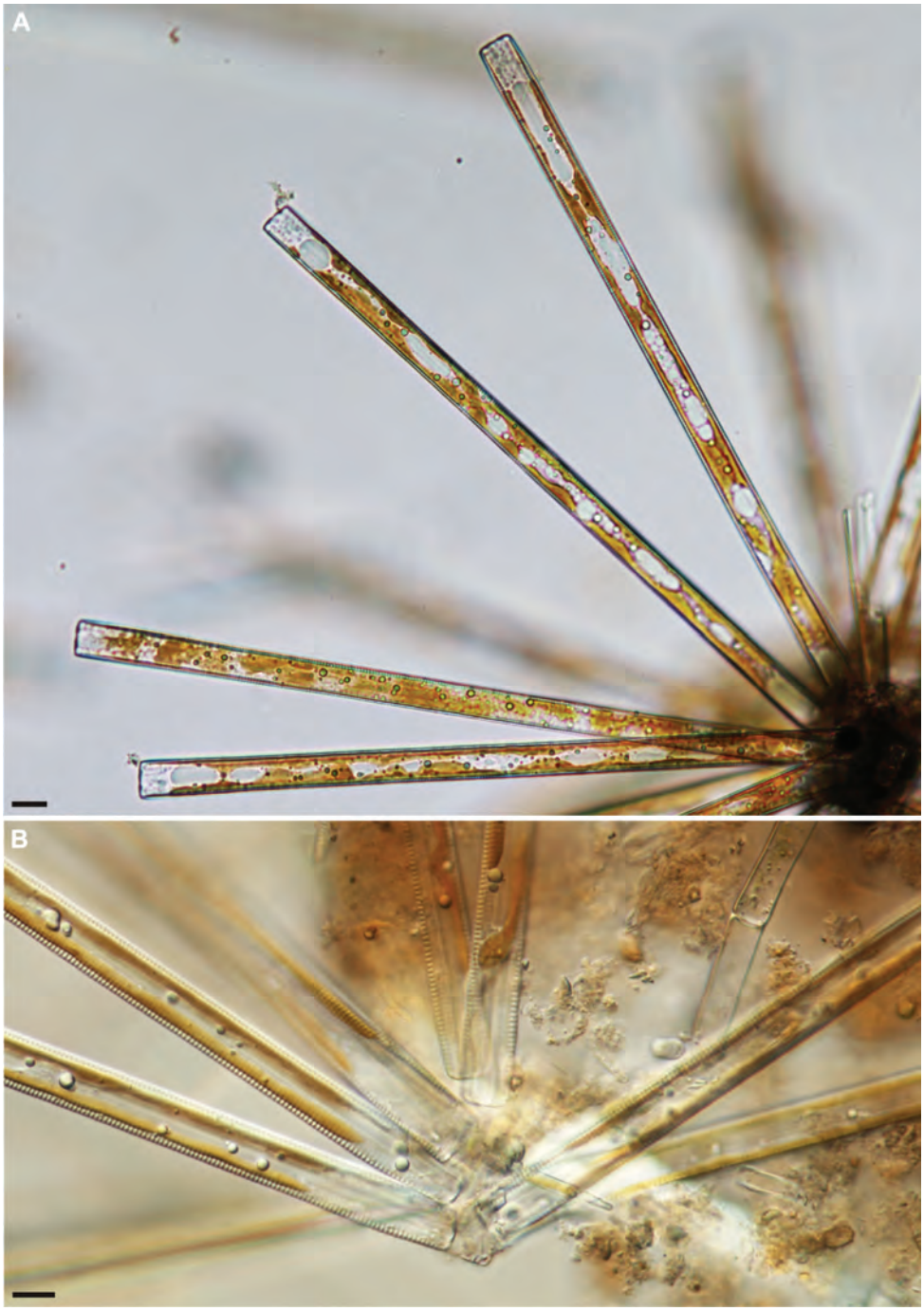


Fig. 50. *Ulnaria* spp. **A-B.** LM, living cells, girdle view, forming colony, cells basally attached.
Scale bars = 10 µm.

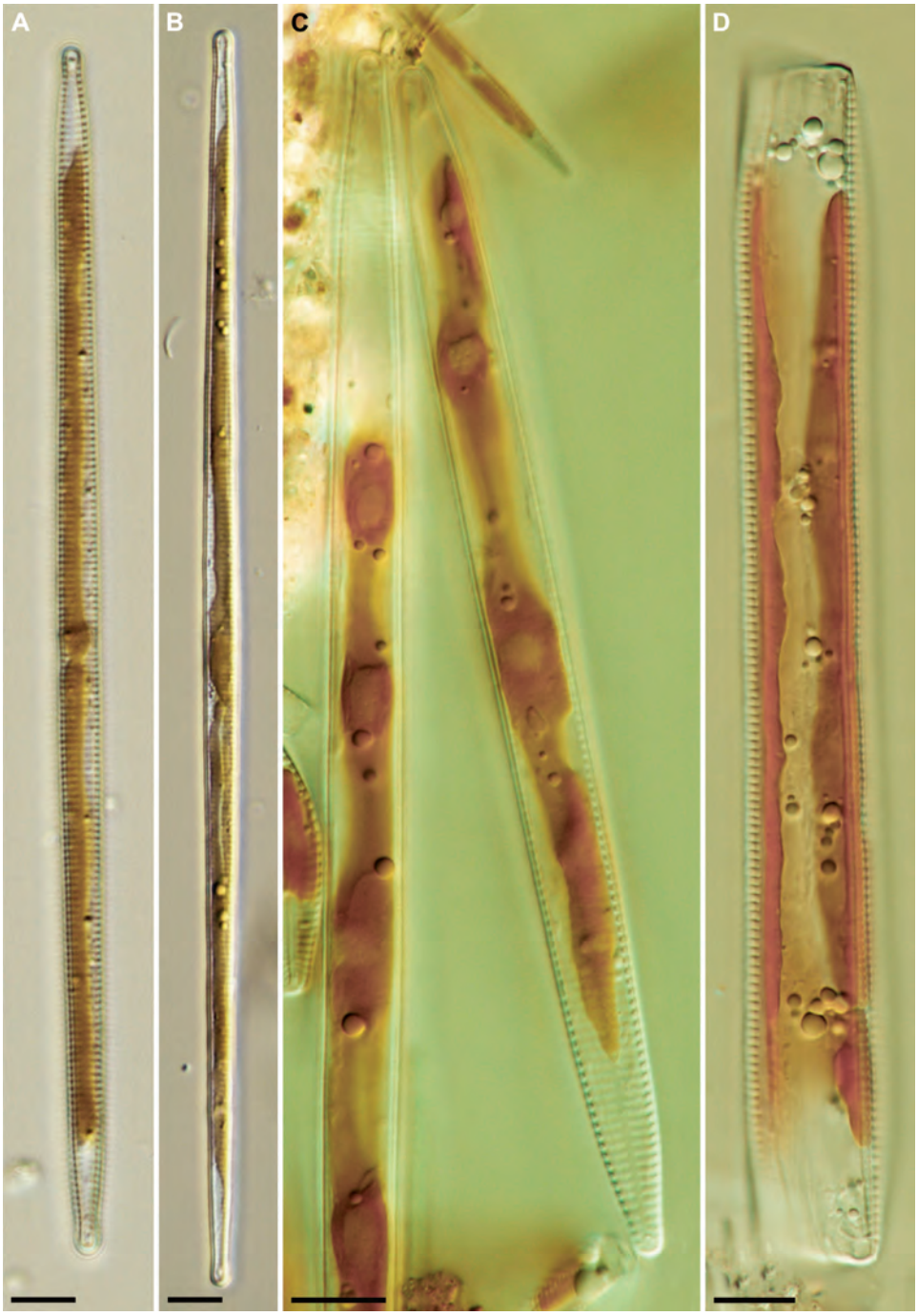


Fig. 51. *Ulnaria* spp. **A-D.** LM, living cells. **A-B.** Valve views. **C.** Valve views, forming colony, cells basally attached. **D.** Girdle view.
Scale bars = 10 µm.

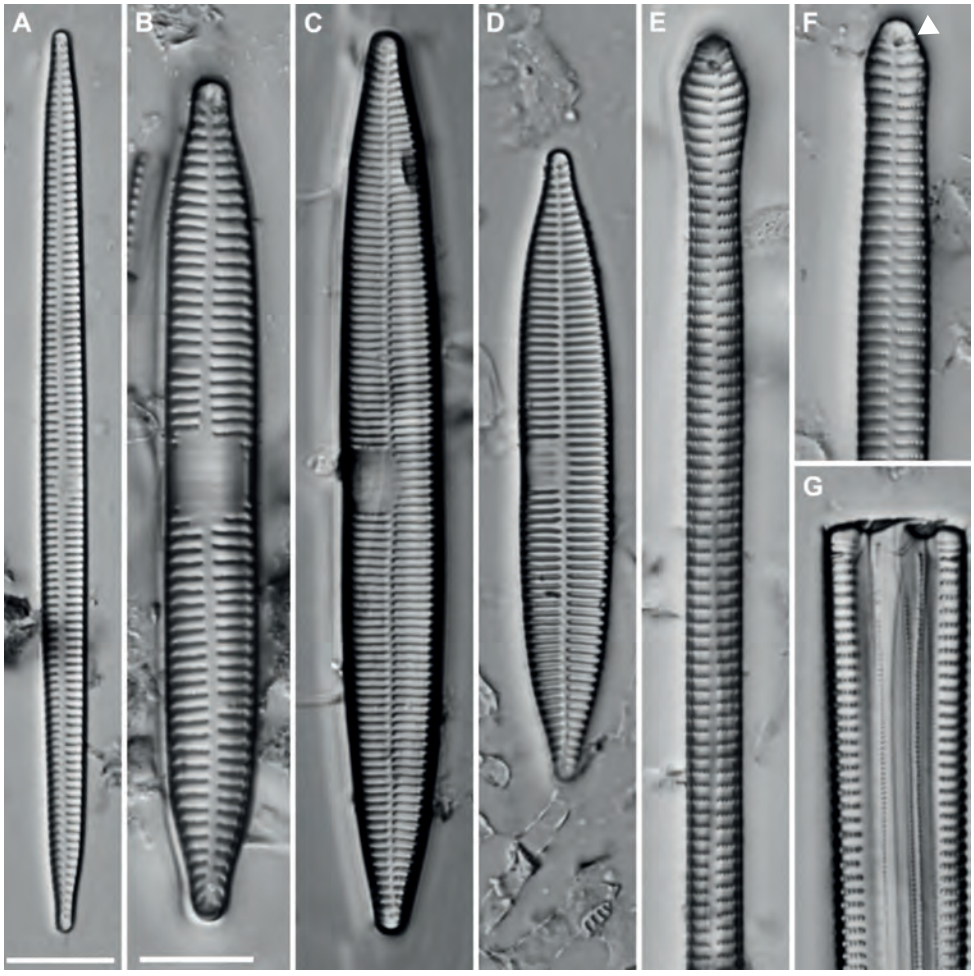


Fig. 52. *Ulnaria* spp. **A-G.** LM. **A-B.** Valve views. **C-D.** Valve views of *Ulnaria nyansae*. **E-F.** Valve views, note rimoportula (arrow - **F**). **G.** Girdle view. Scale bars = 10 µm.

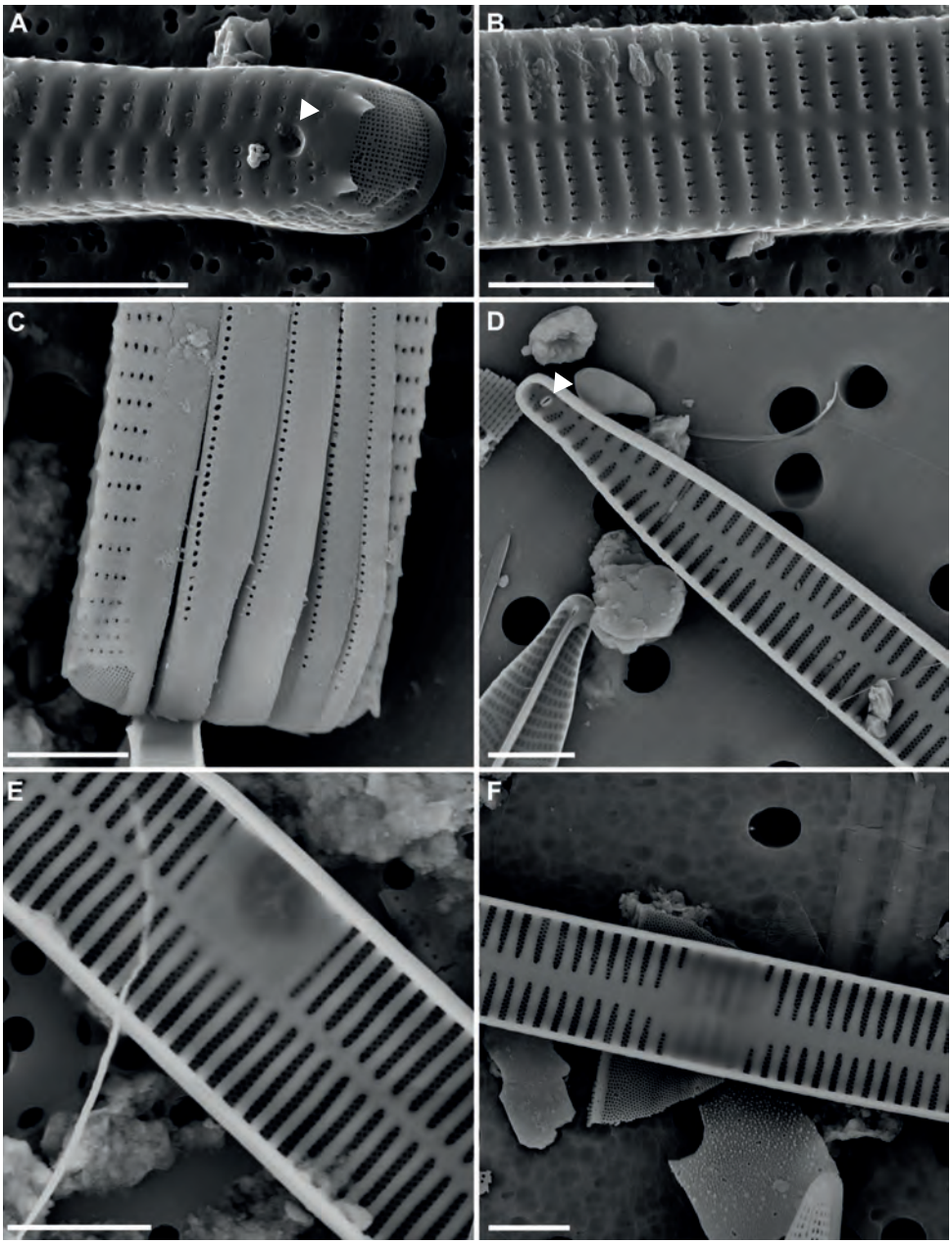


Fig. 53. *Ulnaria* spp. **A-F.** SEM. **A-B.** External view of valve**. A.** Cell apex, note apical pore field and rimoportula (arrow). **C.** External girdle view. **D-F.** Internal view of valve. **D.** Cell apex with internal opening of rimoportula (arrow). **E-F.** Central area, varies in size and may reach both valve margins. Scale bars = 5 µm (A-F).

Tabellaria (Ehrenberg) Kützing 1844

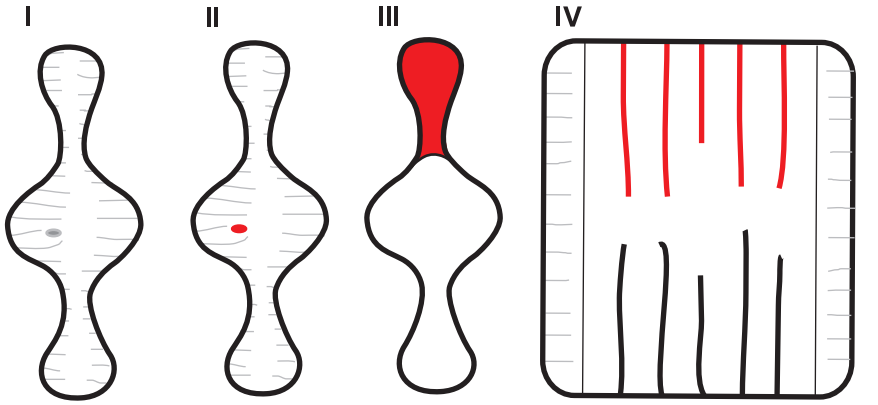
Type species: *Tabellaria flocculosa* (Roth) Kützing

Characteristics – Cells **araphid** with swollen mid-valve and apices. Parallel striae through the length of the valve, areolae fine, not easily observed under LM (Fig. 54: C, E-F). **Axial area** very narrow, a reduced central area may be present. **Rimoportula** (labiate or lipped processes) present mid-valve (II), positioned slightly eccentrically. Apical pore fields at both poles (Fig. 55: A). Numerous girdle bands or **copulae** bear **septa** (III), visible in both valve view (III) and girdle view (IV) (Fig. 54: D; Fig. 55: B, E). Spines may be present at the junction of the valve face and mantle (Fig. 55: A).

Plastid structure – Cells with numerous discoid plastids (Fig. 54: A-B).

Identification of species – Species can be identified by cell size (length), cell shape, presence of a central area, presence of spines as well as the height of complete frustules in girdle view.

Ecology – Cells colonial, joined at the apices of the cells by mucilage pads forming zigzag colonies (Fig. 54: A-B). Found in the benthos of slightly acidic oligotrophic waters with low conductivities, may be re-suspended in the phytoplankton.



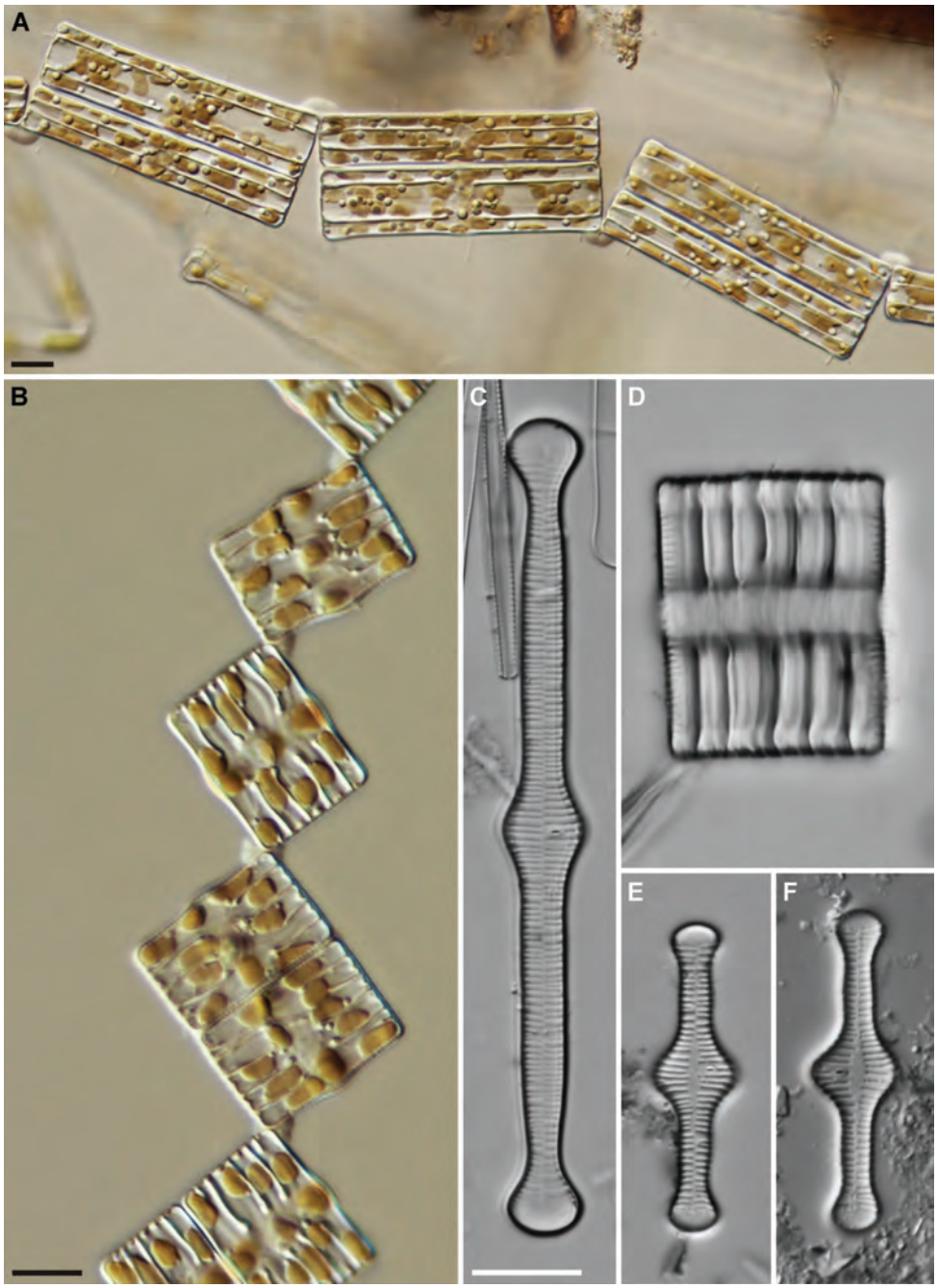


Fig. 54. *Tabellaria* spp. **A-F.** LM. **A-B.** Living cells forming zigzag colonies. **C-F.** Cleaned cells. **C, E-F.** Valve views. **D.** Girdle view. **A, C.** *T. fenestrata* (Lyngbye) Kützing. **B, D, F.** *T. flocculosa.*
Scale bars = 10 µm .

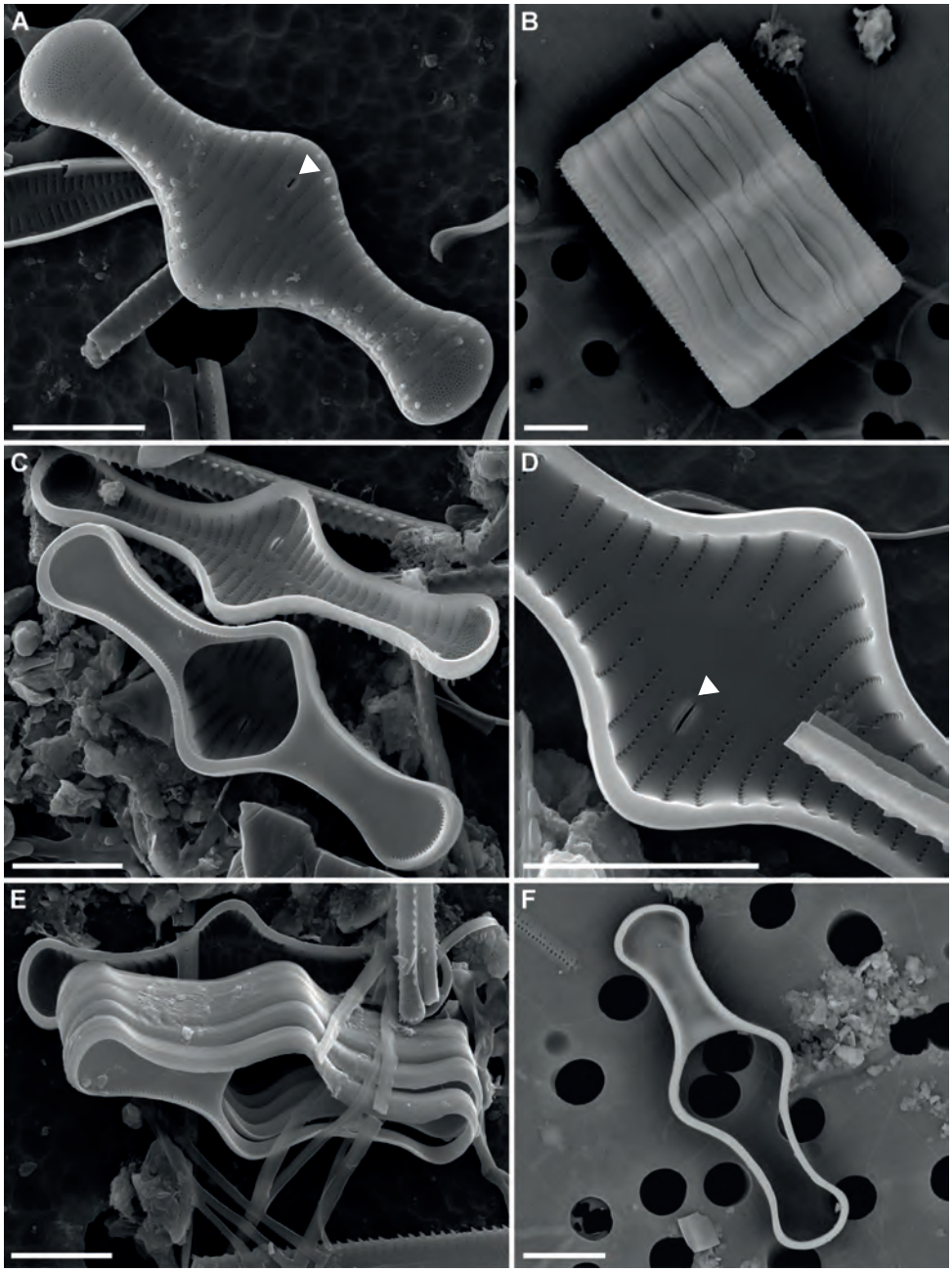


Fig. 55. *Tabellaria flocculosa*. **A-F.** SEM. **A.** External view of valve, note position of the rimoportula (arrow). **B.** Girdle view. **C, E-F.** Internal view of valve showing the septa. **D.** Internal view of valve, note internal opening of rimoportula (arrow).
Scale bars = 5 µm .

Actinella F.W. Lewis 1864

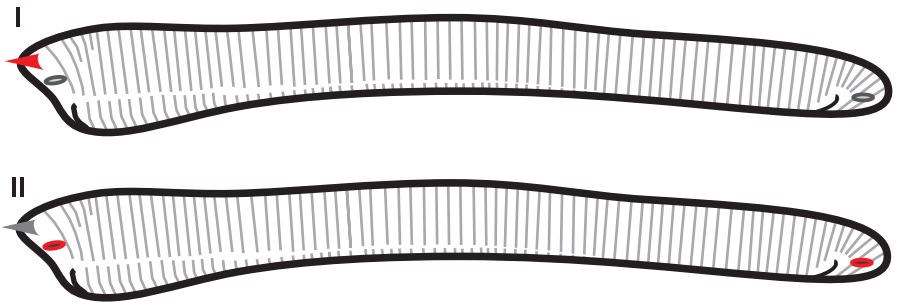
Type species: *Actinella punctata* F.W. Lewis

Characteristics – Cells raphid, usually strongly **heteropolar** (head pole differs in size and shape from foot pole) and this is the chief character differentiating this genus from *Eunotia*. The cell margins have **spines** and the head or larger pole (Fig. 57: F) as well as the foot pole (Fig. 57: G) may carry a single isolated **spine** (I). The raphe is very short on the valve face (comparable to *Eunotia*) with the majority of the length being found on the **valve mantle** (Fig. 57). In girdle view cells have a pronounced wedge shape (Fig. 57: B). A single **rimoportula** (labiate or lipped process) is present at each apex which may be rather difficult to see in LM (II, Fig. 57: A).

Plastid structure – Cell occupied by a single large chloroplast the lobes of which are apressed under each valve and connected centrally by a bridge (Fig. 56: D).

Identification of species – Species and varieties in this genus are distinguished based on cell size and shape and importantly the shape of the apices.

Ecology – Cells solitary. Found in acidic oligotrophic waters.



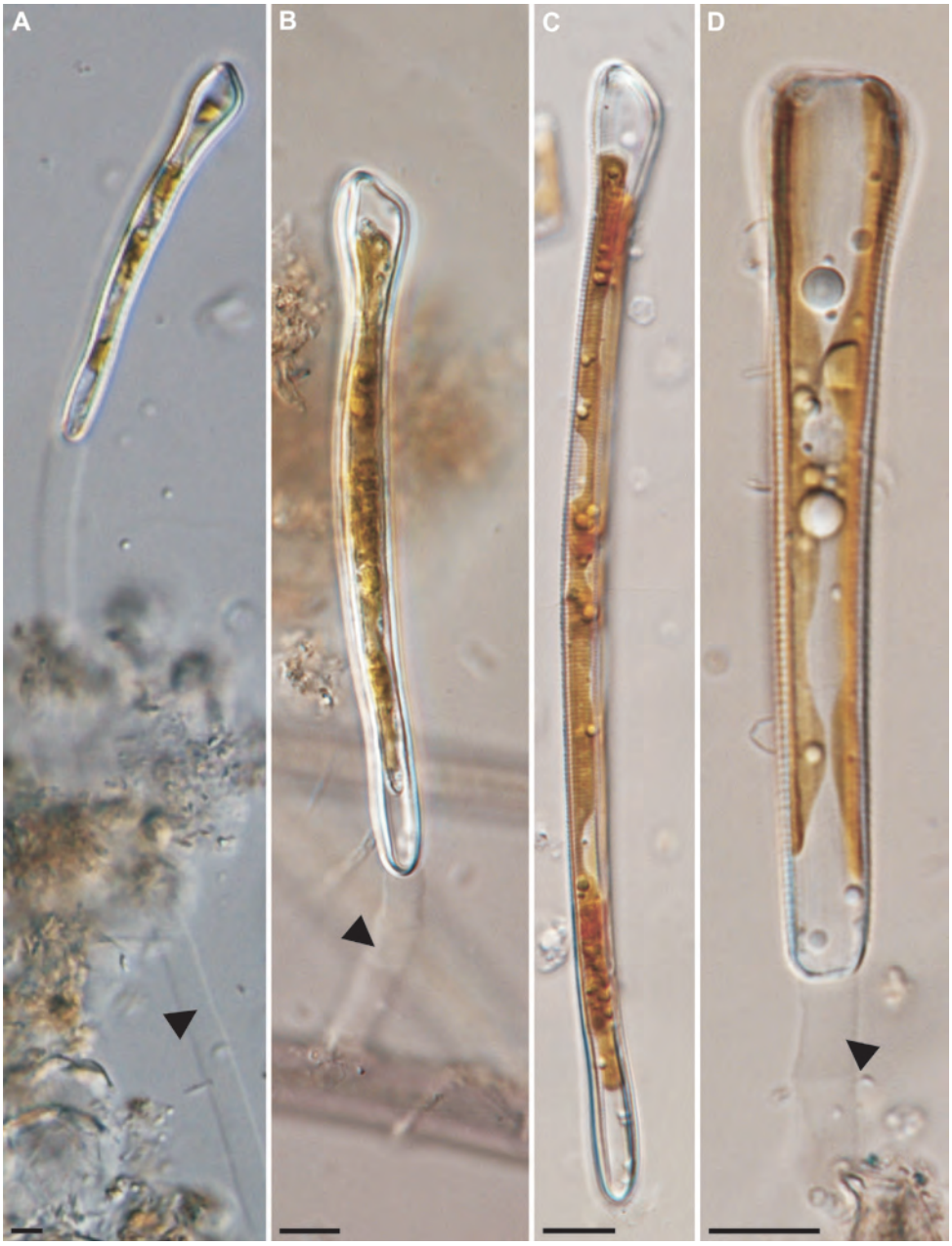


Fig. 56. *Actinella* spp. **A-D**. LM, living cells. **A-C.** *Actinella brasiliensis* Grunow valve view. **D**. *A. brasiliensis* girdle view.
Scale bars = 10 µm (A-D).

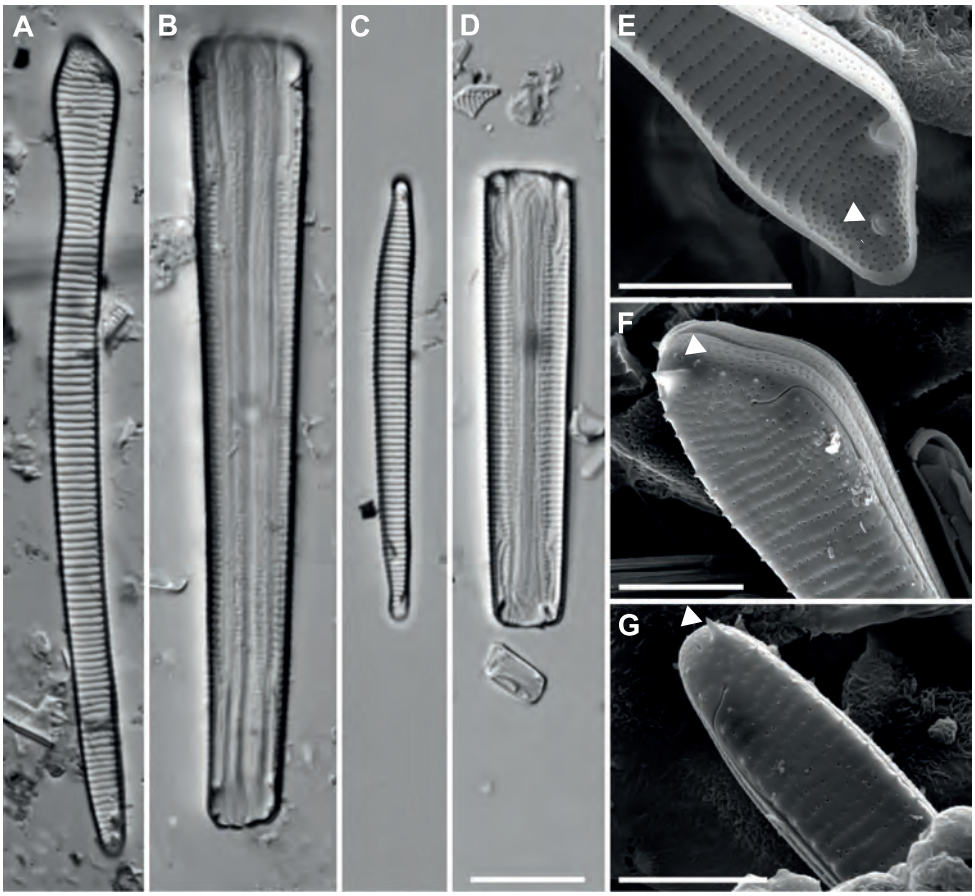


Fig. 57. *Actinella* spp. **A-D**. LM. **A**. *Actinella brasiliensis* valve view. **B**. *A. brasiliensis* girdle view. **C**. *Actinella* sp. valve view. **D**. *Actinella* sp. girdle view. **E-G**. SEM. **E**. Internal view of valve showing rimoportula near head pole (arrow). **F**. Head pole, note position of external opening of rimoportula (arrow). **G**. External view of foot pole, note the single large spine near the apex (arrow). Scale bars = 10 µm (A-D), 5 µm (E-G).

Actinellopsis J.C. Taylor, B. Karthick & Kociolek 2014

Type species: *Actinellopsis murphyi* J.C. Taylor, B. Karthick & Kociolek

SYNONYM:

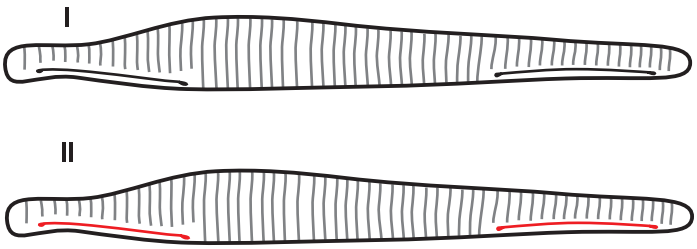
Actinella F. W. Lewis 1864 pro parte

Characteristics – Cells raphid, **heteropolar** (head pole differs in size and shape from foot pole) as well as being **dorsiventral** with a rounded dorsal and flattened ventral margin (I). Complete raphe system located on the valve face alone and does not extend onto the valve mantle (II). Only two species are known thus far for the genus (one recent, one fossil); both small with rather indistinct striae which are difficult to resolve under LM. No spines are present. In girdle view cells have a pronounced wedge shape (Fig. 58: D). A single **rimoportula** (labiate or lipped process; Fig. 58: D) is present on either the head or the foot pole which can only be seen in SEM (Fig. 58: I).

Plastid structure – Plastid structure is unknown at this time.

Identification of species – Species and varieties in this genus are distinguished based on cell size and shape and importantly the shape of the apices.

Ecology – Cells probably solitary. Found in acidic oligotrophic waters.



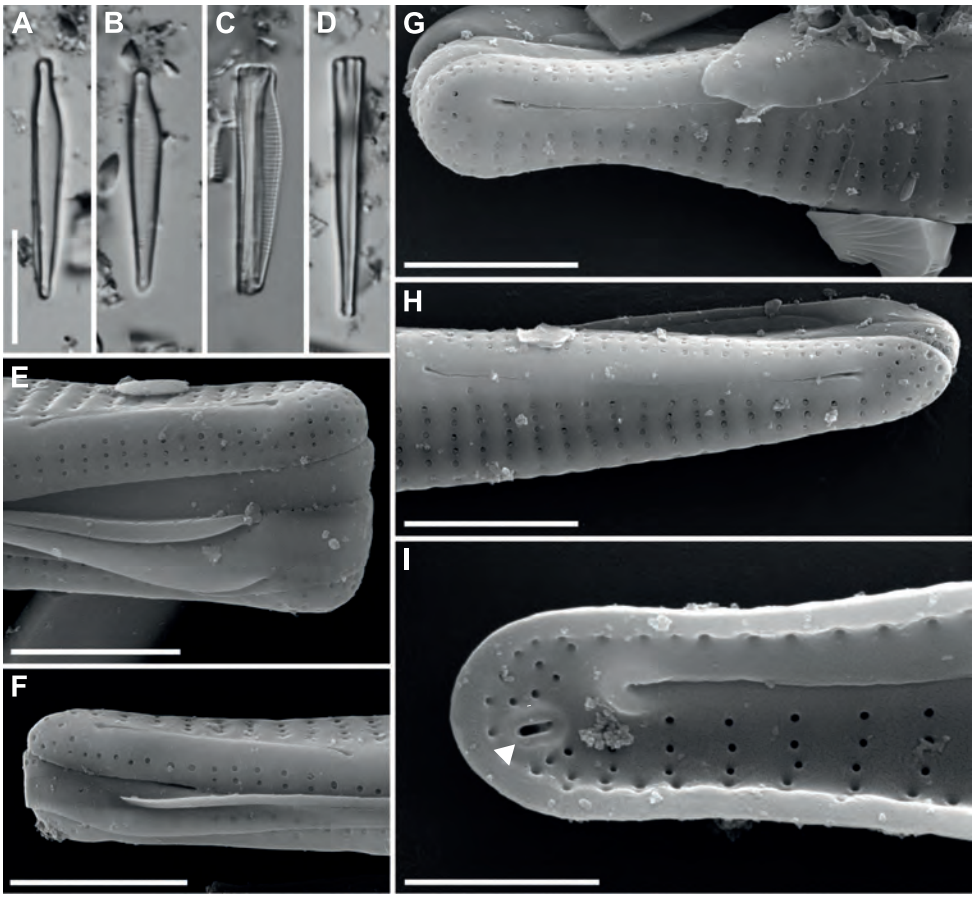


Fig. 58. *Actinellopsis murphyi*. **A-D**. LM. **A-B**. Valve view of cleaned material. **C**. Oblique view showing both valve face and girdle. **D**. Girdle view. **E-I**. SEM. **E.** Head pole, girdle view. **F**. Foot pole, girdle view. **E-F**. Showing the raphe does not extend onto the mantle. **G**. Head pole, external valve face. **H**. Foot pole, external valve face. **I**. Internal view of the head pole showing weakly developed rimoportula (arrow).
Scale bars = 10 µm (A-D), 2 µm (E-H), 1 µm (I).

Desmogonium Ehrenberg 1848

Type species: *Desmogonium guianense* Ehrenberg

SYNONYM:
Eunotia Ehrenberg 1837 pro parte

Characteristics – Cells **raphid**, dorsiventral, slightly **lunate** and large. Striae coarse and easily discernable interrupted near the ventral valve margin forming a narrow longitudinal line running from apex to apex (I). Raphe branches on the valve face are very short and curved with the majority of the raphe structure found on the mantle (Fig. 60: G). Cells always have spines at the junction of the valve face and mantle; these may be more or less visible depending of focal depth (II, Fig. 60: A-H; Fig. 61: A, B).

Plastid structure – Cells with 2 elongate plastids lying on the ventral side of the cell and extending under the valve faces (similar to *Eunotia*) (Fig. 59: D).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices and structure and density of the striae.

Ecology – Cells solitary and motile, or forming colonies and then cells connected at both poles. Found in the benthos of acidic oligotrophic waters with low conductivity.

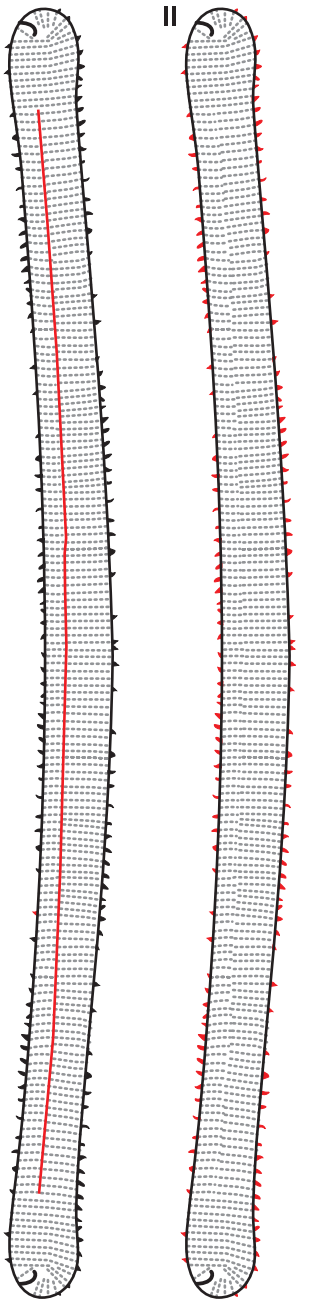


Fig. 59. *Desmogonium* spp. **A-D**. LM, living cells. **A-C**. Cells forming colonies, connected at both apices. **D**. Solitary cell, girdle view.
Scale bars = 10 µm.

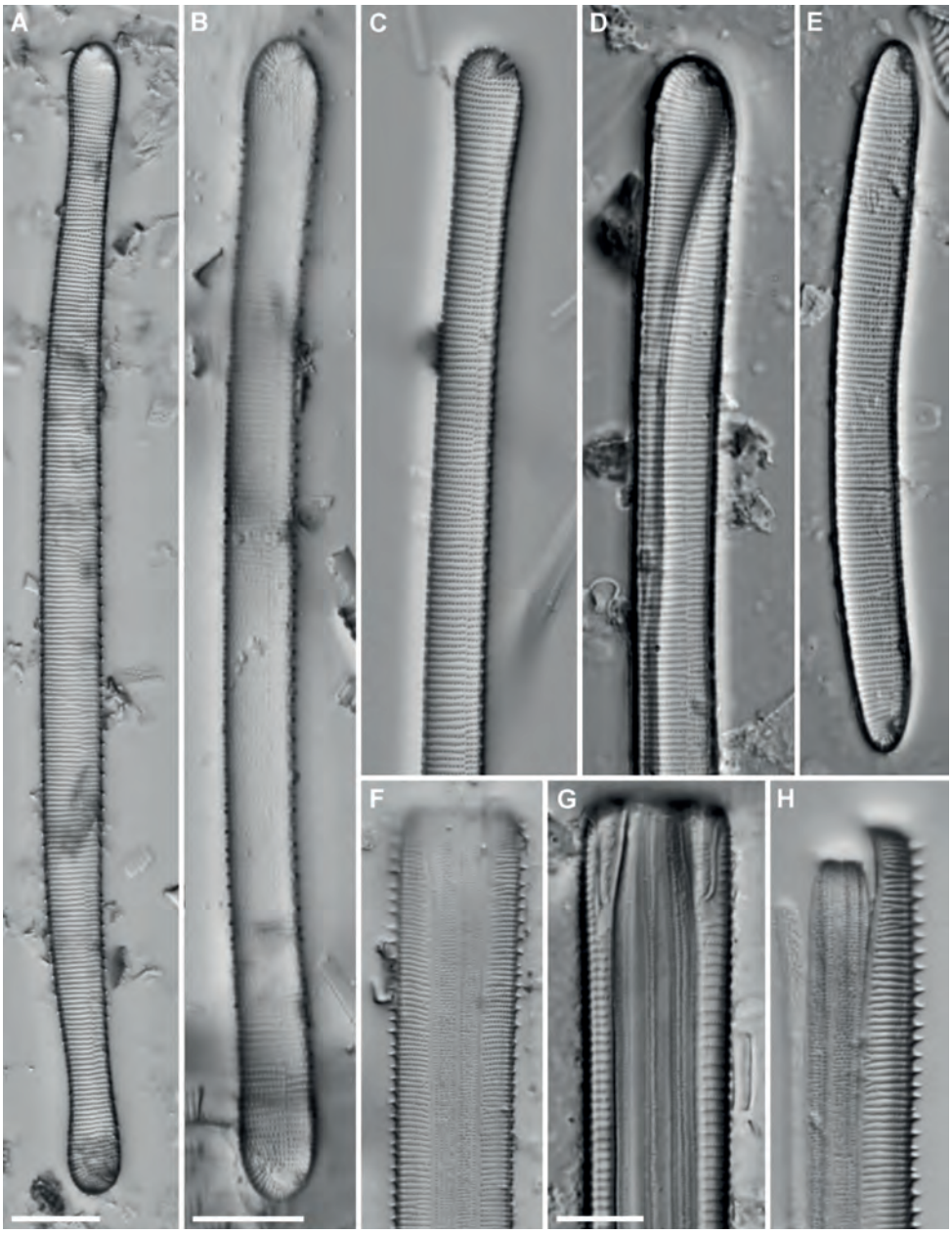


Fig. 60. *Desmogonium* spp. **A-H**. LM. **A-E**. Valve views of cleaned material. **F-H**. Girdle views of cleaned material, note marginal spines. Scale bars = 10 µm.

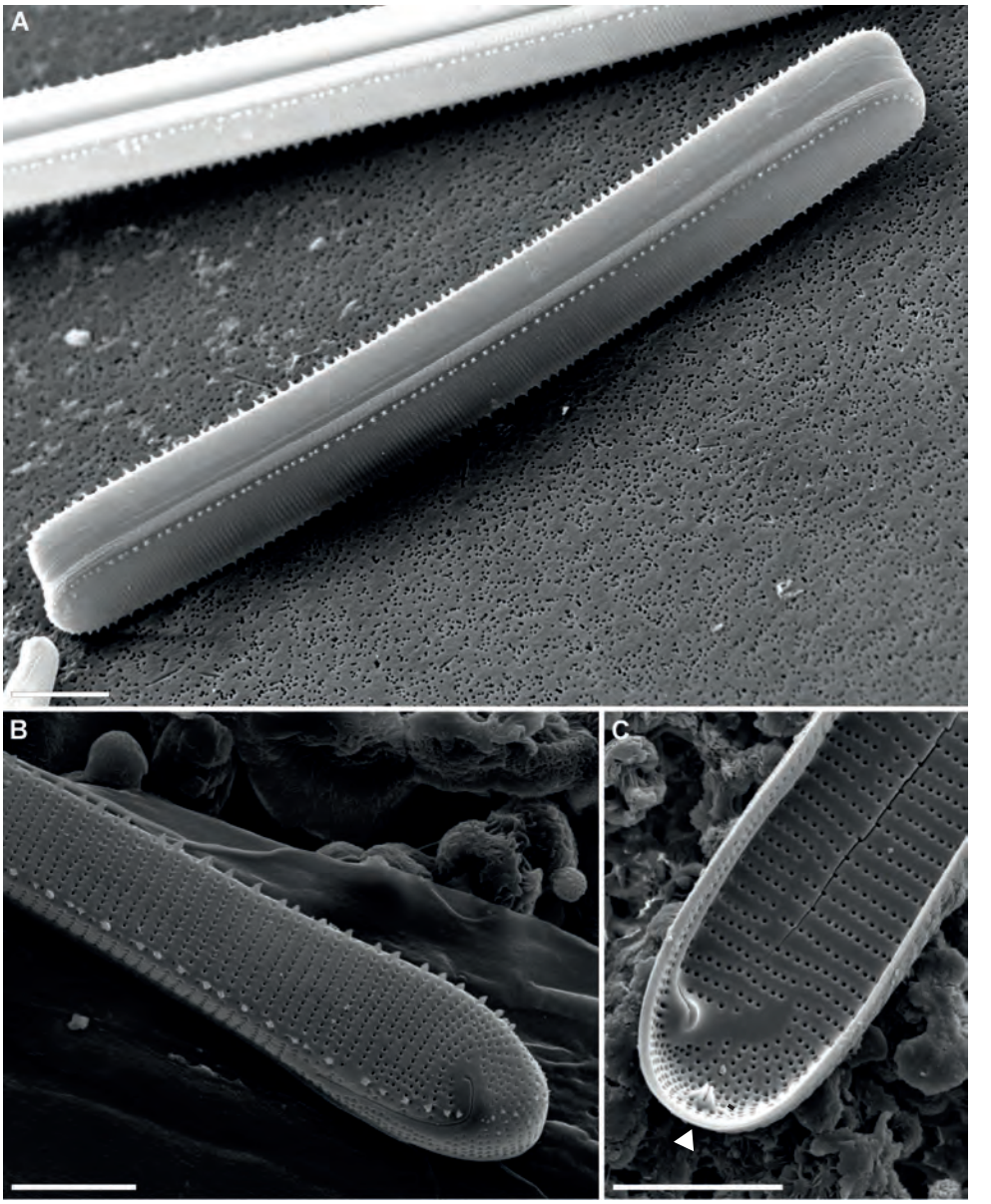


Fig. 61. *Desmogonium* spp. **A-C**. SEM. **A**. Oblique view of whole cell. **B**. External view of valve apex showing raphe ending and marginal spines. **C**. Internal view of valve showing raphe ending and rimoportula (arrow).
Scale bars = 10 µm (A), 5 µm (B-C).

Eunotia Ehrenberg 1837

Type species: *Eunotia arcus* Ehrenberg

Characteristics – Cells **raphid**, **dorsiventral**, **lunate** and highly variable in size. Raphe branches on the valve are very short and curved (I) with the majority of the raphe structure found on the valve mantle (II, Fig. 65: C). Cells rarely have spines at the junction of the valve face and valve mantle, apical spine may be present. Areolae often visible.

Plastid structure – Variable, some species with 2 elongate plastids lying on the ventral side of the cell and extending under the valve faces (Fig. 62: C), others with many granular plastids (Fig. 63: C) .

Identification of species – Species can be identified by cell size, cell shape, shape of the apices and structure and density of the striae and areolae, position of the raphe as well as the degree to which the cell is curved. Number of undulations on the dorsal margin are sometimes, but not always, a good character to distinguish species.

Ecology – Cells solitary and motile, also colonial and linked face to face to form ribbon-like colonies (Fig. 63: A-B) or linked corner to corner (Fig. 63: D) or grouped, joined at the base of the cells (Fig. 63: E). Found in the benthos of acidic oligotrophic waters with low conductivity, some species may be found in waters with higher trophic levels.

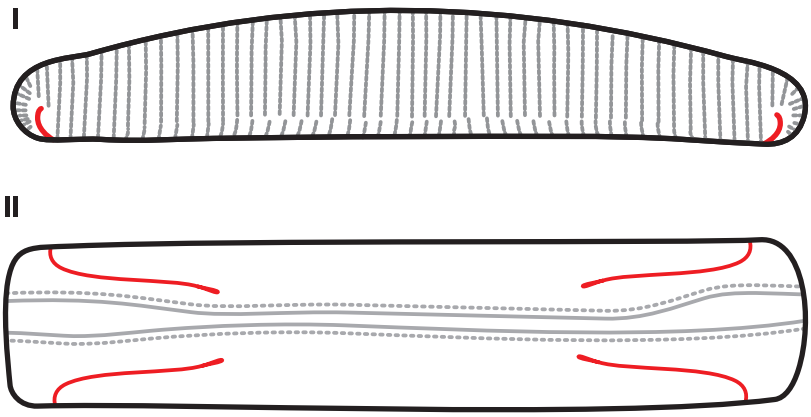


Fig. 62. *Eunotia spp*. **A-E**. LM, living cells. **A**. Valve view. **B-C**. *Eunotia exigua* (Brébisson ex Kützing) Rabenhorst, valve view (**B**), girdle view (**C**). **D-E**. Girdle views of *Eunotia* sp., note large lipid droplets (arrow).
Scale bars = 10 µm (A-E).

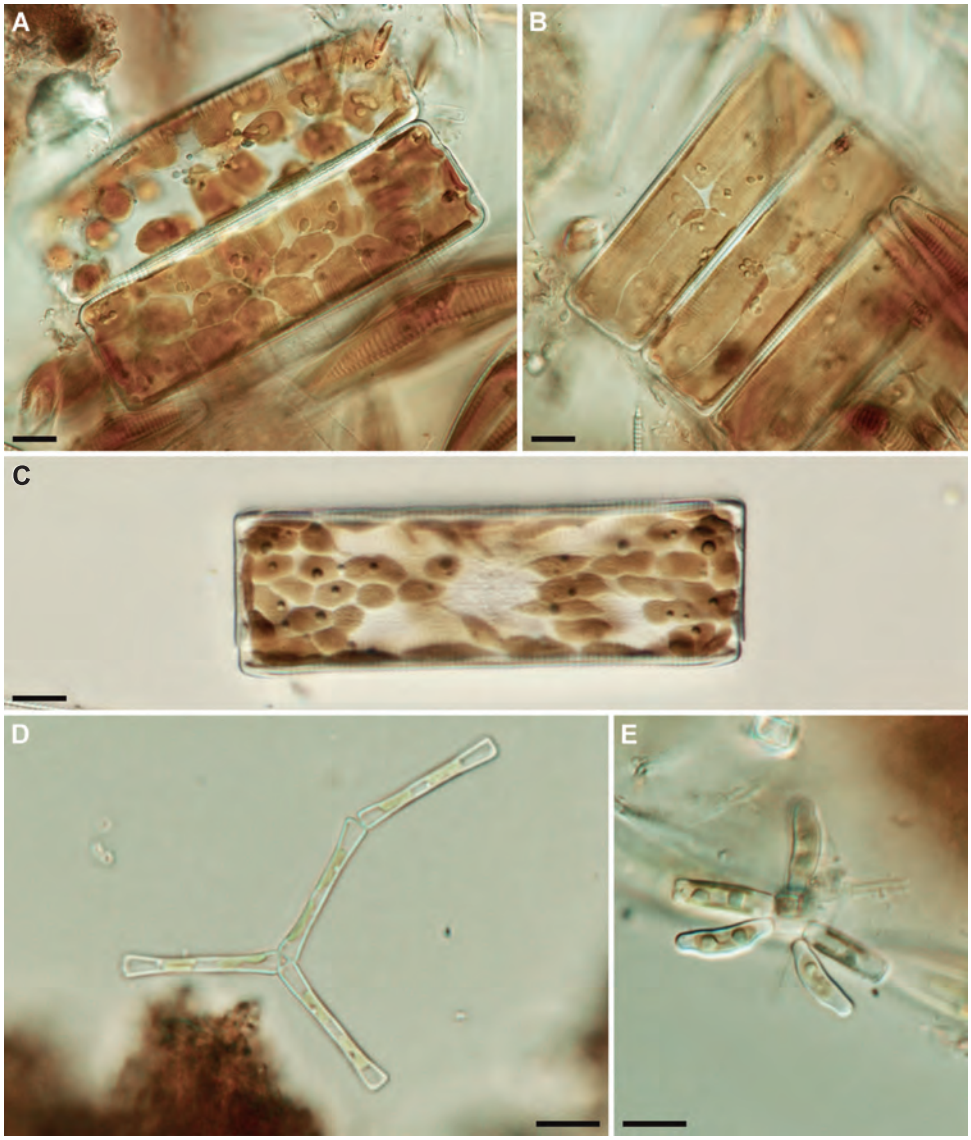


Fig. 63. *Eunotia* spp. **A-E**. LM, living cells. **A-B**. Large chain forming cells. **C**. Girdle view showing many small granular plastids. **D**. Cells linked at the corners to form colony. **E**. Cells united on a single mucilage pad and forming a colony. Scale bars = 10 µm (A-E).

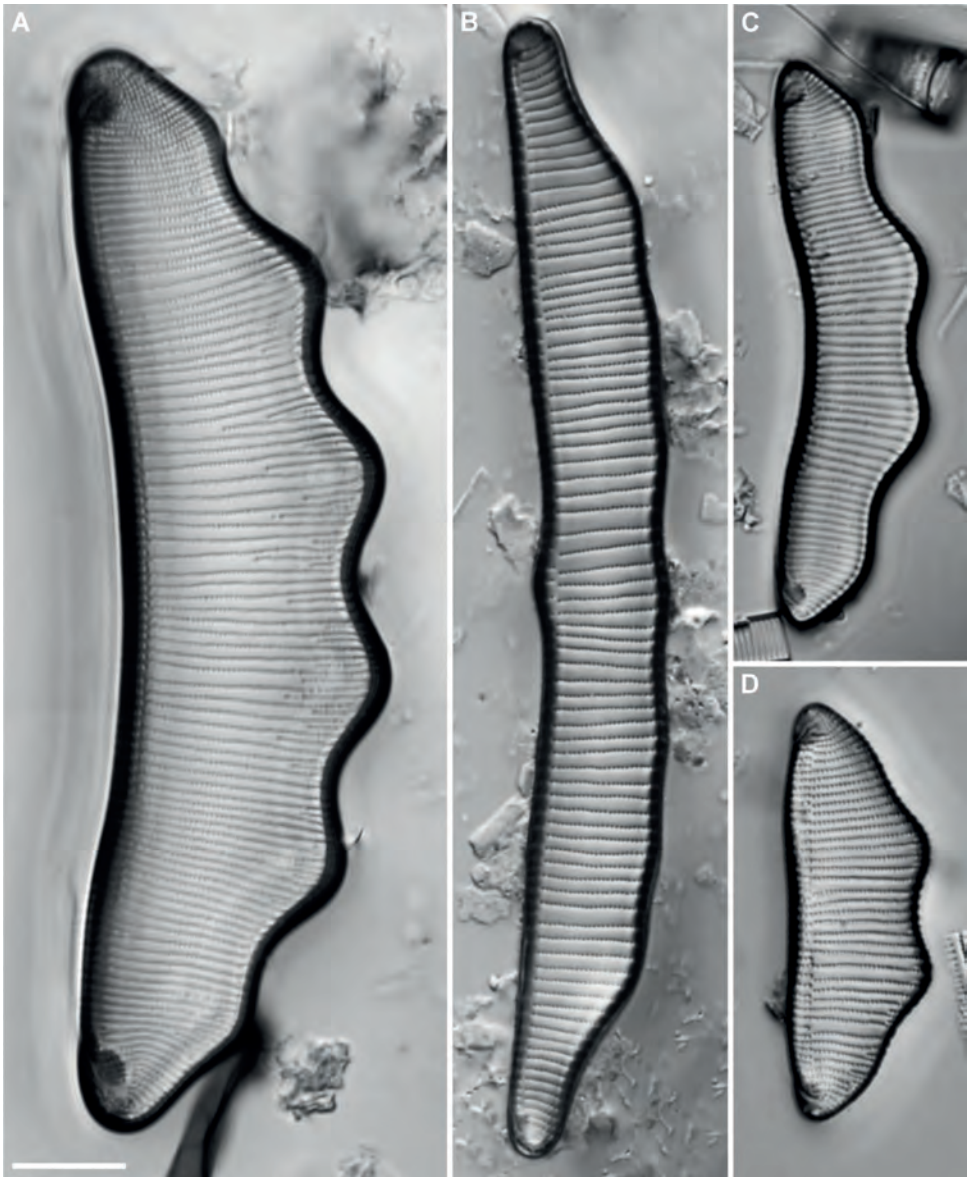


Fig. 64. *Eunotia* spp. **A-D**. LM, cleaned material of large-celled *Eunotia* spp. **B**. *Eunotia pectinalis* (Kützing) Rabenhorst. **C**. *E. zygodon* Ehrenberg. Scale bar = 10 µm.

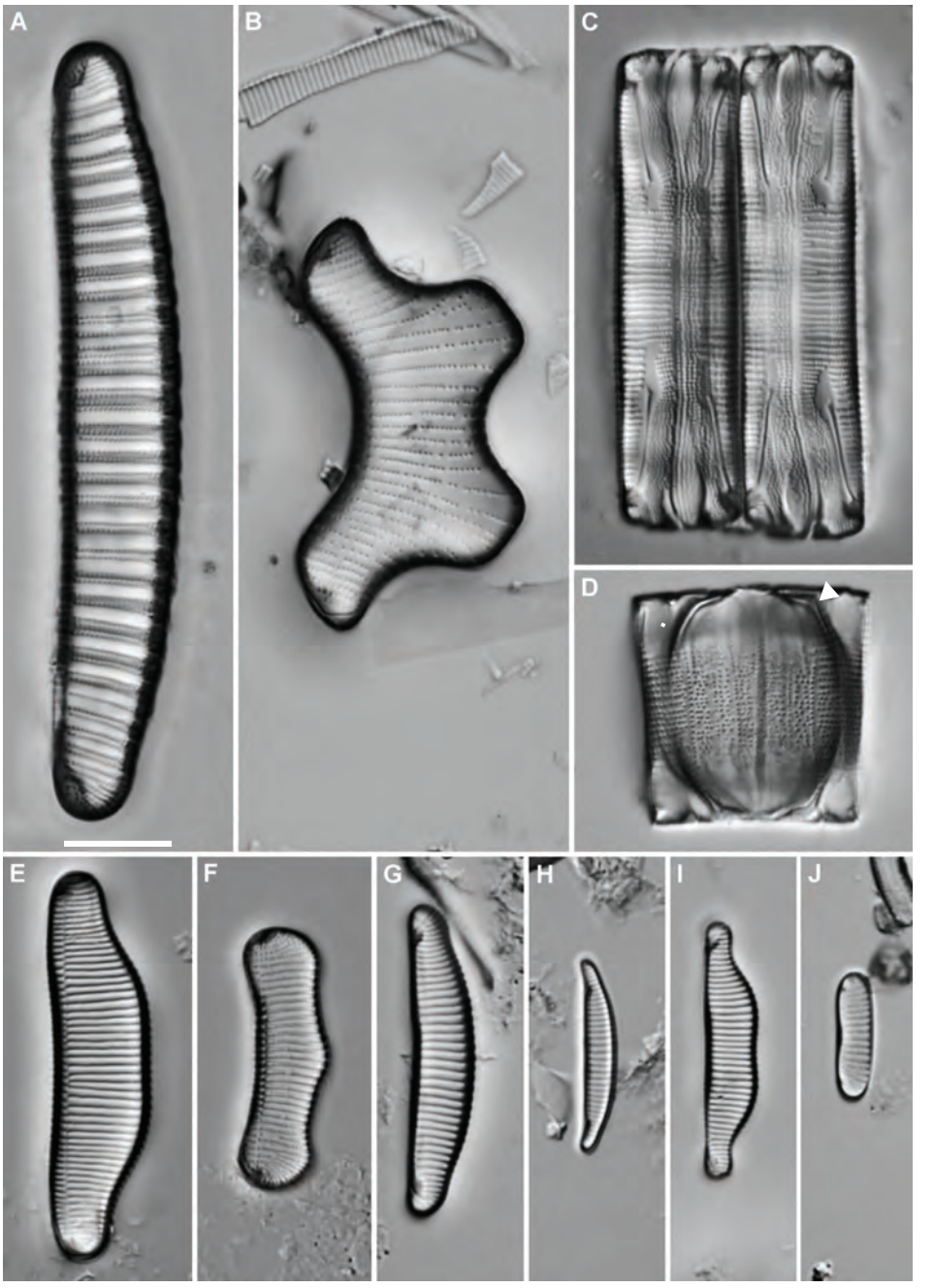


Fig. 65. *Eunotia* spp. **A-J**. LM, cleaned material. **A**. *Eunotia epithemioides* Hustedt. **C**. Ventral girdle view of two cells immediately post cell division. **D**. Girdle view, double thecae or internal septa (arrow), produced during resting spore formation. **F**. *E. rabenhorstii* Cleve & Grunow. Scale bar = 10 µm.

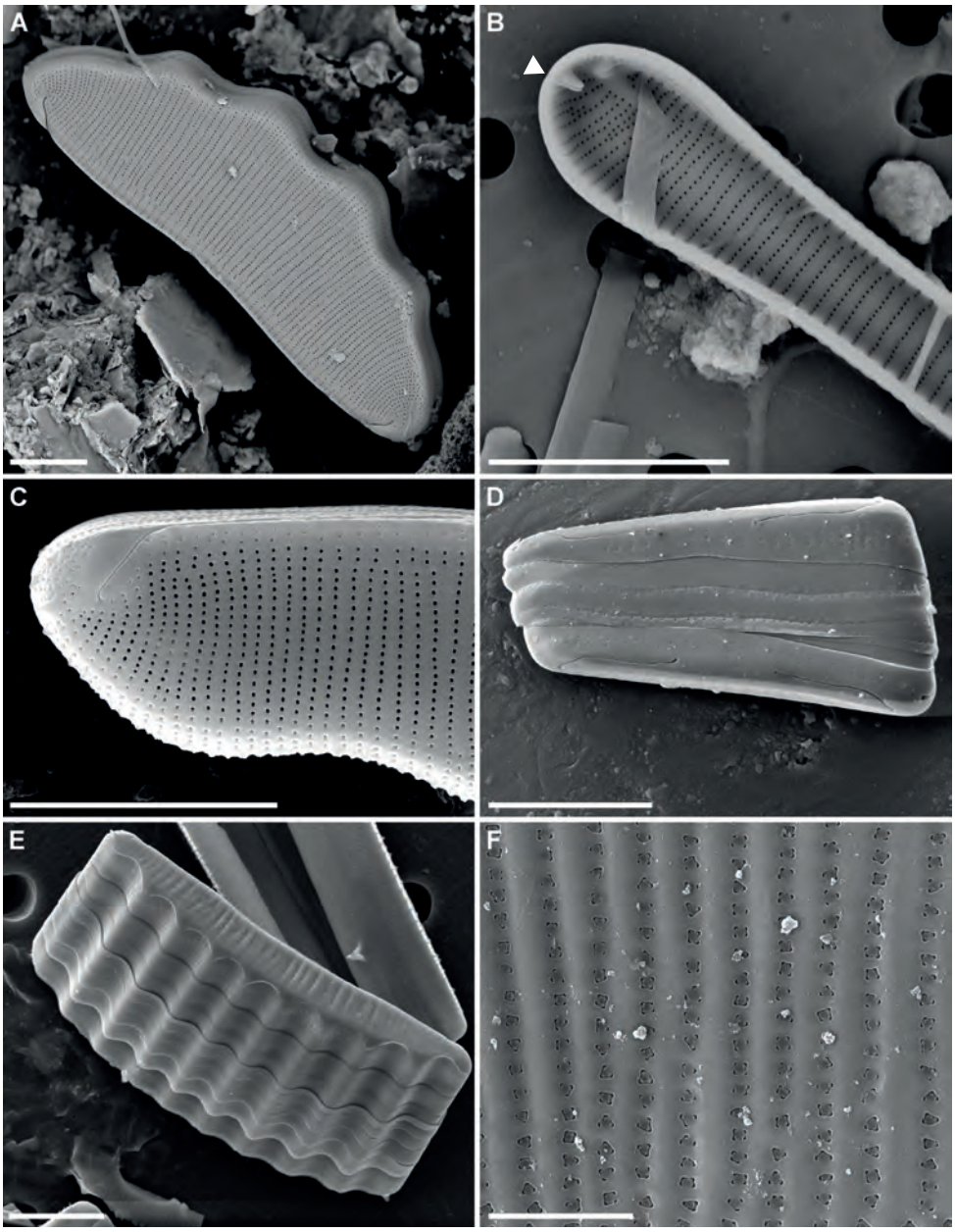


Fig. 66. *Eunotia* spp. **A-F**. SEM. **A**. External view of valve. **B**. Internal view of valve, note position of rimoportula (arrow). **C**. External view of apex of *E. zygodon*. **D**. Girdle view. **E**. Oblique view showing dorsal copulae. **F**. External view of areolae.
Scale bars = 10 µm (A-E), 2 µm (F).

Mastogloia (Thwaites) W. Smith 1856

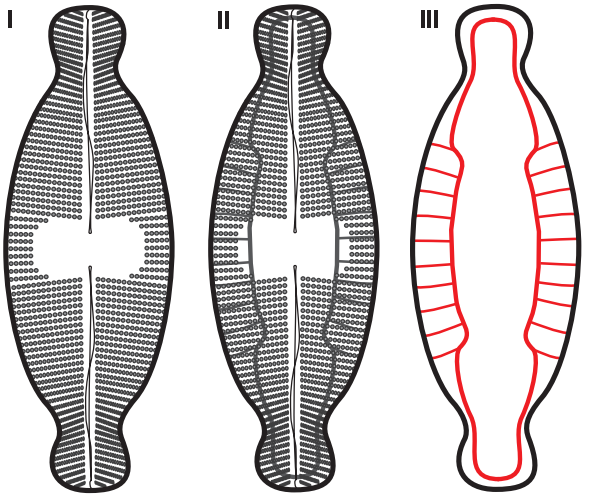
Type species: *Mastogloia dansei* (Thwaites) Thwaites ex W. Smith

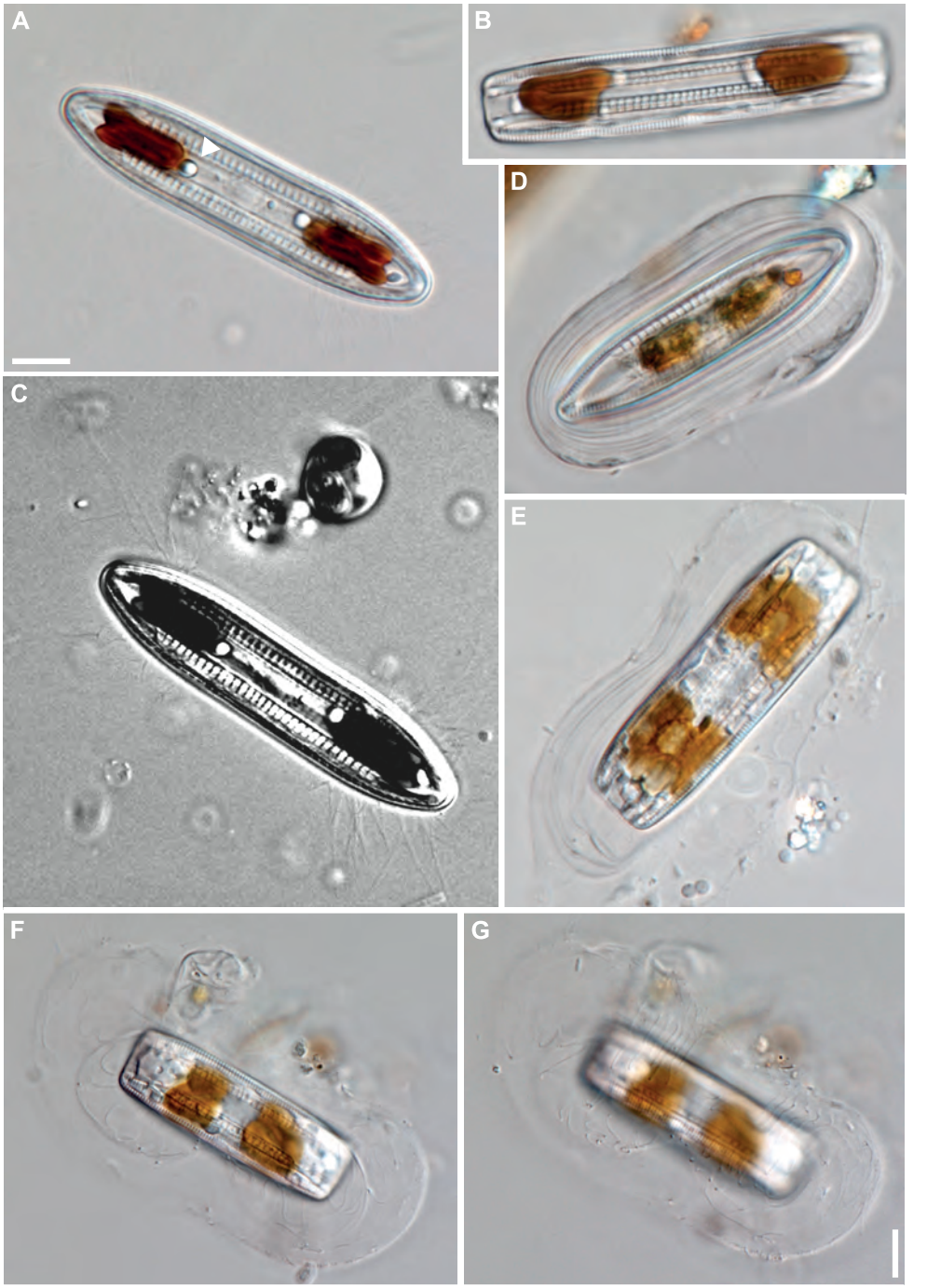
Characteristics – This genus is most noticeably distinguished in light microscopy by the **partecta** or chambers (III, Fig. 68: B, D-F) associated with the first girdle band or **valvocopula**. When seen from the girdle in SEM the large perforations extending into the **partecta** are clearly visible (Fig. 68: G). The raphe usually appears highly sinuous and complex. Areolae are large and clearly visible in LM. In living cells mucilage threads are exuded from the **parteca** (Fig. 67: C), this mucilage often encapsulates the entire cell (as illustrated in Fig. 67: D-G) and may play some role in allowing these cells to survive dessication and other unfavorable circumstances such as shifts in osmotic pressure.

Plastid structure – There are two small double lobed plastids found at each end of the cell (Fig. 67: A, B) with a pyrenoid between the two lobes of each plastid (Fig. 67: E). Usually two lipid droplets are present (Fig. 67: A).

Identification of species – Species in this genus are distinguished based on cell size and shape as well as the shape of the apices. Striae density and orientation are also of importance as well as the size of the areolae.

Ecology – Cells solitary, motile or encased in mucilage. The majority of species are brackish or marine but some are also found in fresh waters of higher electrolyte content and calcium rich waters.




A
B
C
D
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F
G

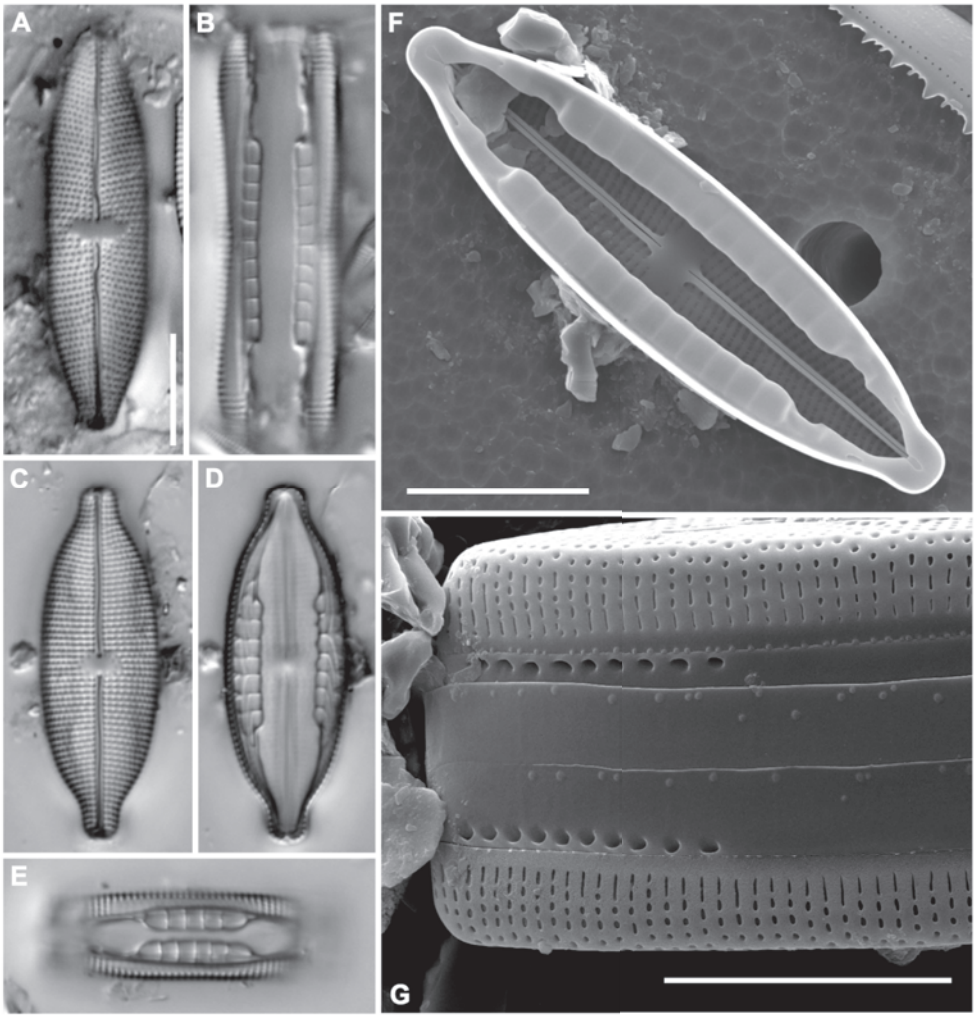

Fig. 68. *Mastogloia* spp. **A-E**. LM of cleaned material. **A, C.** Valve view. **B, E.** Girdle view. **D**. Detail of the valvocopula. **F-G**. SEM. **F**. Internal view of valvocopula showing the partecta. **G**. Girdle view, note external openings of the partecta through which the mucilage is exuded.
Scale bars = 10 µm (A-F), 3 µm (G).

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Fig. 67. *Mastogloia* spp. **A-G**. LM, living cells. **A**. Valve view, note the lipid droplets associated with each plastid (arrow). **B**. Girdle view. **C**. Living cell (high contrast), mucilage threads protruding from the partecta. **D-G**. Living cells encapsulated in mucilage, note threads protruding from partecta.
Scale bars = 10 µm (A-G).

Rhoicosphenia Grunow 1860

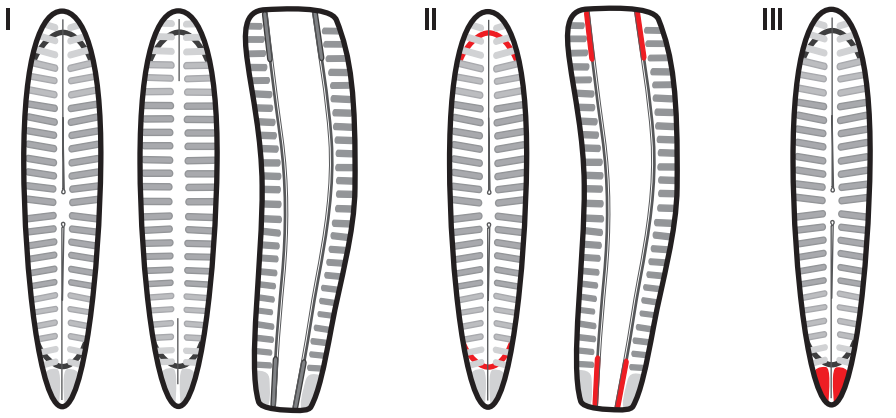
Type species: *Rhoicosphenia curvata* (Kützing) Grunow

Characteristics – Cells **biraphid**, **heterovalvar**, **heteropolar** and curved in girdle view (one valve convex the other concave). Broadly rounded head pole and narrowly rounded foot pole. Striae robust, composed of single rows of elongate areolae. **Pseudosepta** (II, Fig. 69: I) are present at both poles, **apical pore field** (III) present at the base pole. Convex valve bears a full length raphe (Fig. 69: A, F) while the concave valve bears shortened or rudimentary raphe branches near the apices (Fig. 69: B, E).

Plastid structure – Single H-shaped lobed plastid with central narrow pyrenoid.

Identification of species – Up till now only one species known from tropical Africa: *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot (a homonym of *Rhoicosphenia curvata*).

Ecology – Cells solitary or in pairs, attached to substrate by short mucilage stalks, may be re-suspended in the plankton. Found in the benthos of eutrophic waters with moderate conductivities.



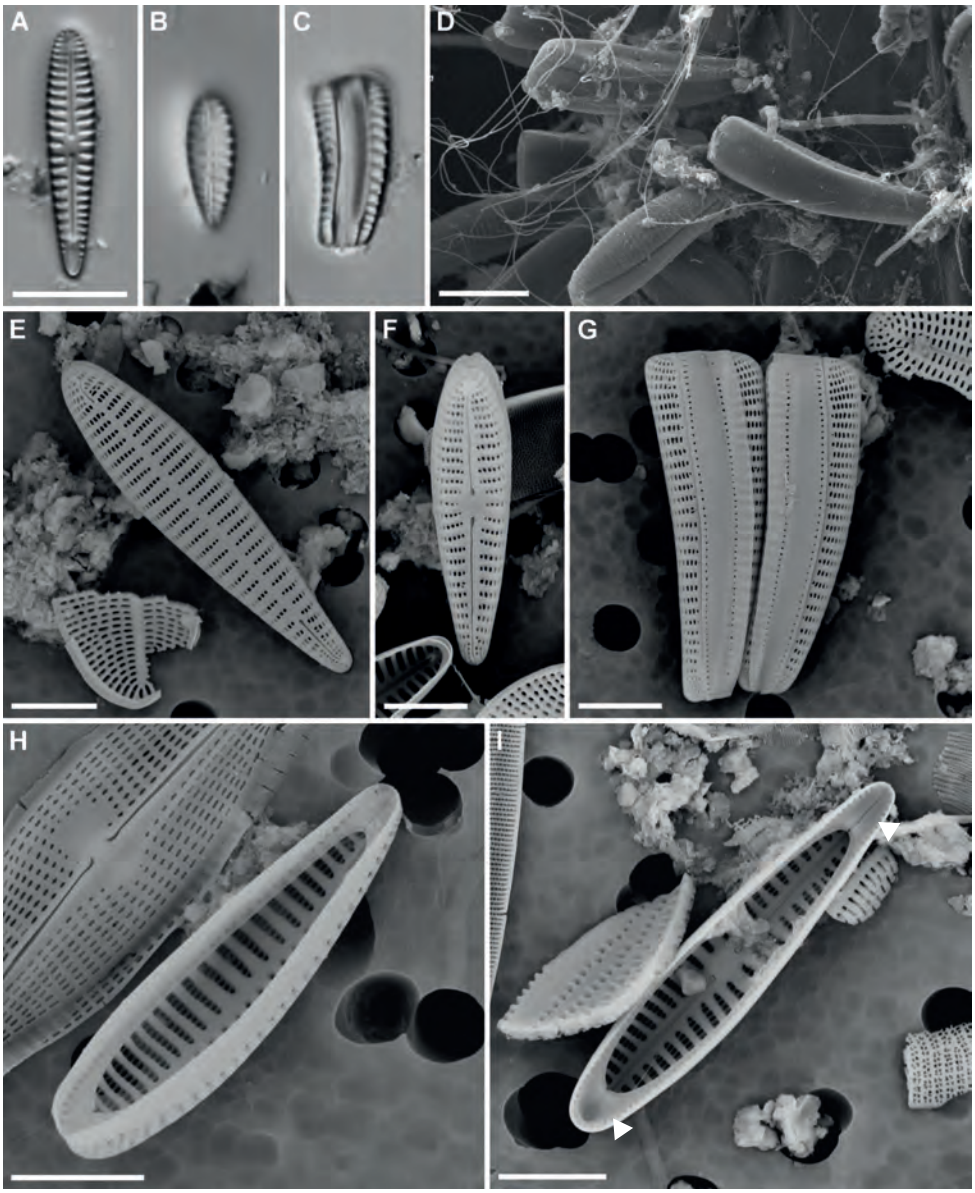


Fig. 69. *Rhoicosphenia abbreviata*. **A-C**. LM. **A-B.** Valve view. **C.** Girdle view. **D-I.** SEM. **D.** Cells of biofilm. **E**. External view of concave valve, note shortened rudimentary raphe. **F.** External view of convexe valve. **G.** Girdle view. **H.** Internal view of concave valve with shortened raphe. **I.** Internal view of convexe valve, note pseudosepta (arrows).
Scale bars = 10 µm (A-D), 5 µm (E-I).

Anomoeoneis Pfitzer 1871

Type species: *Anomoeoneis sphaerophora* Pfitzer

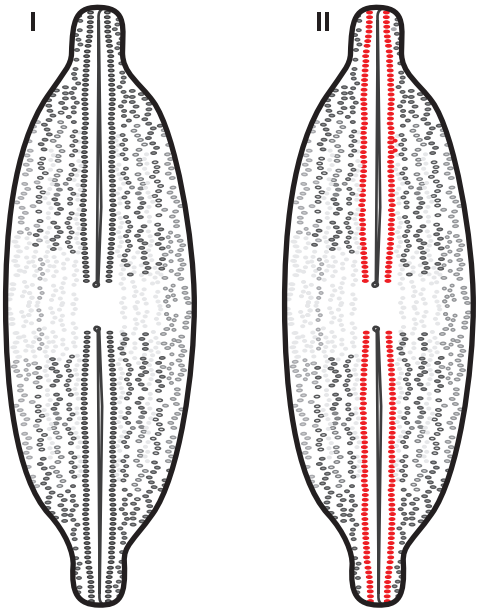
SYNONYM:
Brachysira Kützing 1836 pro parte

Characteristics – This genus is most noticeably distinguished in light microscopy by the scattered areolae on the valve face forming uneven **transapical lines** (I; Fig. 70: D-F). A number of '**ghost areolae**' (pictured as light grey dots - I, II) are found on the valve face and are especially visible in the **central area (**Fig. 70: H), these areolae do not perforate the **valve face**.

Plastid structure – The single plastid is large and occupies most of the cell (Fig. 70: A, B), it has two lobes, one appressed to each valve face forming a H-shape when seen from the girdle (Fig. 70: C). One large pyrenoid is found adjacent to the cell margin. The plastid arrangement is similar to that of *Cymbella* and *Gomphonema*, hence its placement in the order Cymbellales.

Identification of species – Species and varieties in this genus are distinguished based on cell size and shape as well as the shape of the apices.

Ecology – Cells solitary, motile. Commonly found in waters of higher electrolyte content.



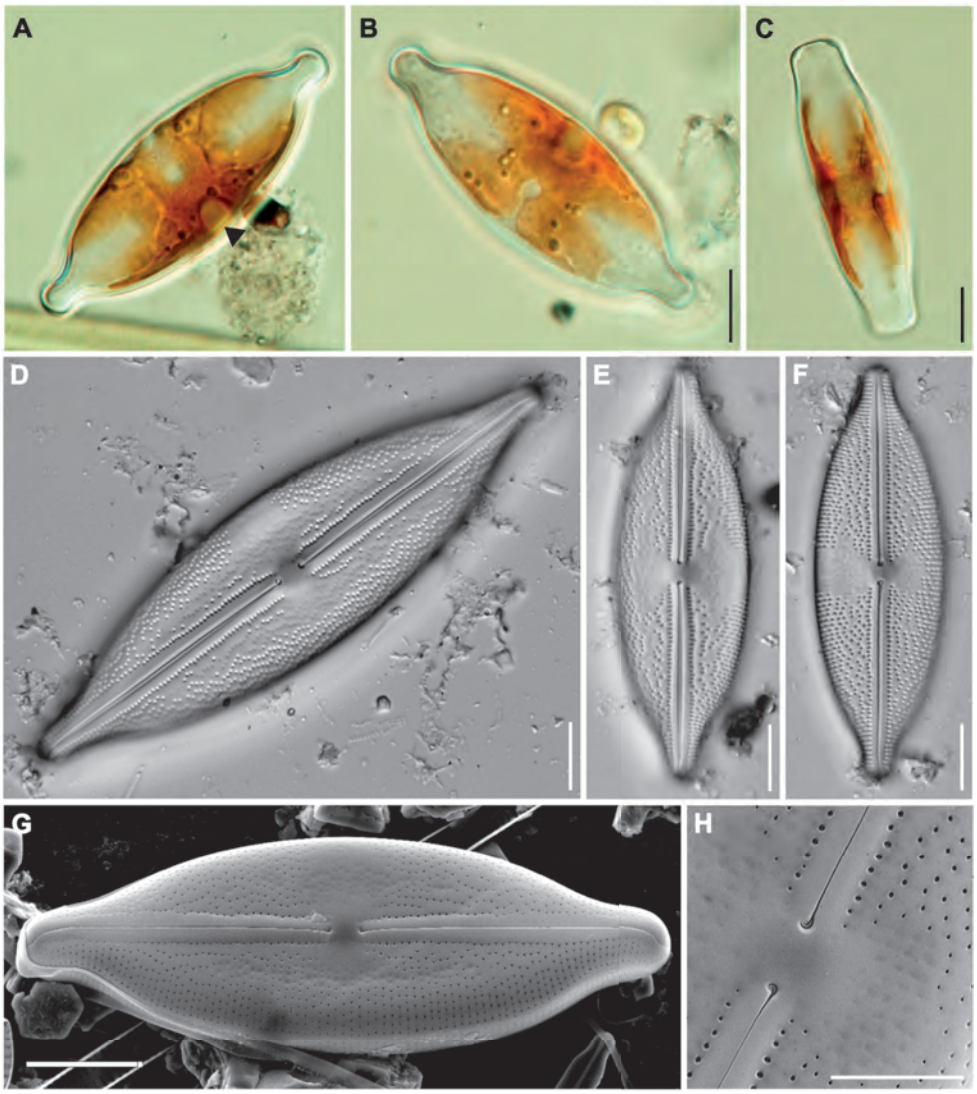


Fig. 70. *Anomoeoneis sphaerophora*. **A-F**. LM. **A**. Living cell, note pyrenoid (arrow) next to the cell margin. **B**. Living cell, note H-shaped plastid. **C**. Living cell, girdle view, note bridge between the two plates of the plastid. **D-F**. Cleaned valves, note the feint ghost areolae in the central area. **G-H.** SEM. **G.** Valve view of complete valve. **H**. Detail of central raphe endings.
Scale bars = 10 µm (A-G), 5 µm (H).

Afrocymbella Krammer 2003

Type species: *Afrocymbella reichardtii* Krammer

SYNONYM:

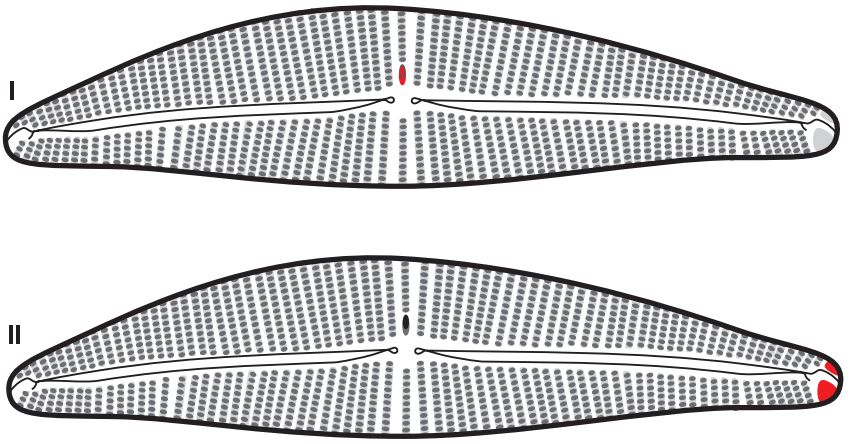
Gomphocymbella O. Müller 1905 pro parte

Characteristics – Cells **biraphid**, large and rather robust, valve shape **dorsiventral** and **heteropolar** (characteristics of both *Cymbella* and *Gomphonema*). Clearly visible elongate **stigma** on the dorsal side of the cell closely associated with the central striae (I, Fig. 72: B-C). Small apical pore field to the right and the left of the raphe on the foot pole (II, Fig. 71: B, Fig. 72: D).

Plastid structure – Single plastid with 2 lobes connected by a bridge (H-shape) (Fig. 72: A). Large pyrenoid against one margin in the central area (see *Cymbella*), several lipid droplets scattered through the cell.

Identification of species – Species in this genus are distinguished based on cell size and shape and the shape of the apices. Striae density and angle relative to the **transapical axis** are also important characteristics to consider.

Ecology – Cells solitary, mostly observed free living occasionally attached. Found in tropical African alkaline oligotrophic waters in both planktonic and benthic habitats.



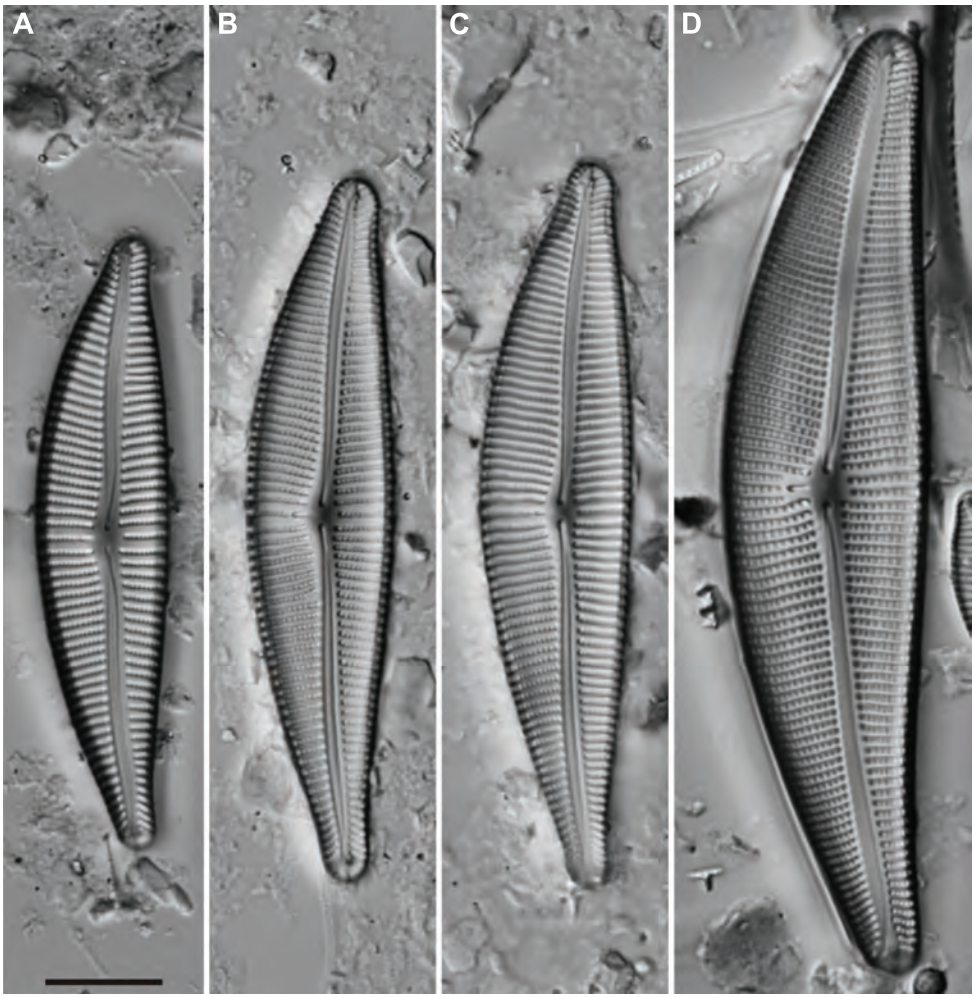


Fig. 71. *Afrocymbella* spp. **A-D**. LM. **A-C**. Valve view of *Afrocymbella beccarii* (Grunow) Krammer. **D**. Valve view of *A. reichardtii* var. *procera* Krammer. Scale bar = 10 µm.

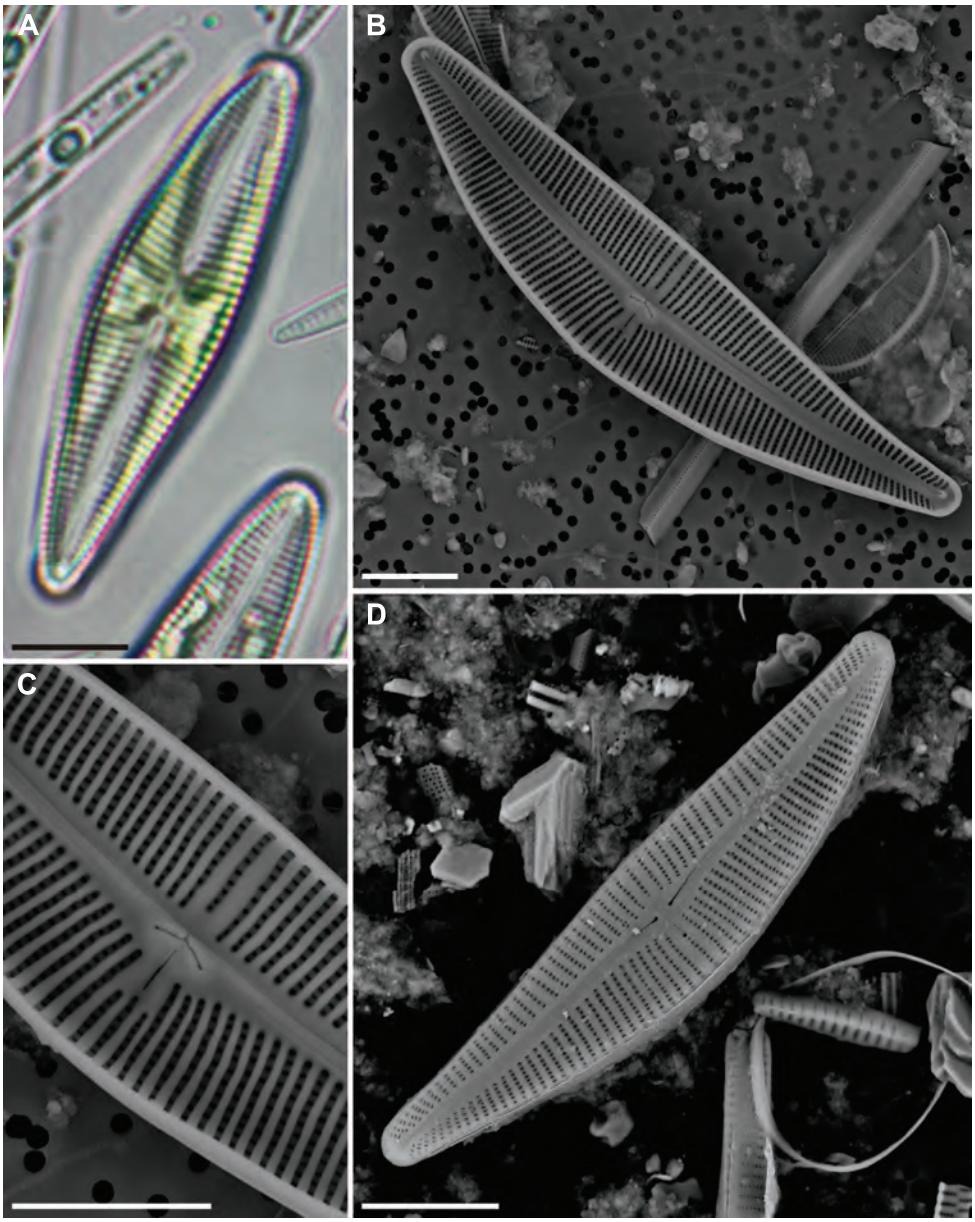


Fig. 72. *Afrocymbella* spp. **A**. LM. Living cell of *Afrocymbella barkeri* Cocquyt & Ryken, valve view . **B-D**. SEM. **B-C**. Internal view of valve of *A. beccarii*. **D**. External view of valve of *A. beccarii*.
Scale bars = 10 µm (A-C), 8 µm (D).

Cymbella C. Agardh 1830

Type species: *Cymbella cymbiformis* C. Agardh

Characteristics – Cells **biraphid**, slightly to strongly **dorsiventral**, raphe complex, terminal raphe endings bent towards the dorsal side (I, Fig. 75: A-C). **Stigma(ta)** (II) in general present in the **central area** on the ventral side. Apical pore field found at the apices (II); may be difficult to discern under LM.

Plastid structure – Cells with one H-shaped plastid and a large pyrenoid (Fig. 74: D) in the centre against one girdle. Several small lipid droplets scattered throughout the cell (Fig. 73: A-B; Fig. 74: B).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae and the size, number and position of the stigmata in relation to the striae. Shape and extent of the central area as well as the curvature of the raphe are important.

Ecology – Cells solitary, mostly attached but occurs also free living and motile. Found in the benthos of oligotrophic to mesotrophic waters preferring alkaline habitats.

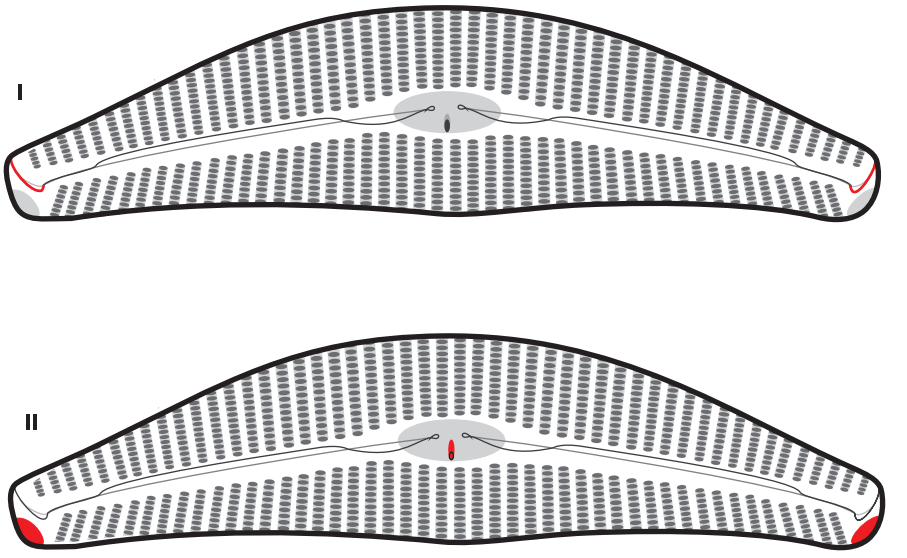


Fig. 73. *Cymbella* spp. **A-B**. LM. **A**. Living cell, girdle view. **B**. Living cells with mucilage stalks (arrow).
Scale bar = 10 µm.

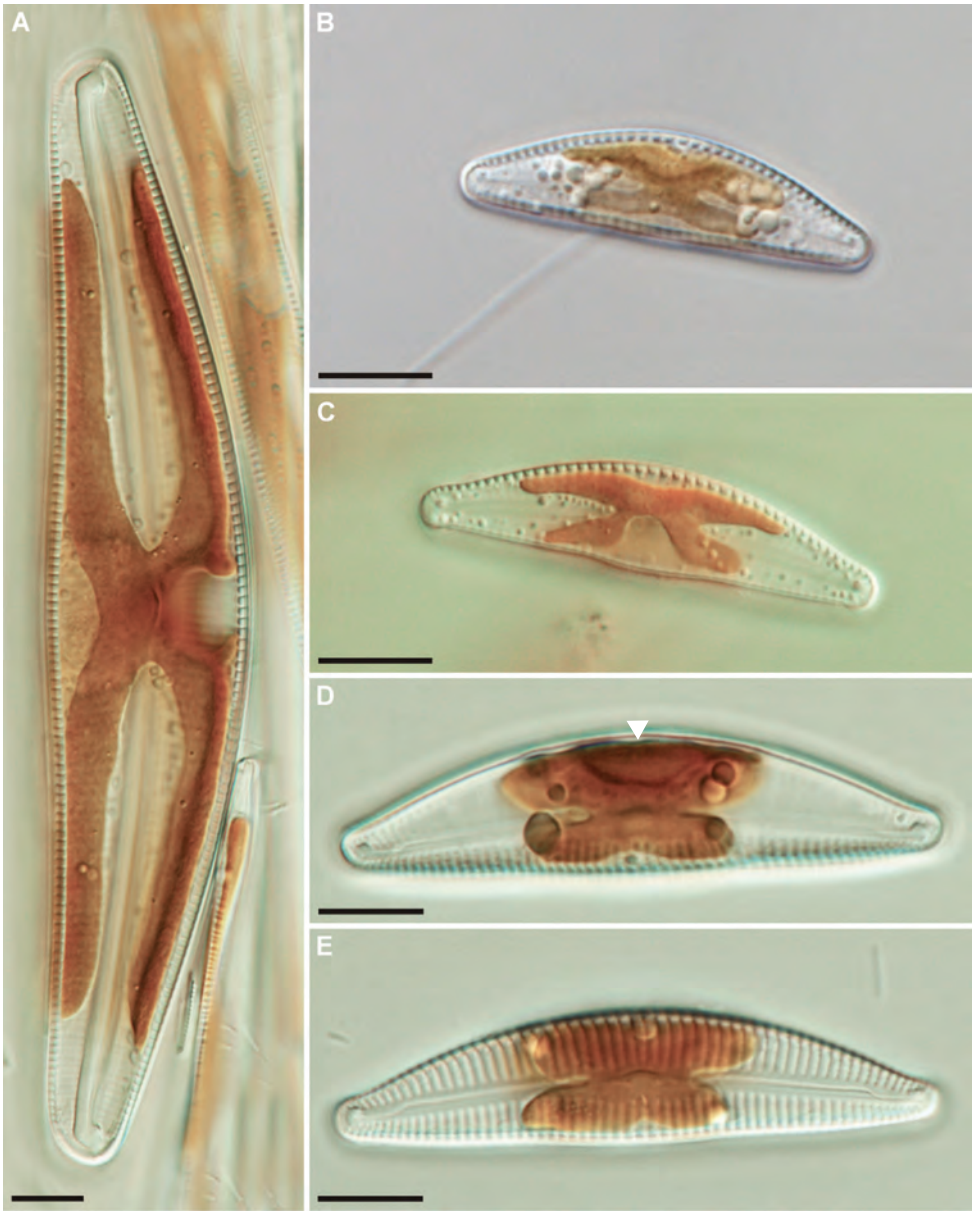
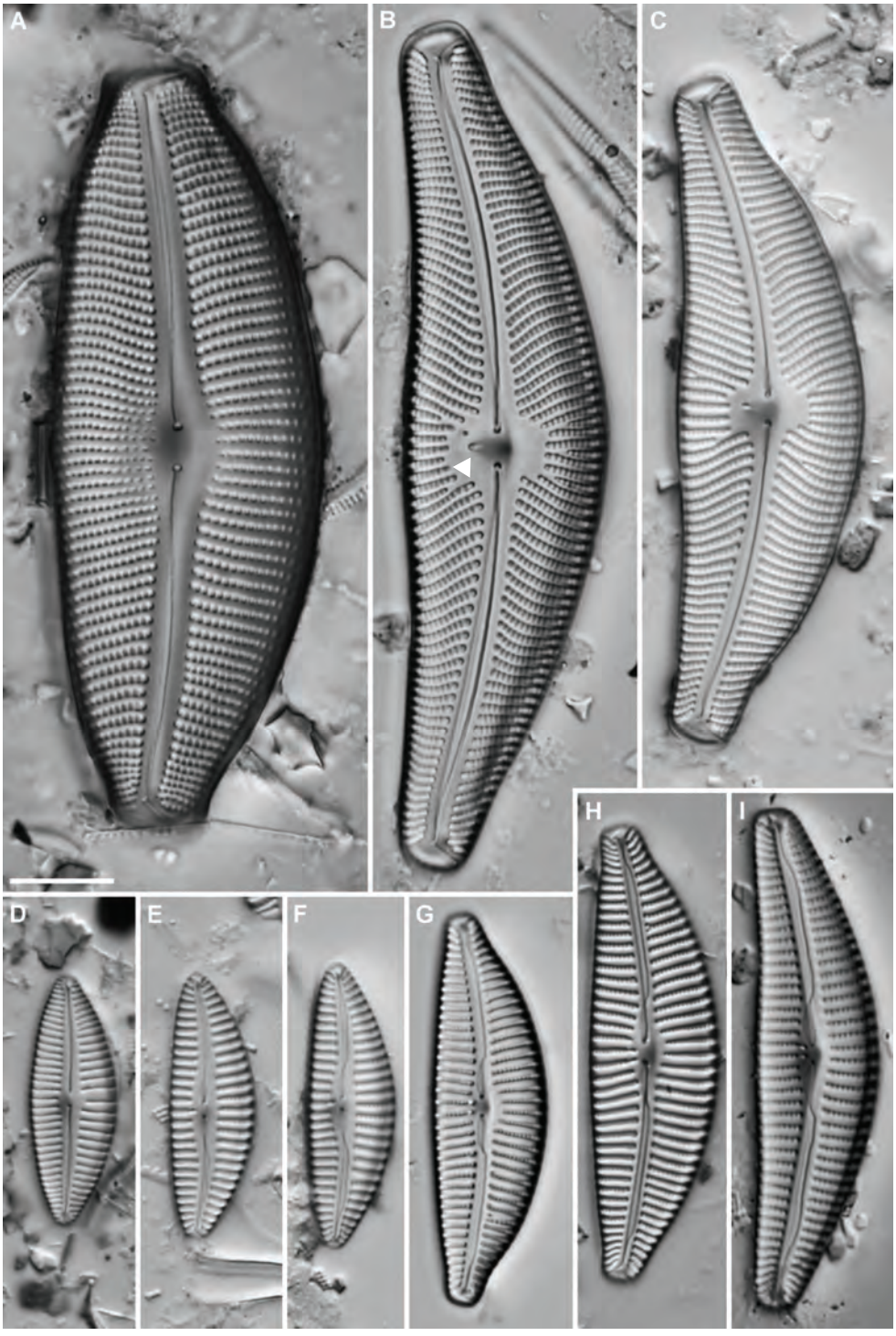


Fig. 74. *Cymbella* spp. **A-E**. LM. **A-B**. Valve views of living cells. **A.** *Cymbella aspera* (Ehrenberg) H. Peragallo. **B**. Cell with a large number of lipid droplets. **C**. *Cymbella kappii* (Cholnoky) Cholnoky. **D-E**. *Cymbella turgidula* Grunow, same cell different foci, note large pyrenoid (arrow **- D**).
Scale bars = 10 µm (A-E).


A
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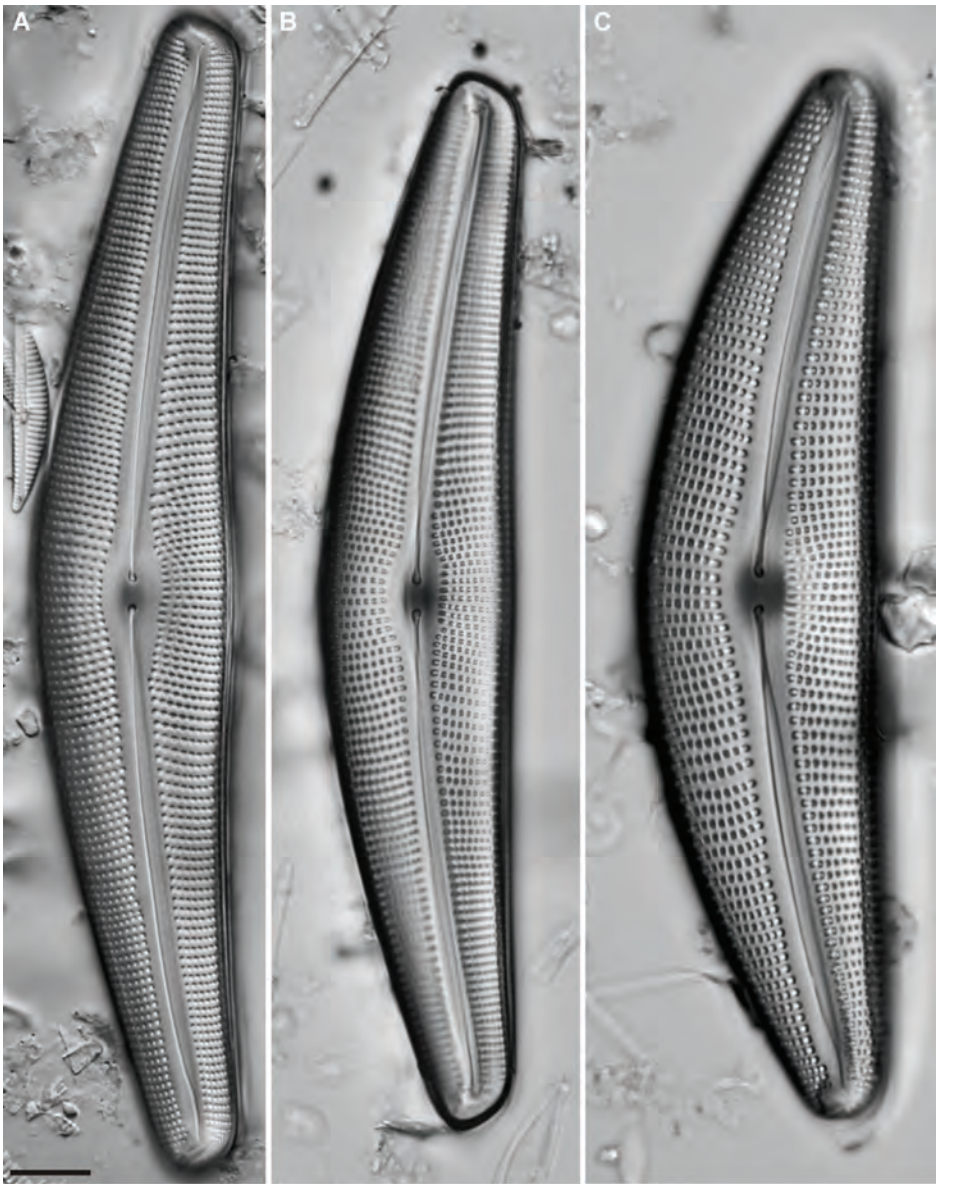

Fig. 76. *Cymbella* spp. **A-C**. LM, valve views. **A-B**. *Cymbella aspera.* **C**. *Cymbella* sp.
Scale bar = 10 µm.

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Fig. 75. *Cymbella* spp. **A-I**. LM, valve views. **A**. *Cymbella cucumis* A.W.F. Schmidt. **B-C**. *C. tumida* (Brébisson) Van Heurk, note stigma (arrow - **B**). **D**. *C. kolbei* Hustedt. **E-F**. *C. zambesiana* Krammer. **G**. *Cymbella* sp. **H**. *C. turgidula*. **I**. *Cymbella* sp.
Scale bar = 10 µm.

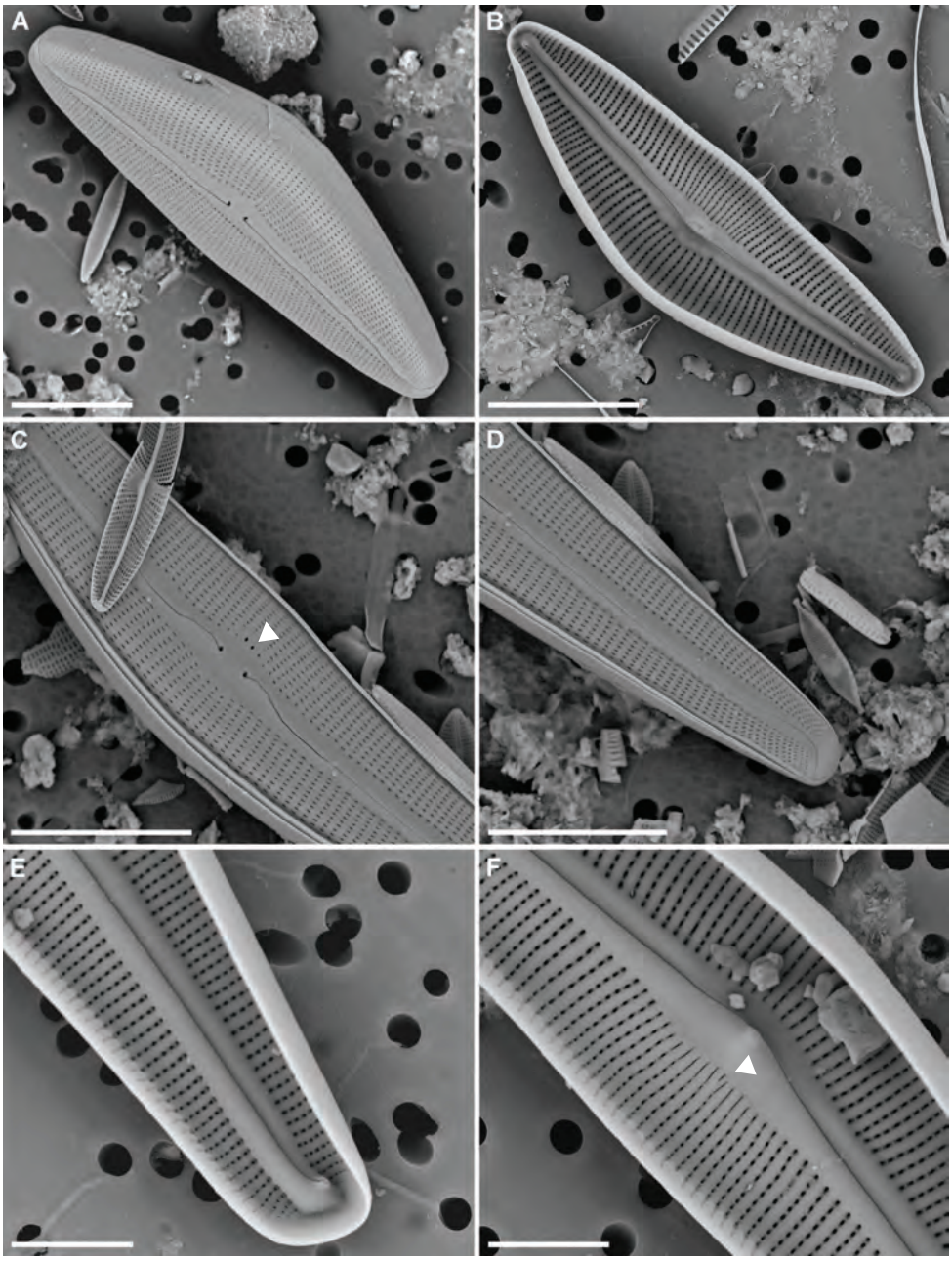


Fig. 77. *Cymbella* sp. **A-F**. SEM. **A**. *Cymbella aspera*, external view of valve. **B**. *C. aspera* internal view of valve. **C-F**. *C. cymbiformis*. **C**. External view of valve, central area, note external openings of stigmata (arrow). **D**. External view of valve, cell apex. **E**. Internal view of valve, cell apex. **F**. Internal view of valve, central area, note structure of stigma (arrow).
Scale bars = 20 µm (A-D), 10 µm (E-F).

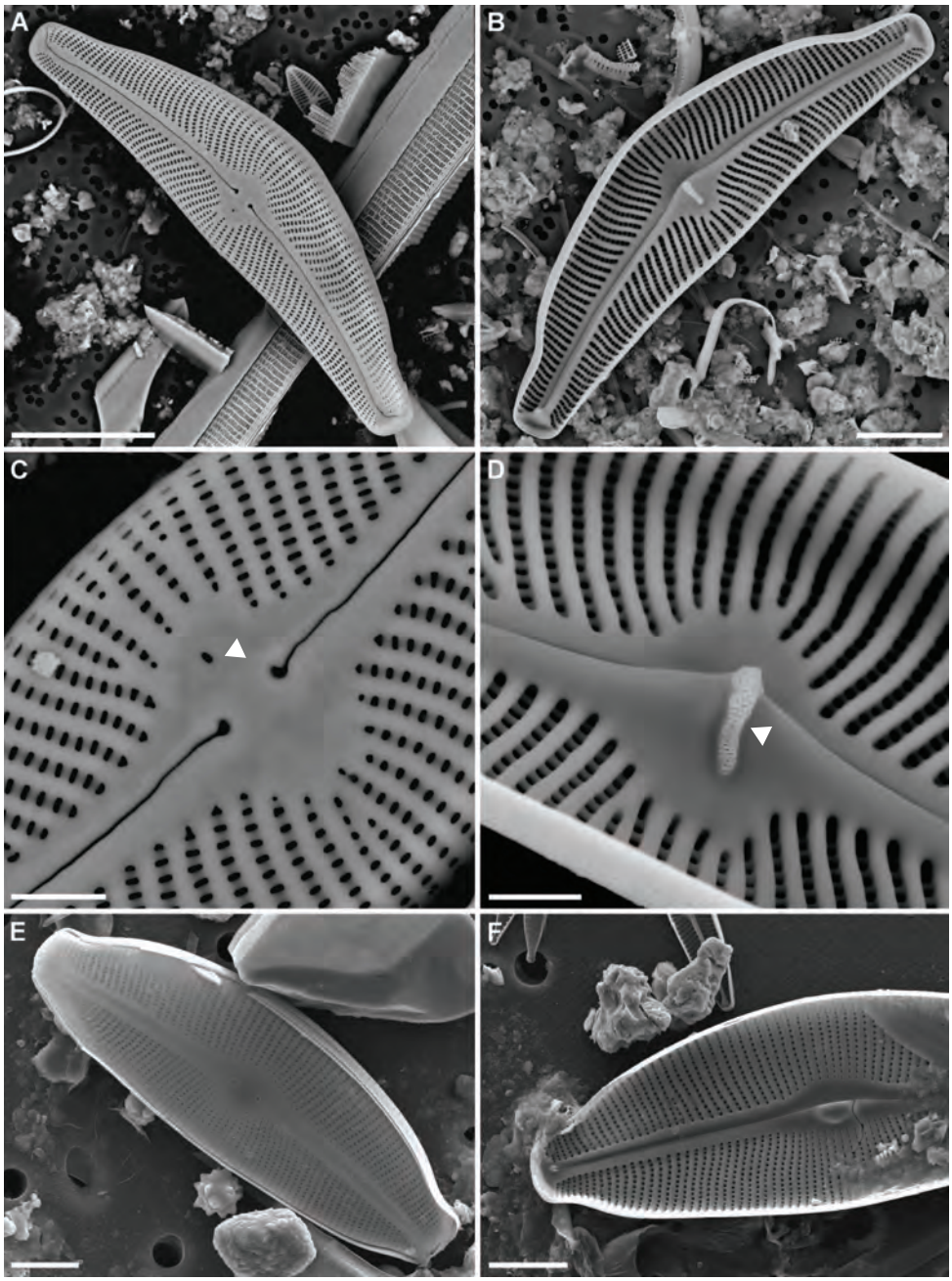


Fig. 78. *Cymbella* sp. **A-F**. SEM. **A-D**. *Cymbella tumida*. **A**. External view of valve. **B**. Internal view of valve. **C**. Central area, external view, note opening of stigma (arrow). **D**. Internal view of stigma (arrow). **E**. *C. cucumis*, external view of valve. **F**. *C. cucumis*, internal view of valve.
Scale bars = 20 µm (A-B), 3 µm (C-D), 10 µm (E-F).

Cymbopleura (Krammer) Krammer 1999

Type species: *Cymbopleura subaequalis* (Grunow) Krammer

SYNONYM:

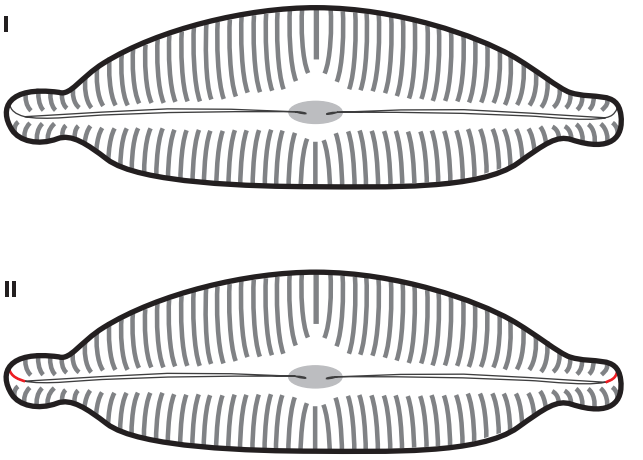
Cymbella C. Agardh 1830 pro parte

Characteristics – Cells **biraphid**, weakly **dorsiventral**, dorsal margin more curved than the ventral margin. Striae slightly radiate throughout the valve. Raphe complex and terminal raphe endings bent towards the dorsal side (II). (Fig. 79: G). **Stigma** absent. **Apical pore fields** absent although SEM may be needed to determine this.

Plastid structure – Cells with one H-shaped plastid and a large pyrenoid in the centre of the cell against one girdle. Several small lipid droplets scattered throughout the cell (Fig. 79: A-B).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices and structure and density of the striae.

Ecology – Cells solitary and motile. Found in the benthos of oligotrophic slightly acidic waters.



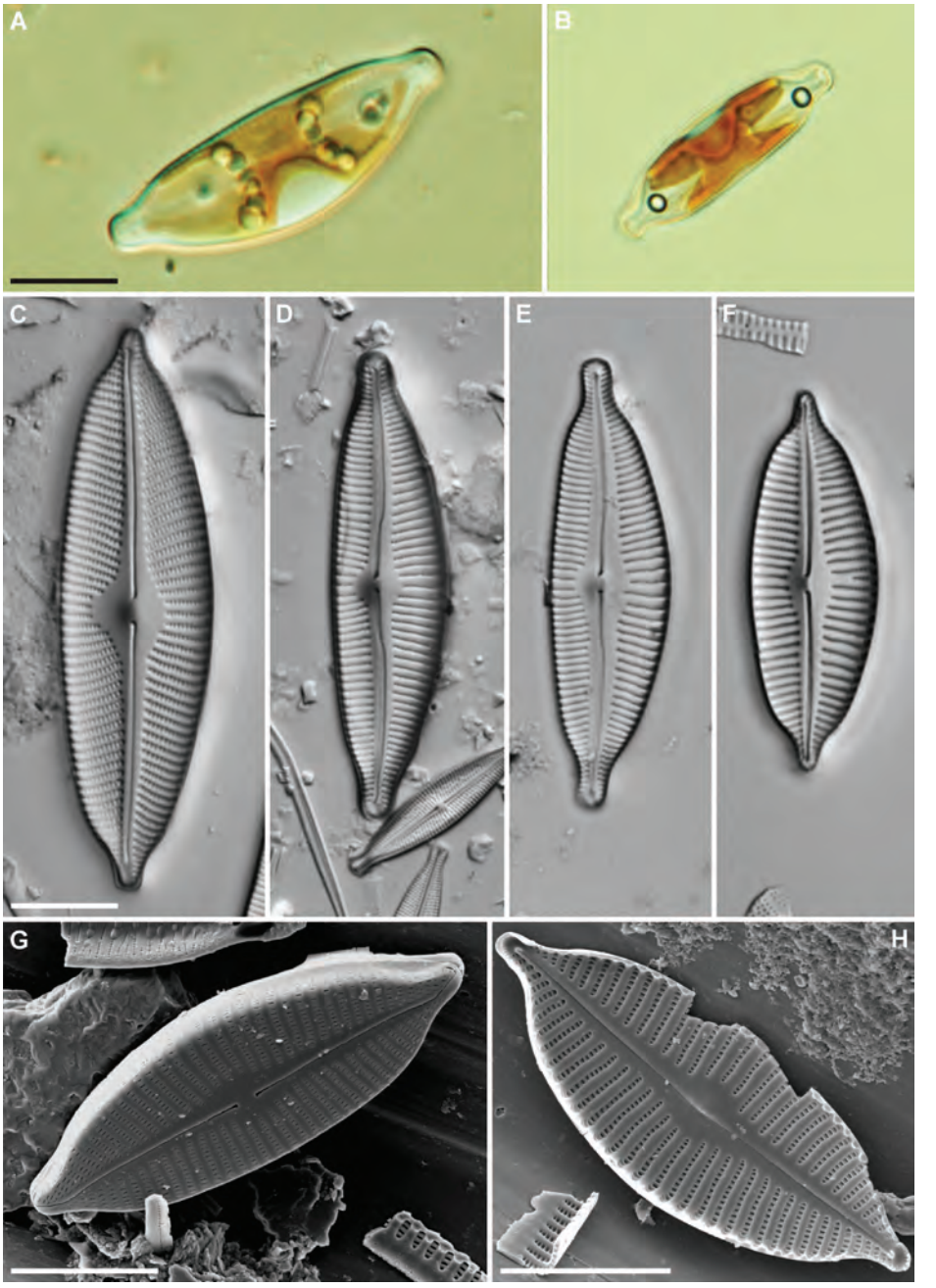


Fig. 79. *Cymbopleura* spp. **A-F**. LM, valve views. **A-B**. Living cells. **C-F.** Cleaned valves. **C**. *Cymbopleura* sp. **D-E**. *Cymbopleura amphicephala* (Nägeli) Krammer. **G-H**. SEM. **G**. *Cymbopleura* sp., external view of valve. **H**. *Cymbopleura* sp., internal view of valve.
Scale bars = 10 µm (A-H).

Encyonema Kützing 1833

Type species: *Encyonema paradoxum* Kützing

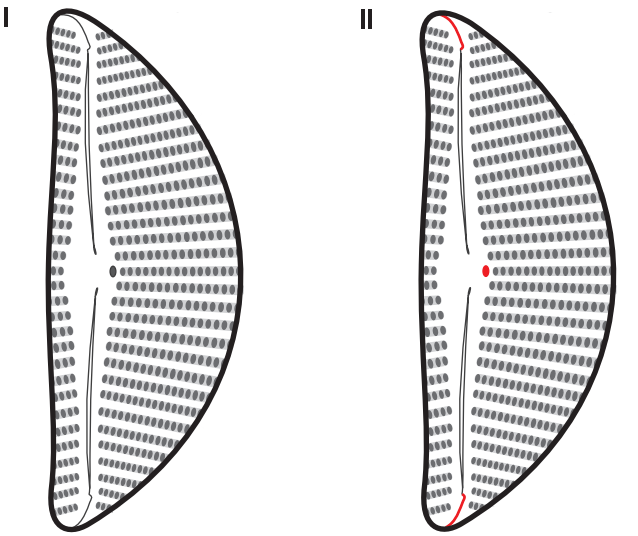
SYNONYM:
Cymbella C. Agardh 1830 pro parte

Characteristics – Cells **biraphid**, **dorsiventral**, dorsal margin strongly curved, ventral margin more or less straight or slightly curved. Raphe complex and terminal raphe endings bent towards the ventral side (II, Fig. 81: A-F). **Stigma(ta)** usually absent but if present located in the central area on the dorsal side (II, Fig. 81: C-E). **Apical pore fields** absent.

Plastid structure – Cells with one H-shaped plastid and a large pyrenoid in the central region against the ventral side (Fig. 80: C). Several small lipid droplets scattered throughout the cell (Fig. 80: E).

Identification of species – Species can be identified by cell size, cell shape, shape and curvature of the apices, structure and density of the striae.

Ecology – Cells solitary, in mucilage tubes or free living and motile. Found in the benthos of oligotrophic to mesotrophic waters in both acidic and alkaline habitats at various trophic levels.



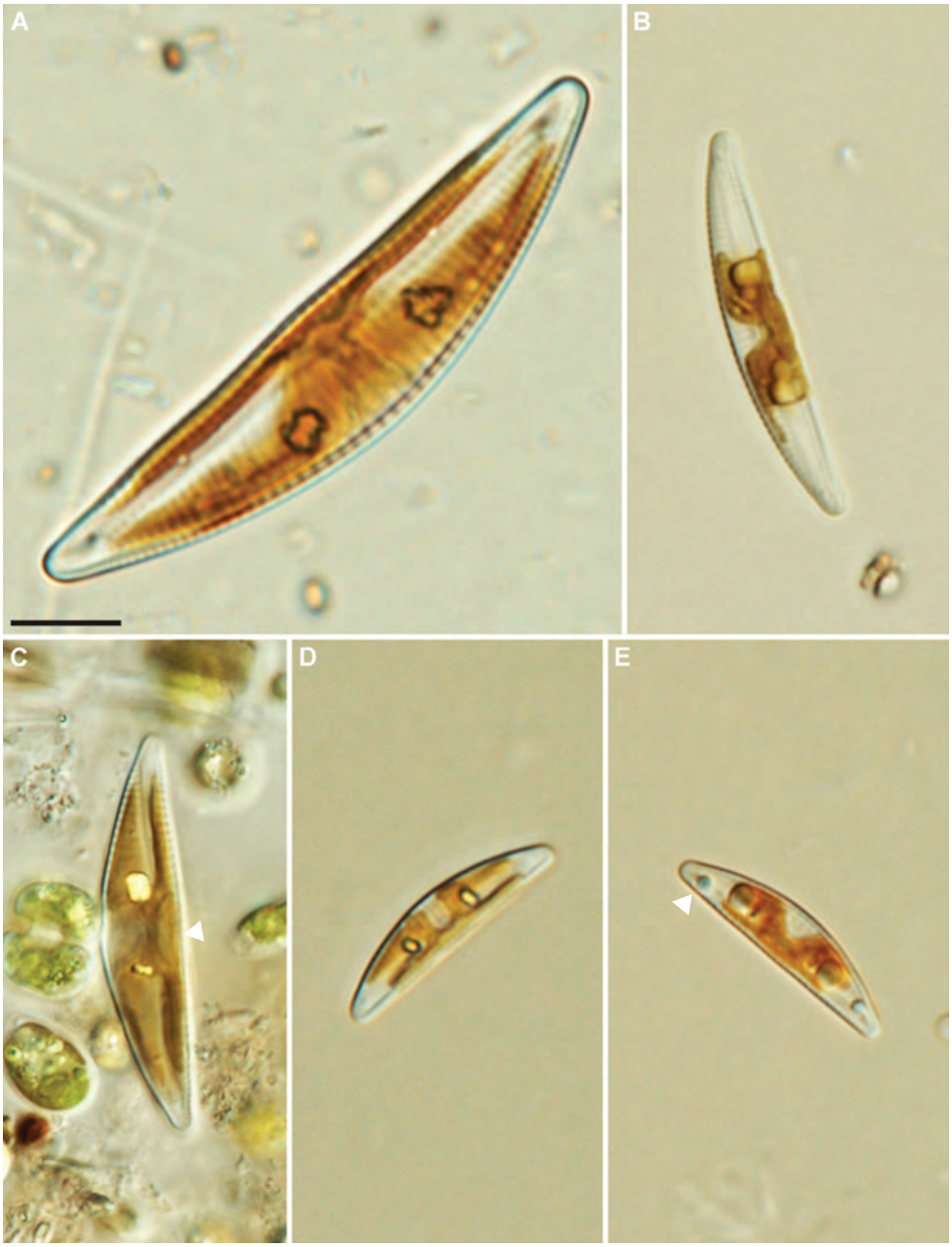


Fig. 80. *Encyonema* spp. **A-E**. LM. Living cells, valve views, note pyrenoid (arrow - **C**) and lipid droplets (arrow - **E**).
Scale bar = 10 µm.

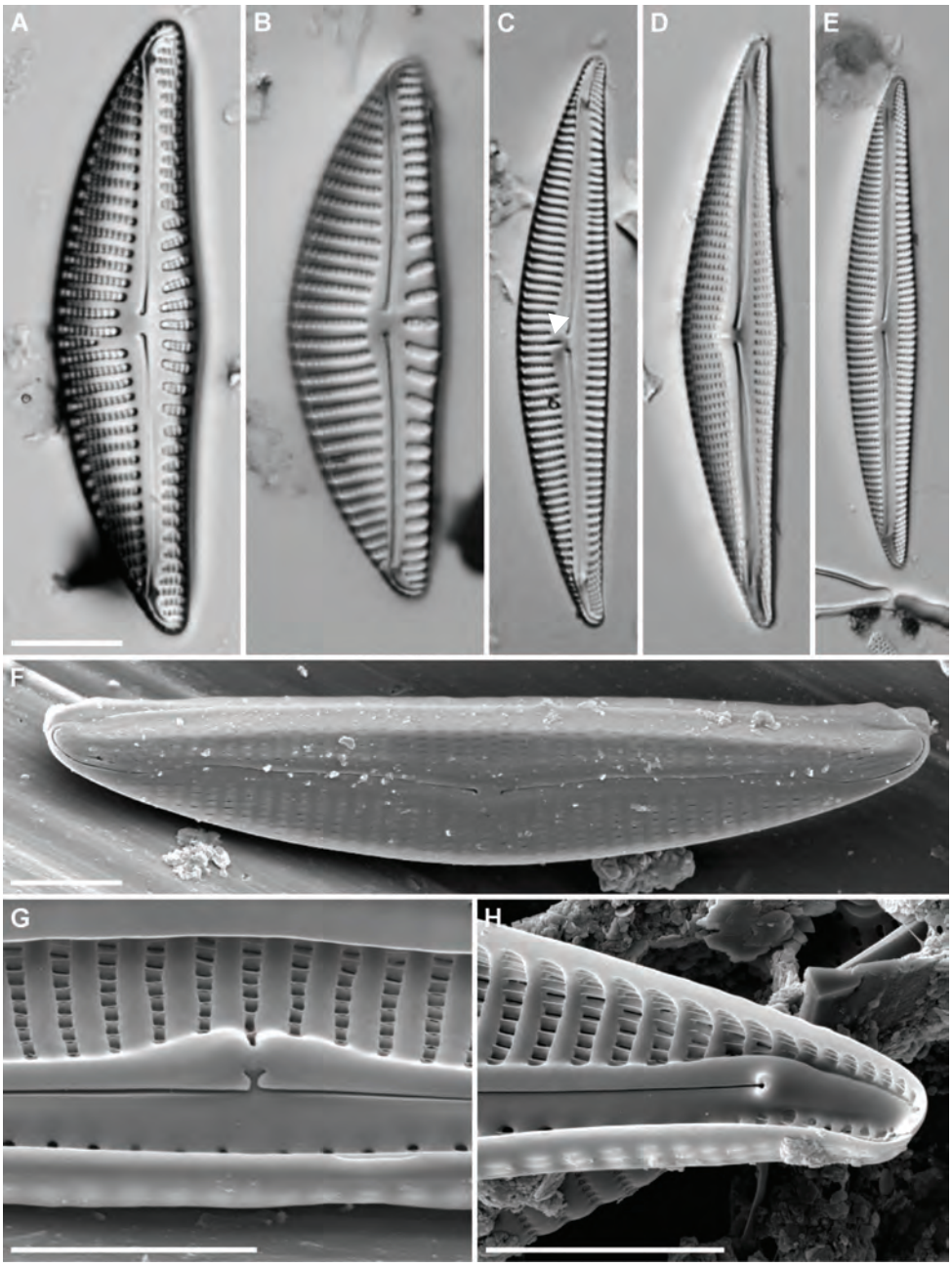


Fig. 81. *Encyonema* spp. **A-E**. LM. Valve views, note stigma on dorsal side (arrow - **C**). **F-H**. SEM. **F**. Valve view of complete valve. **G**. Internal view of valve, detail of central area and central raphe endings. **H**. Internal view of valve, detail of cell apex showing helictoglossa.
Scale bars = 10 µm (A-E), 5 µm (F-H).

Encyonopsis Krammer 1997

Type species: *Encyonopsis cesatii* (Rabenhorst) Krammer

SYNONYM:

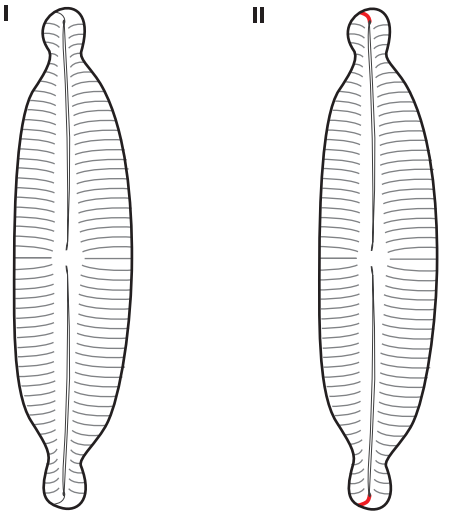
Cymbella C. Agardh 1830 pro parte

Characteristics – Cells **biraphid,** of variable size, slightly to moderately **dorsiventral,** raphe complex and terminal raphe endings bent towards the ventral side (II, Fig. 83: B). **Apical pore fields** absent.

Plastid structure – Cells with one H-shaped plastid and a large pyrenoid in the central region against the ventral side. Several small lipid droplets scattered throughout the cell (Fig. 82: A).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the axial area.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to mesotrophic waters in both acidic and alkaline habitats at various trophic levels.



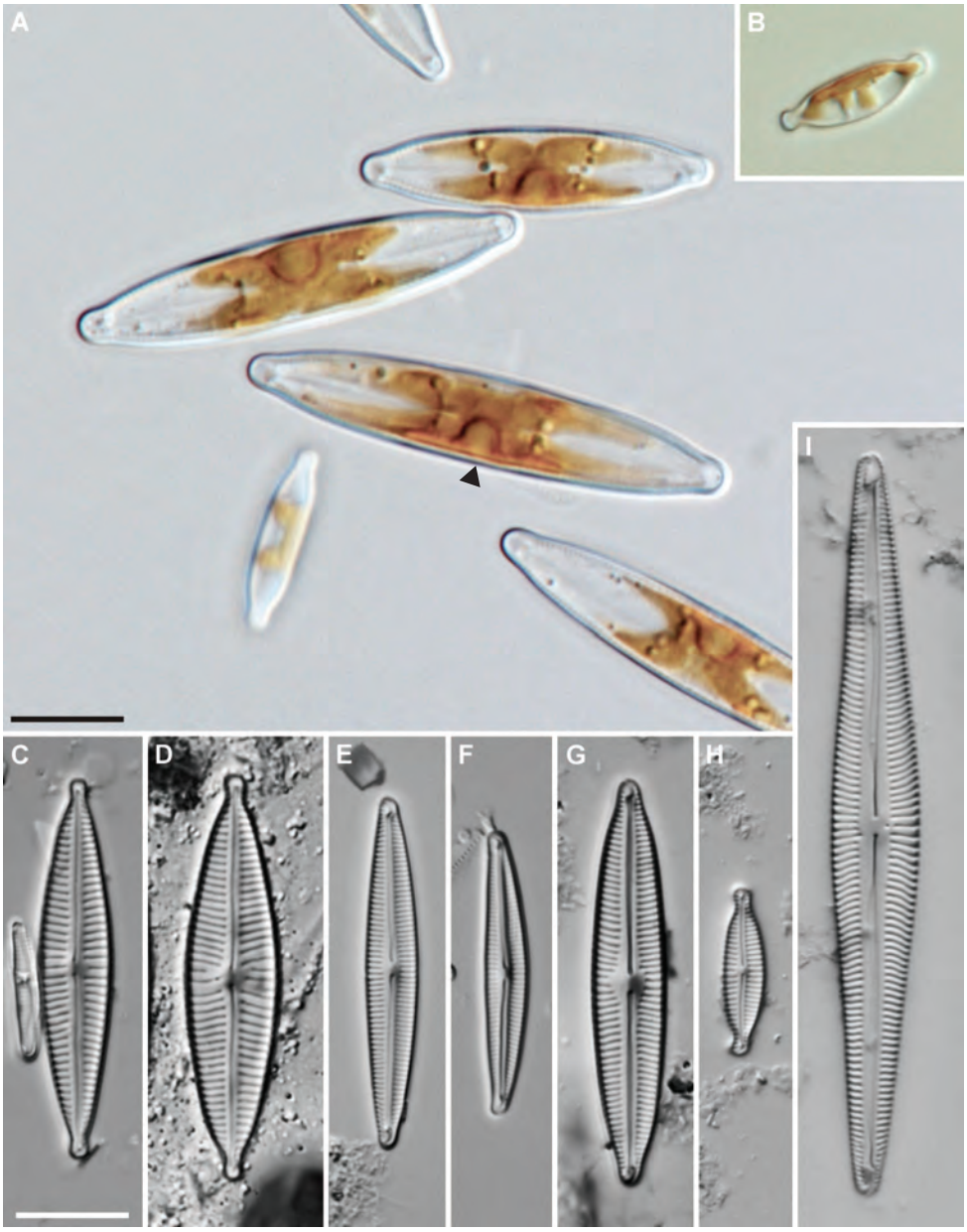


Fig. 82. *Encyonopsis* spp. **A-I**. LM. **A**. Living cells, valve views, note pyrenoid (arrow). **B**. Living cell, valve view of *Encyonopsis microcephala* (Grunow) Krammer. **C-D**. Valve views of *Encyonopsis frequentis* Krammer. **E-F**. Valve views of *E. neerlandica* Van de Vijver, Verweij, Van der Wal & Mertens. **G**. *E. falaisensis* (Grunow) Krammer, valve view. **H**. *E. microcephala*, valve view. **I**. *E. treinishii* Bahls, valve view.
Scale bars = 10 µm.

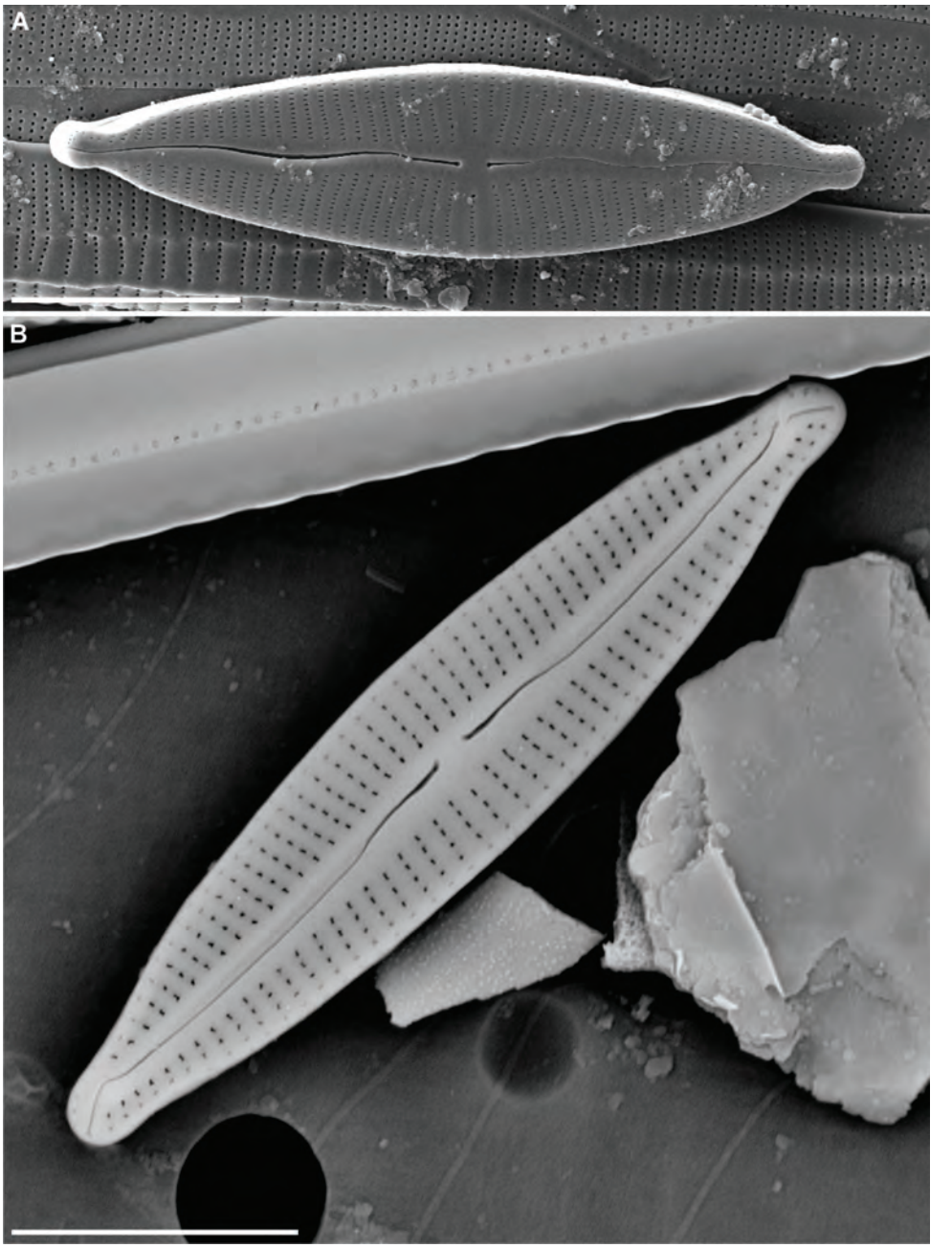


Fig. 83. *Encyonopsis* spp. **A-B**. SEM. **A**. *Encyonopsis frequentis*, external view of valve. **B**. External view of valve of *E. neerlandica*.
Scale bars = 10 µm (A), 5 µm (B).

Placoneis Mereschkowsky 1903

Type species: *Placoneis gastrum* (Ehrenberg) Mereschkowsky

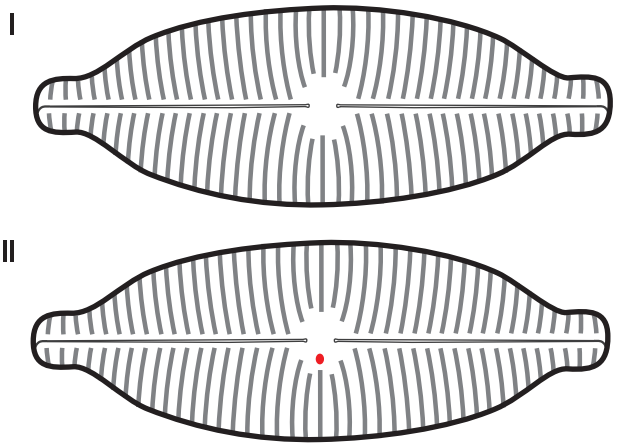
SYNONYM:
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, generally large and robust, elliptical with broadly rounded, rounded or sub-capitate apices. Striae easily discernable under LM (Fig. 84) and composed of single rows of round or elongate, **denticulate** (internally occluded) areolae (Fig. 85: F). Raphe straight with expanded central endings (Fig. 85: A-B), terminal raphe endings bent towards same (Fig. 85: B) or opposite (Fig. 85: A) directions. Central area generally expanded with **stigma(ta)** occasionally present (II; Fig. 84: B; Fig. 85: E).

Plastid structure – Single plastid has a central axis along the apical axis of the cell with four lobes at each end which extend under the valves. Many scattered lipid bodies.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central area and the shape of the central raphe endings and the presence/absence of a stigma.

Ecology – Cells solitary, free living and motile. Found in the benthos of a variety of water types, in tropical Africa this taxon seems to favour oligotrophic waters with low to moderate conductivities.



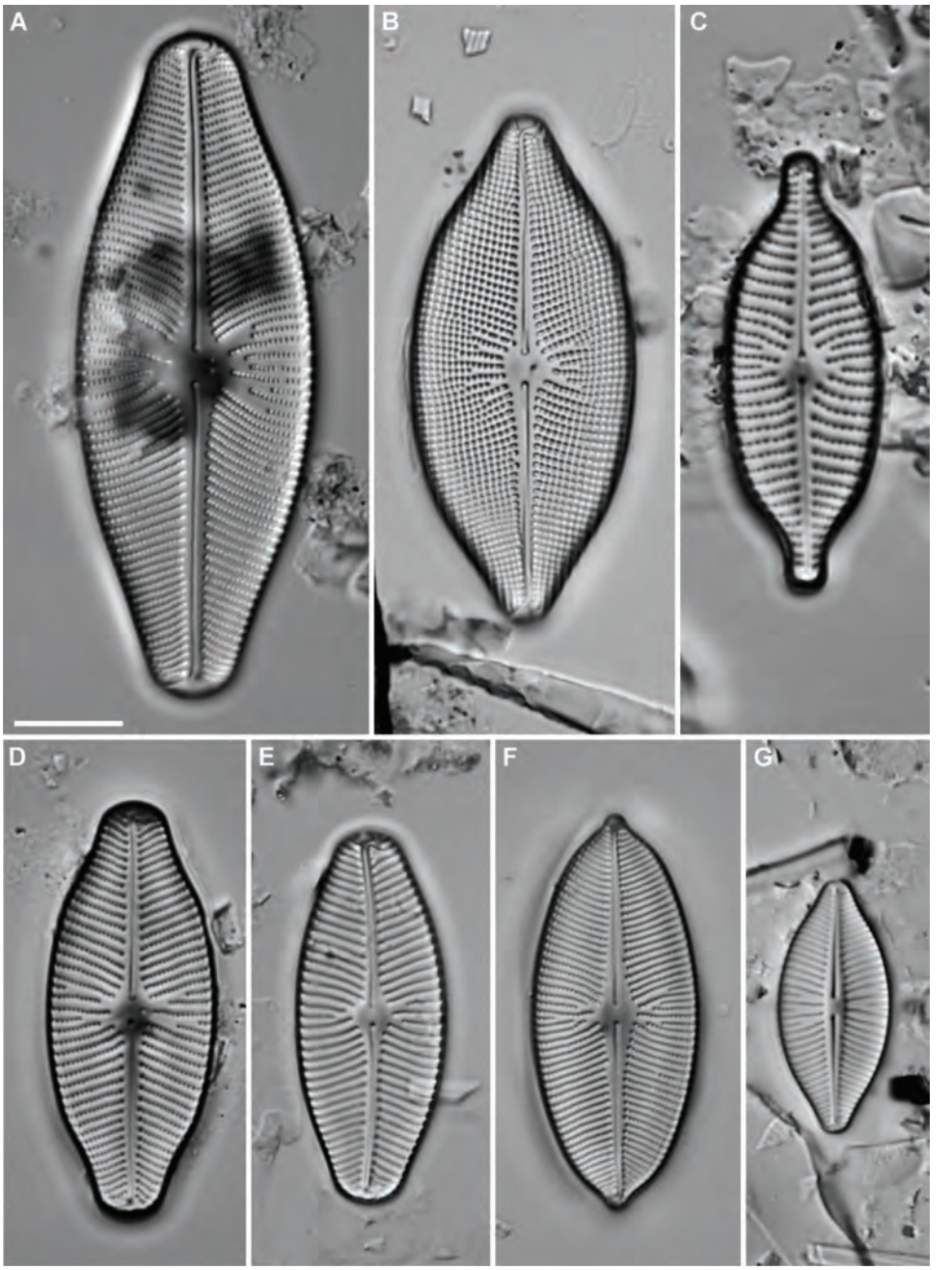


Fig. 84. *Placoneis spp.* **A-G**. LM. **A.** *Placoneis* sp., valve view. **B.** "*Navicula omegopsis*" Hustedt, valve view. **E.** *P. cocquytiae* Fofana, Sow, J.C. Taylor, Ector & Van de Vijver, valve view. **F.** "*Navicula ashantiensis*" Foged, valve view. **G.** *P. hambergii* (Hustedt) Bruder, valve view.
Scale bar = 10 µm.

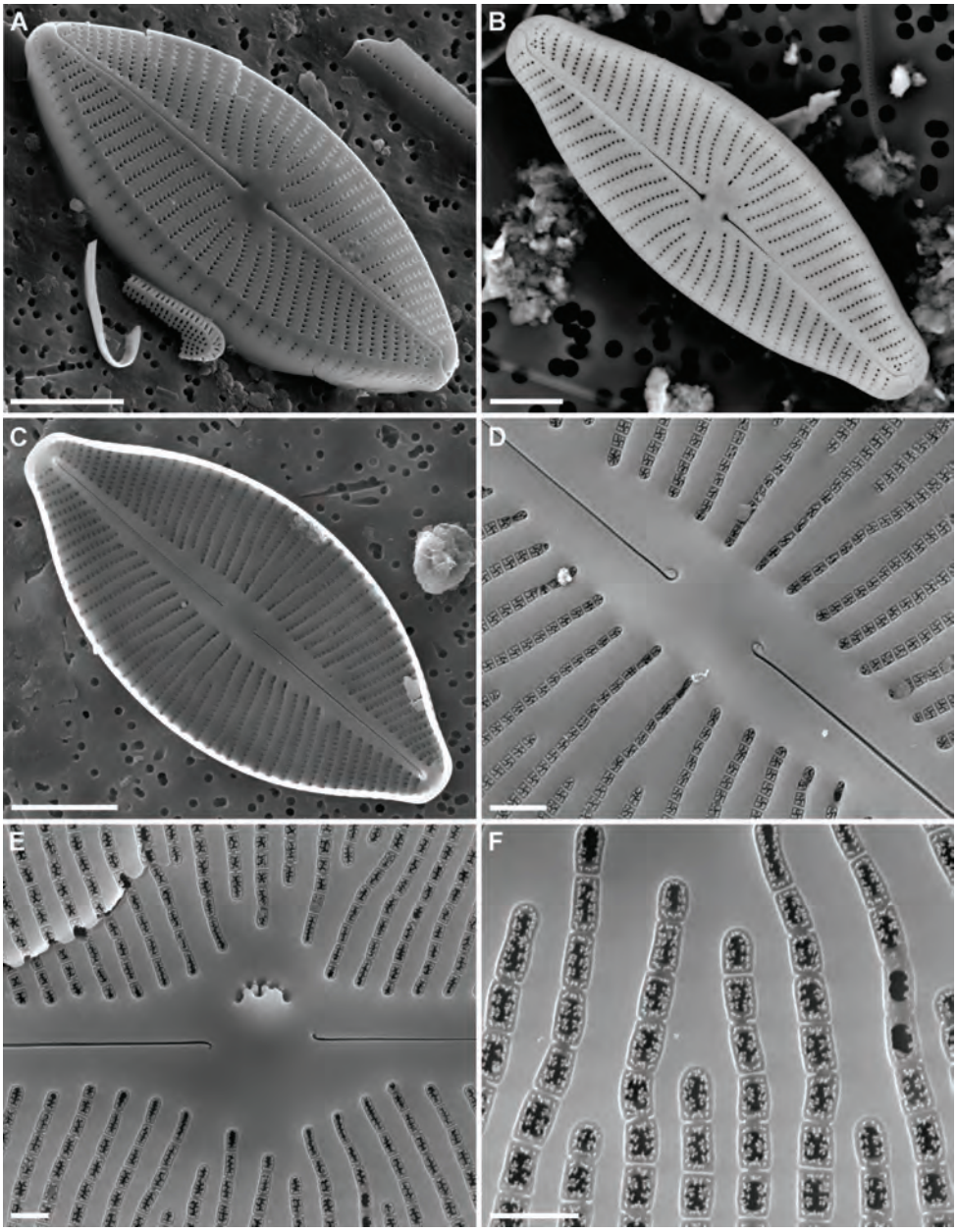


Fig. 85. *Placoneis.* **A-F**. SEM. **A-B.** External view of valve. **C.** Internal view of valve. **D.** Detail of the internal central raphe endings. **E.** Internal view of valve, note the stigmata in the central area. **F.** Internal view of valve, detail of the striae composed of single rows of denticulate areolae.
Scale bars = 10 µm (A-C), 1 µm (D-F).

Gomphonema Ehrenberg 1832

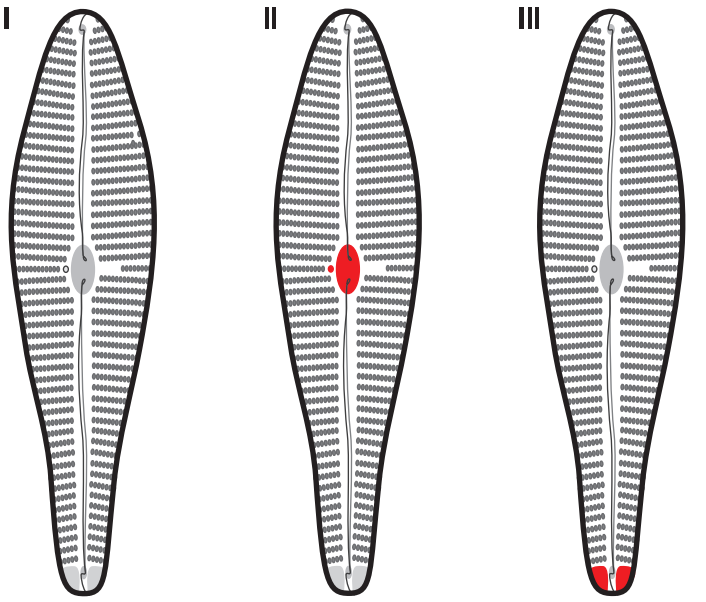
Type species: *Gomphonema acuminatum* Ehrenberg

Characteristics – Cells **biraphid**, **heteropolar**, highly variable in cell size, valve shape and apex shape. Striae composed of single or double rows of areolae which may not be discernable under LM. Raphe straight and simple (Fig. 87: D-H). Central area (II) variable in size and usually with one stigma present. Apical pore field present at the foot pole (III; Fig. 91: C). Rarely large species from tropical Africa have an isolated apical spine (Fig. 91: A, B).

Plastid structure – Single H-shaped plastid extending under both valve faces with a central pyrenoid against the girdle (Fig. 86; Fig. 87: A-C).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central and axial area. The proximity of the stigma to the striae and the presence of an apical spine are also important characters.

Ecology – Cells solitary or in pairs commonly attached by mucilage stalks (Fig. 86; Fig. 87: A-C) and forming colonies. Also solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities.



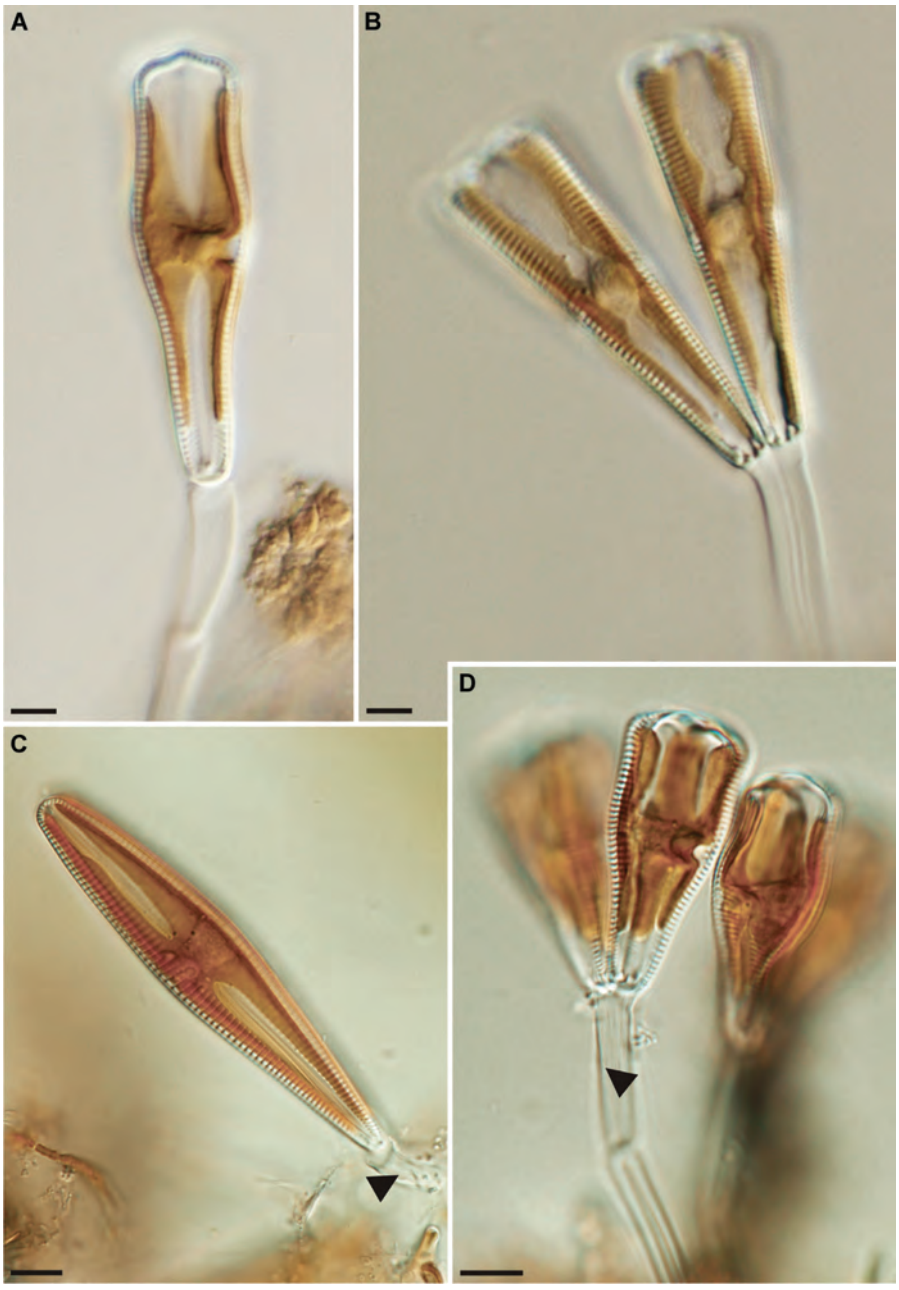


Fig. 86. *Gomphonema* spp. **A-D**. LM, living cells. **A.** *G. truncatum* Ehrenberg, valve view. **B.** *Gomphonema* sp., girlde views. **C.** *Gomphonema* sp., valve view, note mucilage stalk (arrow). **D.** *G. truncatum*, girdle views, note mucilage stalks (arrow).
Scale bars = 10 µm (A-D).

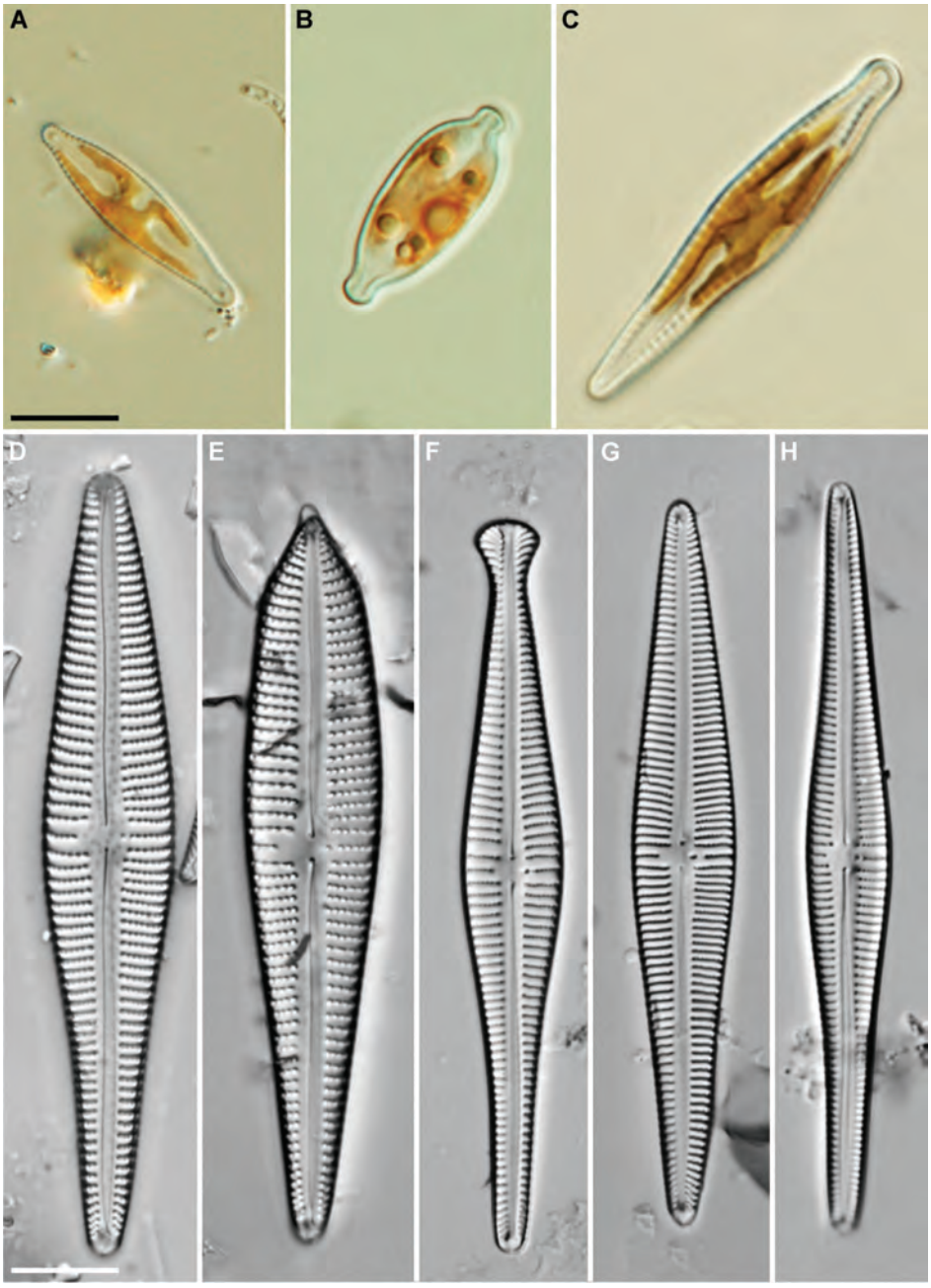


Fig. 87. *Gomphonema* spp. **A H.** LM. **A C.** Living cells, valve views. **B.** *Gomphonema parvulum* Kützing. **D-H.** Cleaned valves. **D.** *Gomphonema affine* Kützing.
Scale bars = 10 µm (A-H).

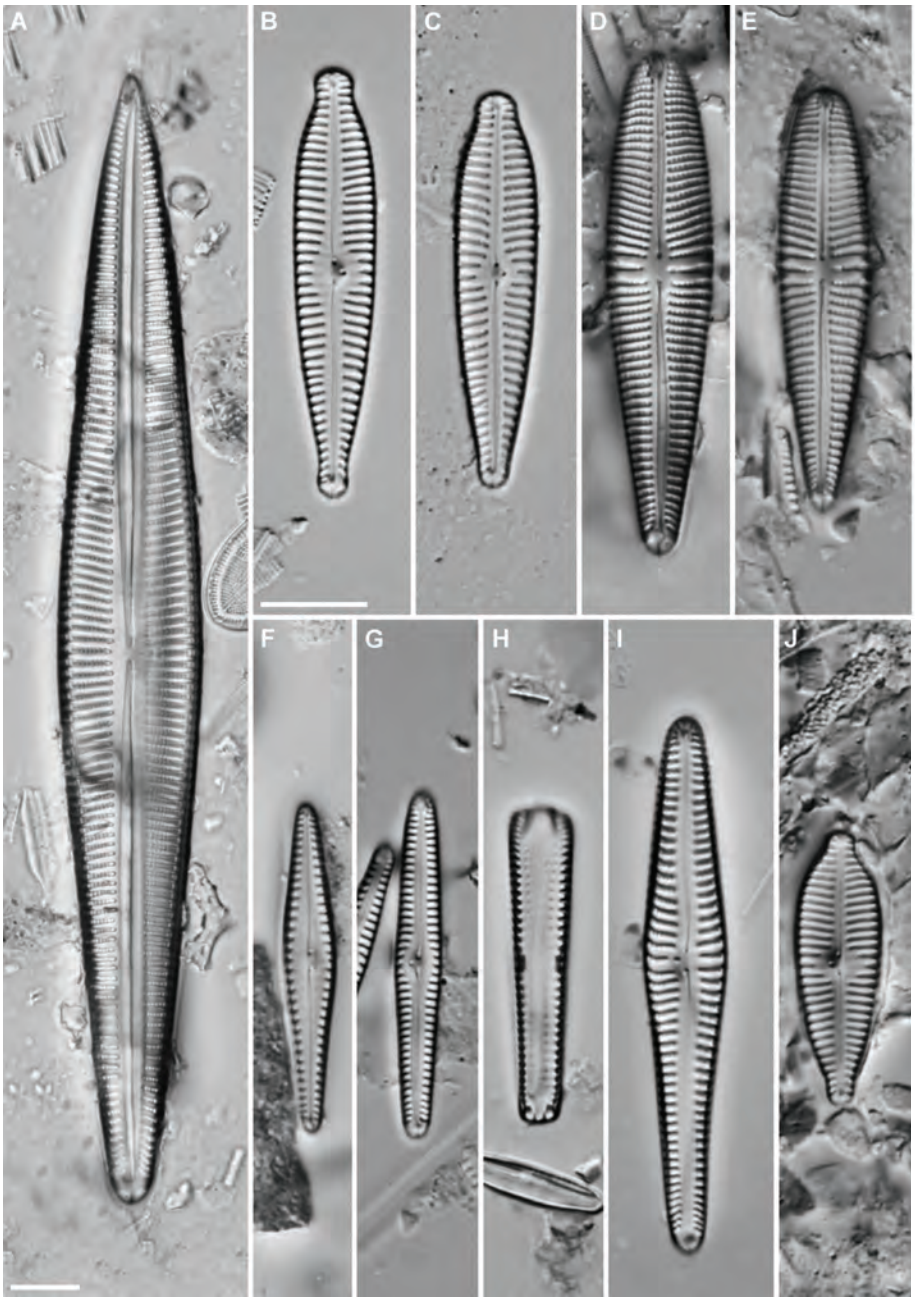


Fig. 88. *Gomphonema* spp. **A-J**. LM, cleaned valves. **A.** *G. kilhamii* Kociolek & Stoermer, valve view. **B-C.** *G. zairense* Compère, valve view. **D-E.** *G. aequatoriale* Hustedt, valve views. **F-G.** *Gomphonema* spp., valve view. **H.** *Gomphonema* sp., girdle view. **I-J.** *Gomphonema* spp., valve view. Scale bar = 10 µm (A-I).

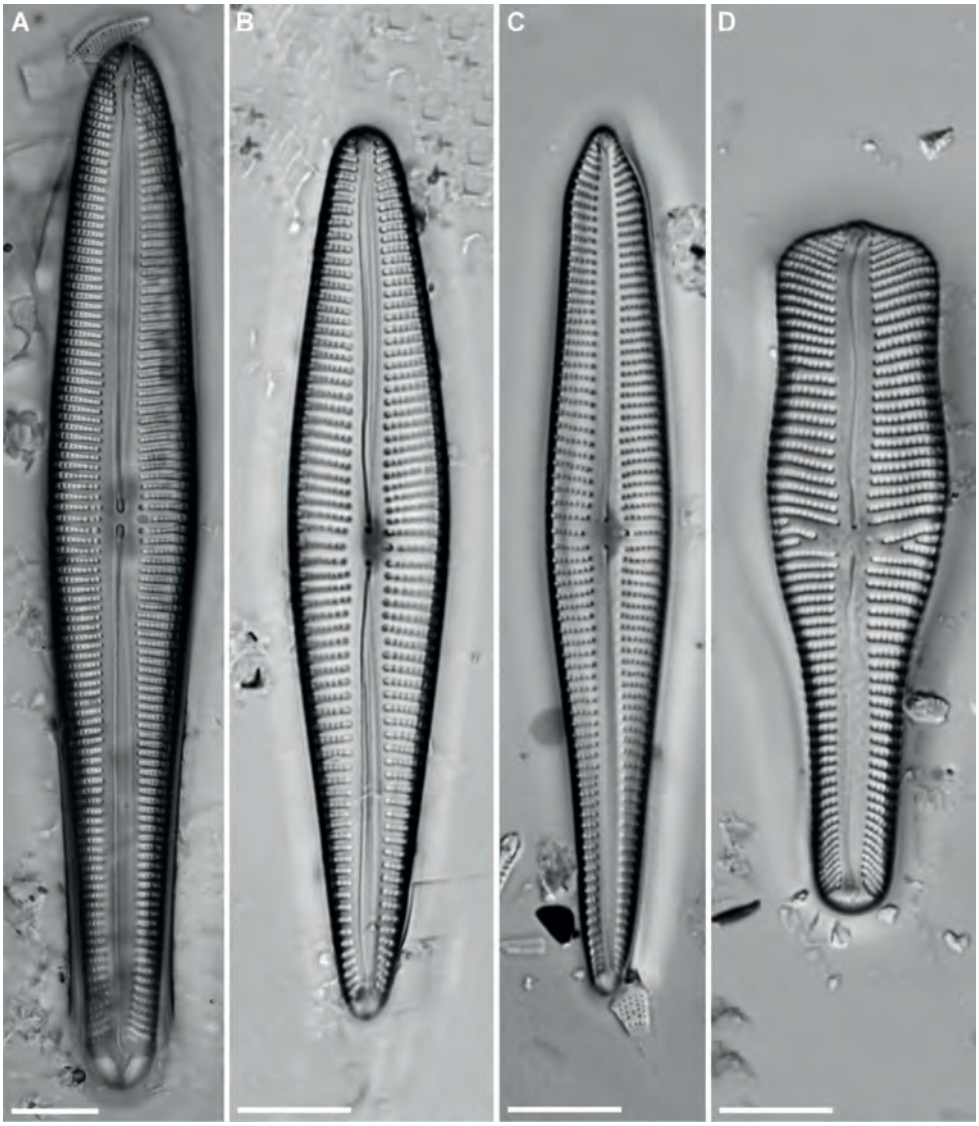


Fig. 89. *Gomphonema* spp. **A-D**. LM, cleaned valves. **A, C.** *G. africanum* G.S. West, valve view. **B.** *Gomphonema* sp., valve view. **D.** *G. truncatum*, valve view. Scale bars = 10 µm (A-D).

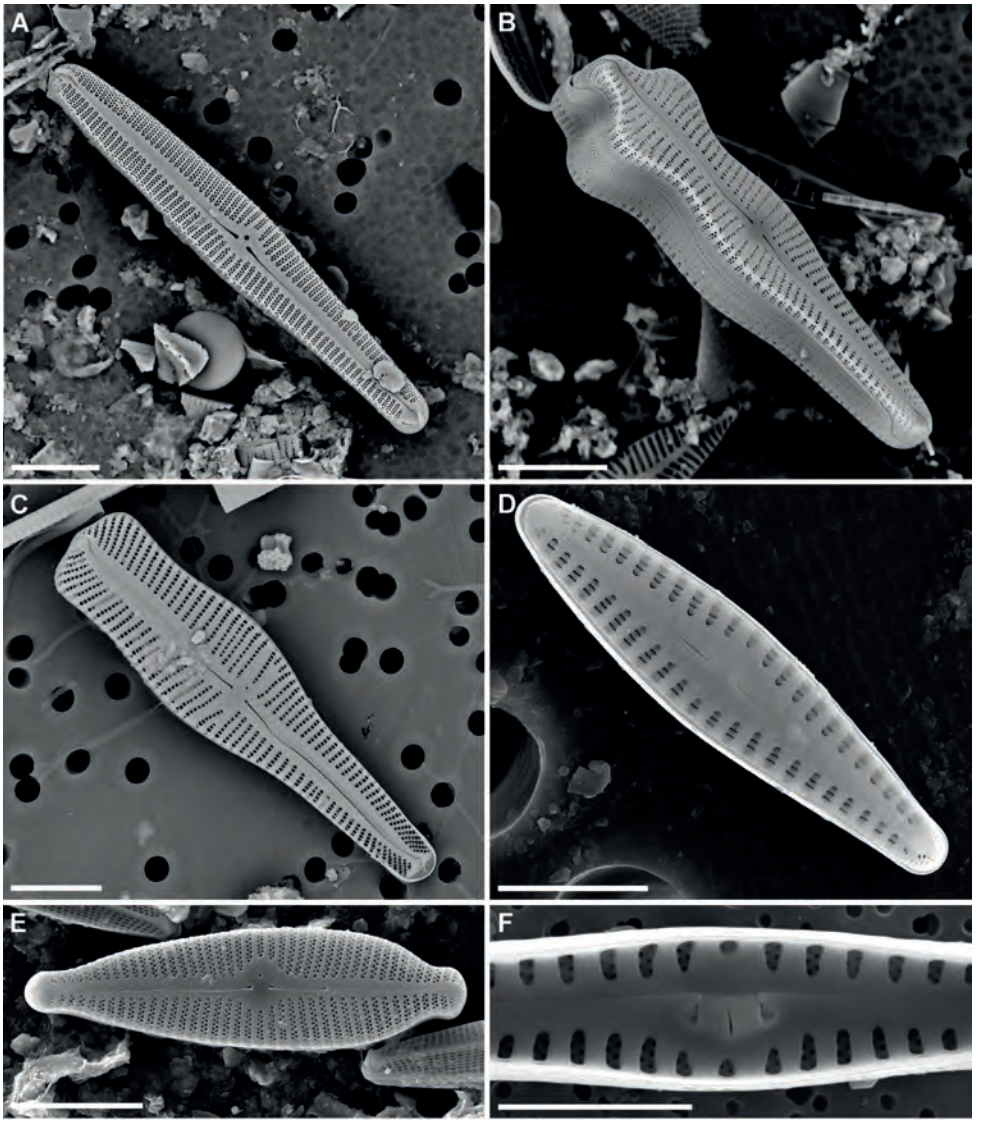


Fig. 90. *Gomphonema* spp. **A-F**. SEM. **A.** *Gomphonema* sp., external view of valve, note striae composed of double rows of areolae. **B.** *G. acuminatum*, external view of valve. **C.** *G. truncatum*, external view of valve, note striae composed of single rows of areolae. **D.** *G. brasiliense* subsp. *pacificum* Gerd Moser, Lange-Bertalot & Metzeltin, external view of valve**. E.** *G. zairense*, external view of valve. **F.** *Gomphonema* sp., internal view of valve. Scale bars = 10 µm (A-C, E), 5 µm (D, F).

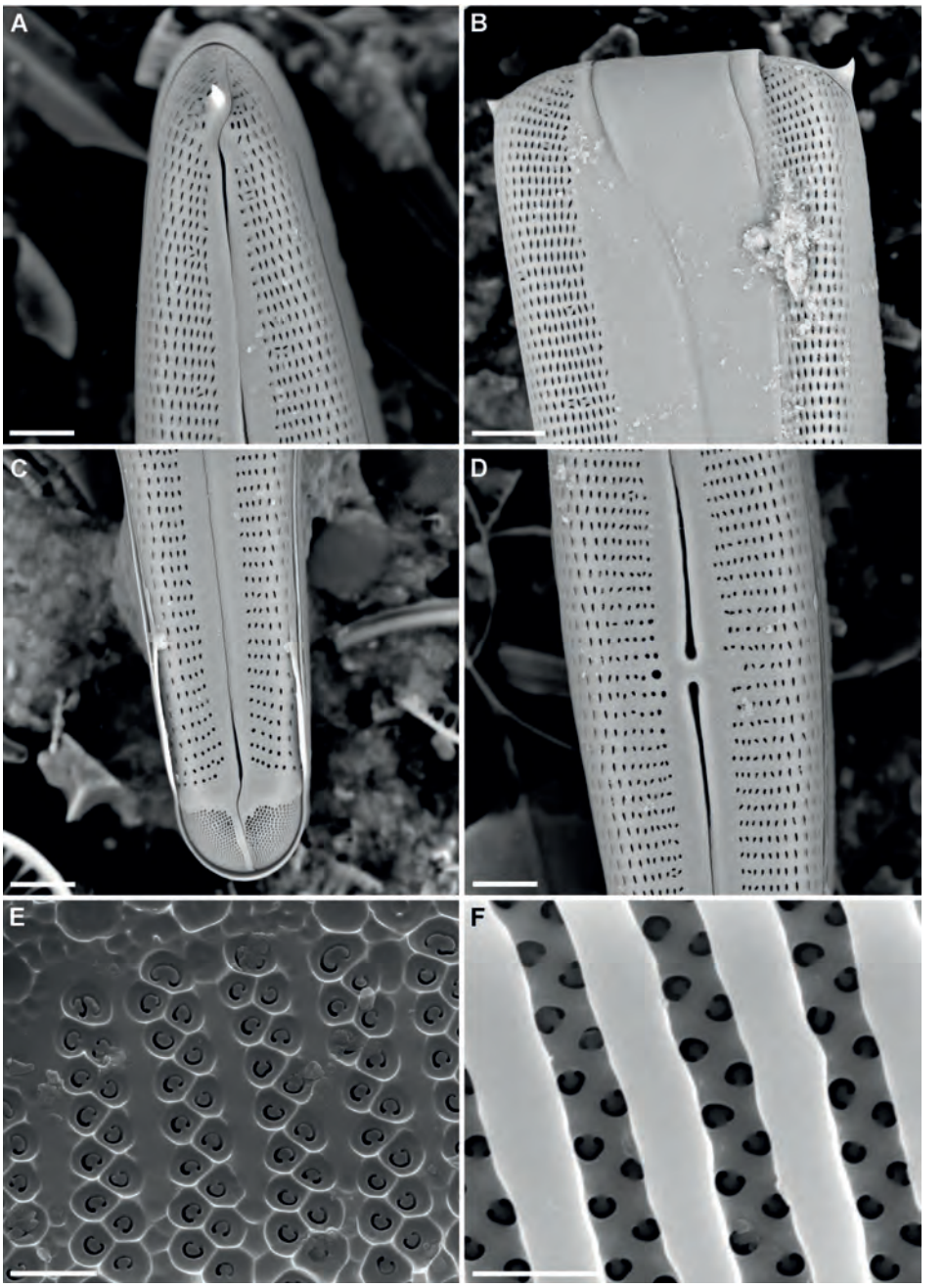


Fig. 91. *Gomphonema* spp. **A-F**. SEM. **A, C-D.** *G. kilhamii*, external view of valve, note apical spine (**A**) and apical pore field (**C**). **B.** *G. kilhamii*, girdle view, note apical spines. **E.** *G. grande* Karthick, Kociolek, J.C. Taylor & Cocquyt, external view of valve, detail of striae. **F.** *G. grande*, internal view of valve, detail of striae. Scale bars = 4 µm (A, C-D), 5 µm (B), 1 µm (E-F).

Gomphosphenia Lange-Bertalot 1995

Type species: *Gomphosphenia lingulatiformis* (Lange-Bertalot & E. Reichardt) Lange-Bertalot

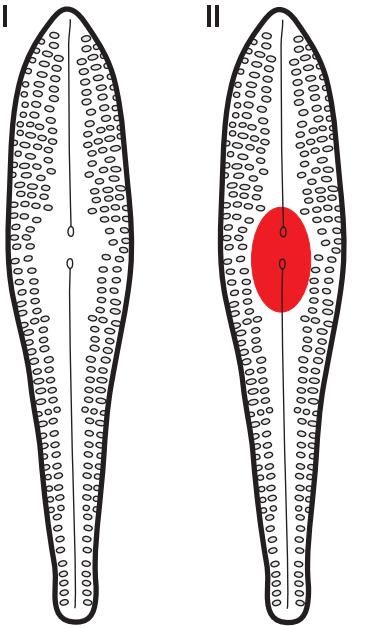
SYNONYM:
Gomphonema Ehrenberg 1832 pro parte

Characteristics – Cells **biraphid**, **heteropolar**, elliptical to linear elliptical with broadly rounded apices. Striae coarse composed of single rows of clearly discernable areolae. Raphe simple, straight, not extending onto the valve mantle. Central area (II) variable in size. Axial area broad to very broad (Fig. 92: B-E, G-J). Mantle with row of single large elongate areolae (Fig. 93: B). Stigma and apical pore field absent.

Plastid structure – Not observed in tropical African material.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central and axial area.

Ecology – Cells solitary or in pairs, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities. Some taxa e.g. *G. pfannkucheae* (Cholnoky) Lange-Bertalot are found in oligotrophic, acidic tropical African waters.



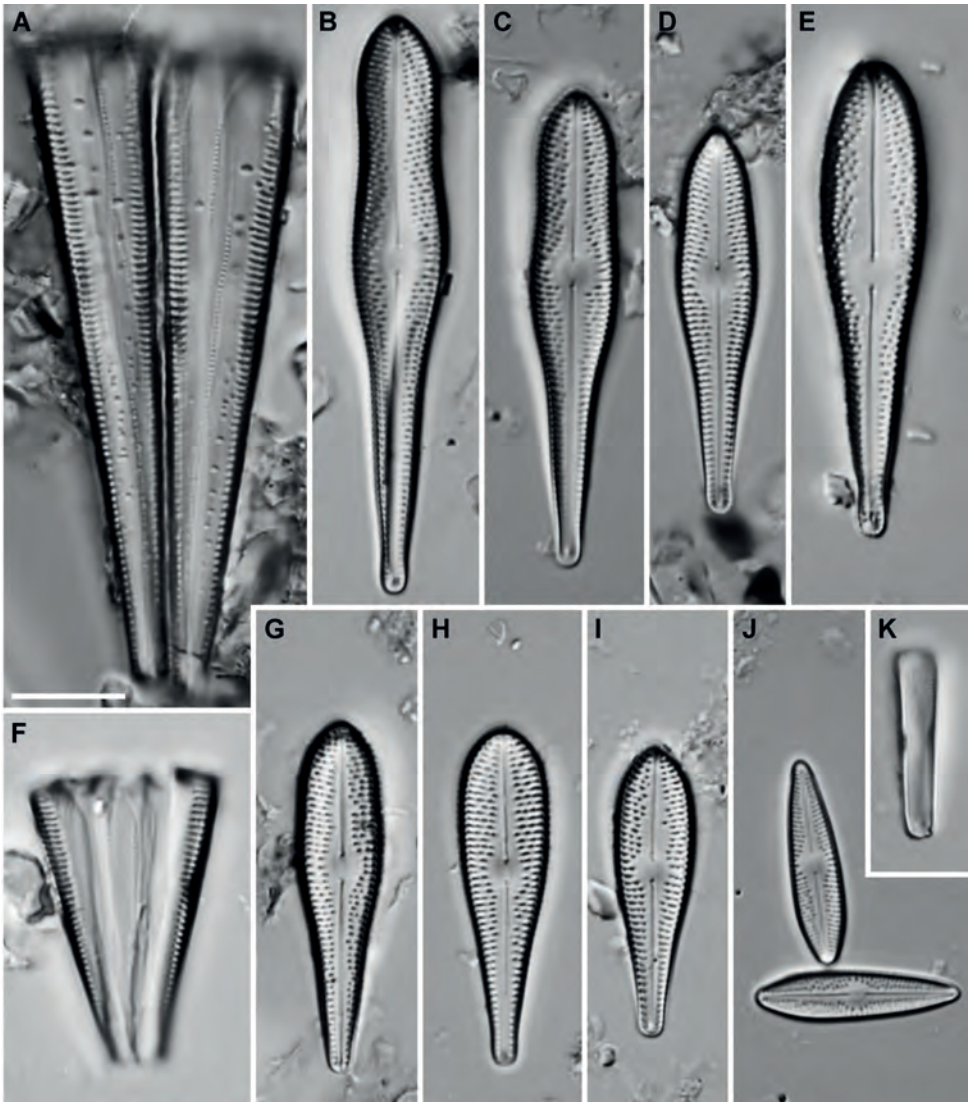


Fig. 92. *Gomphosphenia* spp. **A-K**. LM. **A.** *Gomphosphenia* sp., girdle views. **B-E, G-J.** *Gomphosphenia* spp., valve views, note variable size of central area and broad to very broad axial area. **F, K.** *Gomphosphenia* sp., girdle views. Scale bar = 10 µm (A-K).

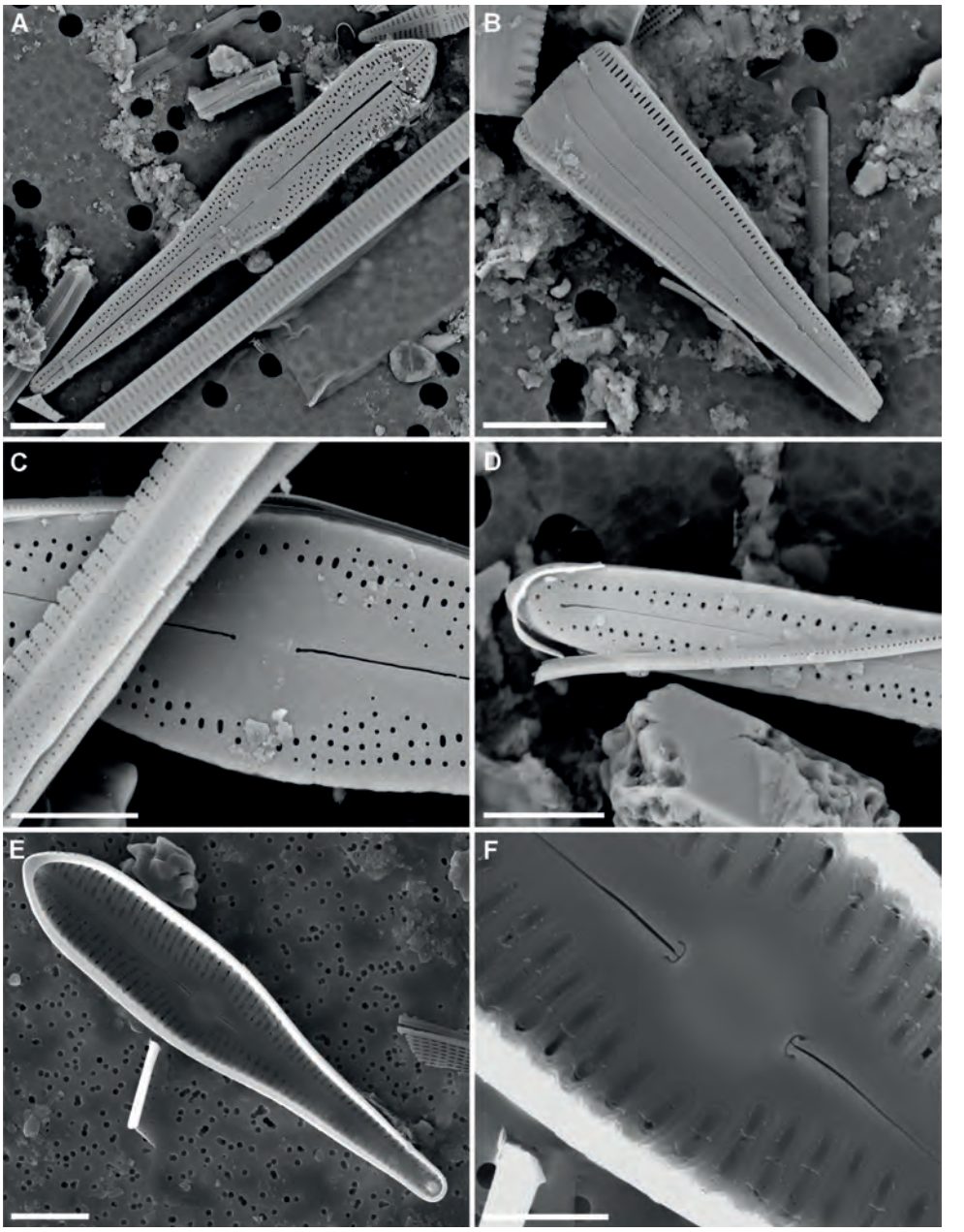


Fig. 93. *Gomphosphenia* spp. **A-F**. SEM. **A.** External view of valve. **B.** Girdle view. **C.** External view of valve, detail of central area. **D.** External view of valve, detail of apex. **E.** Internal view of valve. **F.** Internal view of valve, detail of central raphe endings.
Scale bars = 10 µm (A-B), 5 µm (C-E), 2 µm (F).

Achnanthes Bory 1822

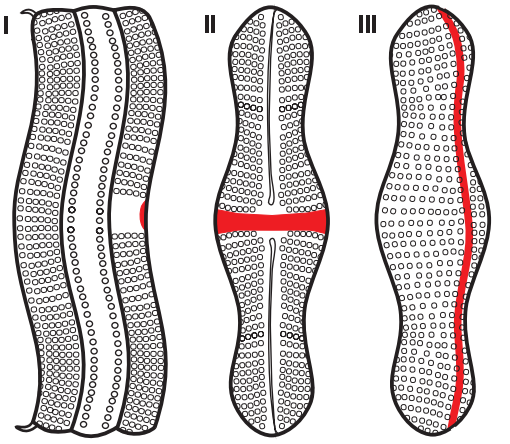
Type species: *Achnanthes adnata* Bory

Characteristics – A relatively large and robust **monoraphid** taxon often seen in girdle view with the cell bent or flexed. One valve carries a raphe while the other does not (**heterovalvar**). When seen in valve view the valve margin is often more or less undulating and the apices are swollen (as in *A. inflata* (Kützing) Grunow – Fig. 94: B-C, E-F). Cells in valve view are difficult to focus due to the flexed shape of the cell (see Figs 94; B-C both represent the same valve). There is a pronounced and clear gap between the striae at the central area of the raphe bearing valve (RV), with a **fascia** or thickening visible on the inside of the cell wall (I, II). This **fascia** is absent on the **rapheless valve** (RLV). A narrow **sternum** is present near one of the margins of the RLV (III). The areolae are clearly visible and appear under LM as large distinctly separate dots, under SEM the areolae can be seen to have a rather complex structure (**cribra** with **volae)** (Fig. 94: I).

Plastid structure – There may be many granular plastids or two large plastids on either side of the transapical plane (Fig. 94: A). In valve view these are H-shaped and connected by a bridge bearing a pyrenoid.

Identification of species – Species and varieties in this genus are distinguished based on cell size and shape as well as the shape of the apices.

Ecology – Cells solitary or in pairs, usually attached by an apical mucilage stalk but also motile. Commonly found in waters of medium to high conductivity.



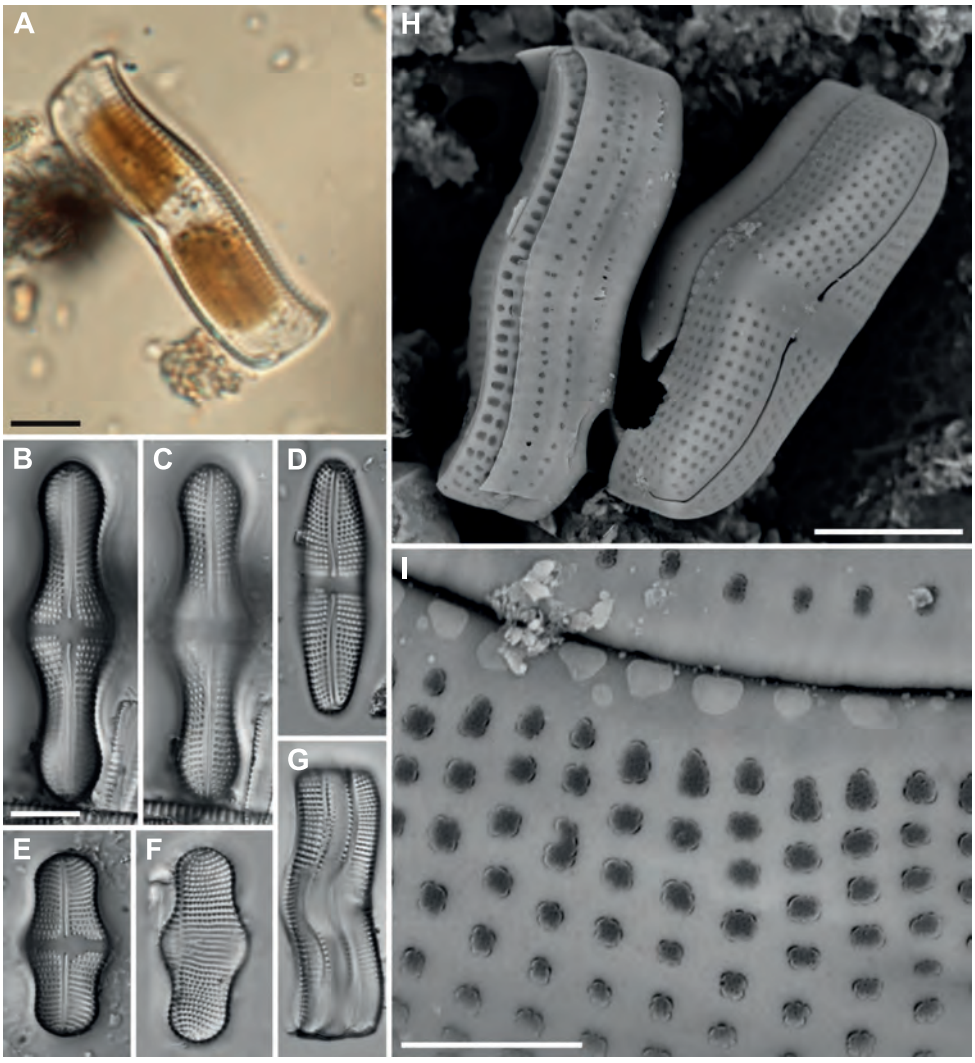


Fig. 94. *Achnanthes* spp. **A-G**. LM. **A**. Living cell, girdle view. **B-C**. Valve view of the RV of *Achnanthes inflata* (Kützing) Grunow, different foci of the same cell. **D**. Valve view of RV of *A. coarctata* (Brébisson ex W. Smith) Grunow. **E**. RV of *A. inflata*, small specimen. **F**. RLV of *A. inflata*, small specimen. **G**. Girdle view of *A. inflata*. **H-I**. SEM. **H**. Broken valve of *A. inflata*, oblique view. **I**. Detail of valve margin of *A. inflata* showing the structure of the areolae occlusions. Scale bars = 10 µm (A-H), 3 µm (I).

Lemnicola Round & Basson 1997

Type species: *Lemnicola hungarica* (Grunow) Round & Basson

SYNONYM:

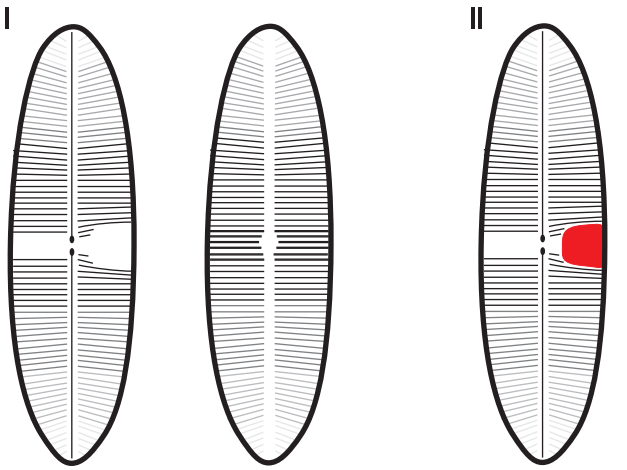
Achnanthes Bory 1822 pro parte

Characteristics – Cells **heterovalvar**, **monoraphid**, linear to elliptical with broadly rounded or cuneate apices. Curved in girdle view (one valve slightly convex the other slightly concave). Striae robust and clearly discernable under LM (Fig. 95: E-K), composed of 2 rows of very small round areolae, visible only under SEM (Fig. 96). Raphe straight and simple (Fig. 95: E-K) with expanded central endings, terminal endings curved to opposite sides. Rapheless valve (RLV) has a narrow axial area and may have a unilateral gap in the central striation. The raphe valve (RV) has a thickened asymmetric **stauros** (II; Fig. 96: A-B).

Plastid structure – Single plate-like plastid lying under the araphid valve extending under one or both girdles (Fig. 95: A-D).

Identification of species – Up till now only one species is included in this genus: *Lemnicola hungarica.*

Ecology – Cells solitary, usually attached (**adnate**) on benthic substrates in particular aquatic plants. Found in neutral to alkaline waters.



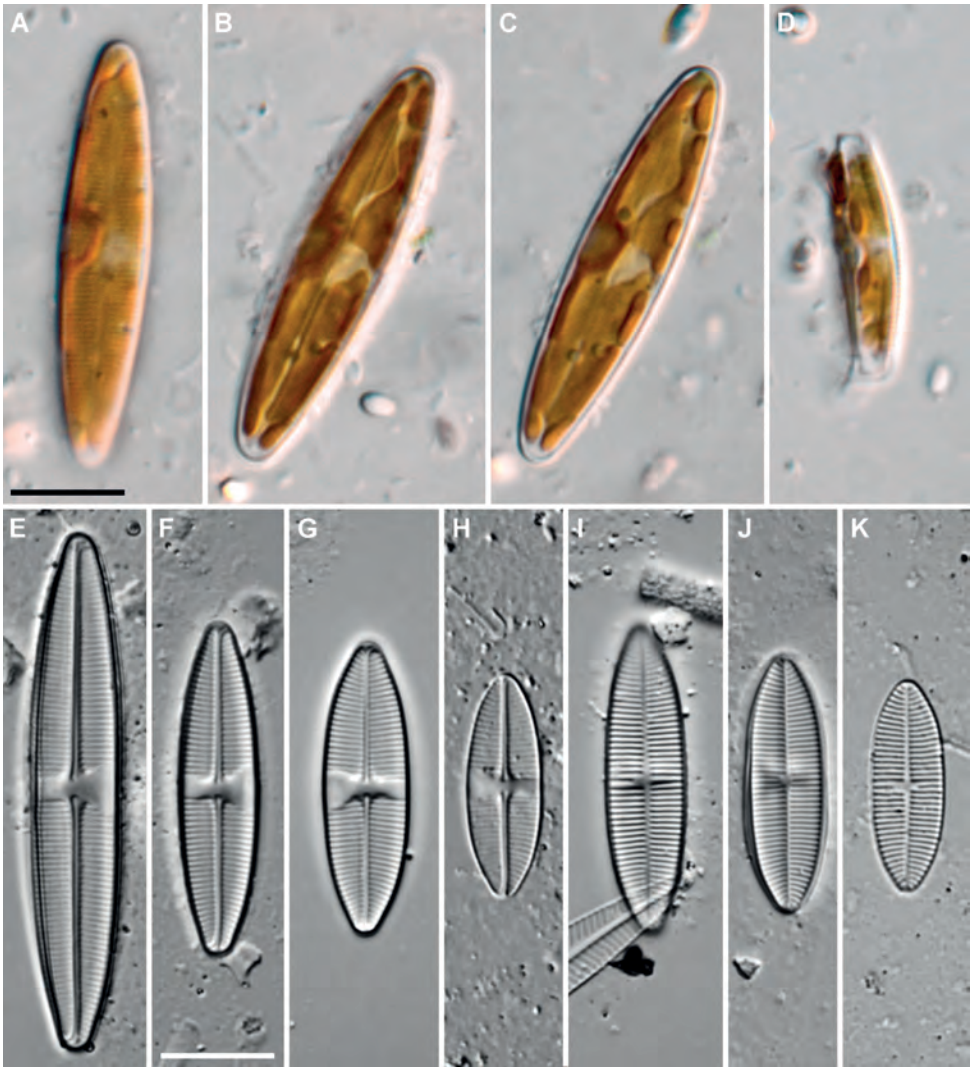


Fig. 95. *Lemnicola hungarica.* **A-K**. LM. **A-D.** Living cells. **E-K.** Cleaned valves. **E-H.** Raphe valves, note asymmetric stauros. **I-K**. Rapheless valves, note narrow axial area.
Scale bars = 10 µm (A-K).

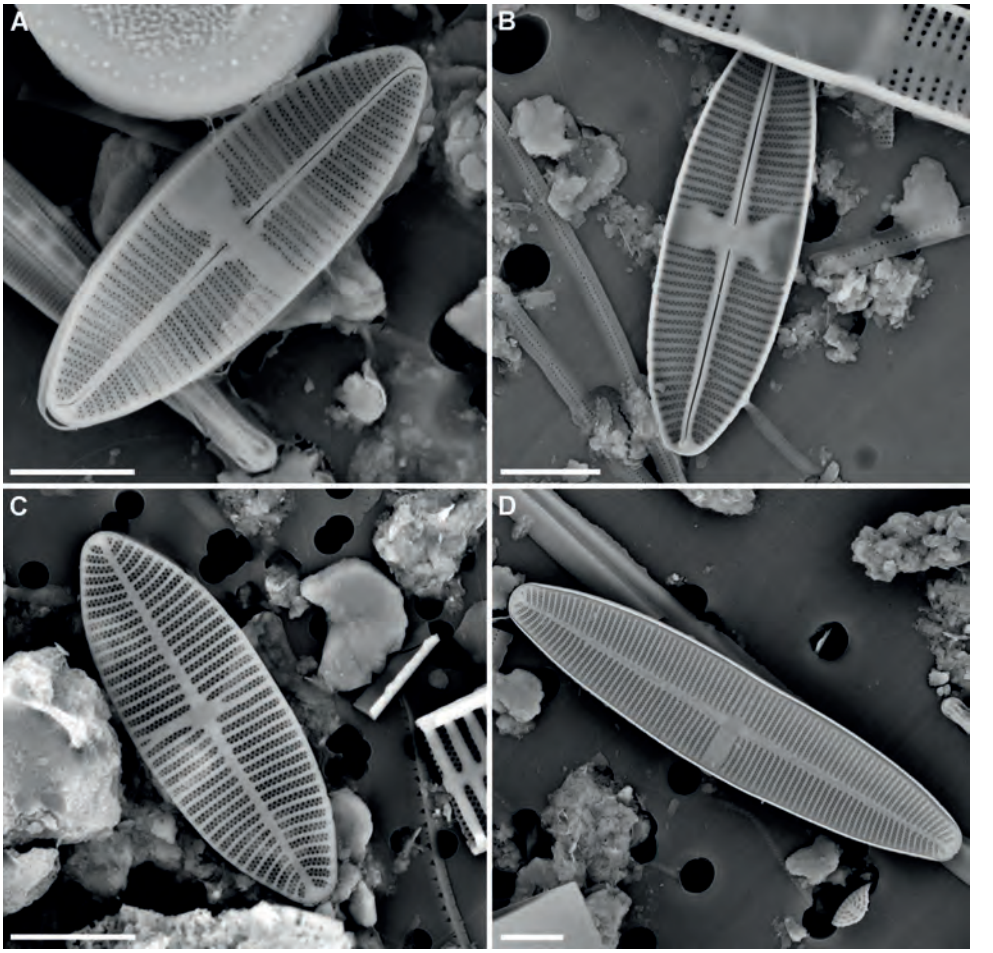


Fig. 96. *Lemnicola hungarica.* **A-D**. SEM. **A.** External view of raphe valve. **B.** Internal view of raphe valve. **C-D.** External view of rapheless valves. Scale bars = 5 µm (A-D).

Psammothidium Bukhtiyarova & Round 1996

Type species: *Psammothidium marginulatum* (Grunow) Bukhtiyarova & Round

SYNONYM:

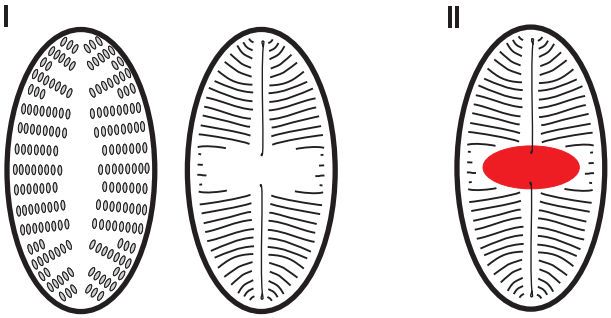
Achnanthes Bory 1822 pro parte

Characteristics – Cells **heterovalvar**, **monoraphid**, elliptical with broadly rounded apices. Slightly curved in girdle view (one valve slightly convex the other slightly concave). Striae robust and clearly discernable under LM (Fig. 97: C-H), composed of 1 row of small round areolae on the raphe valve (RV) and slightly larger areolae on the raphe-less valve (RLV), visible only under SEM (Fig. 97: I-L). Raphe straight and simple (Fig. 97: C-D) with expanded central endings. RLV often has a broad axial area. The RV often has a large central area which may stretch to the valve margins (II; Fig. 97: C-D, K-L).

Plastid structure – Single plate-like plastid lying under the rapheless valve extending under the girdle (Fig. 97: A-B).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae, the structure of the central and axial areas as well as the shape and curvature of the central raphe endings.

Ecology – Cells solitary, attached (**adnate**) by the raphe valve face to the substrata. Found in the benthos of mesotrophic to hypereutrophic waters with moderate to high conductivities.



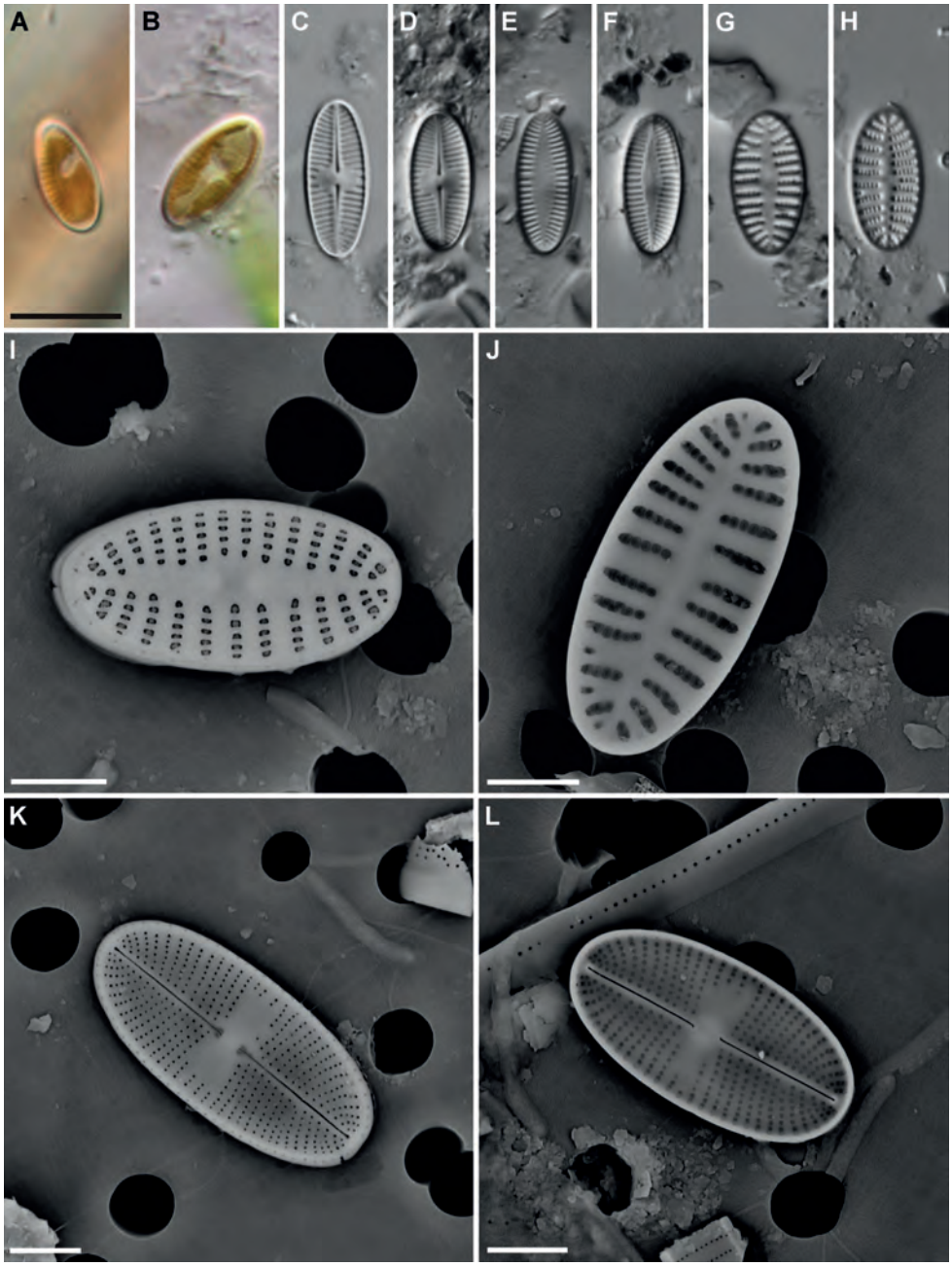


Fig. 97. *Psammothidium* spp. **A-H**. LM. **A-B.** Living cells. **C-H.** Cleaned valves. **C-D.** Raphe valves. **E-H.** Rapheless valves. **I-L.** SEM. **I.** External view of rapheless valve. **J.** Internal view of rapheless valve. **K.** External view of raphe valve. **L.** Internal view of raphe valve.
Scale bars = 10 µm (A-H), 2 µm (I-L).

Anorthoneis Grunow 1868

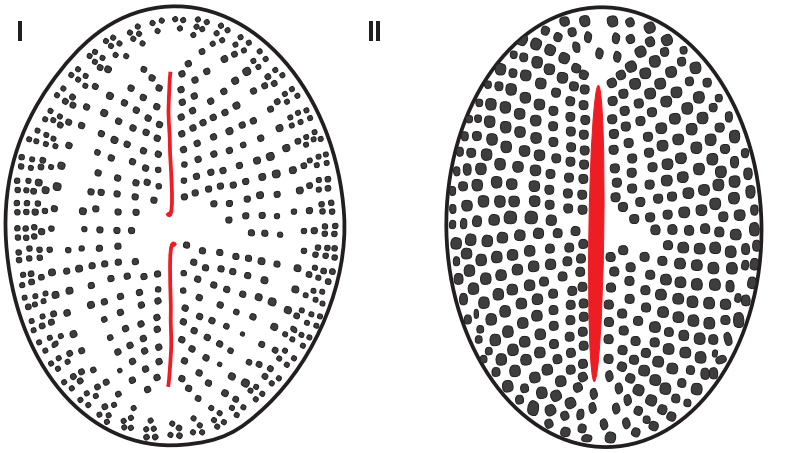
Type species: *Anorthoneis excentrica* (Donkin) Grunow

Characteristics – Cells **monoraphid**, elliptical to almost circular in shape. Cells **heterovalvar**, the raphe (I) and the **axial area** (II) are both located slightly off-center (eccentric). The central and terminal raphe endings are straight. Areolae clearly visible under LM. The valves are very shallow and the mantle is absent.

Plastid structure – Single flat C-shaped plastid (comparable to that of *Cocconeis* Ehrenberg).

Identification of species – Up till now only one species occurs commonly in the freshwaters of the tropics: *Anorthoneis dulcis* M.K. Hein.

Ecology – Cells solitary, free living but usually attached. *Anorthoneis dulcis* is found in benthic habitats in tropical African alkaline oligotrophic waters. Other members of this genus are considered to be restricted to marine habitats.



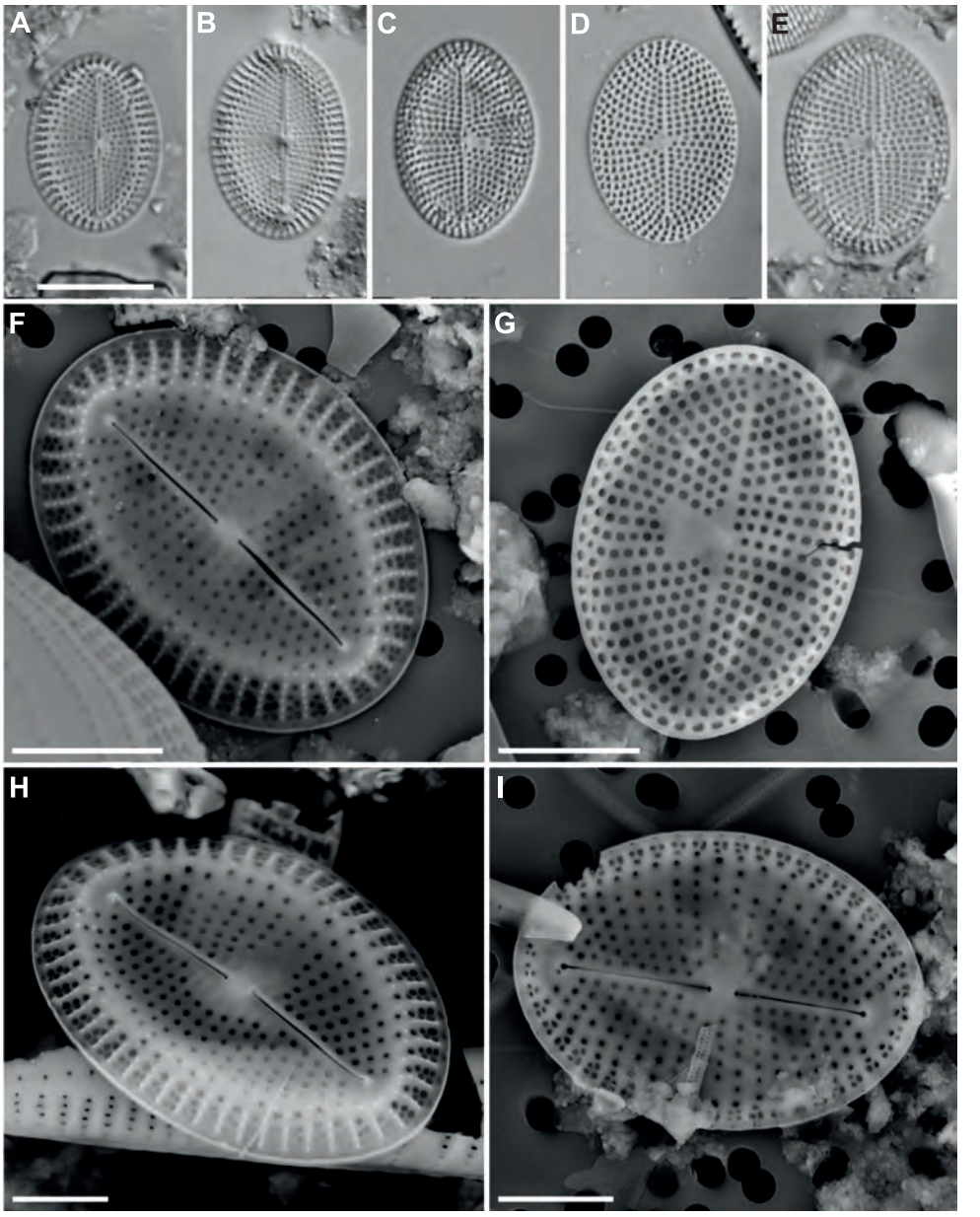


Fig. 98. *Anorthoneis dulcis*. **A-E**. LM, cleaned material. **A-C, E**. Valve view of RV. **D.** Valve view of RLV. **F-I.** SEM. **F, H.** External view of RV. **I**. Internal view of RV. **G**. Internal view of RLV, note unilateral expansion of the central area. Scale bars = 10 µm (A-E), 5 µm (F-G), 3 µm (H), 4 µm (I).

Cocconeis Ehrenberg 1836

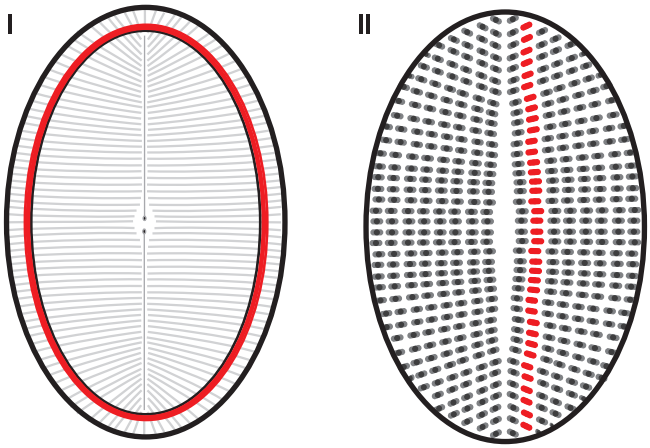
Type species: *Cocconeis scutellum* Ehrenberg

Characteristics – Cells **monoraphid**, ranging in size. Shape elliptical to almost round. Strongly **heterovalvar** with the raphid valve (I) having fine striae composed of small areolae, while the rapheless valve (II) has striae composed of large easily discernable areolae which often form undulating longitudinal lines (II, Fig. 100: C, G). Raphid valve usually has a **hyaline ring** (I, Fig. 100: B, D, H, I) running close to the valve margin. Valve may be strongly curved on the transapical axis (e.g. *Cocconeis pediculus* Ehrenberg; Fig. 101: A, D).

Plastid structure – A single C-shaped plastid is present (Fig. 99: A-E).

Identification of species – Species in this genus are distinguished based on cell size and shape as well as the areolae size and number and distribution on the rapheless valve as well as the width of the axial area. The raphid valve is very similar between species. The structure and presence/absence of the hyaline ring as well as the curvature of the cell in girdle view can be of importance in distinguishing species.

Ecology – Cells solitary and attached. Found in both fresh and brackish waters across a range of pH and trophic levels. Cells adapted to attach to a variety of substrata, may occur *en-masse* completely covering the surface of filaments of green algae (Fig. 99: A-B; Fig. 101: A).



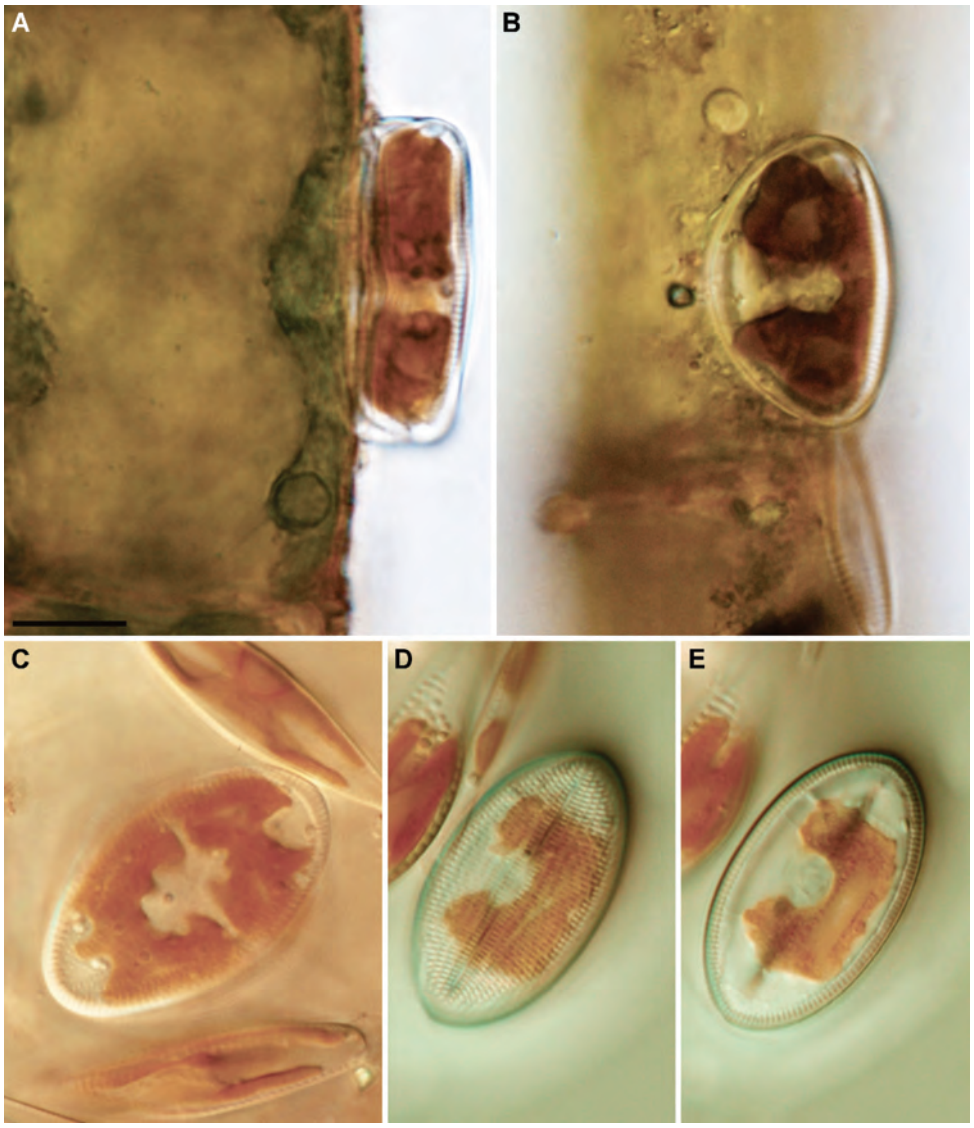


Fig. 99. *Cocconeis* spp. **A-E**. LM. **A-B**. Living cells, girdle view, cells appressed to the surface of filamentous algae. **C**. Living cell showing lobed chloroplast and lipid droplets. **D-E**. Living cells valve view, different foci of the same cell. Scale bar = 10 µm.

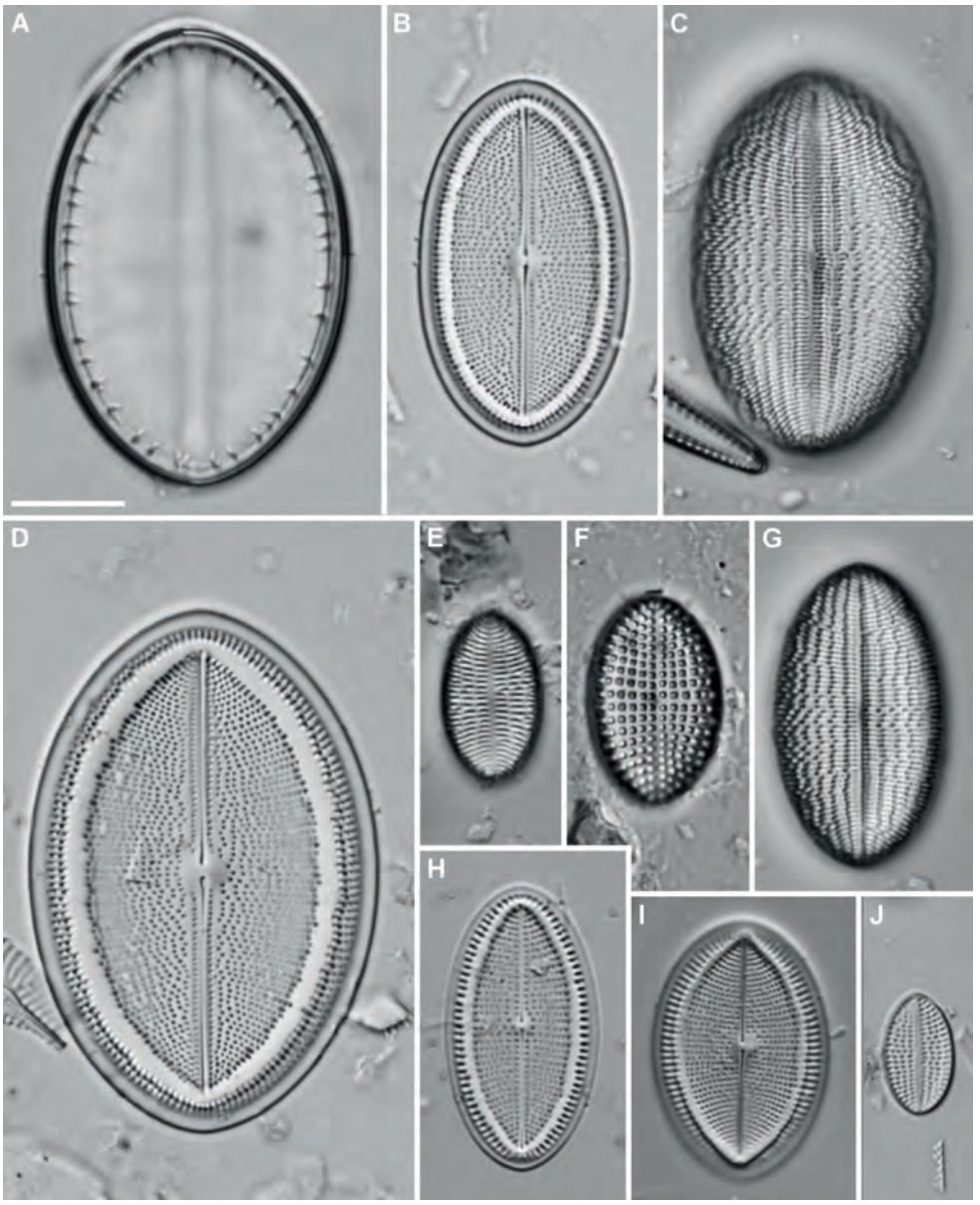


Fig. 100. *Cocconeis* spp. **A-J**. LM. **A**. Copula of *Cocconeis* sp. **B, D, H, I**. RV views of Cocconeis spp. **C, E, F, G, J**. RLV views of *Cocconeis* spp. **F**. *C. schroederi* Foged.
Scale bar = 10 µm.

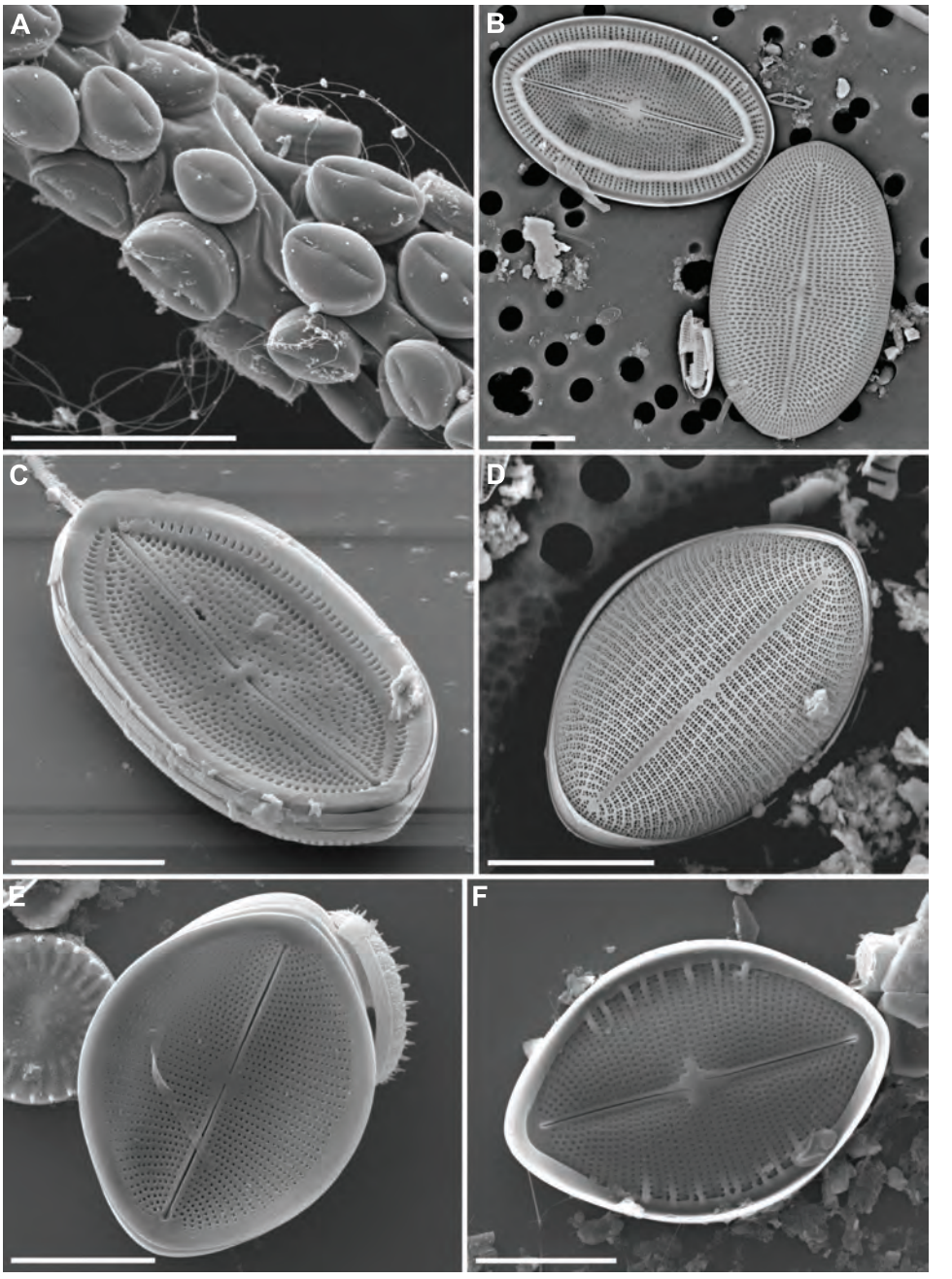


Fig. 101. *Cocconeis* spp. **A-F**. SEM. **A**. Cells of *Cocconeis pediculus* on the surface of a filament of green algae. **B**. *Cocconeis placentula* Ehrenberg RV (left) and RLV (right). **C**. Oblique view of RV of *Cocconeis* sp. **D-F**. External view of *Cocconeis pediculus*, RLV (**D**), RV (**E**), internal view of valve (**F**). Scale bars = 5 µm (A),10 µm (B-F).

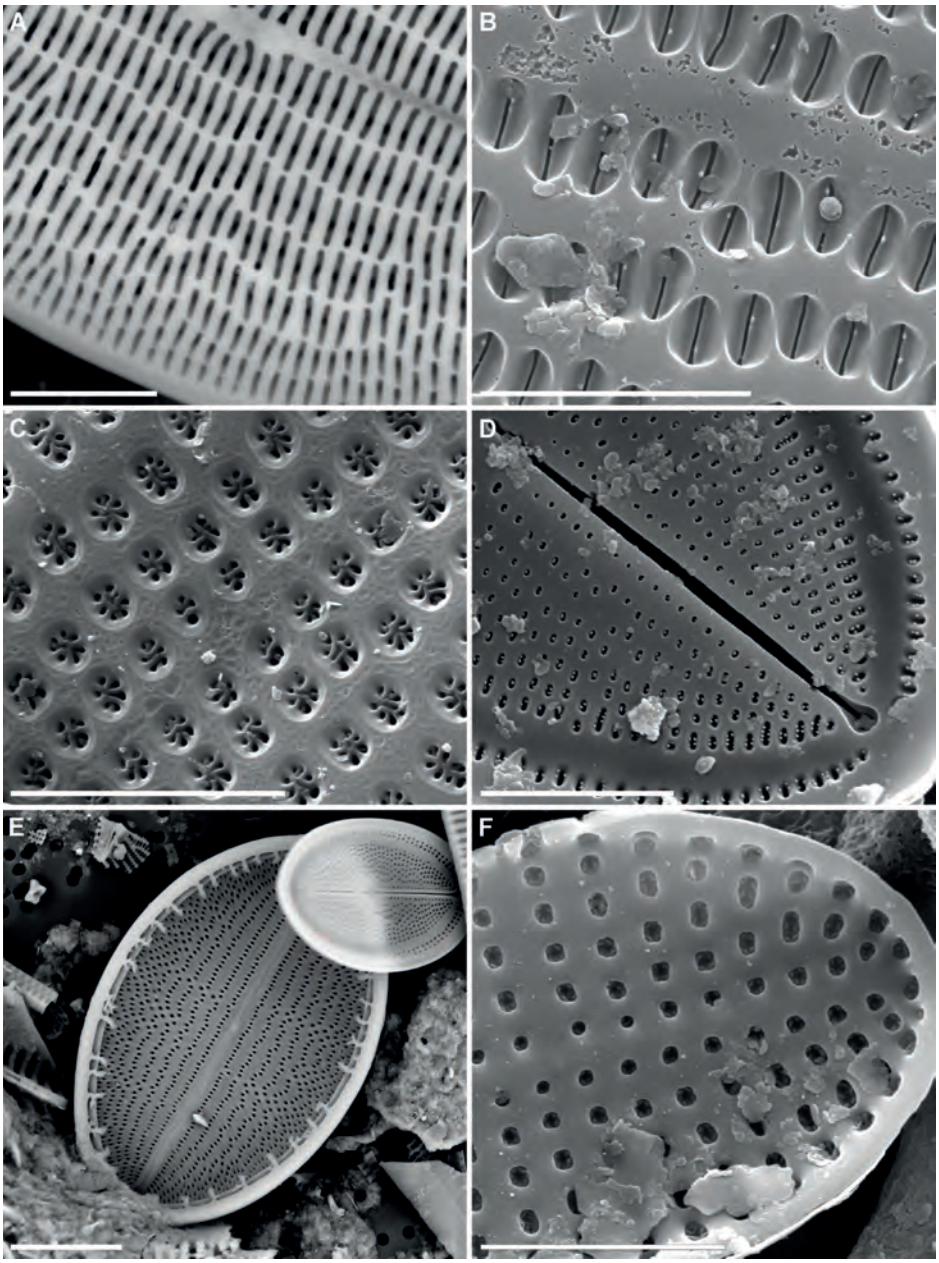


Fig. 102. *Cocconeis* spp. **A-F.** SEM. **A**. Areolae on RLV of *Cocconeis pediculus*. **B**. Areolae on RLV of a *Cocconeis* sp. **C**. Areolae on RLV of *C. schroederi*. **D**. Areolae on RV of a *Cocconeis* sp. **E**. Internal view of RV of *Cocconeis* sp., note copula with silica outgrowths. **F**. Internal view of valve showing areolae on RV of *C. schroederi*.
Scale bars = 3 µm (A-B), 4 µm (C), 5 µm (D, F), 10 µm (E).

Achnanthidium Kützing 1844

Type species: *Achnanthidium microcephalum* Kützing

SYNONYM:

Achnanthes Bory 1822 pro parte

Characteristics – Cells of *Achnanthidium* are **monoraphid**, mostly delicate and the valve structure can be difficult to observe in LM. The cells are bent in girdle view (I) and **heterovalvar** with only one valve bearing a raphe (II) and the second bearing no raphe slit and only an **axial area** (III). Striae are rather difficult to resolve in LM and usually no areolae can be observed. As cells are bent, it is difficult to focus on both the central and apical striae at the same time; this may be a useful tool to distinguish *Achnanthidium* from other similar sized taxa such as *Eolimna* Lange-Bertalot & W. Schiller which have a flat valve face, as well as a more elliptical shape.

Plastid structure – There is one large plastid lying against the girdle which may extend beneath one (Fig. 103: A) or both valves (Fig. 103: D). Often 2 lipid droplets may be observed at each end of the cell (Fig. 103: A, E).

Identification of species – Species and varieties in this genus are distinguished based on cell size and shape as well as the shape of the apices. The orientation and or presence/absence of striae in the central area as well as the shape of the central area are very important.

Ecology – Cells solitary or in pairs, usually attached by an apical mucilage stalk (Fig. 103: A-B) but also motile. Found in waters of varying trophic state but most taxa in this genus are thought to occur in well oxygenated waters. It may occur *en-masse* completely covering the surface of, for example, filamentous green algae.

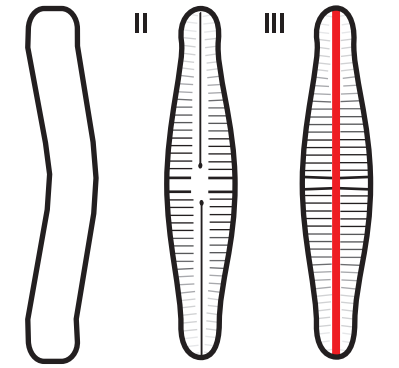


Fig. 103. *Achnanthidium* spp. **A-I**. LM. **A-B**. Living cells with mucilage stalks (arrows). Living cell, girdle view. **C-D**. Living cells of *Achnanthidium exiguum* (Grunow) Czarnecki. **E**. Living cell, valve view, note lipid droplets (arrow). **F-I.** Cleaned material of *Achnanthidium* spp. **F-G**. *Achnanthidium taiaense* (J.R. Carter & Deny) J.C.Taylor, E. Morales & Ector.
Scale bars = 10 µm (A-H).

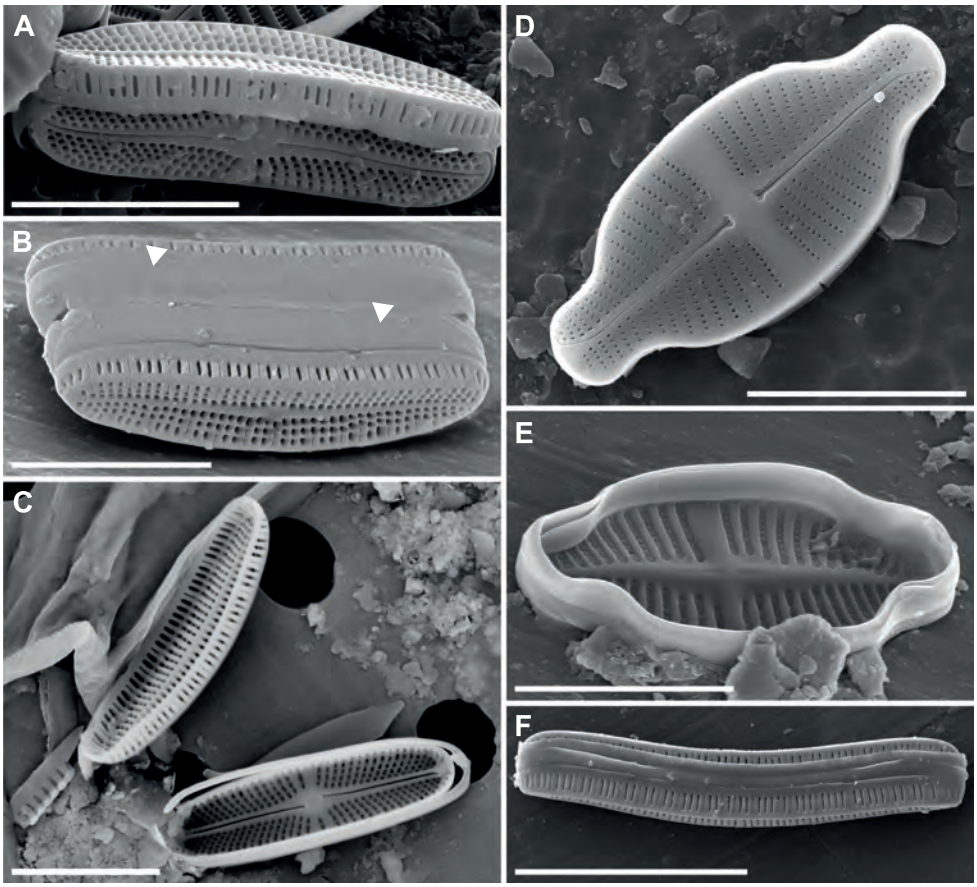


Fig. 104. *Achnanthidium* spp. **A-F**. SEM. **A-B.** Exterior view of valve, oblique view. **B**. Exterior view, detail of the valvocopulae (arrows). **C.** Internal views of valve of RLV and RV. **D**. External view of valve of *Achnanthidium exiguum*. **E**. Internal view of valve of *A. exiguum.* **F**. Girdle view. Scale bars = 5 µm (A-E), 10 µm (F).

Planothidium Round & Bukhtiyarova 1996

Type species: *Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot

SYNONYM:

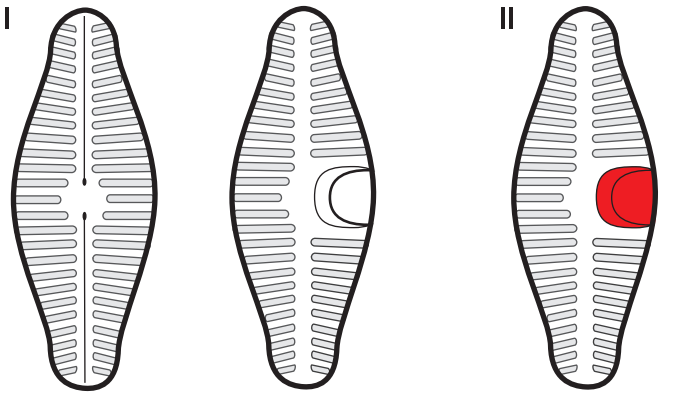
Achnanthes Bory 1822 pro parte

Characteristics – Cells **heterovalvar**, **monoraphid**, elliptical with rounded, broadly rounded or sub-capitate apices. Curved in girdle view (one valve slightly convex, the other slightly concave). Striae robust and clearly discernable under LM (Fig. 105: C-N), composed of 2 rows of very small round areolae, visible only under SEM (Fig. 106: A-D). Raphe straight and simple (Fig. 105: C, E, G, K, M) with expanded central endings. Rapheless valve (RLV) has a narrow axial area and may possess a **silica hood** (also known as a "horseshoe structure") or other unilateral silica thickening on the interior of the valve (II).

Plastid structure – Single plate-like plastid lying under the RLV valve extending under the girdle (Fig. 105: A-B).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central and axial areas, the shape and curvature of the central raphe endings as well as structure and positioning of the silica thickenings of the RLV.

Ecology – Cells solitary, attached (**adnate**) by the raphe valve face to the substrata. Found in the benthos of mesotrophic to hypereutrophic waters with moderate to high conductivities.



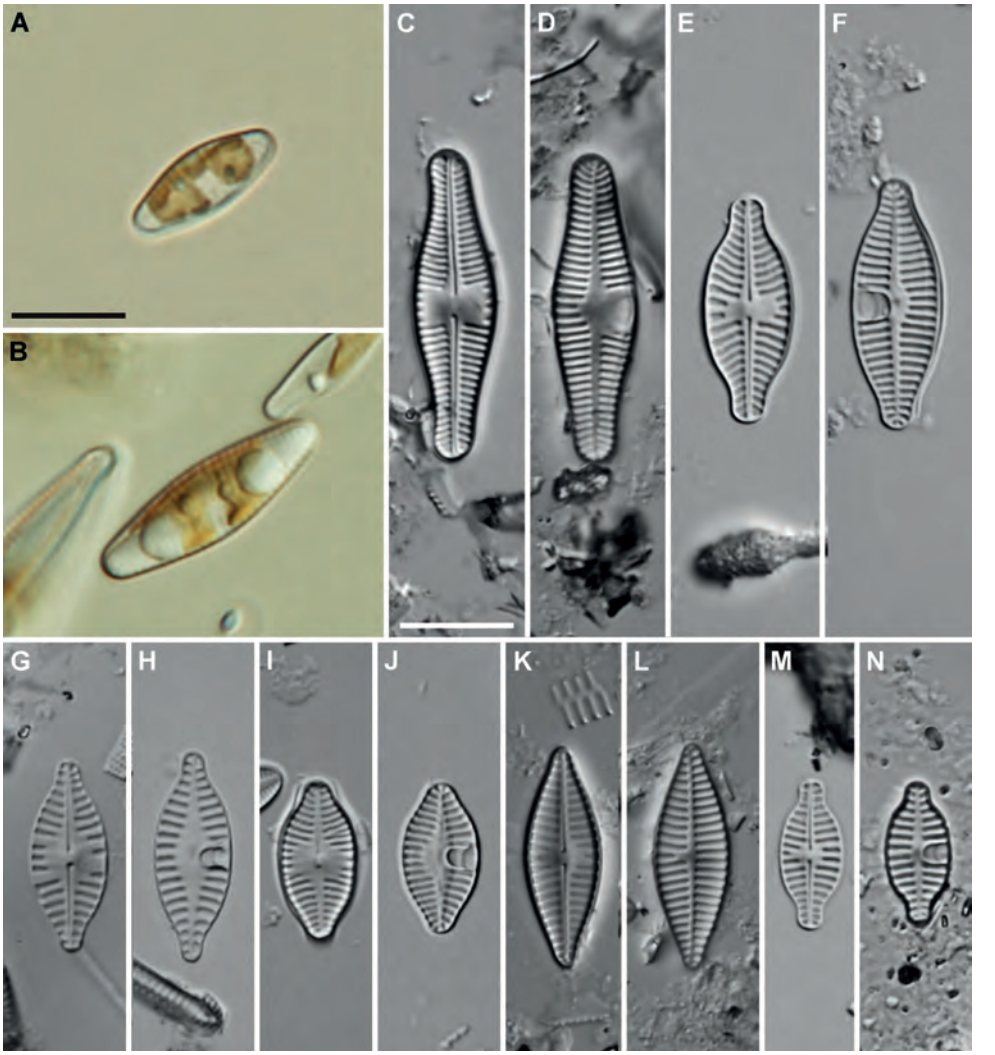


Fig. 105. *Planothidium* spp. **A-N**. LM. **A-B.** Living cells. **C-N.** Cleaned valves. **C, E, G, I, M.** *Planothidium* spp., raphe valves. **D, F, H, J, N.** *Planothidium* spp., rapheless valve, note "horseshoe structure" of silica hood. **K.** *Planothidium delicatulum* (Kützing) Round & Bukhtiyarova, raphe valve. **L.** *Planothidium delicatulum*, rapheless valve.
Scale bar = 10 µm (A-N).

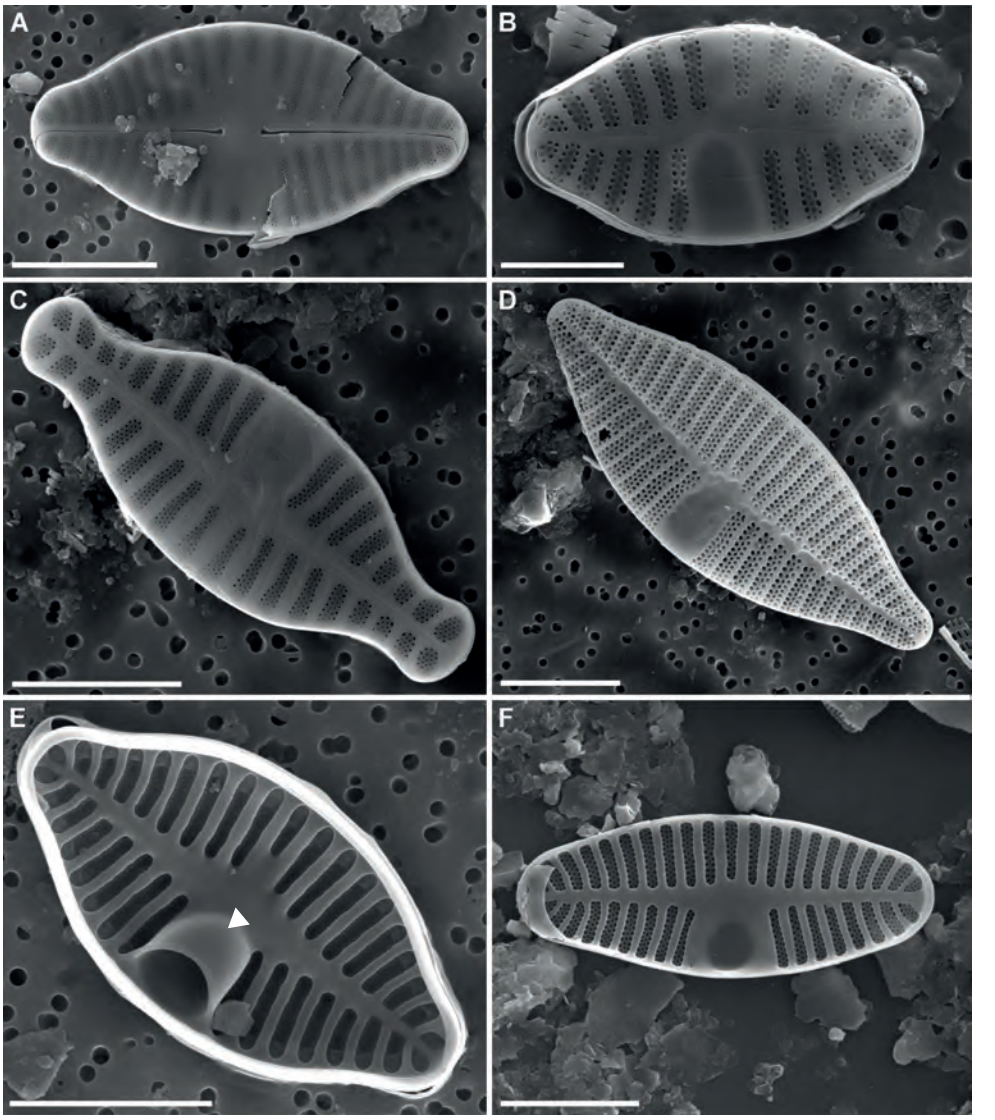


Fig. 106. *Planothidium* spp. **A-F**. SEM. **A.** External view of raphe valve. **B-C.** External view of rapheless valves. **D.** *Planothidium delicatulum*, external view of rapheless valve. **E-F.** Internal view of rapheless valves, note "horseshoe structure" of silica hood (arrow **- E)**.
Scale bars = 2 µm (A-F).

Cavinula D.G. Mann & Stickle 1990

Type species: *Cavinula cocconeiformis* (W. Gregory ex Greville) D.G. Mann & Stickle

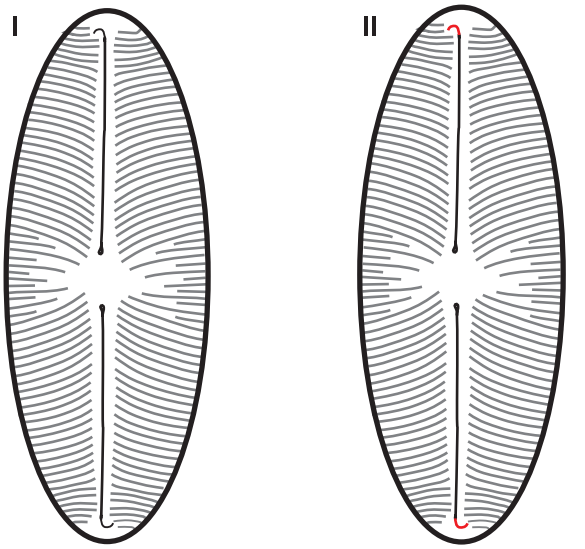
SYNONYM:
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid** with radiate striae, areolae may be small and difficult to observe under LM (Fig. 107: C, D) or large and very clearly distinguishable (Fig. 107: E, H-I). In general, the terminal raphe fissures endings do not extend onto the valve mantle and are usually curved in opposite directions (II).

Plastid structure – Cells with one or two H-shaped plastids often with many lobes (Fig. 107: A-B).

Identification of species – Species in this genus are distinguished based on cell size and shape as well as striae pattern, density and the structure of the areolae.

Ecology – Cells solitary and motile. Found in the benthos of oligotrophic waters and extending to moist sub-aerial habitats. Some species may be found in water with higher conductivities.



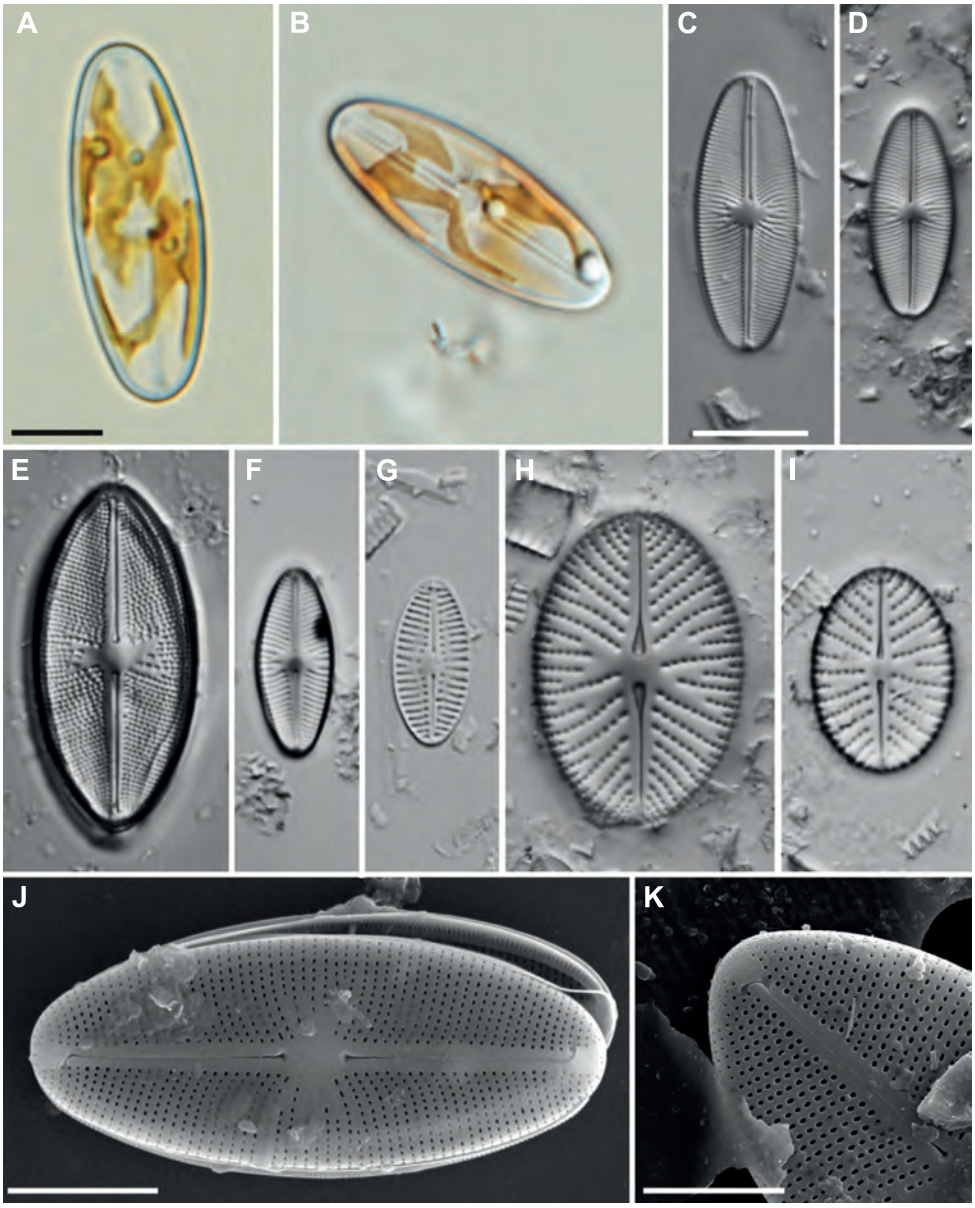


Fig. 107. *Cavinula* spp. **A-I.** LM. **A-B.** Living cells of *Cavinula davisiae* Bahls, note highly lobed plastid structure. **C-D.** Cleaned cells of *C. davisiae.* **E, F, H.** Various tropical African taxa. **G.** *Cavinula lilandae* Cocquyt, de Haan & J.C. Taylor. **I.** *C. scutelloides* (W. Smith) Lange-Bertalot. **J-K.** SEM, external view of valve of *C. davisiae* showing complete valve (**J**) and detail of terminal raphe ending (**K**). Scale bars = 10 µm (A-J), 5 µm (K).

Diadesmis Kützing 1844

Type species: *Diadesmis confervacea* Kützing

SYNONYM:

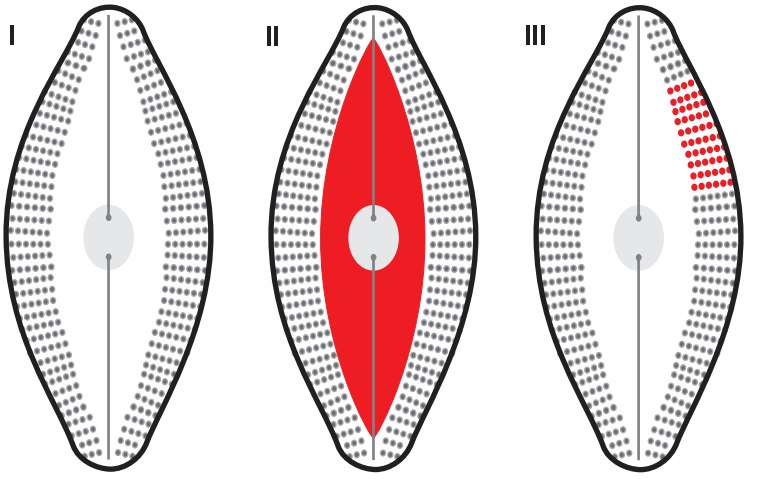
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, with broad **axial area** (II). Striae easily discernable composed of relatively widely spaced round areolae (III). Raphe with straight central and terminal endings. Cells often observed in girdle view as the individual cells form chains which may often not be separated during cleaning (Fig. 108: A, I, J). The valve mantle has a single row of large and distinctly visible elongate areolae (Fig. 108: A, I, J). Cells may have connective spines at the junction of the valve face and mantle which are not easily visible under LM.

Plastid structure – Cells with a single lobed plastid.

Identification of species – Up till now only one species known from tropical Africa: *Diadesmis confervacea.*

Ecology – Cells always linked face to face to form ribbon-like colonies. Found in the benthos of eutrophic waters with moderate conductivity.



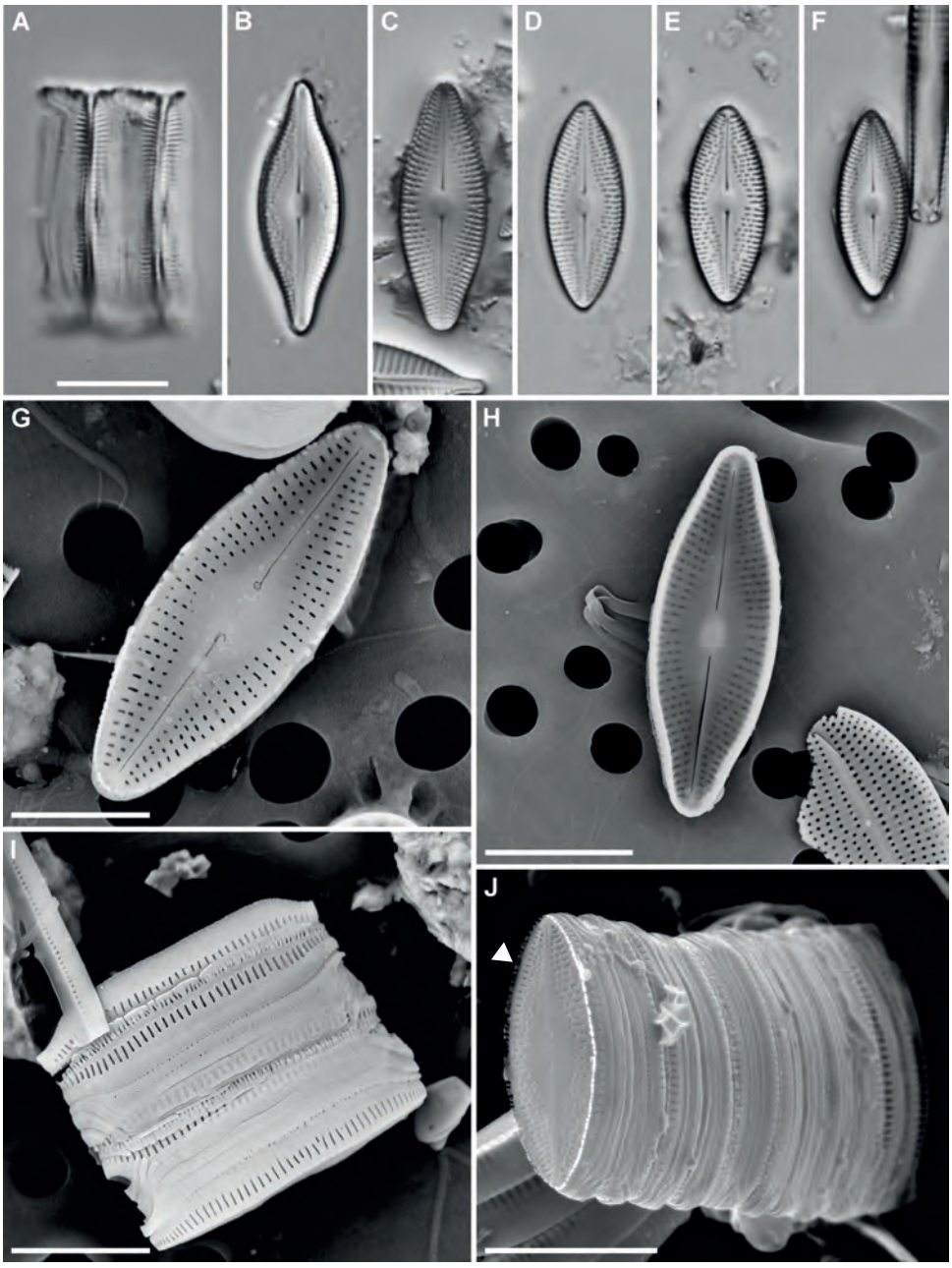


Fig. 108. *Diadesmis* spp. **A-F**. LM. **A**. Girdle view of *Diadesmis confervacea*. **B**. *Diadesmis* sp. **C-F**. Valve view *D. confervacea*. **G-J**. SEM. **G**. External view of valve. **H**. Internal view of valve. **I**. Girdle view of two frustules. **J**. Oblique view of a chain of frustules, note broad axial area and marginal spine-like structures (arrow).
Scale bars = 10 µm (A-F, J), 5 µm (G), 8 µm (H-I).

Humidophila R.L. Lowe, Kociolek, J.R. Johansen, Van de Vijver, Lange-Bertalot & Kopalová 2014

Type species: *Humidophila undulata* R.L. Lowe, Kociolek & J.R. Johansen

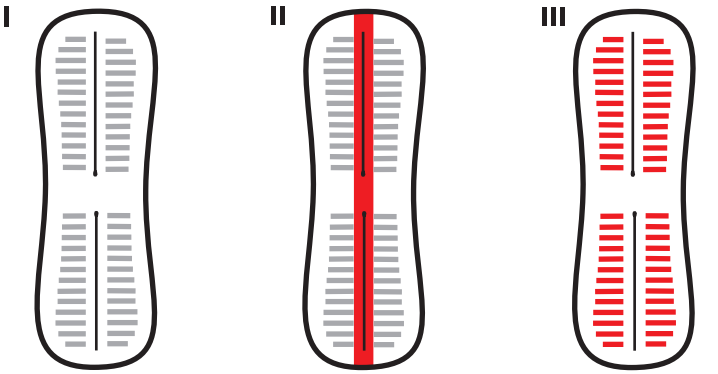
SYNONYM:
Diadesmis Kützing 1844 pro parte

Characteristics – Cells **biraphid**, usually small in size, with narrow **axial area** (II). Striae composed of few elongate areolae (often only 1-2) (III, Fig. 109: G). The mantle has a single row of large and distinctly visible areolae (Fig. 109: G). The raphe endings are straight both in the centre of the cell and at the apices and do not extend onto the margin.

Plastid structure – Cells with a single lobed plastid (Fig. 109: A).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices and structure and density of the striae as well as the number of areolae in each stria.

Ecology – Cells solitary and motile. Found in the benthos of acidic oligotrophic waters, most common in moist sub-aerial habitats such as mosses and damp rocks. Washed into streams by anthropogenic activities such as mining, deforestation, road building etc.



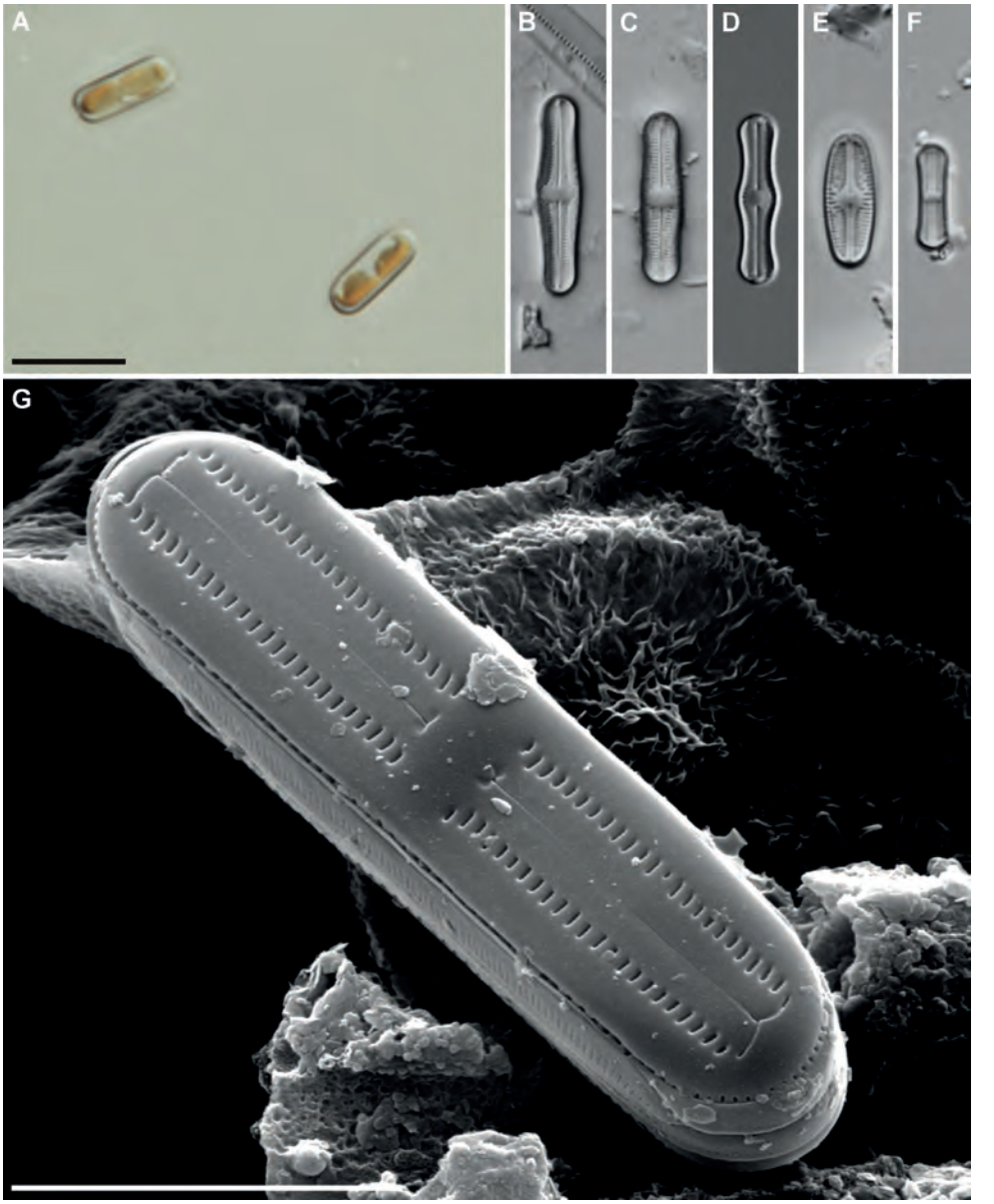


Fig. 109. *Humidophila* spp. **A-F**. LM. **A**. Living cells, girdle view (left), valve view (right). **B-F**. Cleaned material, valve views. **G**. SEM. Oblique external view of valve, note single areolae comprising the striae.
Scale bars = 10 µm (A-F), 5 µm (G).

Luticola D.G. Mann 1990

Type species: *Luticola mutica* (Kützing) D.G. Mann

SYNONYM:

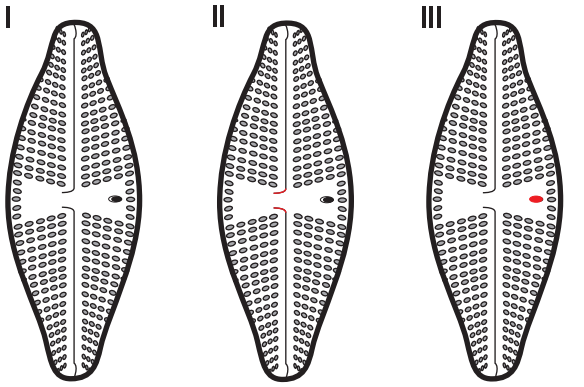
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, small, elliptical to linear elliptical with broadly rounded or capitate apices. Valve margins may undulate. Striae parallel or radiate mid-valve becoming radiate towards the apices, composed of single rows of large areolae easily discernable under LM. Raphe straight and simple (Fig. 110: D-N). with central endings either hooked or bent in the same direction (II) opposite the side with the stigma. Central area variable in shape and extent with single isolated stigma (III; Fig. 110: D-N; Fig. 111: A-F).

Plastid structure – Single plastid with a central pyrenoid (Fig. 110: A-B), lying with its centre along one side of the girdle, 2 lobes extending under each valve face, indented longitudinally under the raphe (Fig. 110: C).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central area and the shape and curvature of the central raphe endings.

Ecology – Cells solitary, free living and motile. Found mostly in terrestrial and sub-aerial habitats, may be washed into rivers and streams.



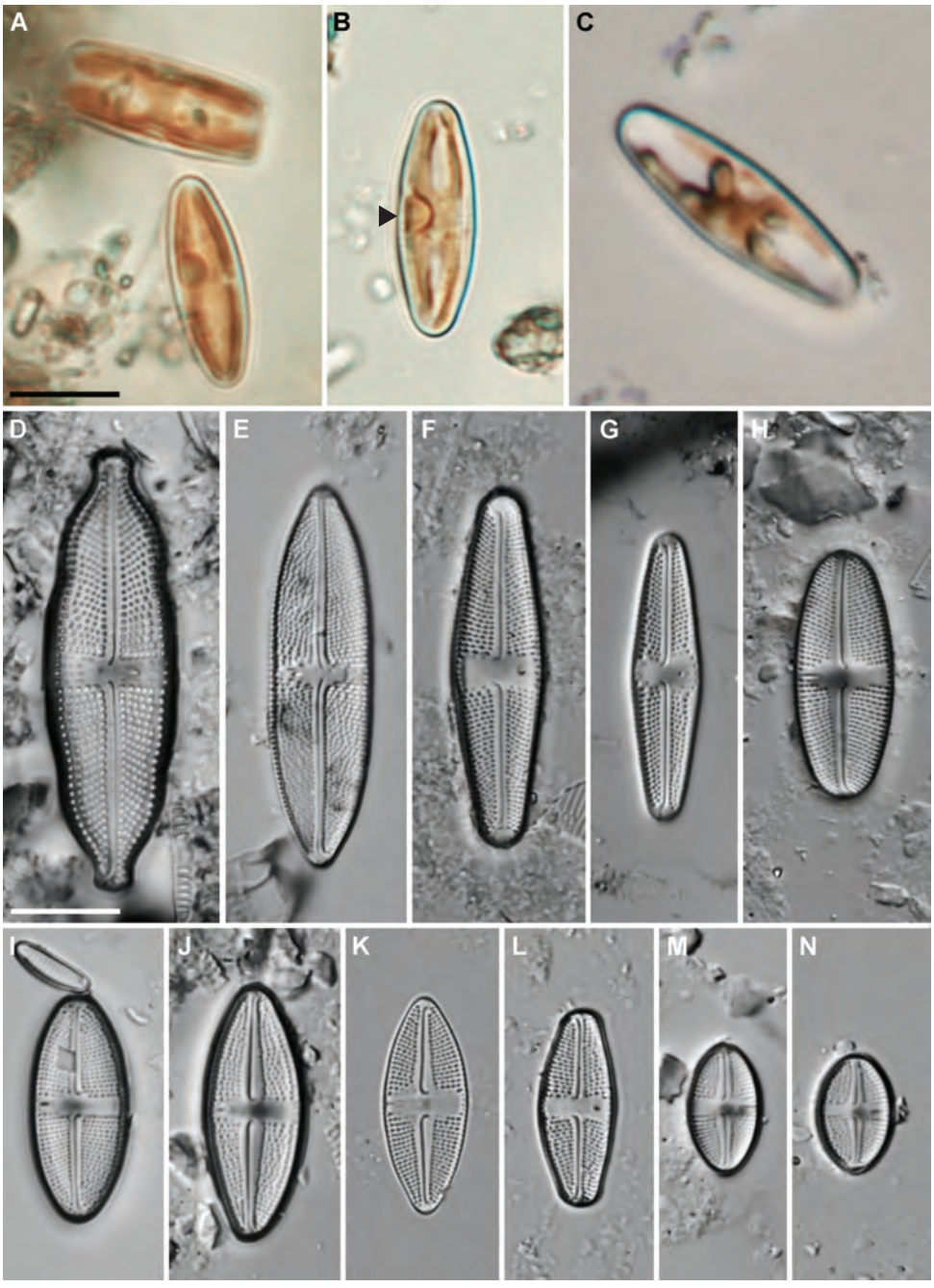


Fig. 110. *Luticola* spp. **A-N.** LM. **A-C.** Living cells, note the central pyrenoid (arrow - **B**). **D-N.** Cleaned valves.
Scale bars = 10 µm (A-N).

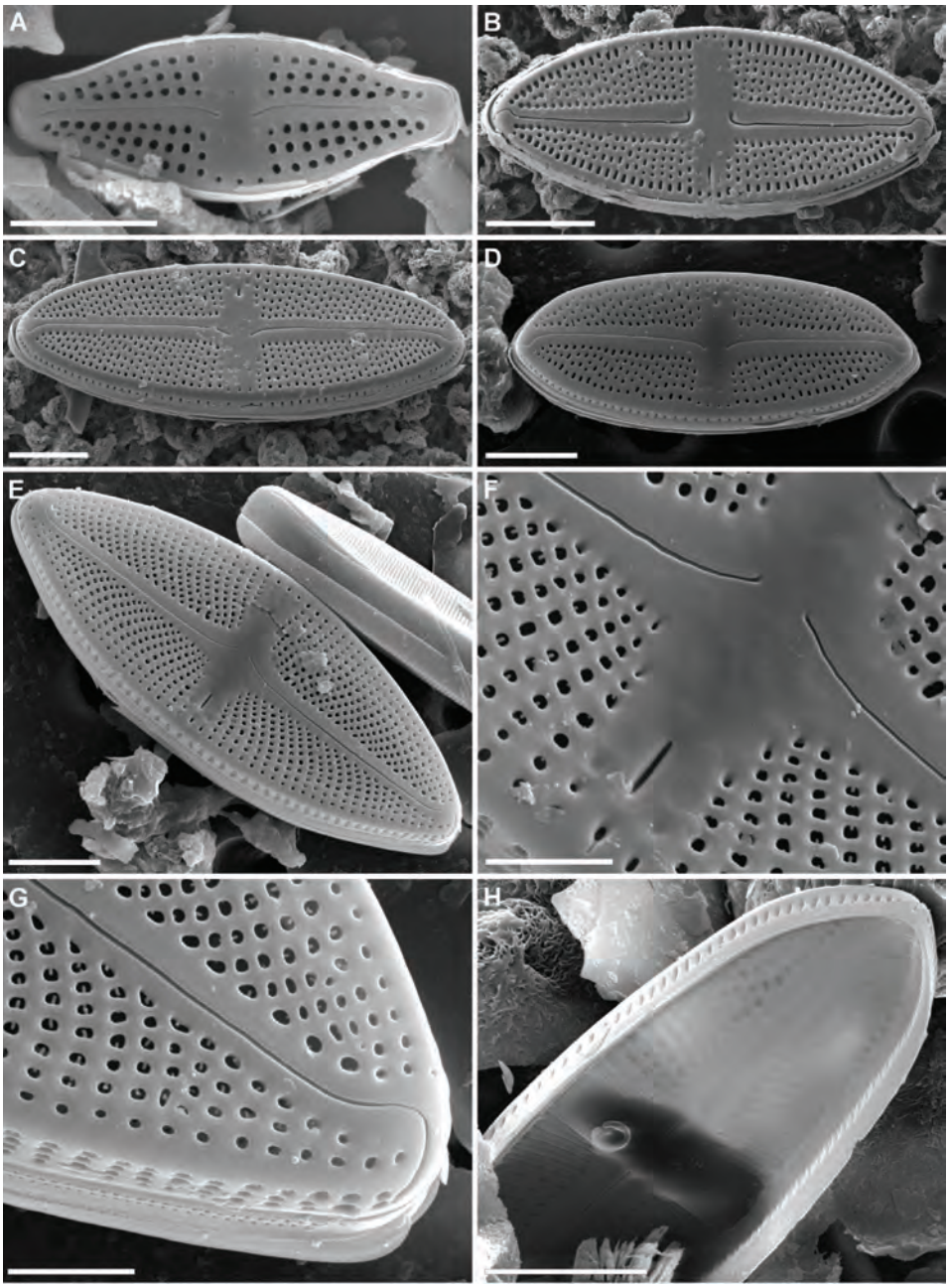


Fig. 111. *Luticola* spp. **A-H.** SEM. **A-E.** External view of valves. **F.** External view of valve, detail of bent central raphe endings and stigma. **G.** External view of valve, detail of apex and hooked terminal raphe ending. **H.** Internal view of valve, detail of stigma.
Scale bars = 5 µm (A-E, H), 2 µm (F-G).

Amphipleura Kützing 1844

Type species: *Amphipleura pellucida* (Kützing) Kützing

Characteristics – Cells **biraphid**, large and long. Striae are very difficult to resolve in LM. The raphe is very short and present only near the apices (Fig. 113: A-D). The raphe branches are not visible under LM and are located between ribs which in LM resemble the eye of a needle (I). These ribs fuse into a single structure (**median rib**) running the length of cell (II).

Plastid structure – Single plastid with 2 lobes (H-shaped, Fig. 112: A-B). Large pyrenoid in the center of the cell (C), several lipid droplets scattered through the cell.

Identification of species – Up till now only one species known from tropical Africa: *Amphipleura pellucida*.

Ecology – Cells solitary, free living in the benthos. Occurs in oligo- to mesotrophic waters.

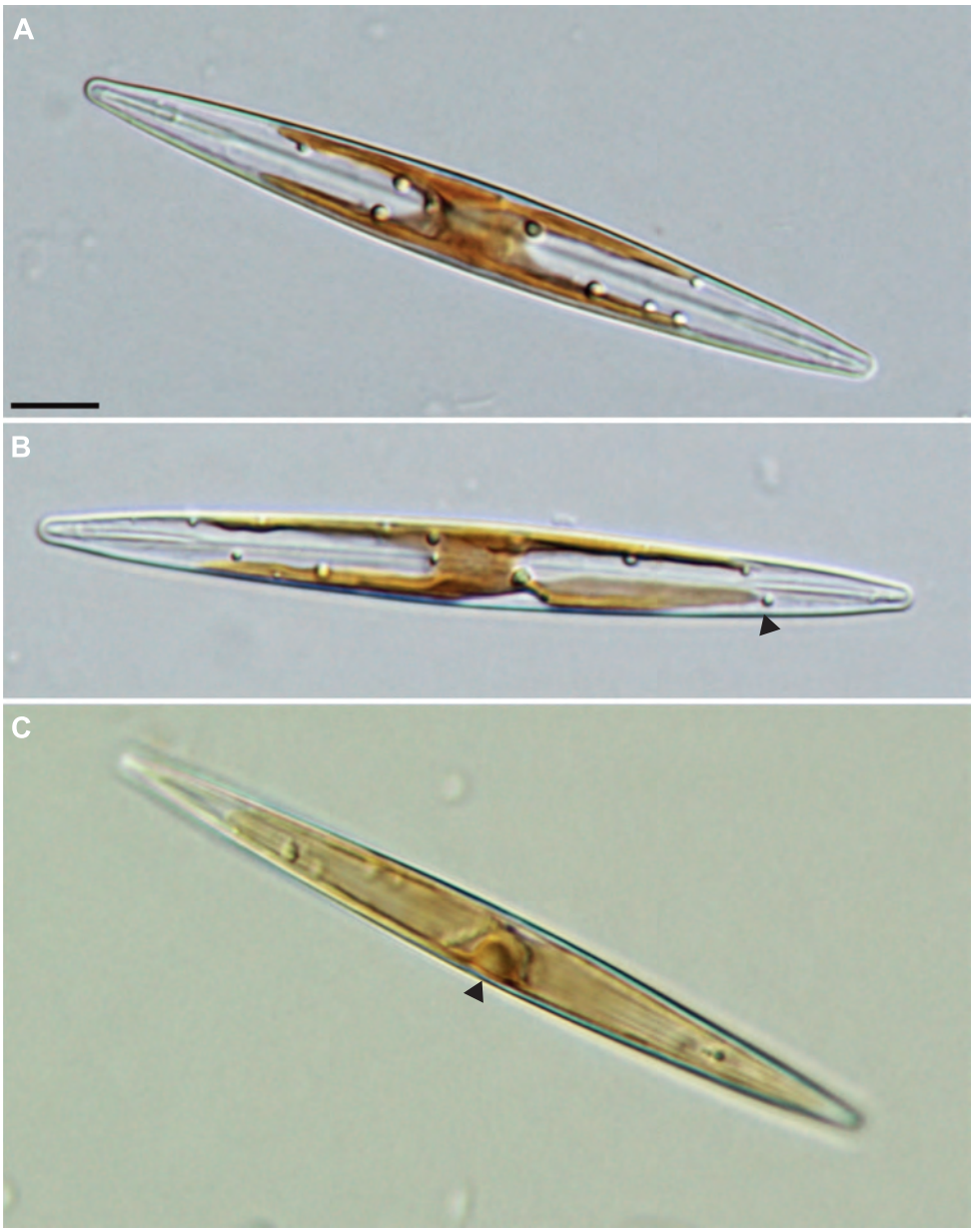


Fig. 112. *Amphipleura pellucida*. **A-C.** LM. **A-B.** Living cells, valve view, note lipid droplets (arrow - **B**). **C.** Living cell, girdle view, note large central pyrenoid (arrow). Scale bar = 10 µm.

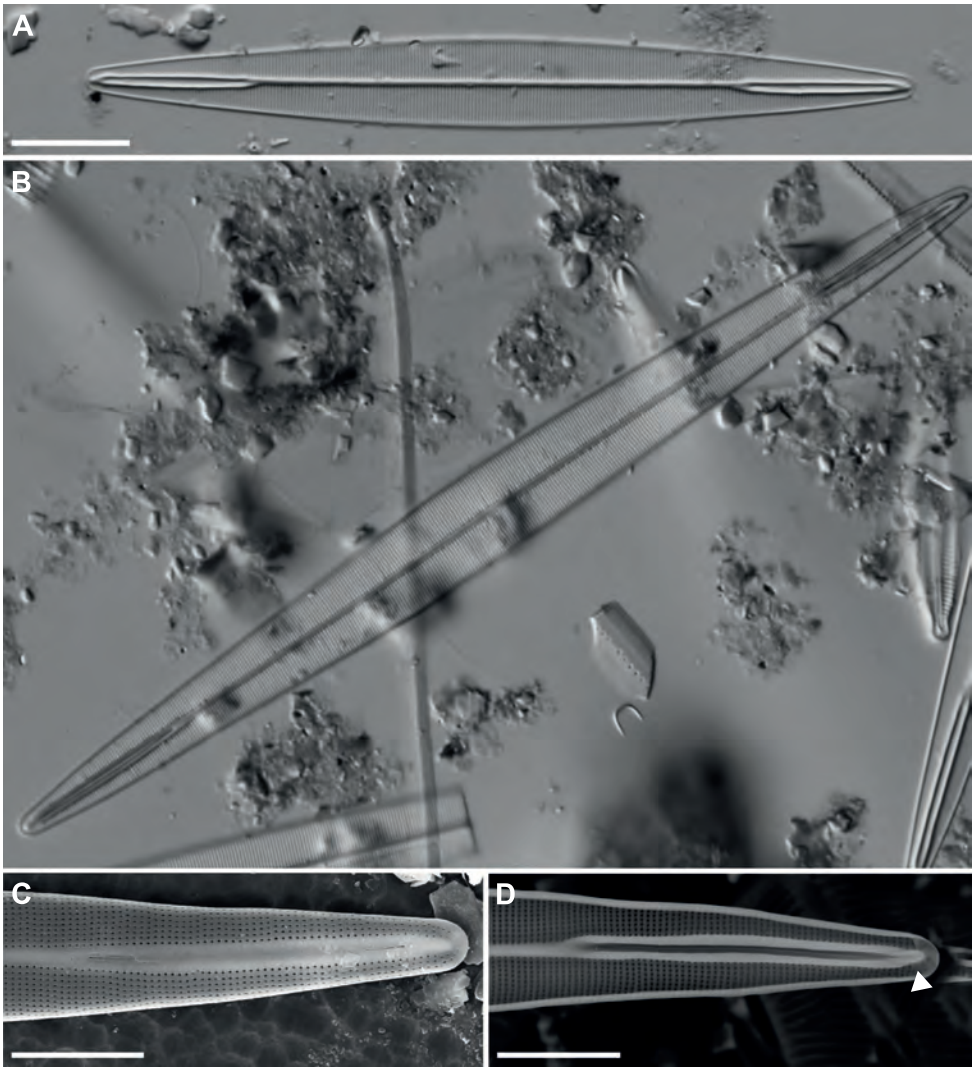


Fig. 113. *Amphipleura pellucida*. **A-B.** LM, cleaned material, valve view. **C-D.** SEM. **C.** External view of valve showing shortened raphe slit. **D.** Internal view of valve view showing thickened central rib, axial ribs parallel to the raphe, and the helictoglossa (arrow).
Scale bars = 10 µm (A-B), 5 µm (C-D).

Frustulia Rabenhorst 1853

Type species: *Frustulia saxonica* Rabenhorst

Characteristics – Cells **biraphid**, ranging in size. Margins may undulate or have a constriction mid-valve. Raphe between two clearly visible thickened ribs (III). Raphe terminates near the apices in characteristic **porte-crayon endings**, visible both in LM (II; Fig. 115: A) and under SEM (Fig. 116: F). Striae composed of very small areolae arranged into both transapical and longitudinal striae.

Plastid structure – Two plate-like plastids each containing a central pyrenoid (Fig. 114).

Identification of species – Species can be identified by cell size, cell shape, undulations of the valve margin, shape of the apices, structure and density of the striae as well as structure of the axial and central area including whether the silica ribs are continuous or interrupted in the central area (Fig. 115).

Ecology – Cells solitary, free living and motile or colonial living in mucilage tubes (Fig. 114: D). Found in the benthos of acidic oligotrophic waters with low conductivities.

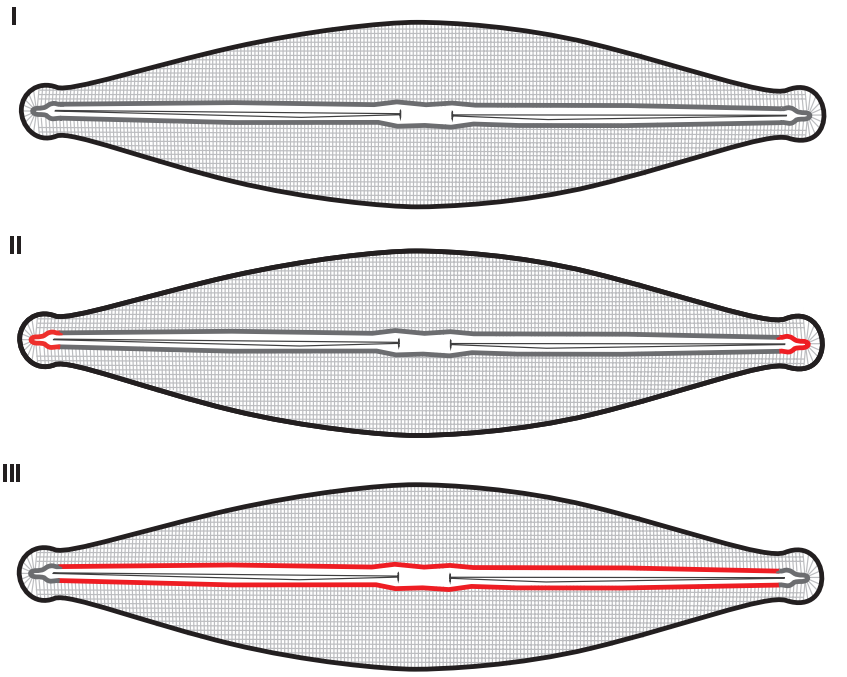


Fig. 114. *Frustulia* spp. **A-D.** LM, living cells. **A, D.** Cells inhabiting mucilage (arrow) tubes. **B.** Valve view, not large lipid droplets. **C.** Girdle view. Scale bars = 10 µm (A-D).

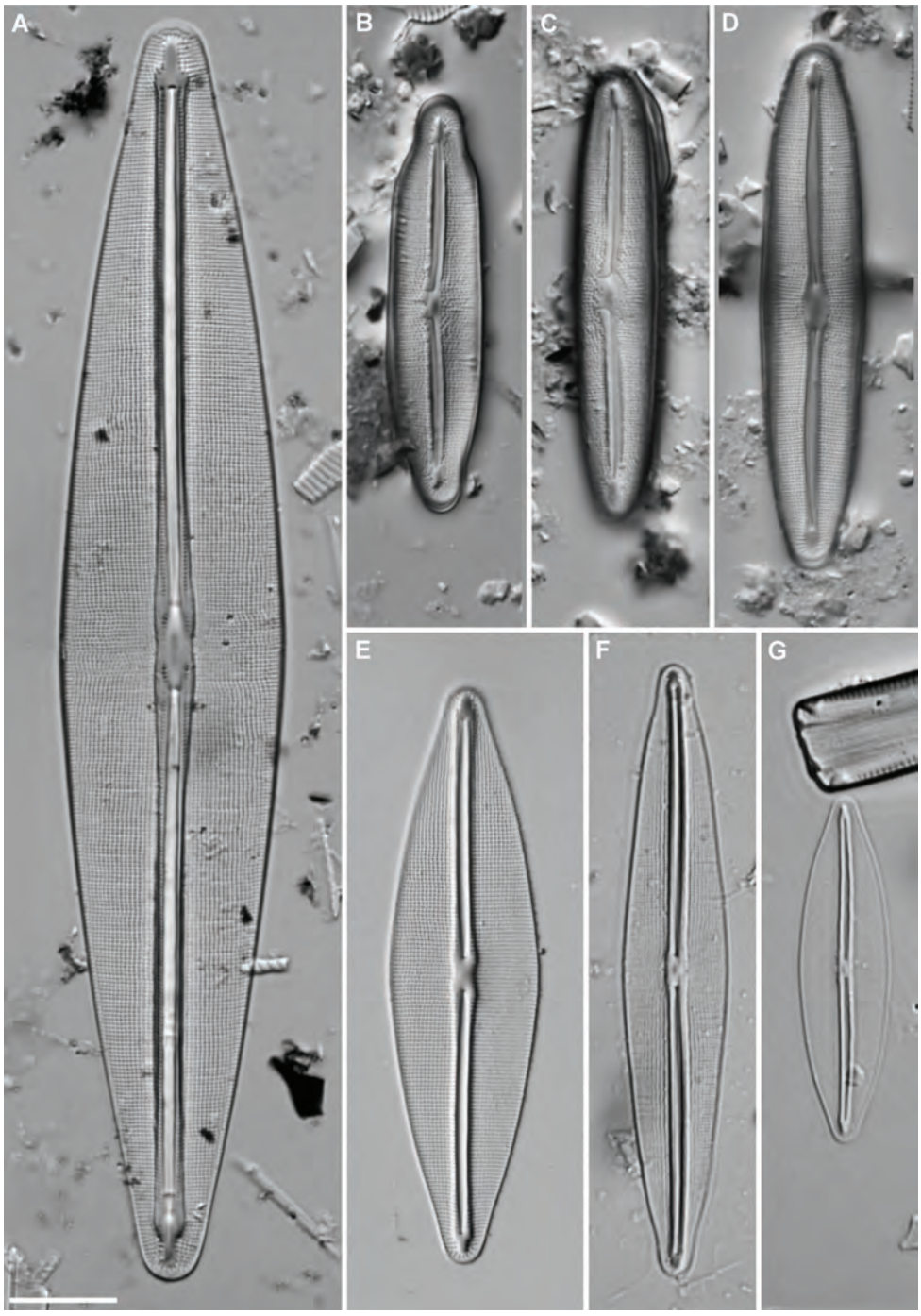


Fig. 115. *Frustulia* spp. **A-G.** LM, cleaned valves.
Scale bar = 10 µm (A-G).

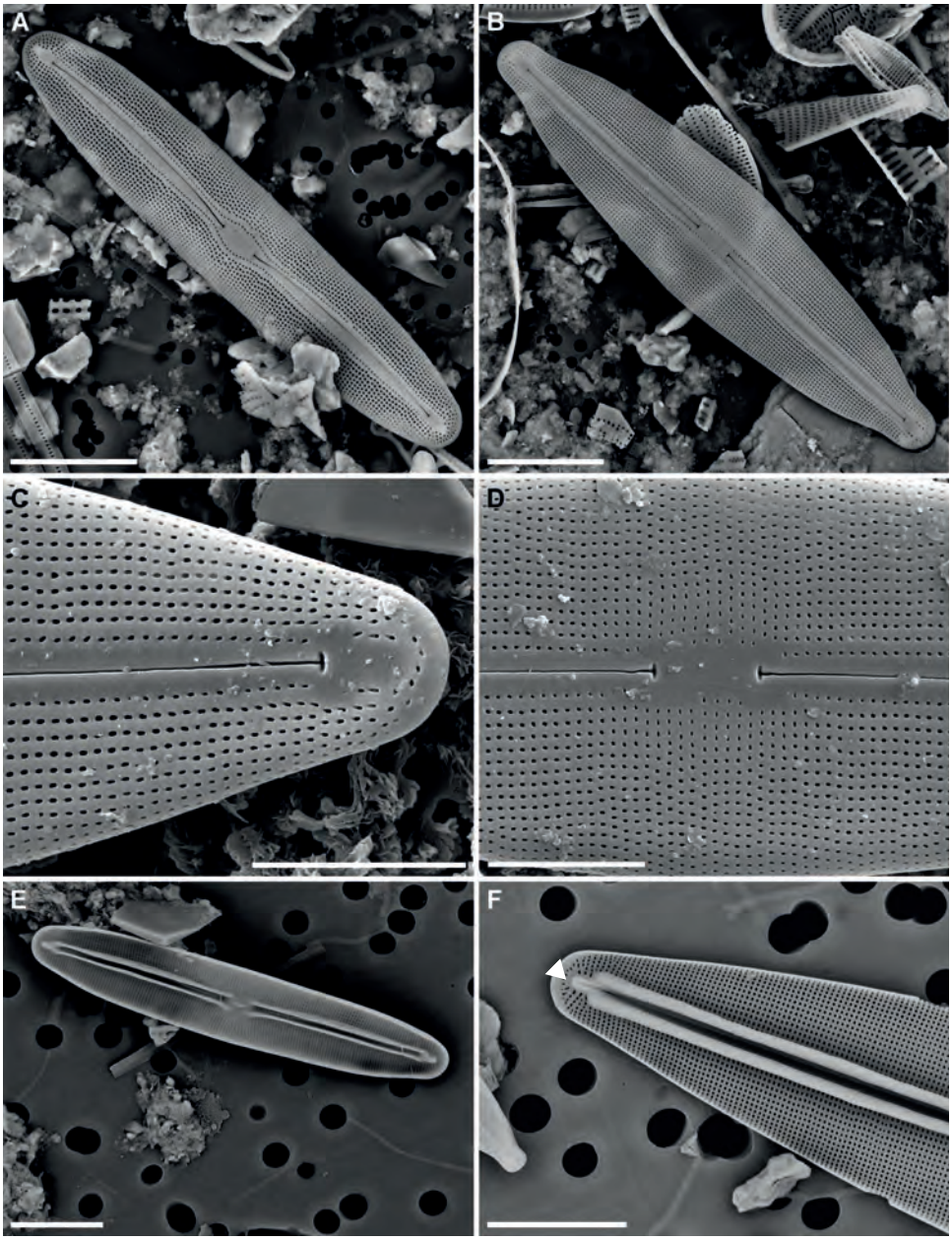


Fig. 116. *Frustulia* spp. **A-F.** SEM. **A.** *F. vulgaris* (Thwaites) De Toni, external view of valve. **B.** External view of valve of *Frustulia* sp. **C.** External view of valve, detail of apex. **D.** External view of valve, detail of central area, note T-shaped raphe endings. **E.** *F. vulgaris*, internal view of valve. **F.** *F. vulgaris*, internal view of valve, detail of apex, note helictoglossa (arrow).
Scale bars = 10 µm (A-B, E-F), 5 µm (C-D).

Brachysira Kützing 1836

Type species: *Brachysira aponina* Kützing

SYNONYM:

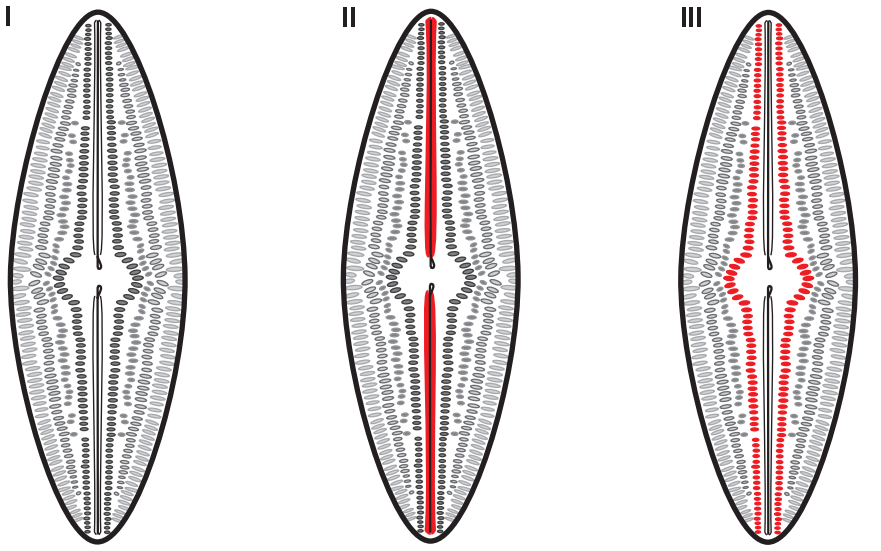
Anomoeoneis Pfitzer 1871 pro parte

Characteristics – Cells **biraphid**, size and shape variable, linear or linear-lanceolate sometimes cruciform, **biraphid** with raphe located between 2 distinct transapical ribs (II, Fig. 117: K, Fig. 118: B). Axial area very narrow. Areolae distinct and irregular in distribution creating undulating longitudinal lines (III).

Plastid structure – Single plastid with lobes extending under each valve face (Fig. 117: A-D). Large lipid droplets visible (Fig.117: B).

Identification of species – Species in this genus are distinguished based on cell size and shape and the shape of the apices. Size of the areolae is an important characteristic to consider as well as the presence or absence of a distinct swelling in the central area.

Ecology – Cells solitary and motile. Found in acidic oligotrophic waters.



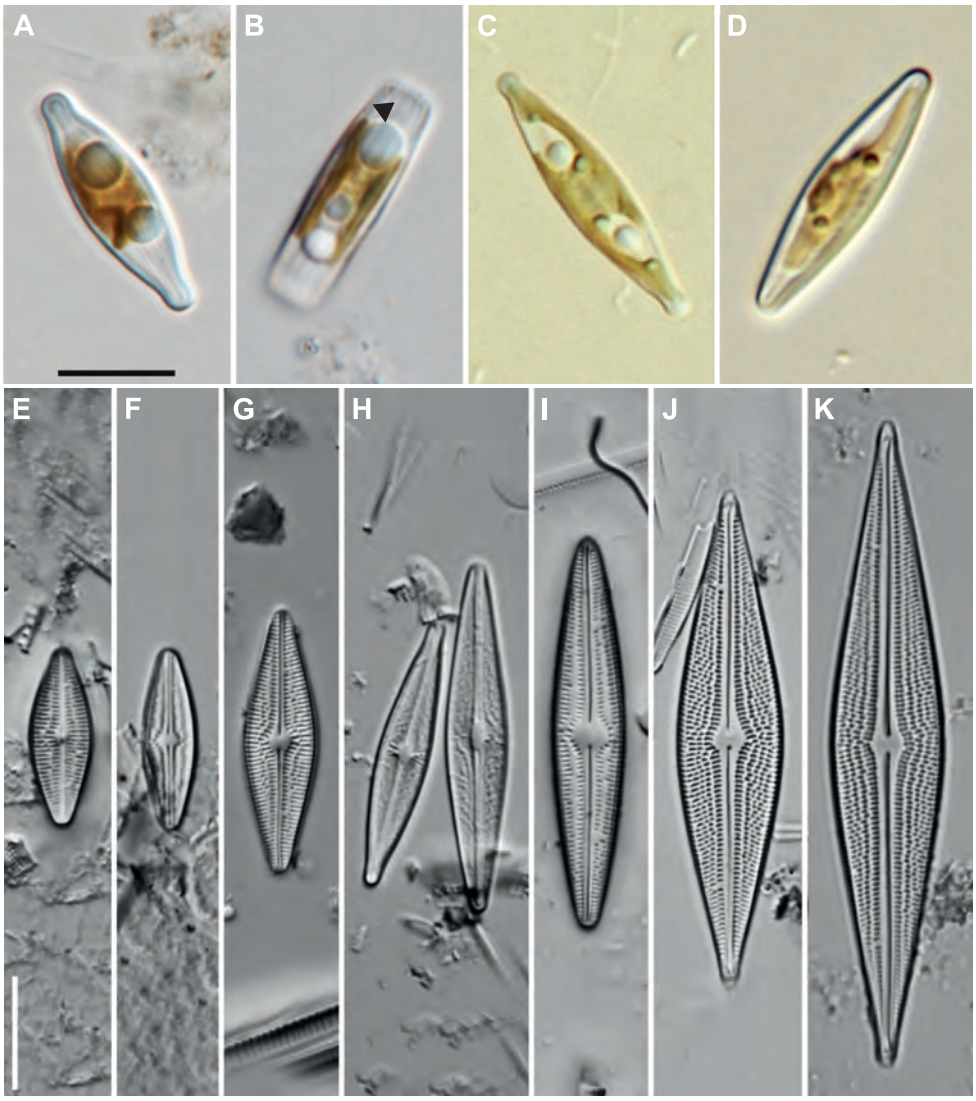


Fig. 117. *Brachysira* spp. **A-K.** LM. **A-D**. Living cells. **A, C-D.** Valve view. **B.** Girdle view, note large lipid droplets (arrow). **E-K.** Cleaned material showing valve views. Scale bars = 10 µm (A-K).

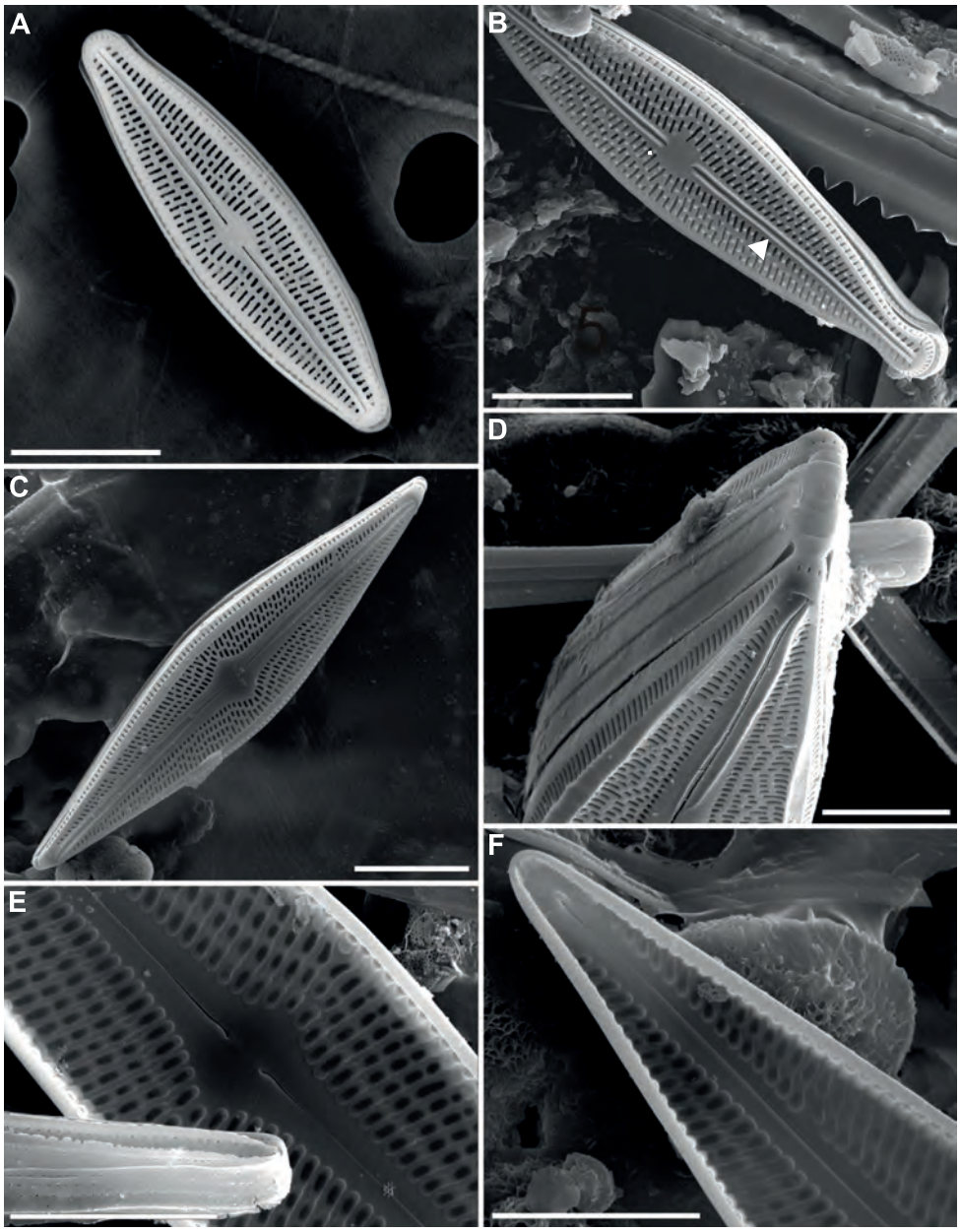


Fig. 118. *Brachysira* spp. **A-F.** SEM. **A-C.** External view of valve, note transapical rib (arrow **- B**). **D.** External view of valve, cell apex showing structure of terminal raphe ending. **E.** Internal view of valve showing central raphe endings. **F.** Internal view of valve showing terminal raphe ending and helictoglossa.
Scale bars = 5 µm (A-B, D-F), 10 µm (C).

Neidium Pfitzer 1871

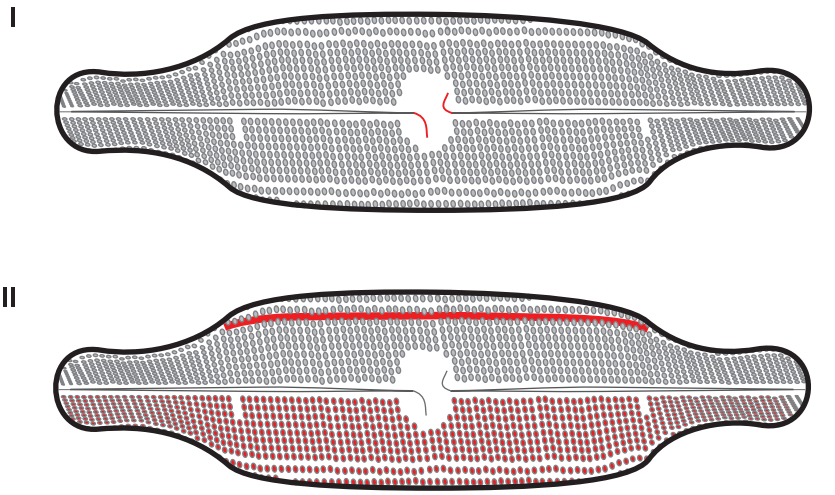
Type species: *Neidium affine* (Ehrenberg) Pfitzer

Characteristics – Cells **biraphid**, variable in size and outline, usually linear to linear elliptic with strongly protracted capitate or rostrate apices. Some taxa have undulate (Fig. 119: E) or tri-undulate valve margins and acutely rounded apices (Fig. 119: D). Striae are coarse, composed of single rows of easily discernable areolae. Striae may be convergent on the upper half of the valve and radiate on the lower half (II). Raphe has distinctive central endings, deflected in opposite directions, which can be hooked or curved or have one hooked and one curved ending (I; Fig. 120: A-C; Fig. 121: A, C). Striae interrupted near the margin by one or several longitudinal hyaline lines (II; Fig. 119: B-E, G-I; Fig. 120: A-C). Voight discordance is clearly discernable (II; Fig. 120: B; Fig. 121: B).

Plastid structure – Cells with 4 plastids each containing a pyrenoid and extending under the valve faces (Fig. 119: A).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, orientation and density of the striae as well as shape of the central area and the shape and curvature of the central raphe endings.

Ecology – Cells solitary, free living and motile. Found in the benthos of acidic and alkaline oligotrophic waters with moderate conductivities.



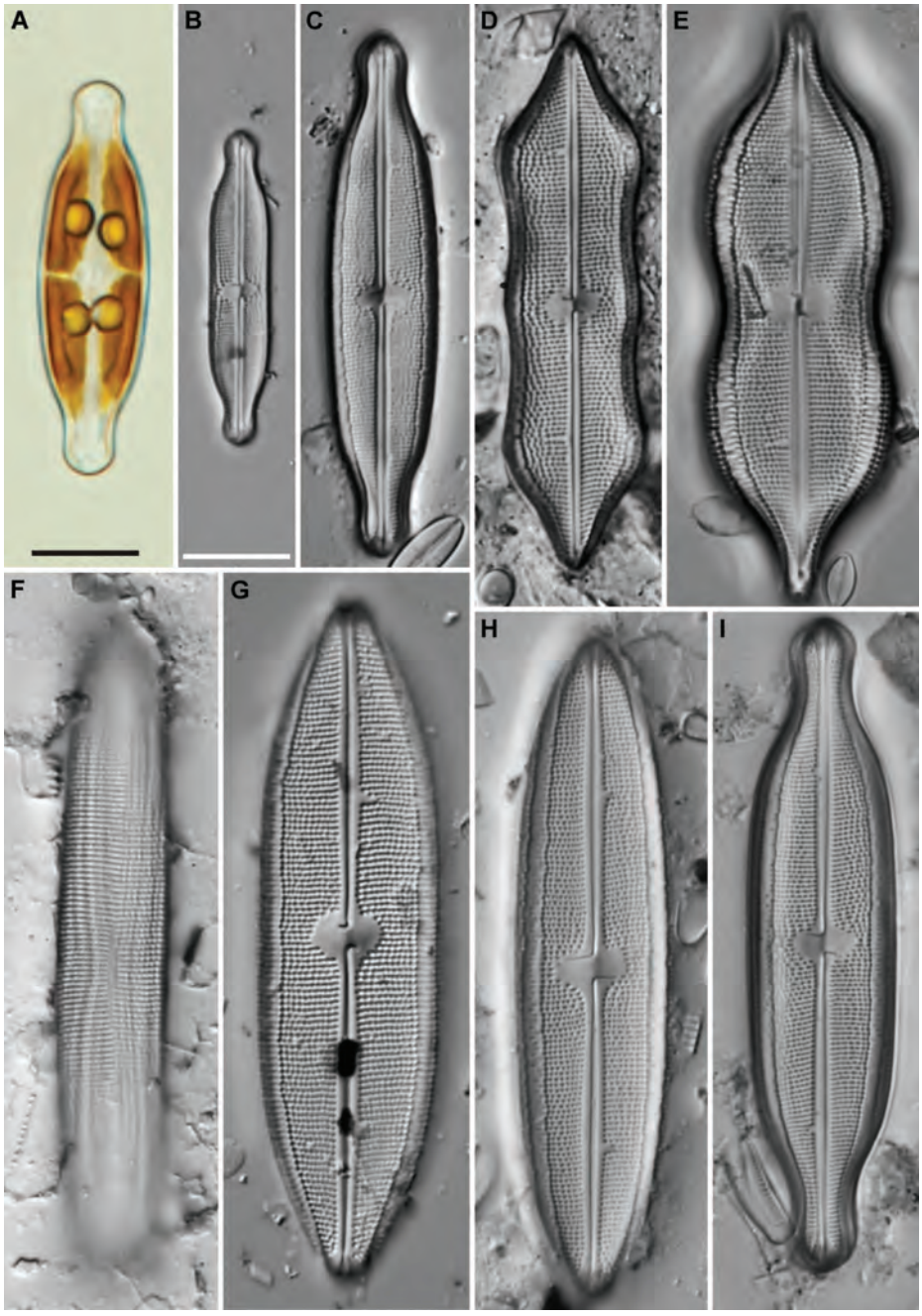


Fig. 119. *Neidium* spp. **A-I.** LM. **A.** Living cell, note the 4 plastids each bearing a pyrenoid. **B-I.** Cleaned valves. **B-E, G-I.** Valve views, note longitudinal hyaline lines near the valve margin. **F.** Girdle view.
Scale bars = 10 µm (A-I).

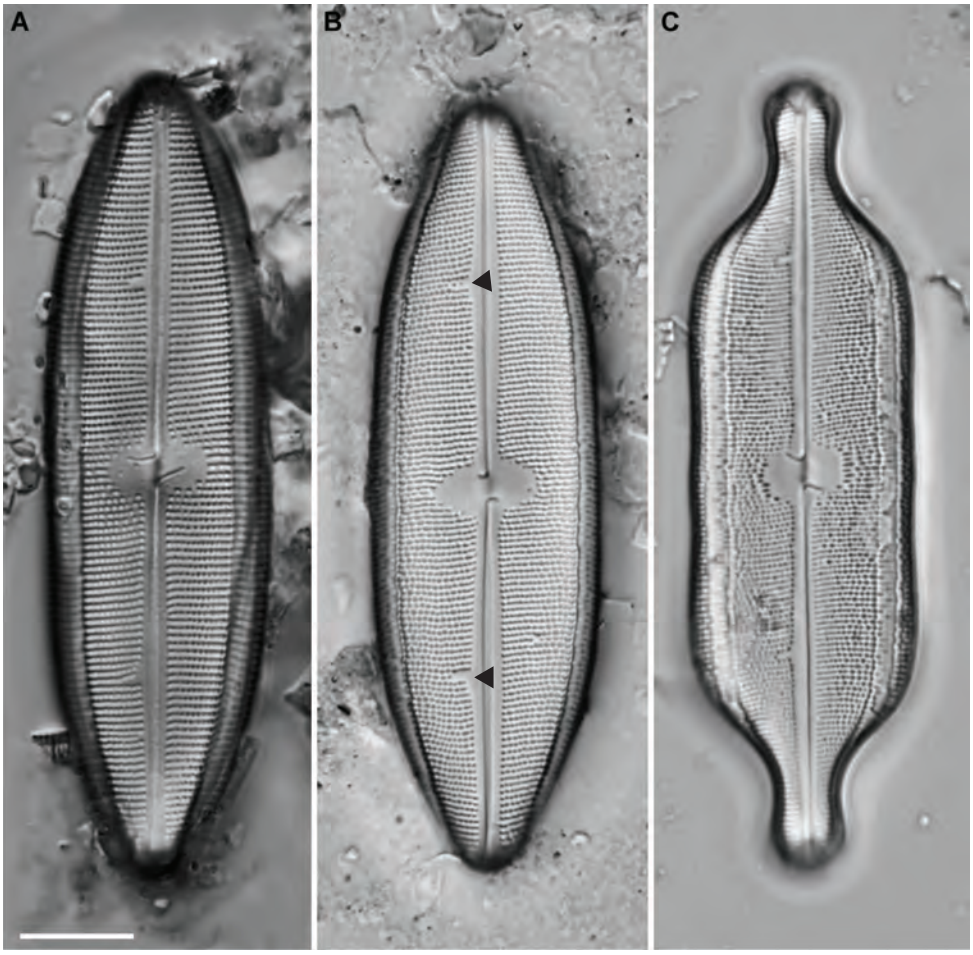


Fig. 120. *Neidium* spp. **A-C.** LM, valve views, note longitudinal hyaline lines near the valve margin and the Voight discordance (arrows - **B**).
Scale bar = 10 µm (A-C).

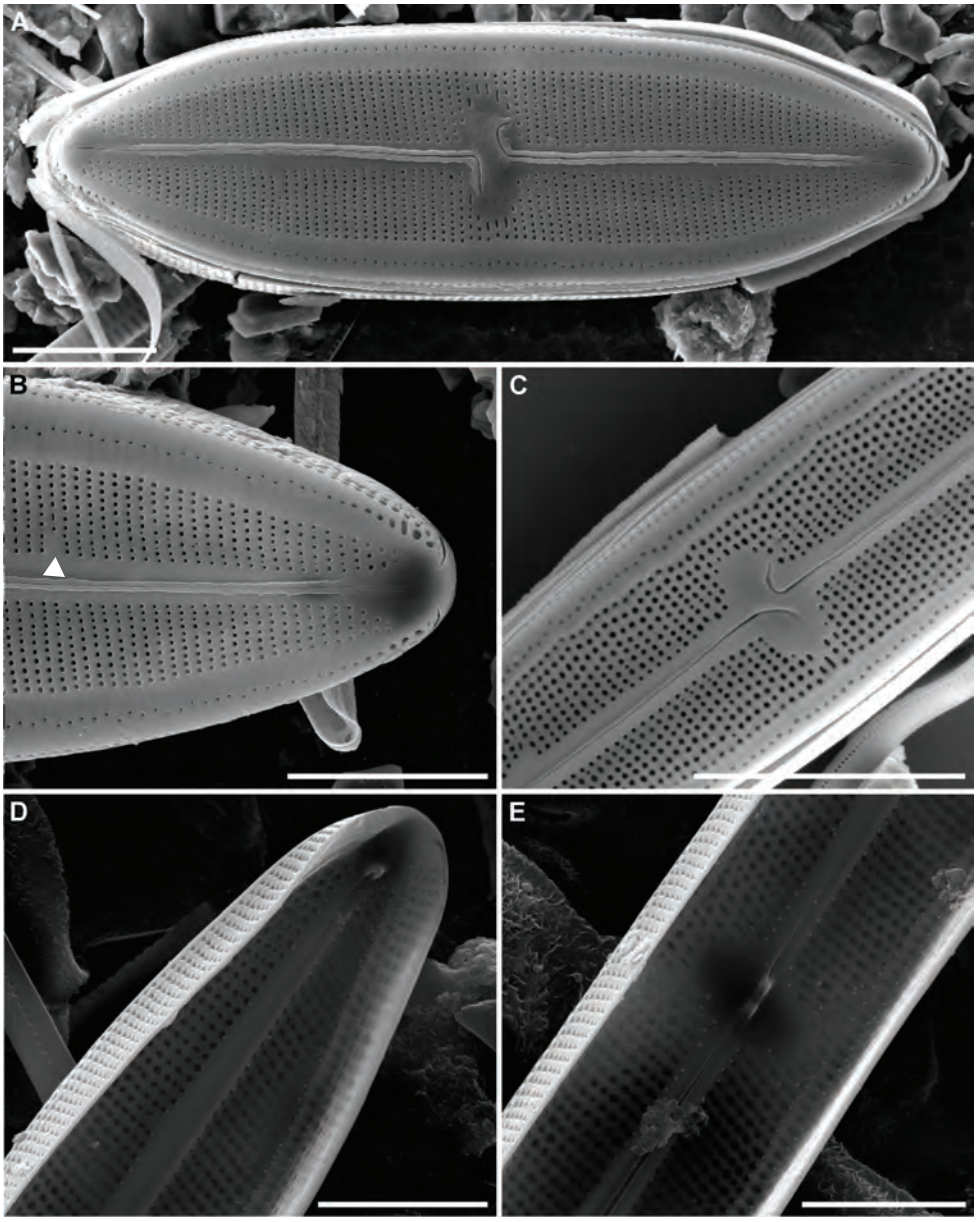


Fig. 121. *Neidium* spp. **A-E**. SEM. **A.** External view of entire valve. **B.** Detail of apex, note Voight discordance (arrow). **C.** Detail of central raphe endings, deflected in opposite directions, **D-E.** Internal view of valve. Scale bars = 10 µm (A-C), 5 µm (D-E).

Fallacia Stickle 1990

Type species: *Fallacia pygmaea* (Kützing) Stickle & D.G. Mann

SYNONYM:

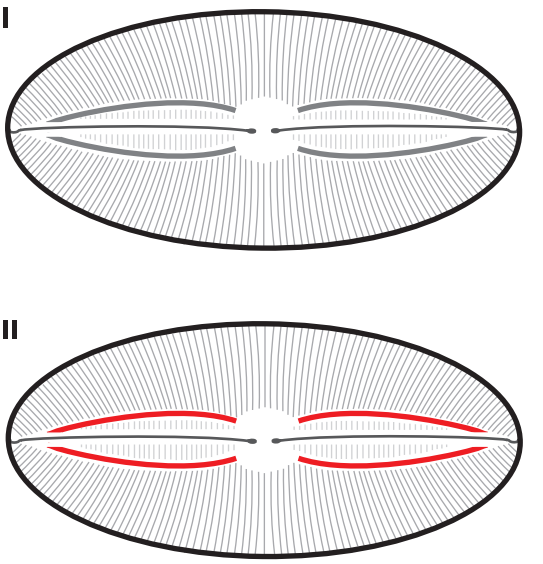
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, elliptical with broadly rounded apices. Striae fine, radiate throughout composed of single rows of areolae which may not be discernable under LM (Fig. 122: B-D). Raphe straight and complex, striae interrupted by H-shaped (lyre-shaped) hyaline area parallel to the raphe (II, Fig. 122: B-E).

Plastid structure – Cells with H-shaped plastid with 2 plates connected by a narrow isthmus (Fig. 122: A).

Identification of species – Up till now only one species known from tropical Africa: *Fallacia pygmaea.*

Ecology – Cells solitary, free living and motile. Found in the benthos of eutrophic waters with moderate to high conductivities.



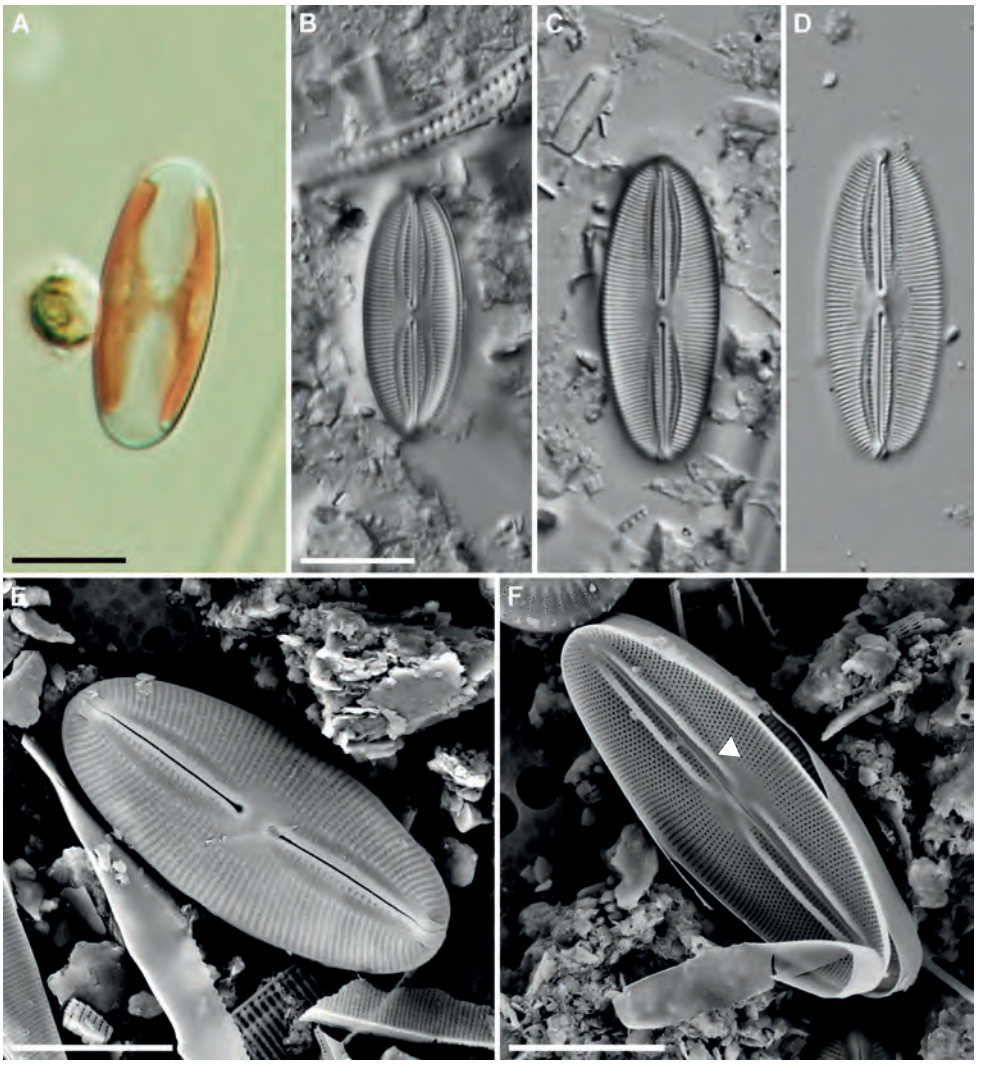


Fig. 122. *Fallacia pygmaea*. **A-D.** LM. **A.** Living cell, valve view. **B-D.** Valve views of cleaned material. **E-F.** SEM. **E.** External view of valve. **F.** Internal view of valve, note thickened silica ribs (arrow) in axial area which appear as hyaline lines in LM. Scale bars = 10 µm (A-D, F), 8 µm (E).

Pseudofallacia Y. Liu, Kociolek & Q.X. Wang 2012

Type species: *Pseudofallacia occulata* Y. Liu, Kociolek & Q.X. Wang

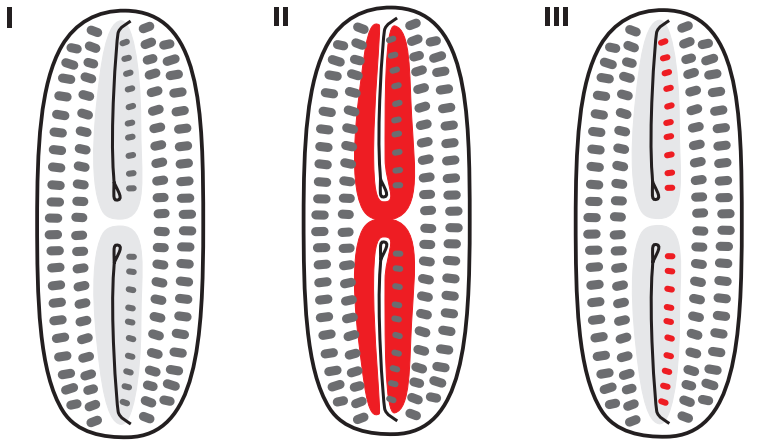
SYNONYM:
Fallacia Stickle & D.G. Mann 1990 pro parte
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, small in size, elliptical to linear elliptical with broadly rounded apices. Striae fine, radiate or parallel composed of single rows of areolae which may not discernable under LM (Fig. 123) or more robust (Fig. 123). Raphe straight and simple (Fig. 123) with H-shaped hyaline area parallel to the raphe (II). Longitudinal lines of isolated areolae are present adjacent to the raphe. Under SEM the conopeum has fine perforations (Fig. 123).

Plastid structure – Cells with one H-shaped plastid (Fig. 123).

Identification of species – Species can be identified by cell size, cell shape, structure and density of the striae as well as structure and extent of the H-shaped hyaline area.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities.



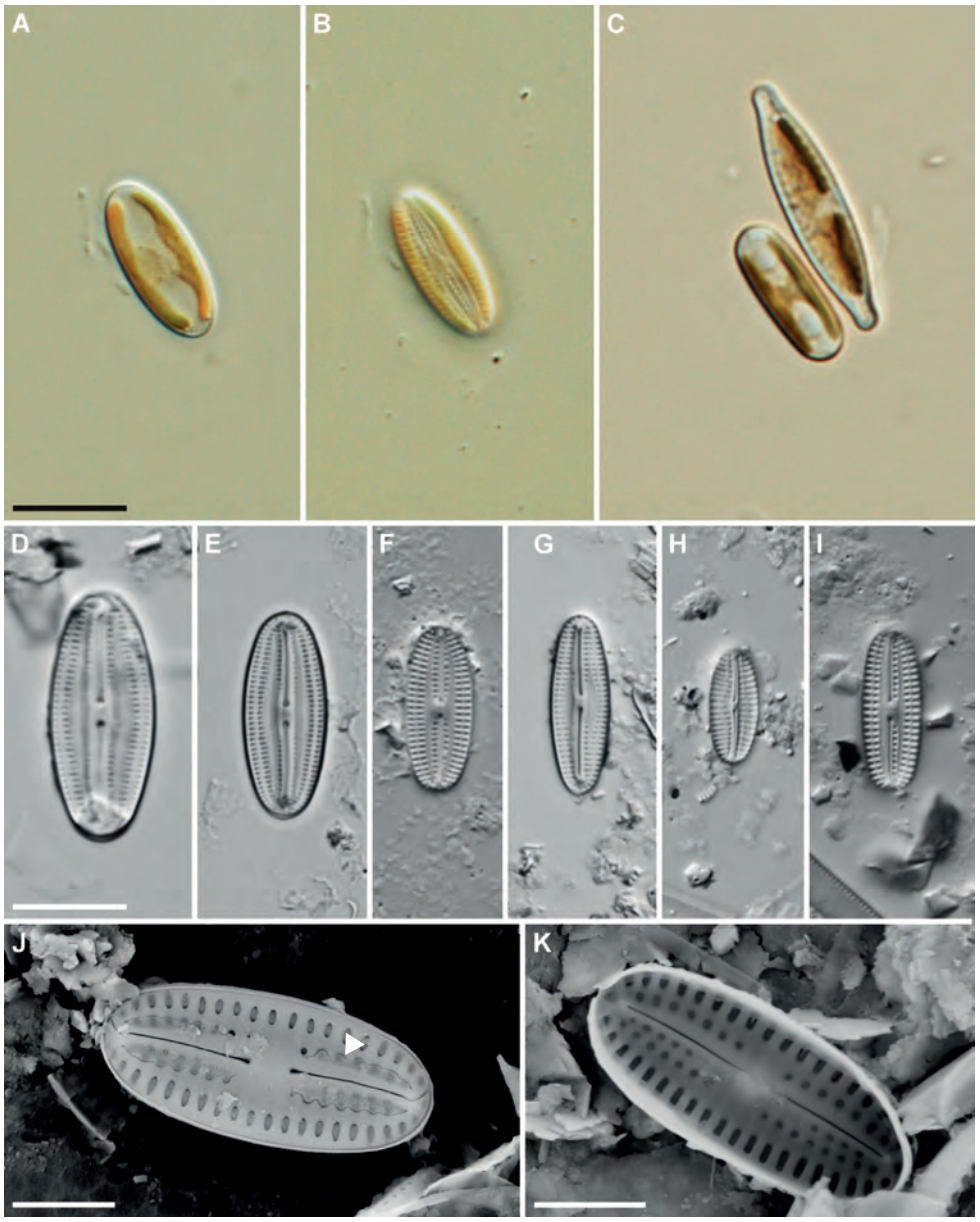


Fig. 123. *Pseudofallacia* spp. **A-I.** LM. **A-B.** Living cell, single cell, different foci. **C.** Living cell with typical H-shaped chloroplast. **D-I.** Valve views of *Pseudofallacia* species. **J-K.** SEM. **J.** External view of valve of *Fallacia* [*Pseudofallacia*] *umpatica* (Cholnoky) D.G. Mann, note conopeum covering external openings of areolae close to the axial area (arrow). **K.** Internal view of valve of *Fallacia [Pseudofallacia] umpatica.*
Scale bars = 10 µm (A-I), 3 µm (J-K).

Sellaphora Mereschkowsky 1902

Type species: *Sellaphora pupula* (Kützing) Mereschkowsky

SYNONYM:

Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, with broadly rounded to sub-capitate apices. Striae fine but discernable under LM (Fig. 125), composed of single rows of small round areolae. Raphe straight and simple (Fig. 125) carried in a sternum, terminal raphe endings extend onto the valve mantle. Thickened bars of silica present at the poles (II; Fig. 126: F) on the valve interior in most taxa, which appear as hyaline areas on the valve exterior (Fig. 125: I-J; Fig. 126: A). Central area is usually rectangular and well delimited.

Plastid structure – Cells with 2 plate-like plastids, one along each side of the girdle with central bridge (Fig. 124). Large lipid bodies present.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central area and the shape and curvature of the terminal raphe endings.

Ecology – Cells solitary, free living and motile, occasionally planktonic. Found in the benthos of eutrophic to hypereutrophic waters with moderate to high conductivities.

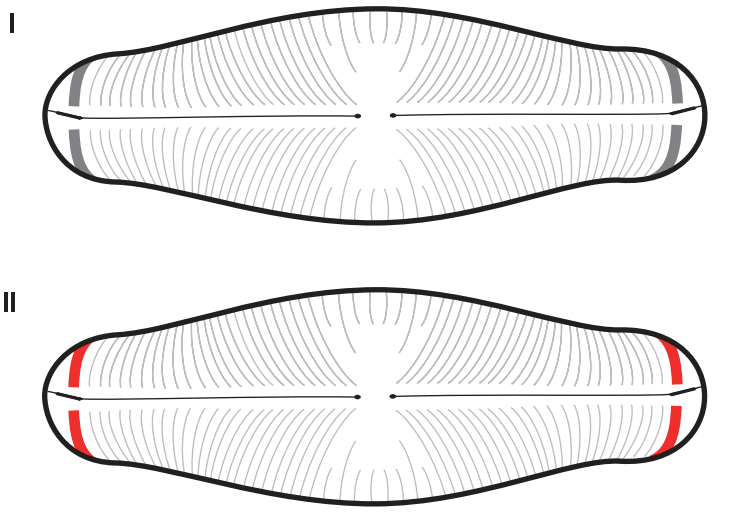


Fig. 124. *Sellaphora* spp. **A-D.** LM, living cells. **A-C.** *Sellaphora pupula* sensu lato, note lipid bodies. **D.** *Sellaphora seminulum* (Grunow) D.G. Mann. Scale bars = 10 µm (A-D).

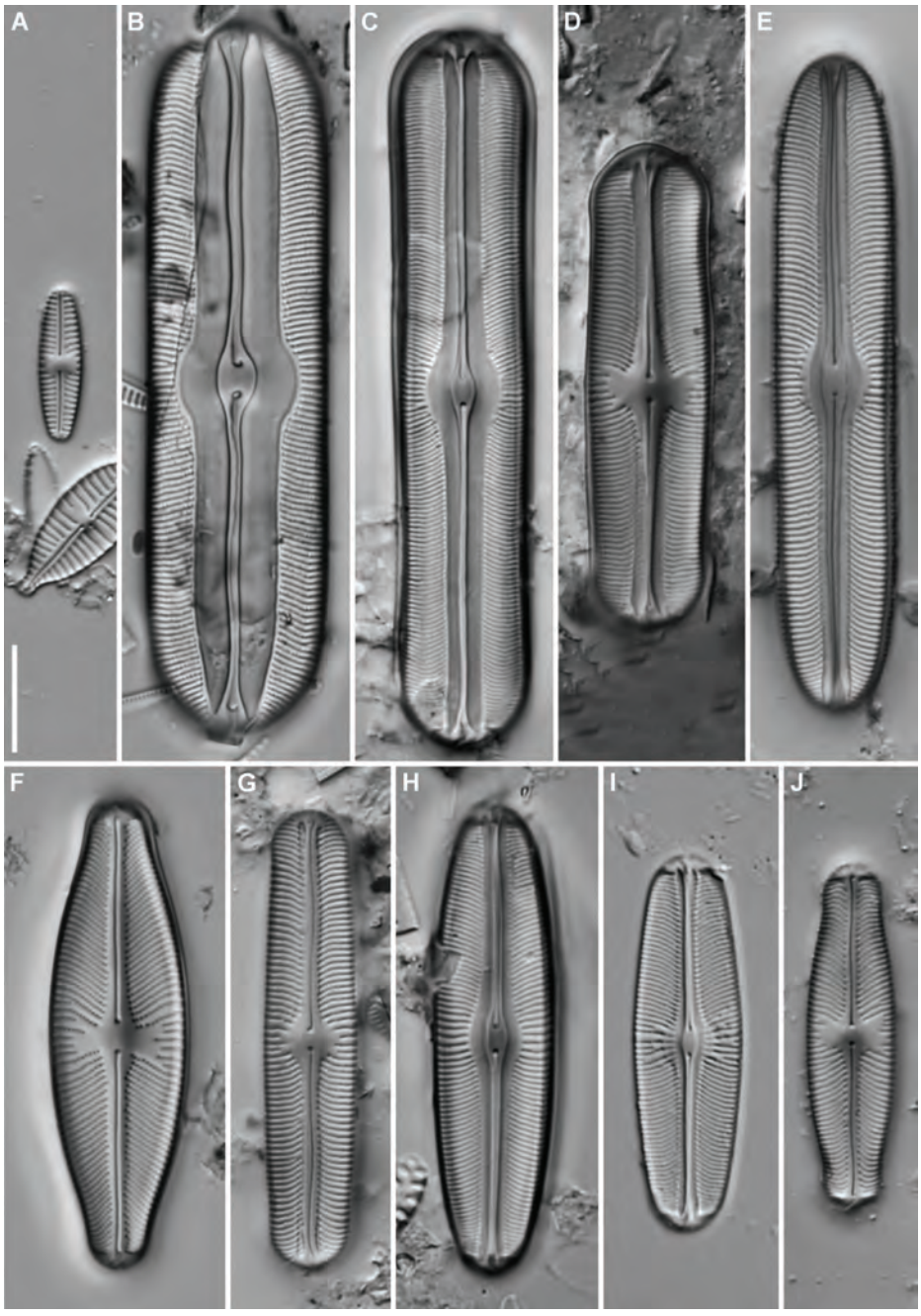


Fig. 125. *Sellaphora* spp. **A-J.** LM, cleaned valves. **A.** *Sellaphora seminulum*. **B.** *Sellaphora americana* (Ehrenberg) D.G. Mann. **F.** *Sellaphora nyassensis* (O. Müller) D.G. Mann. **J.** *Sellaphora pupula* sensu lato.
Scale bar = 10 µm (A-J).

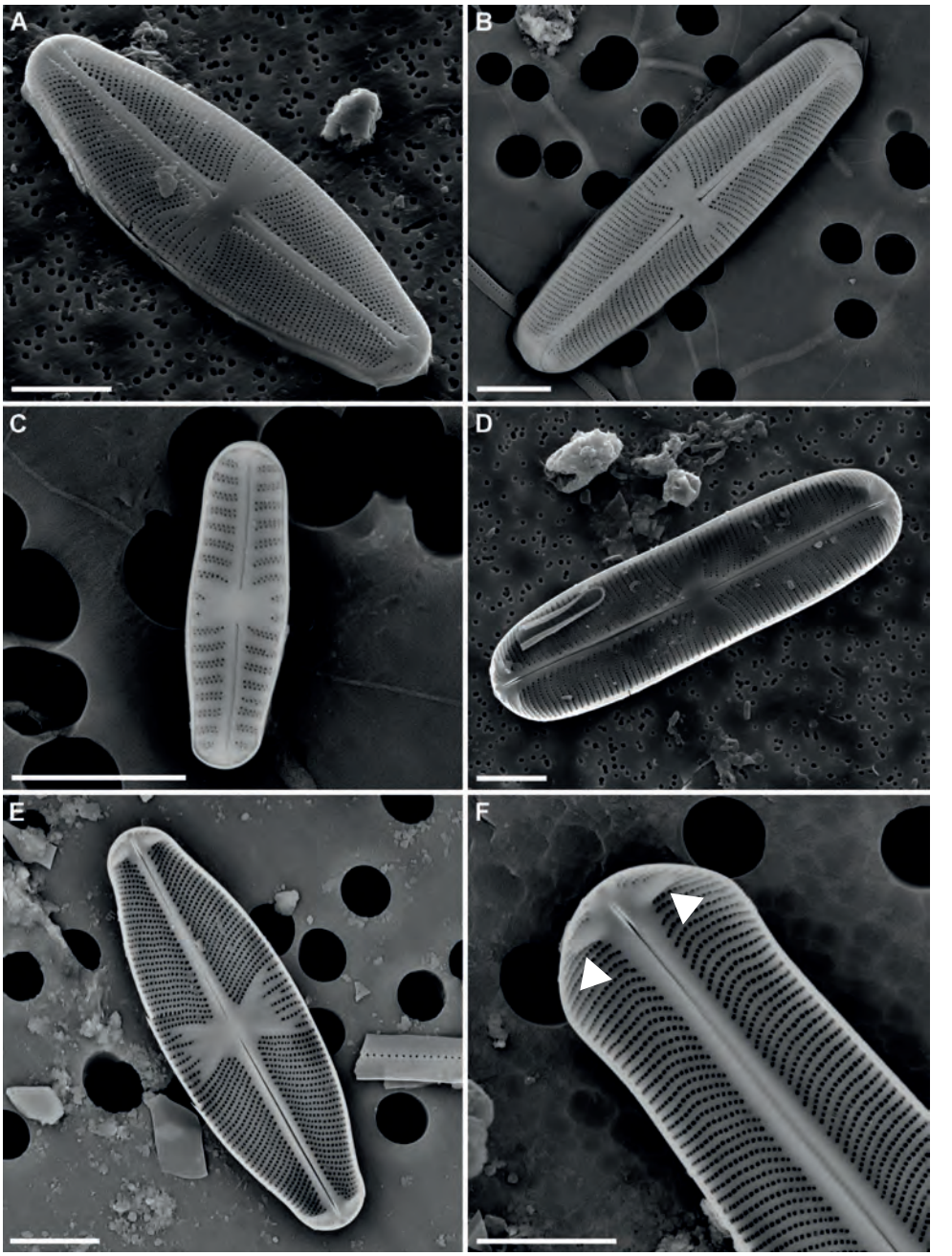


Fig. 126. *Sellaphora* spp. **A-F.** SEM. **A-B.** *Sellaphora* spp., external view of valves. **C.** *Sellaphora seminulum*, external view of valve. **D-F.** *Sellaphora* spp., internal view of valves, note silica bars (arrows - **F**).
Scale bars = 5 µm (A-F).

Caloneis Cleve 1894

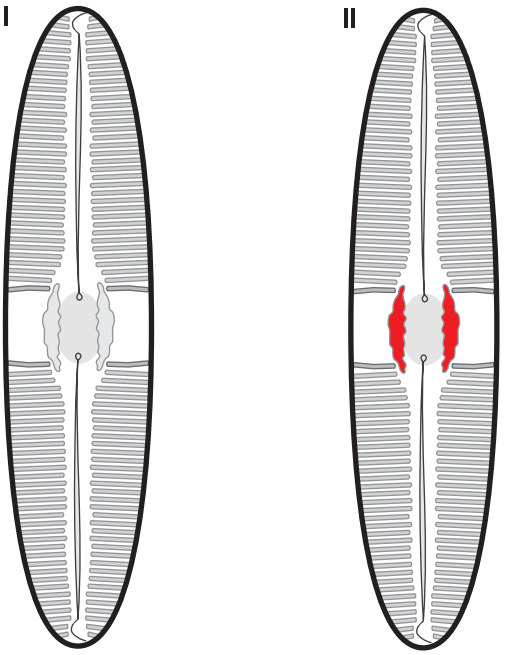
Type species: *Caloneis amphisbaena* (Bory) Cleve

Characteristics – Cells size and shape variable and may be strongly triundulate (Fig. 127: I), **biraphid**. Tube striae are present, individual areolae cannot be observed under LM. Central area broad usually reaching the valve margins and often bearing irregular depressions in the valve face (II).

Plastid structure – Cells with one plastid with a narrow bridge across the centre of the cell (Fig. 127: A) or two plastids along the girdle sides. Large lipid droplets visible.

Identification of species – Species in this genus are distinguished based on cell size and shape (especially valve outline), striae density, the shape of the apices, the shape of the central area and structure of the depressions found in the central area (II).

Ecology – Cells solitary and motile. Found in acidic and alkaline waters across all trophic levels.



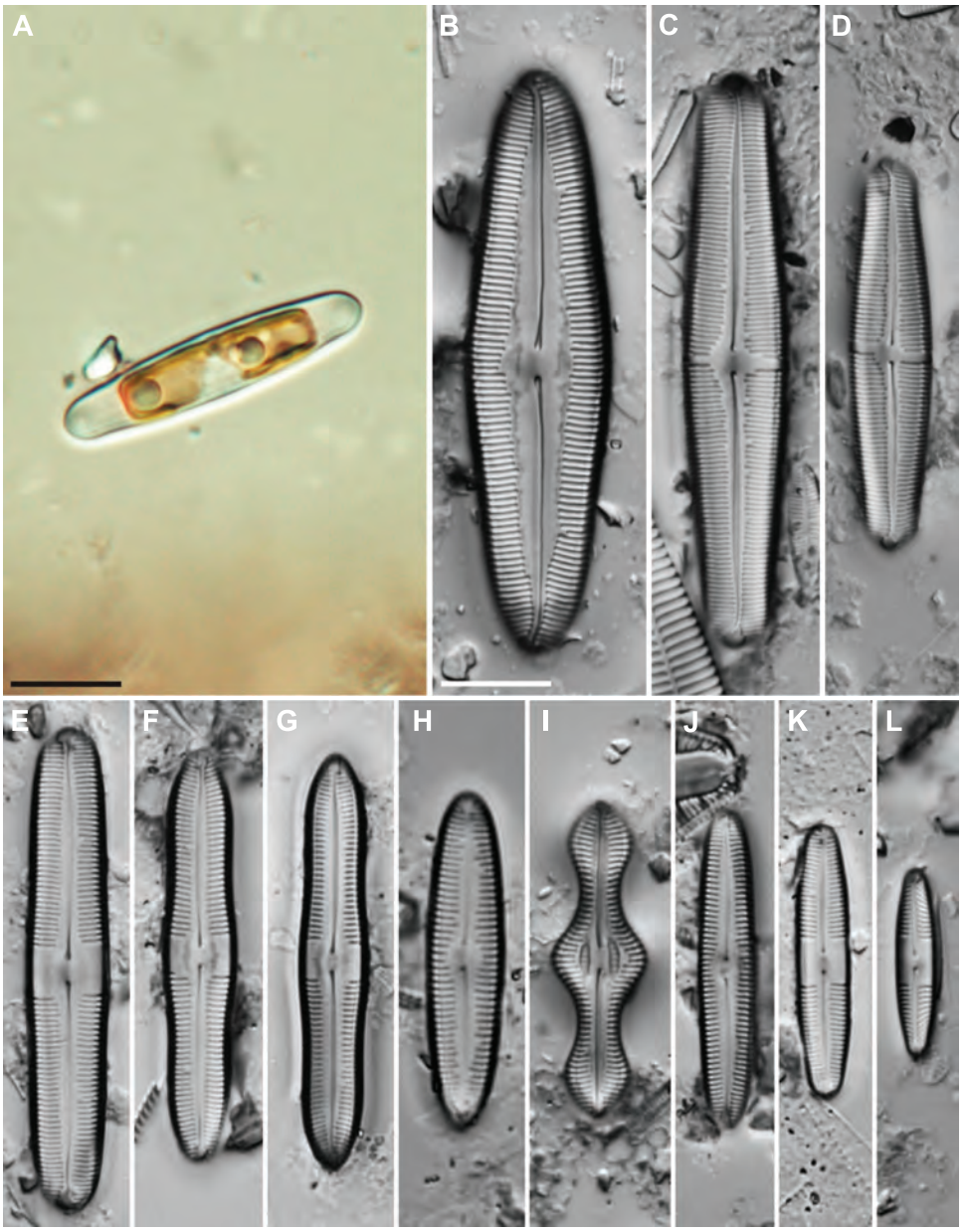


Fig. 127. *Caloneis* spp. **A-L.** LM. **A.** Living cell, valve view. **B-L.** Cleaned material, illustrating various taxa.
Scale bars = 10 µm (A-L).

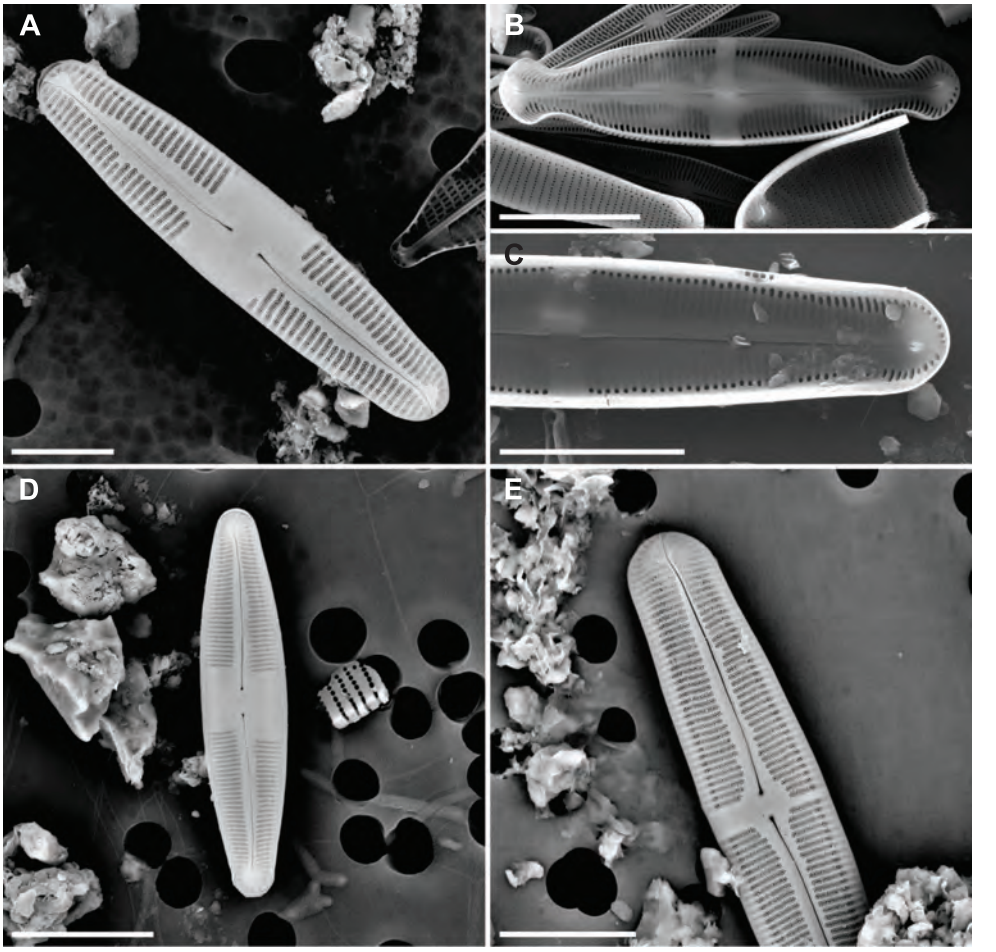


Fig. 128. *Caloneis* spp. **A-E.** SEM. **A, E.** External view of valve showing structure of tube striae. **B-C.** Internal view of valve showing internal occlusion of the striae, these occlusions appear as longitudinal lines in LM. **D.** External view of valve of *Caloneis hyalina* Hustedt.
Scale bars = 5 µm (A), 10 µm (B-C), 8 µm (D-E).

Pinnularia Ehrenberg 1843

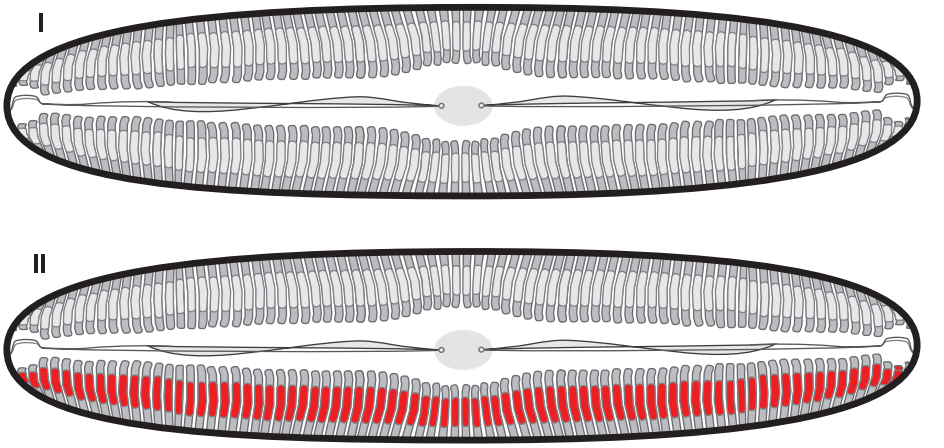
Type species: *Pinnularia viridis* (Nitzsch) Ehrenberg

Characteristics – Cells **biraphid**, can be very large in size, valve shape generally linear to linear-elliptical with broadly rounded, capitate or sub-capitate apices. Striae **alveolate**, easily discernable under LM (Fig. 130; Fig. 131) and composed or numerous small round areolae (Fig. 132: C). Raphe system complex or simple. Central area may be expanded and reach both valve margins. Sometimes longitudinal lines are present (II).

Plastid structure – A range of chloroplast types, usually 2 plate-like plastids, and one along each side of the girdle (Fig. 129). Plastids may be undulate (Fig. 129: C). Many scattered lipid bodies present.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure and extent of the central and axial areas and the structure and curvature of the central and terminal raphe endings.

Ecology – Cells solitary, free living and motile. Abundant in slightly acidic, oligotrophic waters with low conductivity. Some taxa are found in eutrophic conditions and others are considered typical of sub-aerial habitats.



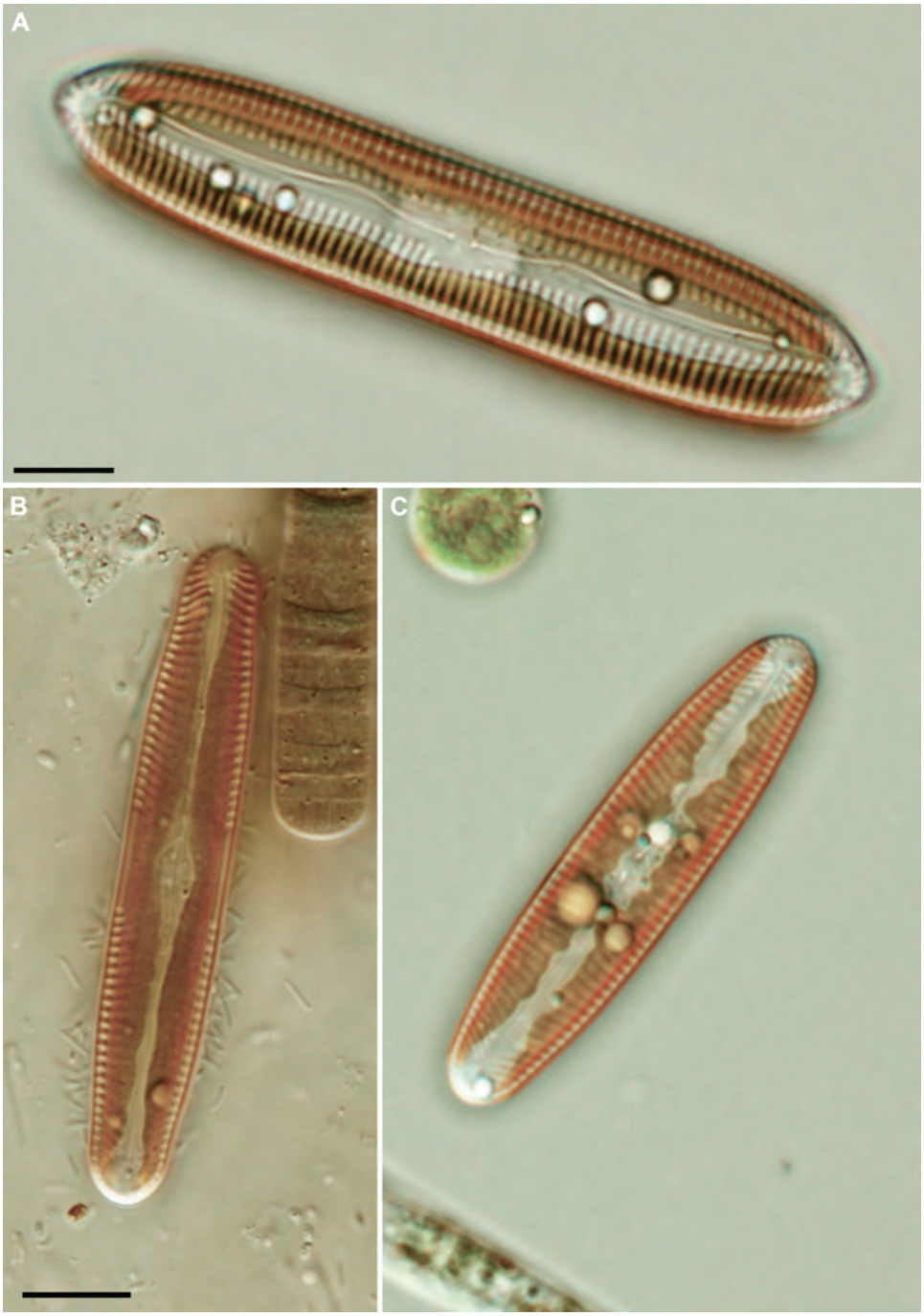


Fig. 129. *Pinnularia* spp. **A-C.** LM, living cells, note the scattered lipid bodies. **C.** undulate plastid.
Scale bars = 10 µm (A-C).

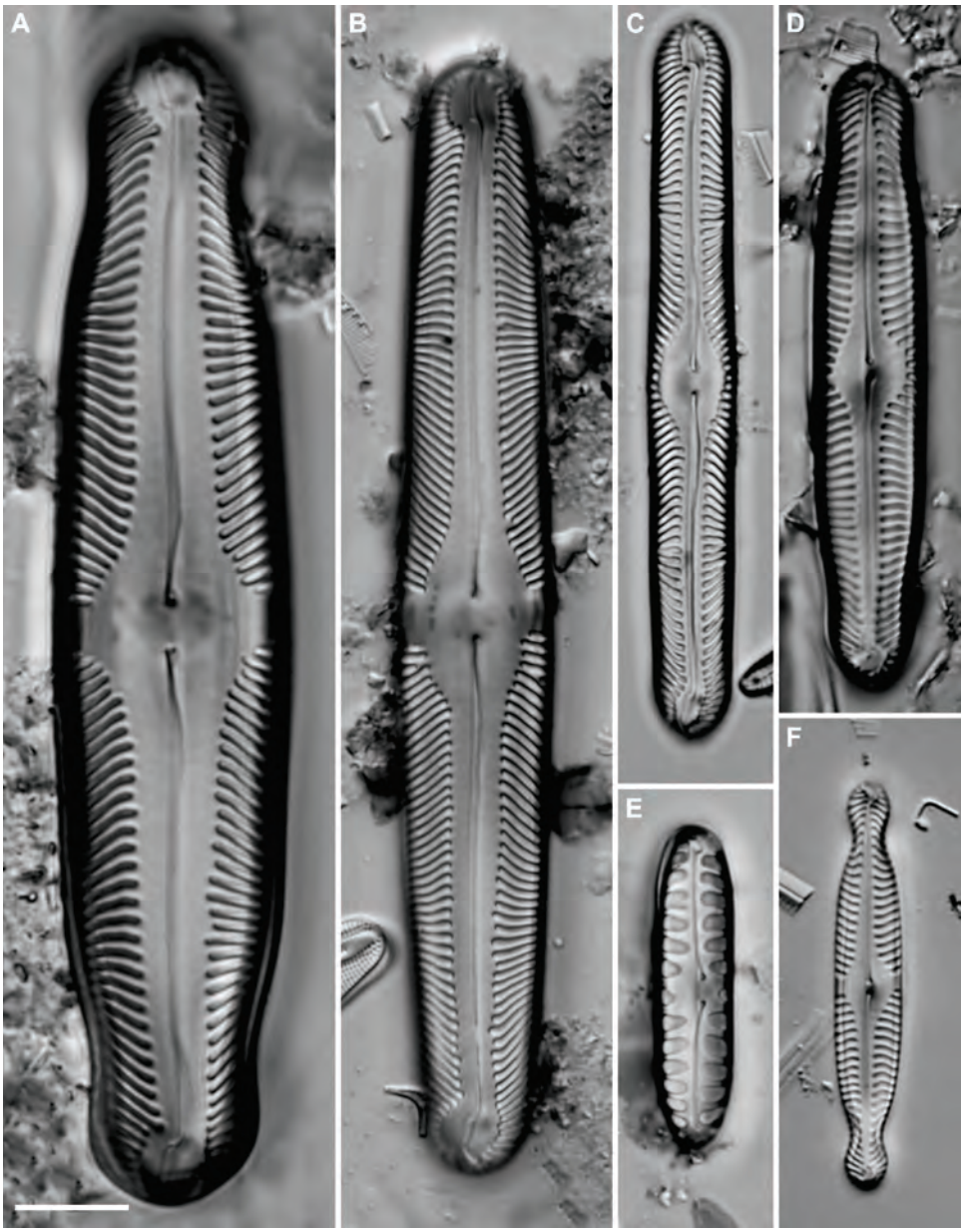


Fig. 130. *Pinnularia* spp. **A-F**. LM, valve views of cleaned material. **E.** *P. borealis* Ehrenberg sensu lato.
Scale bar = 10 µm (A-F).

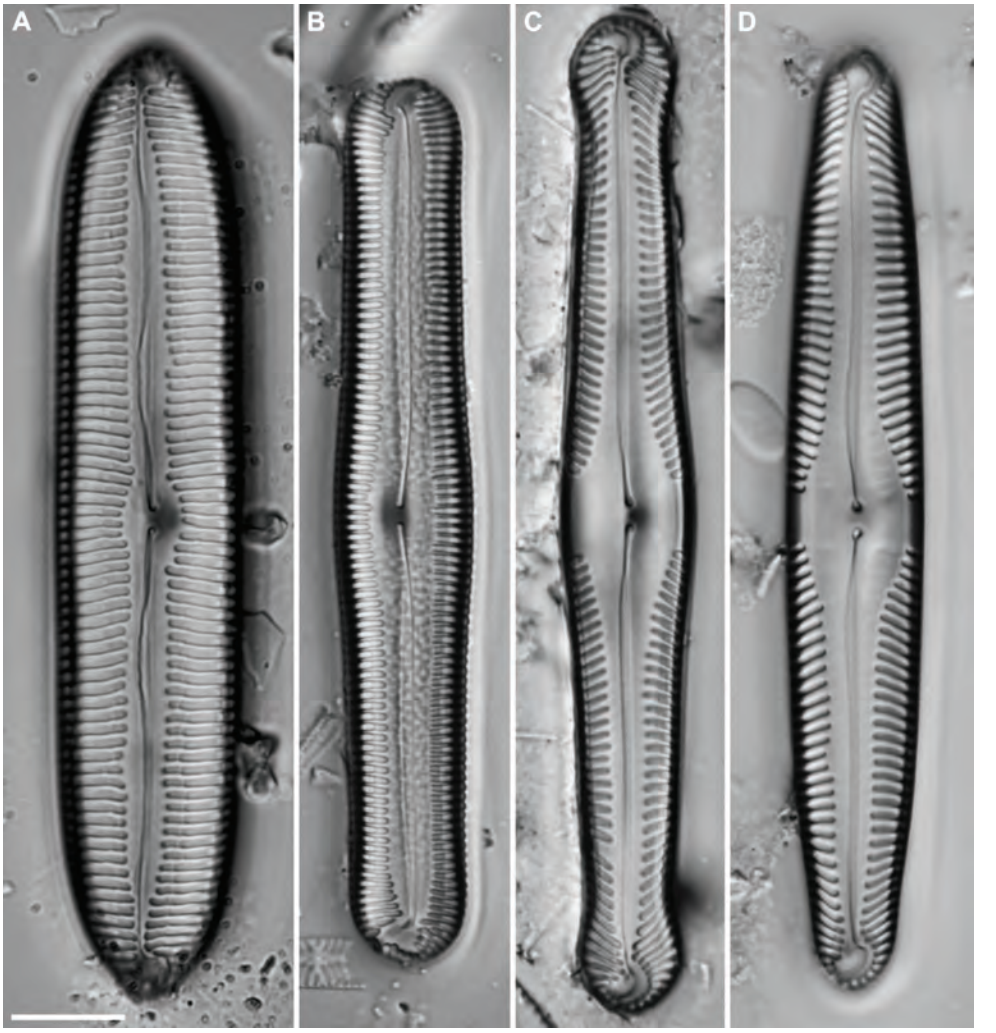


Fig. 131. *Pinnularia* spp. **A-D**. LM, valve views of cleaned material. **B.** *P. acrosphaeria* (Brébisson) Rabenhorst. Scale bar = 10 µm (A-D).

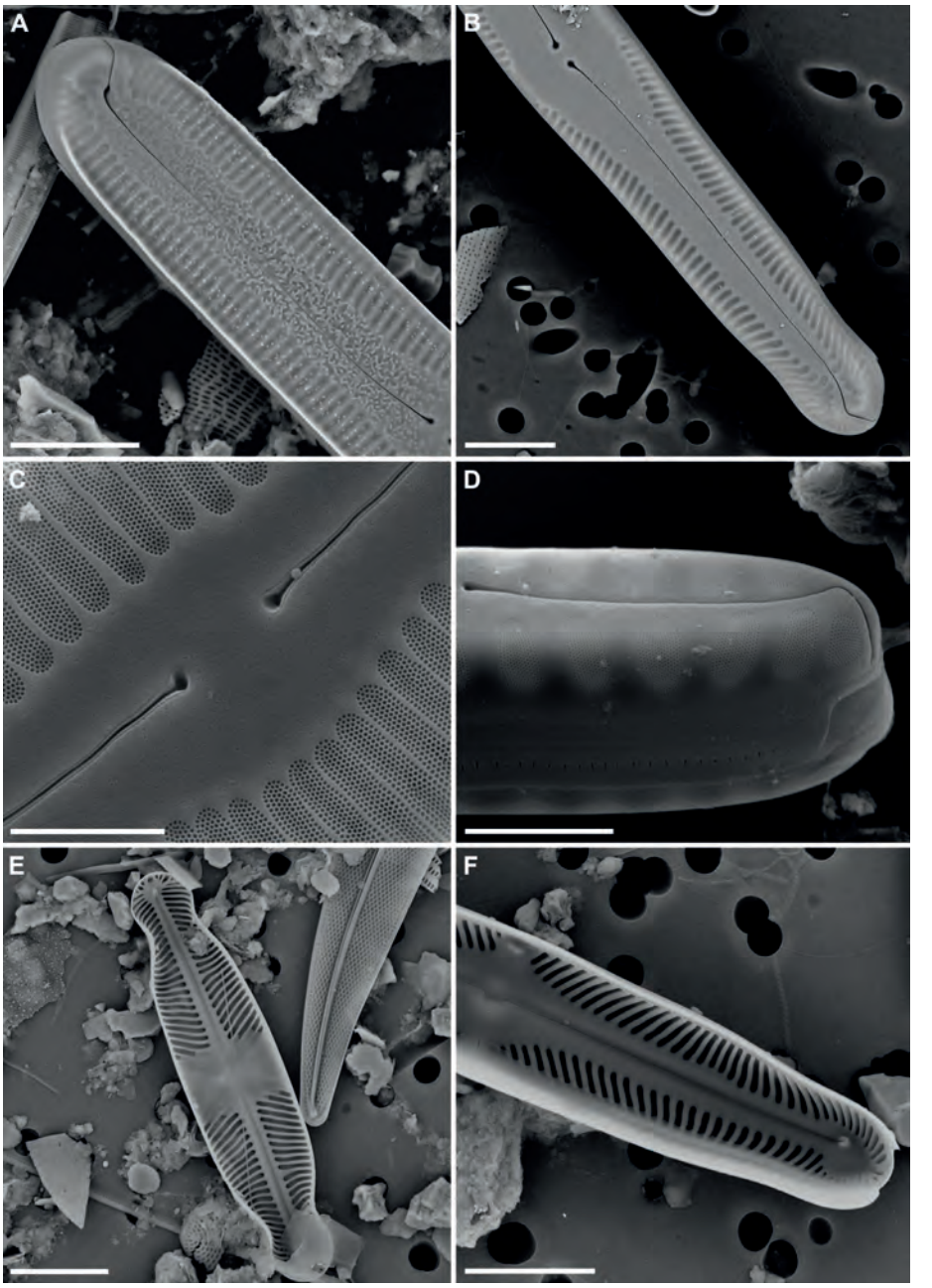


Fig. 132. *Pinnularia* spp. **A-F.** SEM. **A-D.** External view of valves. **A.** *P. acrosphaeria*, note irregular silica ornamentations in axial area. **B.** Detail of central and terminal raphe ending. **C.** Detail of central raphe endings and striae, composed of numerous small round areolae. **D.** Mantle view. **E-F.** Internal view of valves, note the alveolate striae.
Scale bars = 10 µm (A, B, E, F), 5 µm (C, D).

Diploneis (Ehrenberg) Cleve 1894

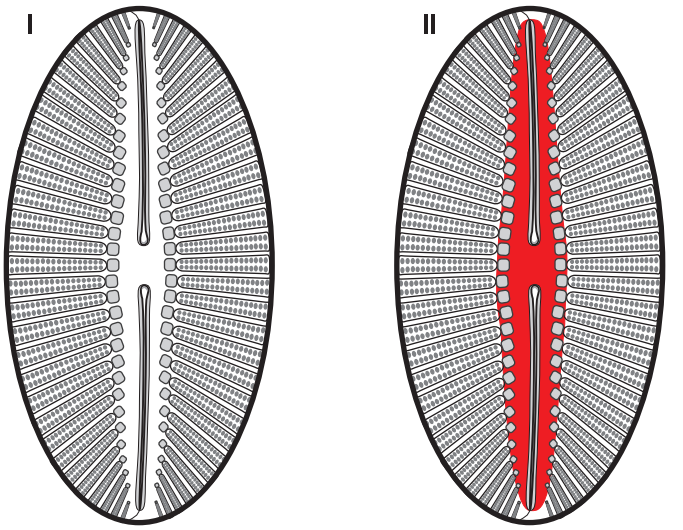
Type species: *Diploneis didyma* (Ehrenberg) Cleve

Characteristics – Cells **biraphid**, elliptical with bluntly rounded apices, sometimes constricted mid-valve (Fig. 133: C). **Longitudinal canals** (ll) parallel to the raphe, striae composed of complex (**loculate**) areolae, usually clearly visible under LM (Fig. 133: E-G; Fig. 134: D). When observed under SEM the longitudinal canals are perforated on the exterior of the valve with areolae but not on the interior (Fig. 134: C). Cells heavily silicified.

Plastid structure – Cells with two plastids, one on either side of the apical plane, may be many lobed (Fig. 133: A, C, D) or simple (Fig. 133: B).

Identification of species – Species can be identified by cell size, cell shape and structure and density of the striae as well as the shape of the axial and central area and the presence and degree of the mid-valve constriction. Some species have unique structures such as square openings in the longitudinal canals (Fig. 134: A).

Ecology – Cells solitary and motile. Freshwater forms found in the benthos of acidic oligotrophic waters as well as alkaline waters with higher trophic status and conductivity. Also found in moist sub-aerial habitats.



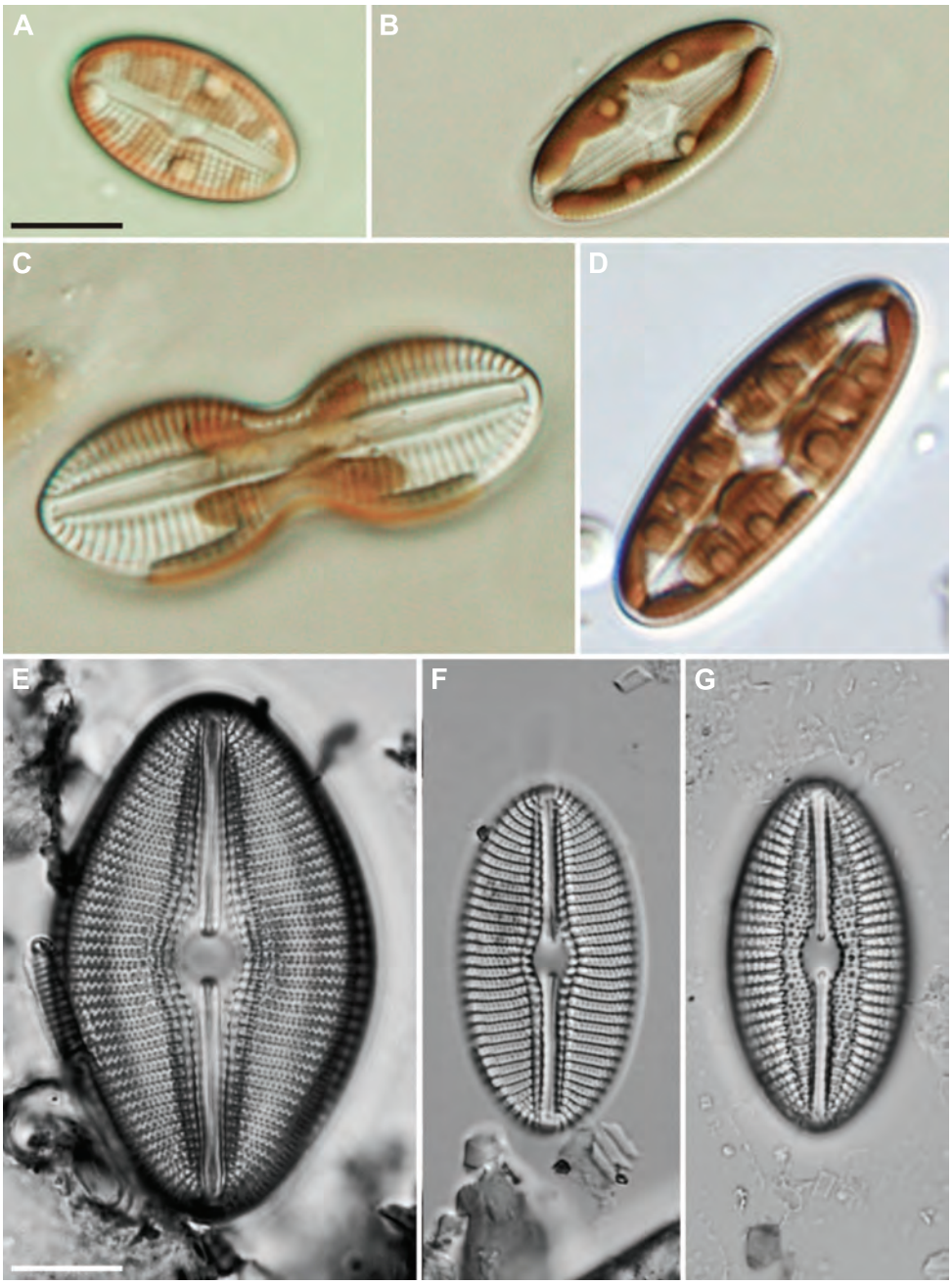


Fig. 133. *Diploneis* spp. **A-G.** LM. **A-D.** Living cells, valve views showing a variety of plastid shapes. **E-F.** Valve views of cleaned material. **G.** Valve view of *Diploneis fenestrata* J.C. Taylor & B. Karthick. Scale bars = 10 µm (A-G).

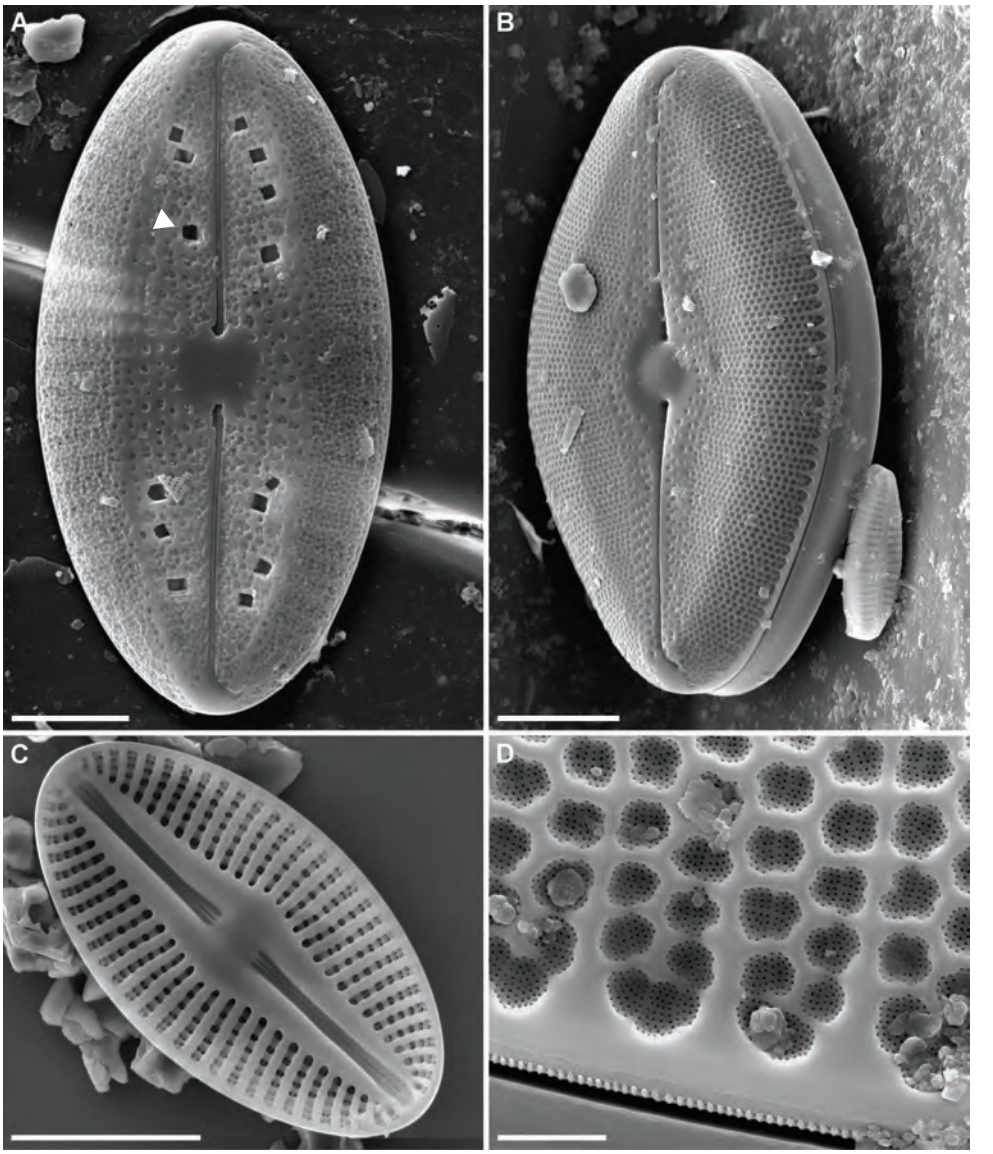


Fig. 134. *Diploneis* spp. **A-D.** SEM. **A.** *Diploneis fenestrata*, valve view, note square openings in longitudinal canals (arrow). **B.** *Diploneis* sp., oblique view of valve exterior. **C.** *Diploneis* sp., view of valve interior. **D.** Exterior view, detail of complex loculate areolae.
Scale bars = 5 µm (A), 10 µm (B-C), 1 µm (D).

Adlafia Gerd Moser, Lange-Bertalot & Metzeltin 1998

Type species: *Adlafia muscora* (Kociolek & Reviers) Gerd Moser, Lange-Bertalot & Metzeltin

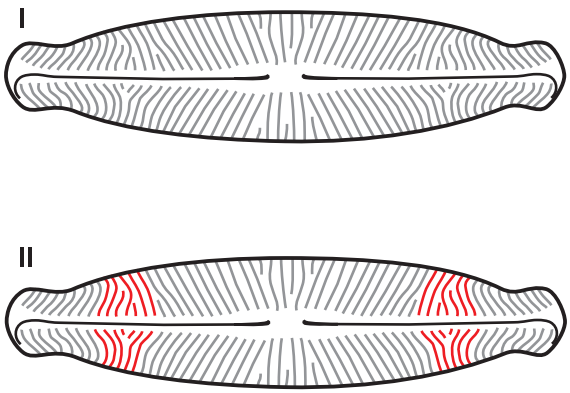
SYNONYM:
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid,** small, striae can often be rather fine and difficult to resolve in LM. Striae mid-valve are strongly radiate and curved becoming strongly **convergent** towards the apices (II). Cells may have slightly undulating margins (Fig. 135: C) and in some cases the areolae may be visible (Fig. 135: C-D). The closely related *Kobayasiella* (see Fig. 141) usually has denser striation and a small bend or kink about halfway along the length of the raphe which is not found in *Adlafia*.

Plastid structure – Single plastid with two lobes connected by a bridge (H-shape) (Fig. 135: B).

Identification of species – Species in this genus are distinguished based on cell size and shape and the shape of the apices. Striae density and angle relative to the **transapical axis** are also important characteristics to consider.

Ecology – Cells solitary. Found in acidic oligotrophic waters and moist sub-aerial habitats.



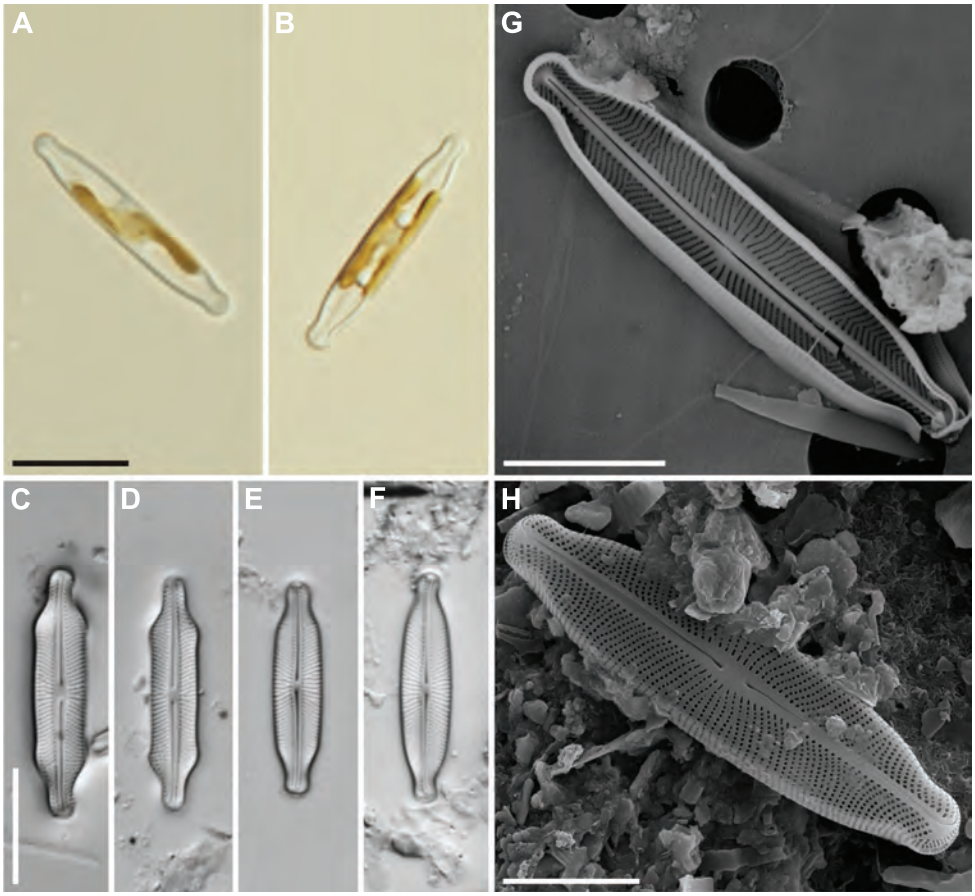


Fig. 135. *Adlafia* spp. **A-F.** LM. **A-B.** Living cells, valve views. **C-F.** Valve views of cleaned material. **G-H.** SEM. **G.** Internal view of valve. **H.** External view of valve. Scale bars = 10 µm (A-F), 5 µm (G-H).

Capartogramma Kufferath 1956

Type species: *Capartogramma jeanii* Kufferath

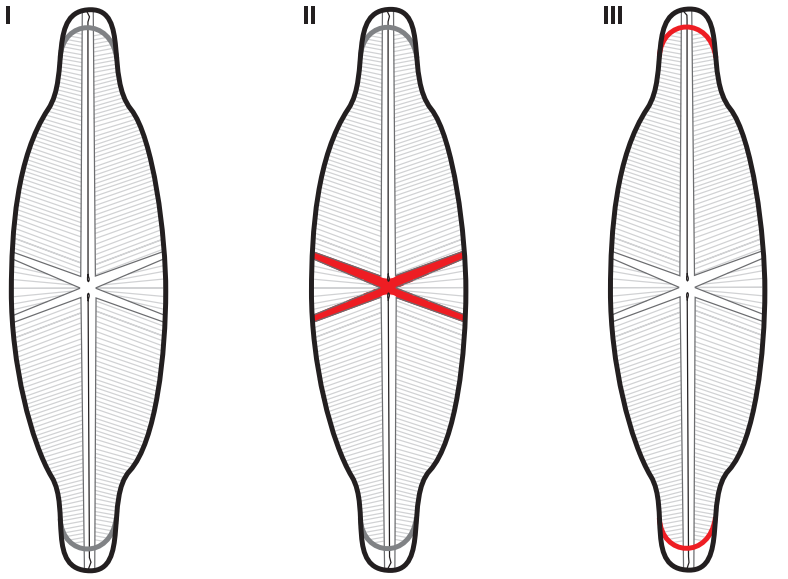
SYNONYM:
Schizostauron Grunow 1867 pro parte
Stauroneis Ehrenberg 1843 pro parte

Characteristics – Cells **biraphid** with fine striae, areolae small and difficult to observe under LM. This genus is characterised by X-shaped silica thickening in the central area (II, Fig. 136: L) and a **pseudoseptum** (III) which is present at each apex. Axial area very narrow. Cells usually bilaterally symmetrical, however *Capartogramma amphoroides* R. Ross has a dorsiventral symmetry.

Plastid structure – Cells with one large plastid (Fig. 136: A).

Identification of species – Species in this genus are distinguished based on cell size, cell symmetry and shape, and the shape of the apices.

Ecology – Cells solitary and motile. Found in the benthos and plankton, with greatest species diversity in tropical African waters



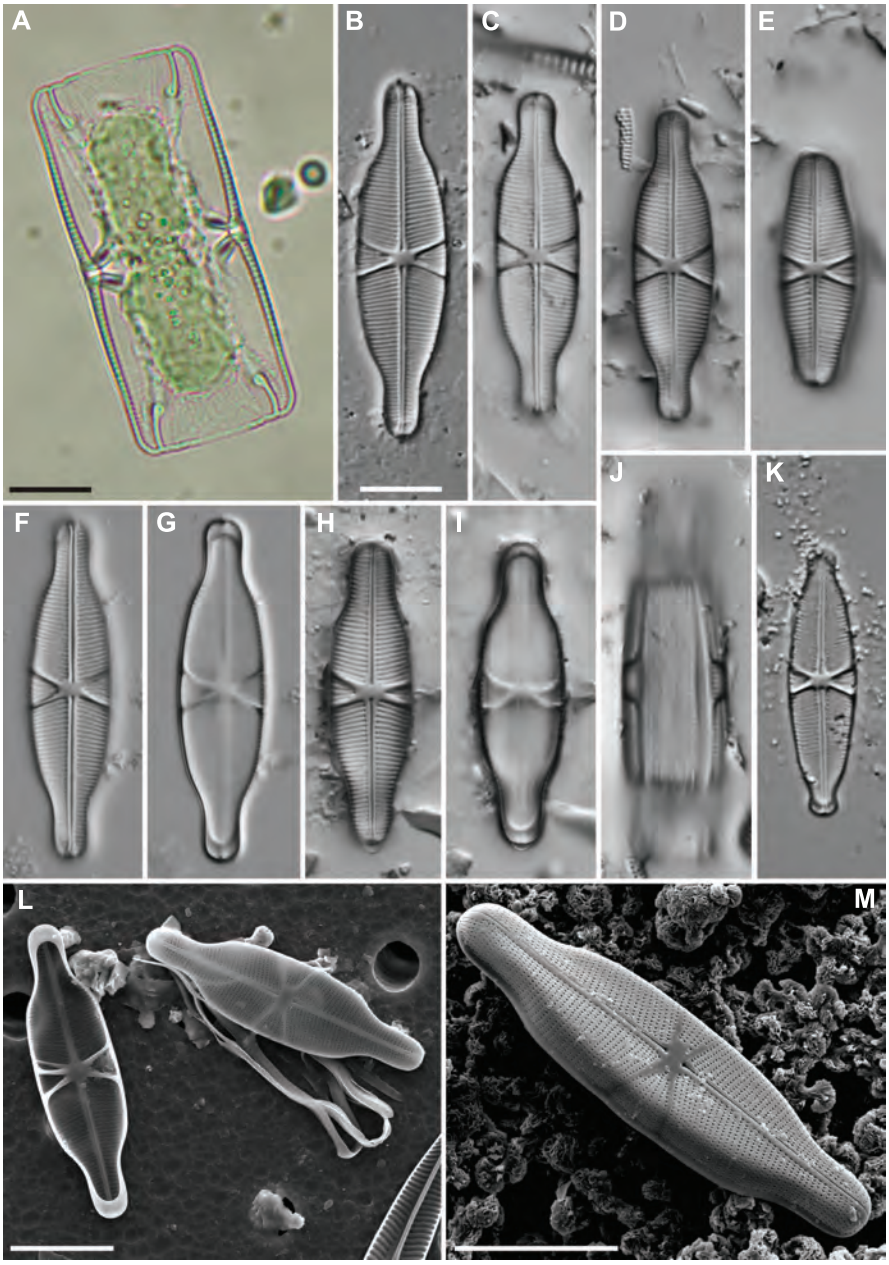


Fig. 136. *Capartogramma* spp. **A-K.** LM. **A.** Living cell of *C. karstenii* (O. Müller) R. Ross, girdle view. **B-J.** *C. crucicula* (Grunow ex R. Cleve) Ross; valve views at various foci (**B-I.**); girdle view (**J**). **K.** Valve view of *C. crucicula* [var. *parva* Fusey]. **L-M.** SEM. **L.** External view of valve and copulae (right); internal view of valve (left). **M.** External view of valve showing valve mantle.
Scale bars = 10 µm.

Eolimna Lange-Bertalot & W. Schiller 1997

Type species: *Eolimna martinii* W. Schiller & Lange-Bertalot

SYNONYM:
Navicula Bory 1822 pro parte

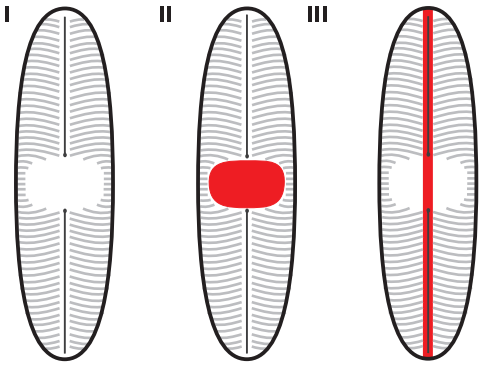
Characteristics – Cells **biraphid**, very small, elliptical to linear elliptical with broadly rounded apices. Striae fine, radiate or parallel composed of single rows of areolae which are not discernable under LM. Raphe straight and simple (I). Central area (II) variable in size but never extending to the valve margins. Axial area very narrow (III).

Plastid structure – Cells with one plastid which may be simple (Fig. 137: A) or lobed (Fig. 137: C).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as shape of the central area.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities.

Note – We have provided a description and illustration of the genus *Eolimna* to demonstrate the recent (last decade) concept of this genus. This genus was originally described from fossil material. Recently small naviculoid diatoms ascribed to *Eolimna* have been examined in terms of plastid structure and genetic relationships and it has been concluded that the majority of the small species we currently consider *Eolimna* (e.g. *Eolimna minima* (Grunow) Lange-Bertalot) should be included with *Selllaphora* or in other genera such as *Craticula* (e.g. *Craticula subminuscula* (Manguin) Wetzel & Ector).



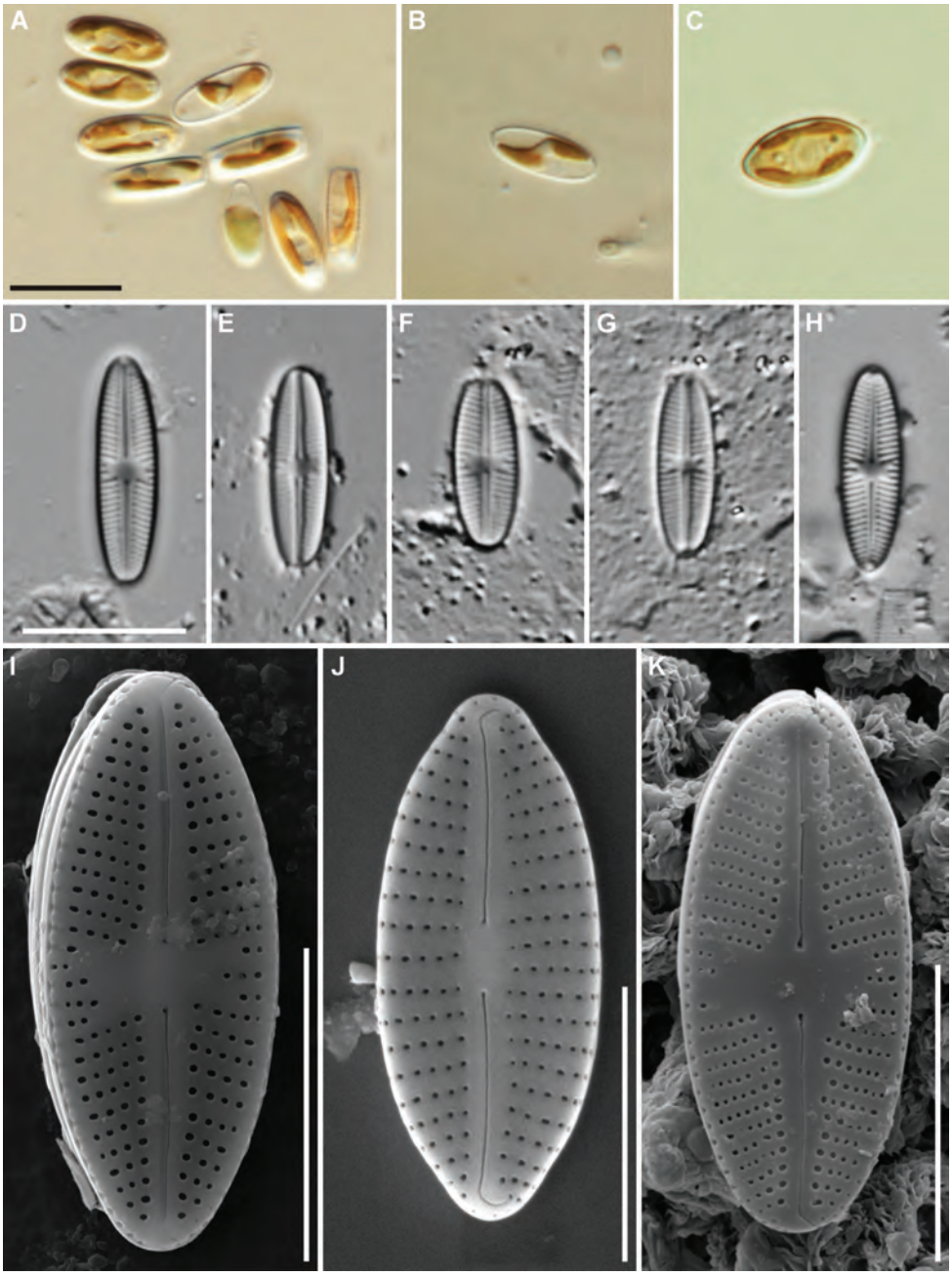


Fig. 137. *Eolimna* spp. **A-H.** LM. **A-B.** Living cells, valve and girdle views. **C.** Living cell, valve view of *Eolimna subminuscula* (Manguin) Gerd Moser, Lange-Bertalot & Metzeltin. **D-H.** *Eolimna* sp., valve view. **I-K.** SEM. **I, K.** External view of valve of *Eolimna* sp. **J.** *E. subminuscula*, external view of valve.
Scale bars = 10 µm (A-H), 5 µm (I-K).

Fistulifera Lange-Bertalot 1997

Type species: *Fistulifera saprophila* (Lange-Bertalot & Bonik) Lange-Bertalot

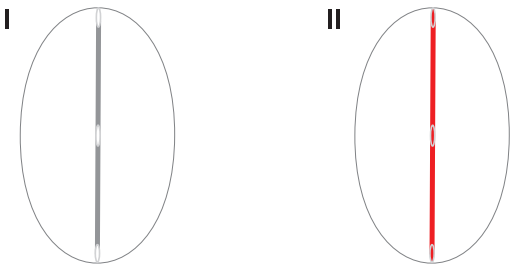
SYNONYM:
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, very small, elliptical with broadly rounded apices. Striae not discernable under LM (Fig. 138: A-D) and also difficult to resolve with SEM (Fig. 138: E). Raphe straight and simple (Fig. 138: A-D) carried in a sternum which is usually the only structure which can be seen using LM (II). Slight swellings present in the sternum at the central nodule and apices.

Plastid structure – Cells with one H-shaped plastid with 2 large lipid bodies.

Identification of species – Up till now only one species known from tropical Africa: *Fistulifera saprophila.*

Ecology – Cells solitary, free living and motile. Found in the benthos of eutrophic to hypereutrophic waters with moderate to high conductivities.



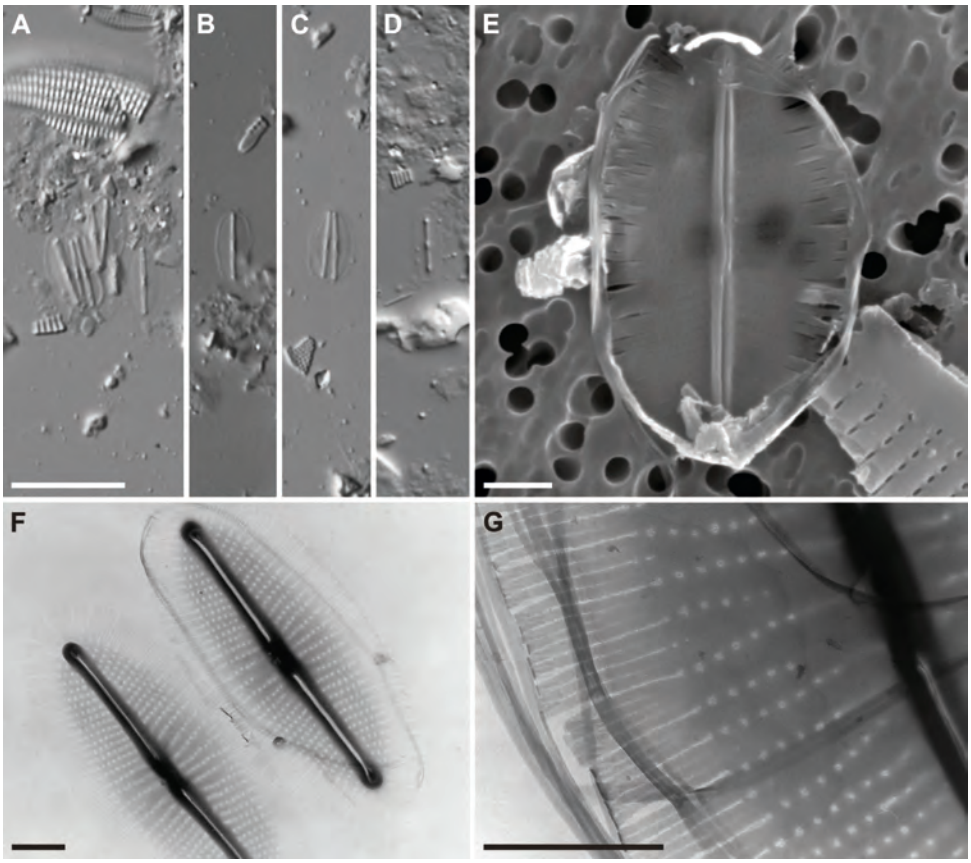


Fig. 138. *Fistulifera saprophila*. **A-D.** LM, valve views. **E.** SEM, internal view of valve. **F-G.** Transmission electron microscopy.
Scale bars = 10 µm (A-D), 1 µm (E-G).

Geissleria Lange-Bertalot & Metzeltin 1996

Type species: *Geissleria moseri* Metzeltin, Witkowski & Lange-Bertalot

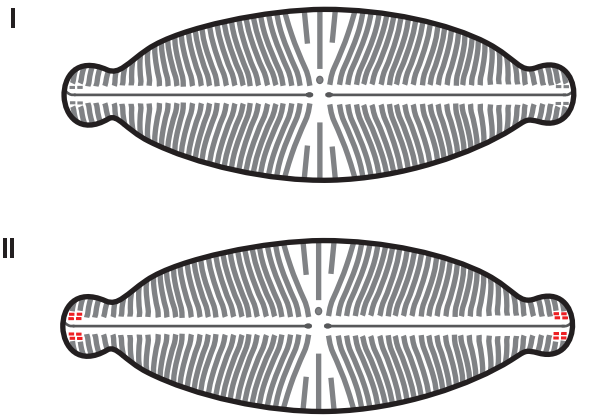
SYNONYM:
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, elliptical to linear elliptical with capitate to broadly rounded apices. Raphe straight. Striae parallel in the mid-valve becoming radiate and often curved (Fig. 139), and parallel to convergent at the apices. Areolae are discernable under LM. Isolated punctum often present in the central area (Fig. 139: D-E). Chief distinguishing characteristic of this genus is the presence of **annulae** at the poles (II). **Annulae** are 1-4 transapical striae, often composed of areolae with a distinctive structure, which interrupt the striae.

Plastid structure – Not observed in tropical African material.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, and orientation, curvature and density of the striae as well as shape of the central area. Presence/absence and position of an isolated punctum and the structure of the **annulae**.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities.



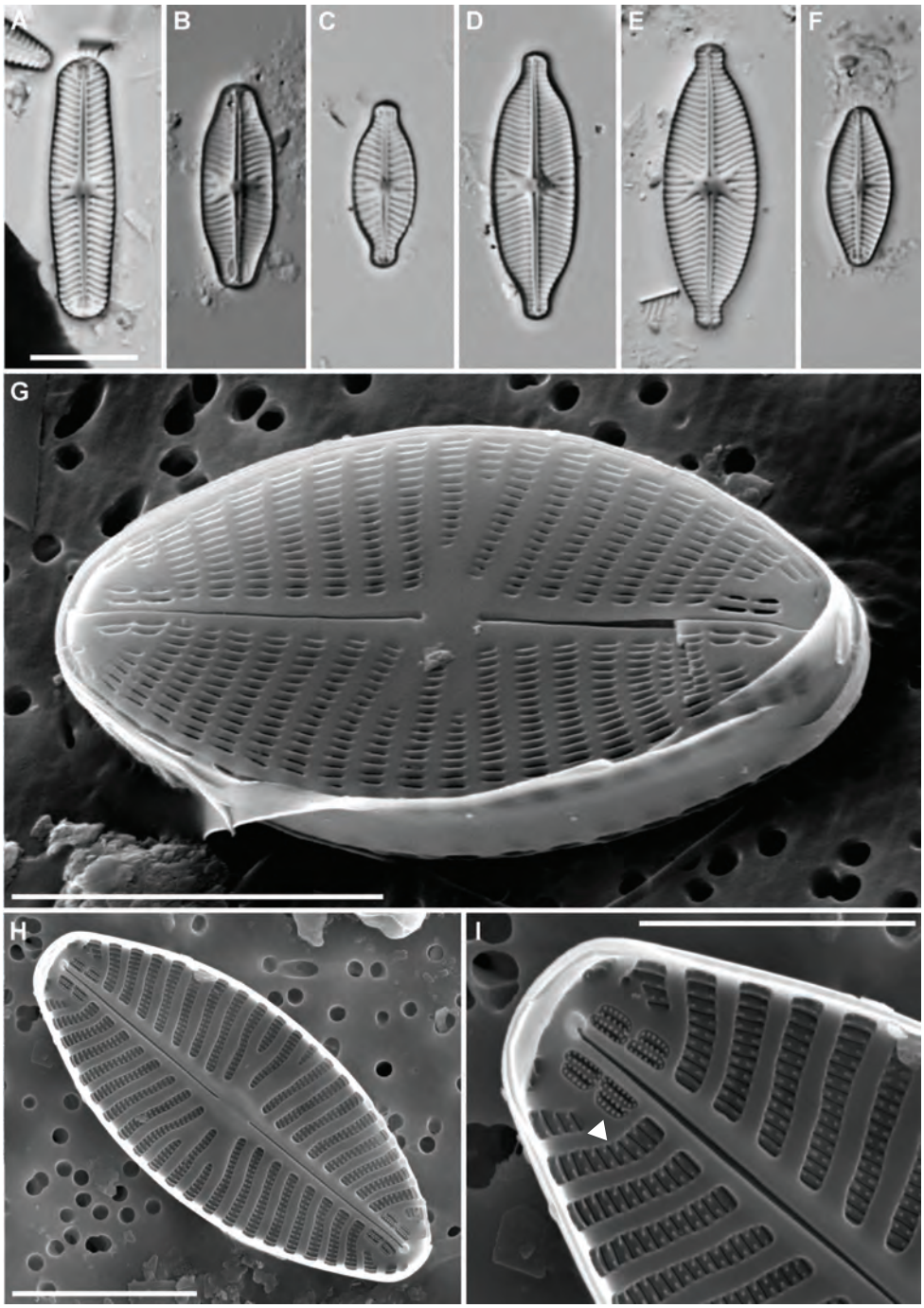


Fig. 139. *Geissleria* spp. **A-F.** LM, valve views of various species. **G-I.** SEM. **G.** External view of valve. **H-I.** Internal view of valve. **I.** Detail of annulae (arrow). Scale bars = 10 µm (A-F), 5 µm (G-H), 3 µm (I).

Hippodonta Lange-Bertalot, Metzeltin & Witkowski 1996

Type species: *Hippodonta lueneburgensis* (Grunow) Lange-Bertalot, Metzeltin & Witkowski

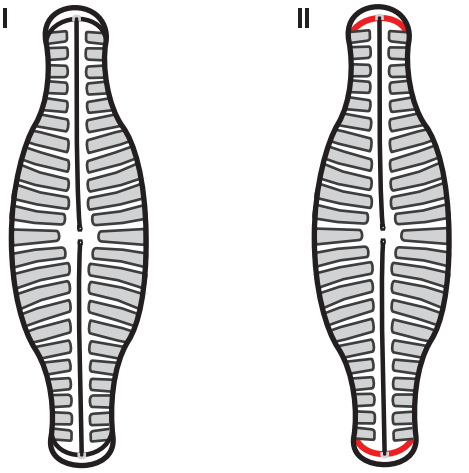
SYNONYM:
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, small, elliptical to linear elliptical with broadly rounded, rounded or subcapitate apices. Striae very robust composed of double, rarely single rows of areolae which are usually not discernable under LM. Raphe straight and simple (Fig. 140: C-P), terminal endings do not extend onto the valve mantle. Thickened bars of silica present at the poles (II; Fig. 141: F) on the valve interior.

Plastid structure – Two plastids one each side of the cell next to the girdles (Fig. 140: A-B).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, orientation and density of the striae as well as structure of the central area.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities.



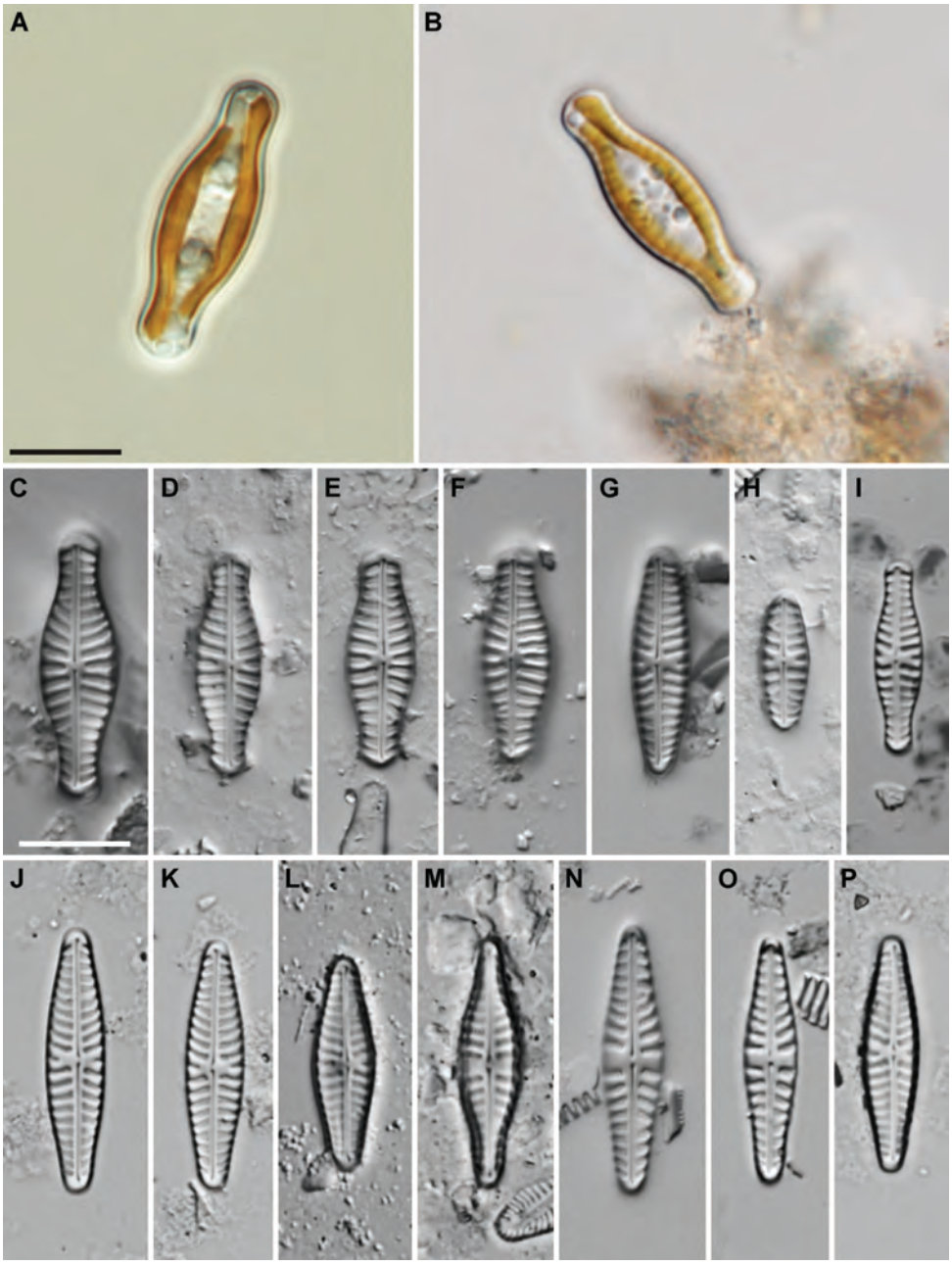


Fig. 140. *Hippodonta* spp. **A-F**. LM. **A-B.** Living cells of *Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski. **B-P.** Cleaned valves. **G-H.** *Hippodonta hungarica* (Grunow) Lange-Bertalot, Metzeltin & Witkowski. Scale bar = 10 µm (A-P).

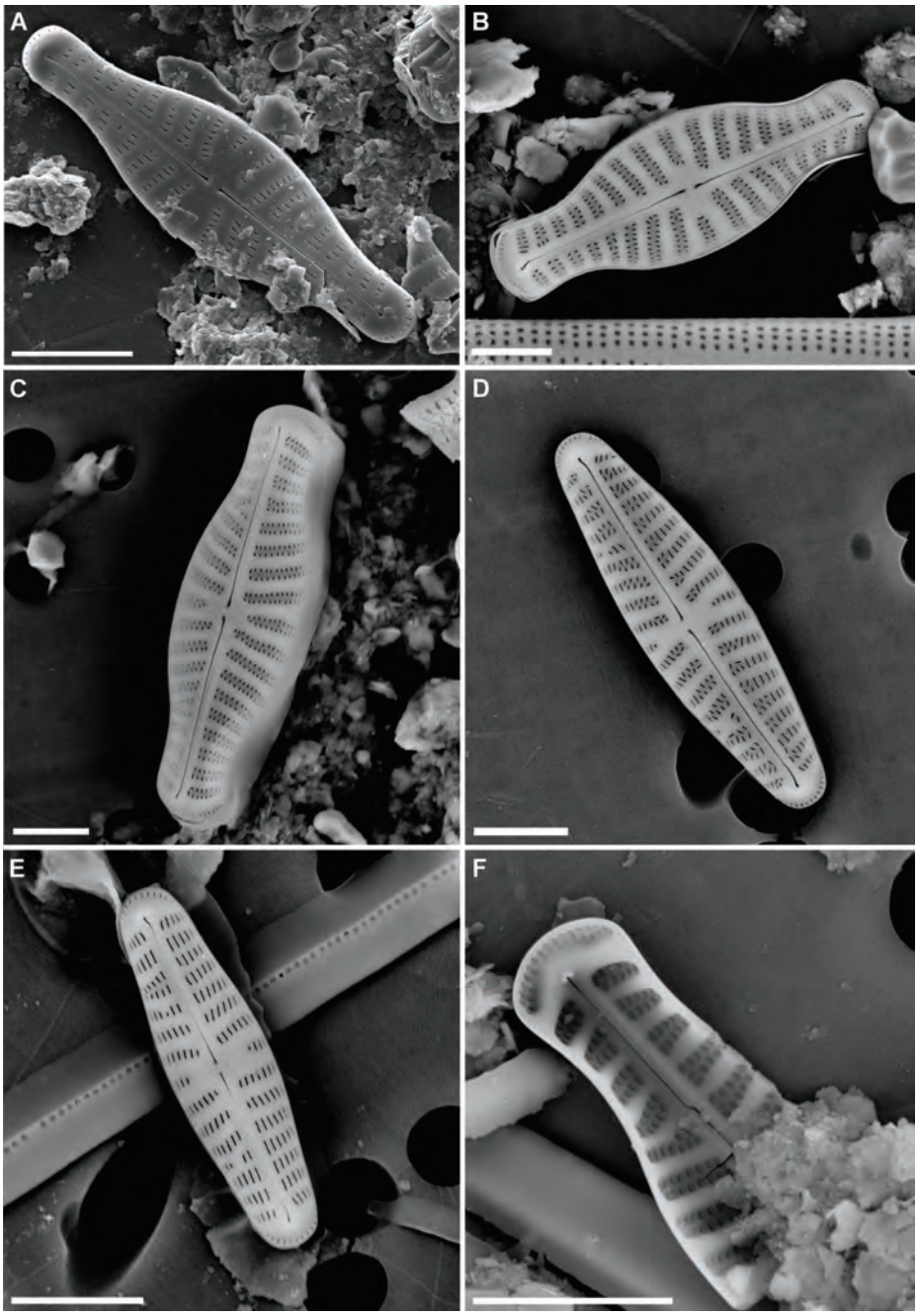


Fig. 141. *Hippodonta* spp. **A-F**. SEM. **A.** *Hippodonta* sp., external view of valve. **B-C.** *H.* capitata, external view of valve. **D-E.** *Hippodonta* spp., external view of valves. **F.** *H. capitata*, internal view of valve, note thickened bar of silica at apex. Scale bars = 5 µm (A, E-F), 4 µm (C-D), 2 µm (B).

Kobayasiella Lange-Bertalot 1999

Type species: *Kobayasiella bicuneus* (Lange-Bertalot) Lange-Bertalot

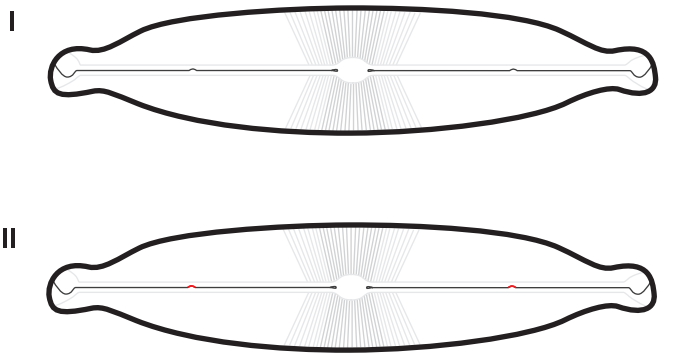
SYNONYM:
Navicula Bory 1822 pro parte
Kobayasia Lange-Bertalot 1996

Characteristics – Cells **biraphid**, mostly linear elliptical in shape with broadly subcapitate, capitate or rostrate apices. Striae very fine, composed of areolae difficult to resolve even under SEM, radiate at mid-valve becoming abruptly convergent near the apices. Raphe straight and simple (Fig. 142: B-F) with a characteristic undulation or kink approximately halfway along the length of the raphe branch (II; Fig. 142: G). Central area variable in size, usually small but may be slightly expanded. Axial area very narrow.

Plastid structure – Single plastid with 2 lobes connected by one or more bridges (Fig. 142: A).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, orientation and density of the striae as well as structure of the central area.

Ecology – Cells solitary, free living and motile. Found in the benthos of acidic, oligotrophic waters in low conductivities.



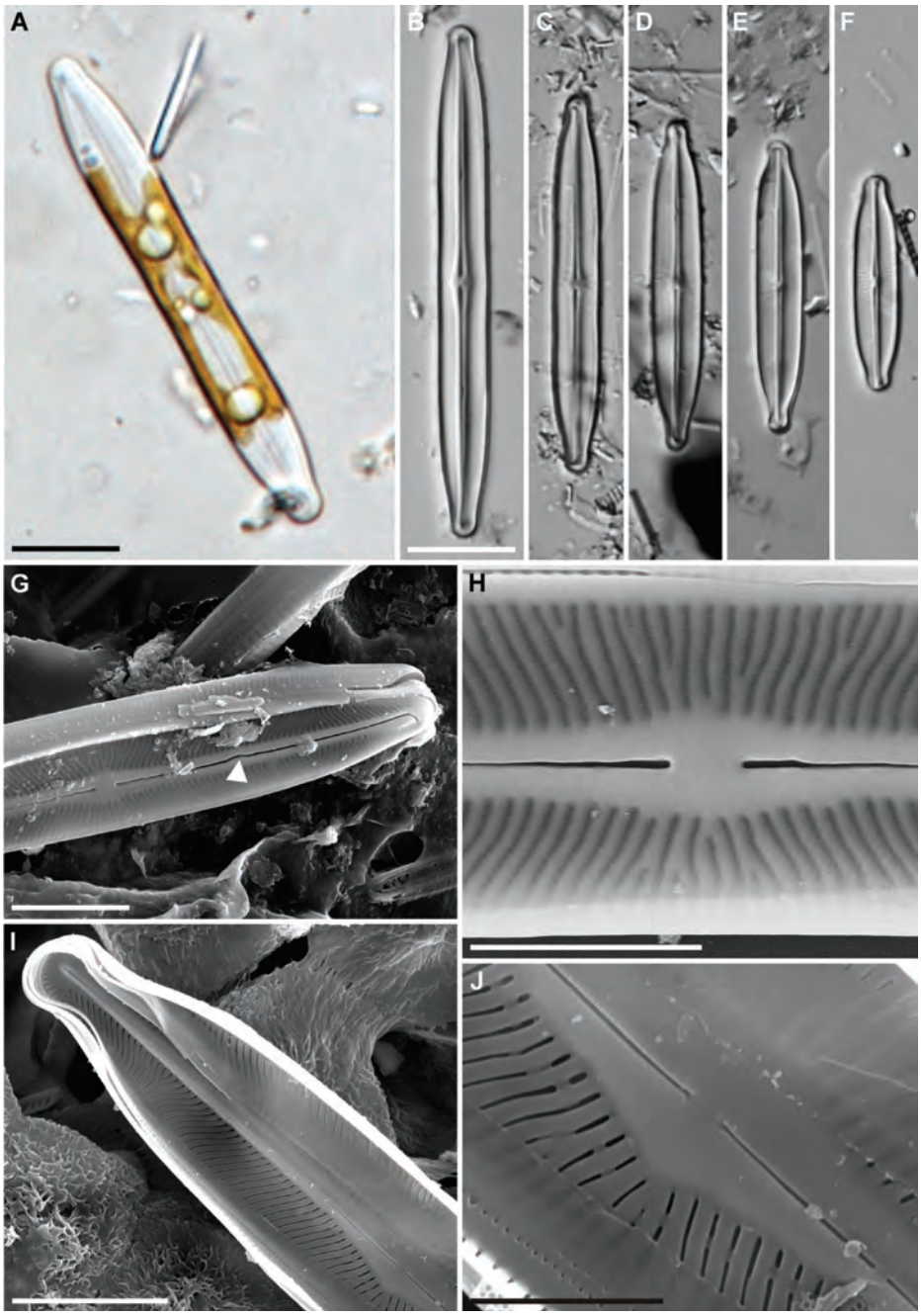


Fig. 142. *Kobayasiella* spp. **A-F.** LM. **A.** Living cell. **B-F.** Cleaned valves. **G-J.** SEM. **G-H.** External view of valve, note kink in the raphe (arrow). **I-J.** Internal view of valve.
Scale bars = 10 µm (A-F), 5 µm (G, I), 3 µm (H), 2 µm (J).

Mayamaea Lange-Bertalot 1997

Type species: *Mayamaea atomus* (Kützing) Lange-Bertalot

SYNONYM:

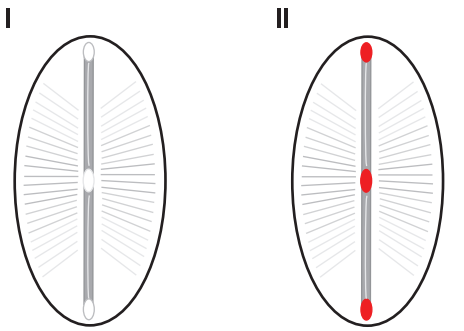
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid**, very small, elliptical with broadly rounded apices. Striae very difficult to discern under LM (Fig. 143: C-K) and also rather difficult to resolve with SEM. Raphe straight and simple (Fig. 143: C-K) carried in a sternum which, along with the striae mid-valve and near the valve margin, are usually the only structures which can be seen using LM. Slight swellings denoting the central and terminal nodules in the sternum at the central area and apices (II).

Plastid structure – Cells with one lobed plastid (Fig. 143: A-B), several lipid bodies scattered throughout the cell.

Identification of species – Species can be identified by cell size, cell shape, orientation and density of the striae as well as structure of the axial area.

Ecology – Cells solitary, free living and motile. Found in the benthos of alkaline eutrophic to hypereutrophic waters with moderate to high conductivities.



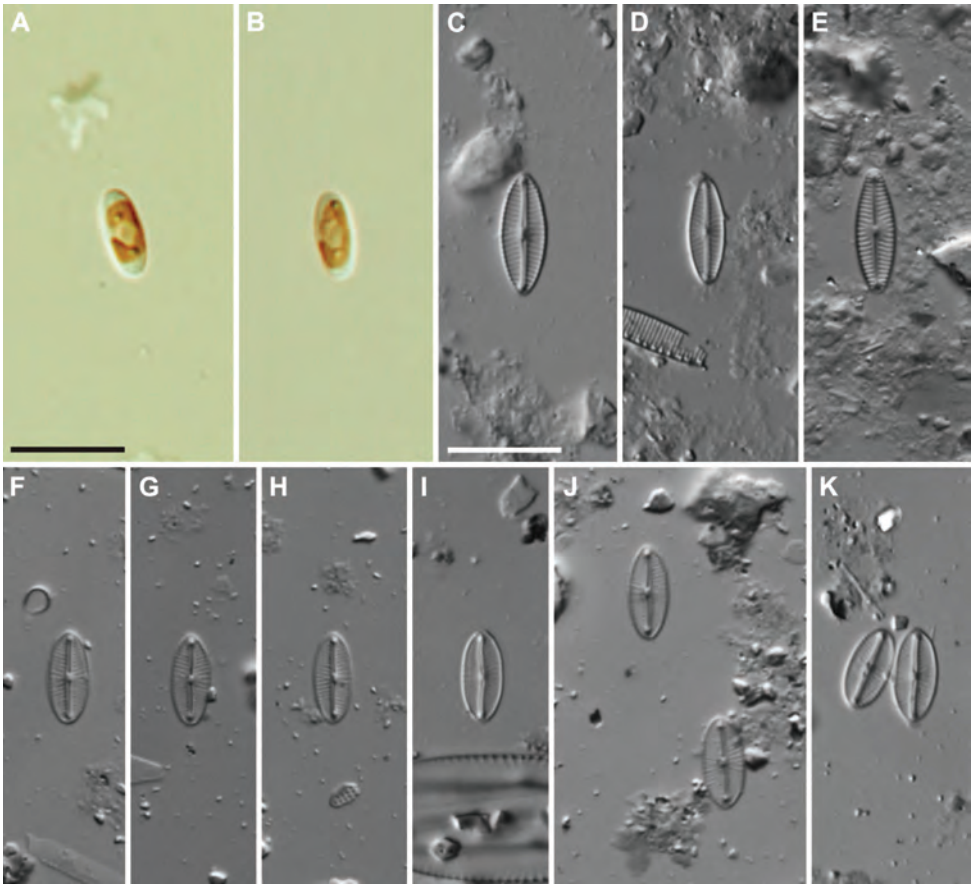


Fig. 143. *Mayamaea* spp. **A-B.** LM, living cells. **C-K.** LM, valve view of cleaned material.
Scale bar = 10 µm (A-K).

Navicula Bory 1822

Type species: *Navicula tripunctata* (O.F. Müller) Bory

Notes – Throughout this book many genera have *Navicula* listed as a synonym. For many years all diatoms cells exhibiting isobilateral symmetry and having a median raphe were placed into *Navicula* sensu lato. *Navicula* sensu stricto (in the strict sense) is now restricted to the former section lineolatae or those taxa having striae composed of linear areolae. Over the last 3 decades many taxa have been split off from *Navicula*; it is important to remember that this is an on-going process and that many more species currently in *Navicula* may in future be placed in other genera. In the interim, what may be termed as a 'catch all' genus has been established - *Naviculadicta* Lange-Bertalot 1994. This genus contains taxa without enough characteristics for description as a separate genus and which cannot be placed in *Navicula* sensu stricto. As more data (morphological or molecular) become available these taxa will be placed in new genera. We will not discuss or illustrate *Naviculadicta* in this volume as we do for the other genera as it not clearly a delimited entity.

Navicula Bory 1822

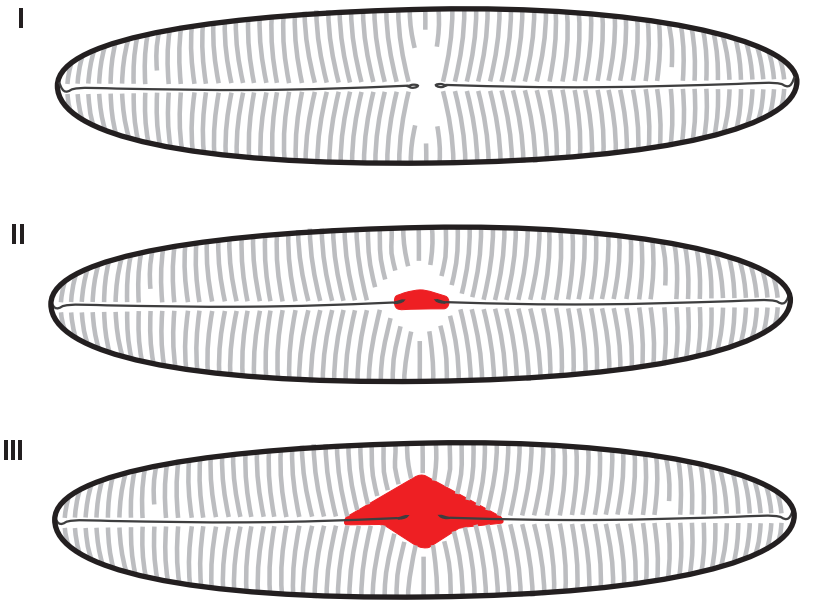
Type species: *Navicula tripunctata* (O.F. Müller) Bory

Characteristics – Cells **biraphid**, size, shape and apex structure variable. Striae discernable under LM (Fig. 145) and composed of a single row of linear areolae (**lineolae;** Fig. 146). In general striae are parallel mid-valve, become radiate and then often convergent towards the apices. Raphe carried in a sternum which in some taxa has a slight unilateral inflation (II) at the central nodule. The central area is variable in size and may not always be symmetrical (III).

Plastid structure – Cells with 2 plate-like chloroplasts, one along each side of the girdle (Fig. 144: B-E).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the axial area and central area and the shape of the central and terminal raphe endings.

Ecology – Cells solitary, free living and motile. Found in the benthos of waters ranging from acidic to alkaline, oligotrophic to hypereutrophic and from low to high conductivities.



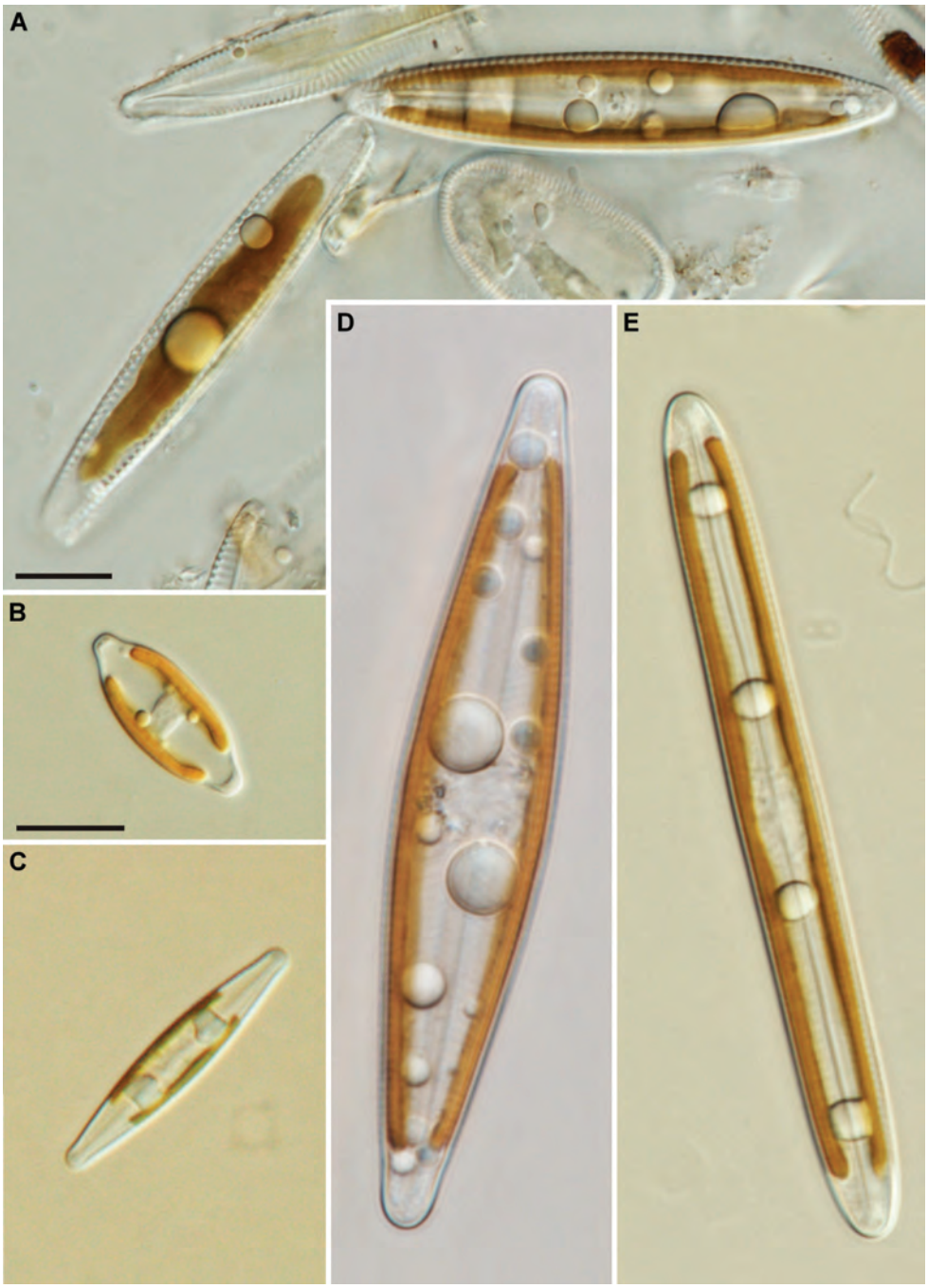


Fig. 144. *Navicula* spp. **A-E.** LM, living cells. **A.** *N. tripunctata*, valve view (right) and girdle view (left). **B-E.** Valve views. **B.** *N. radiosa* Kützing. **E.** *N. angusta* Grunow.
Scale bars = 10 µm (A-E).

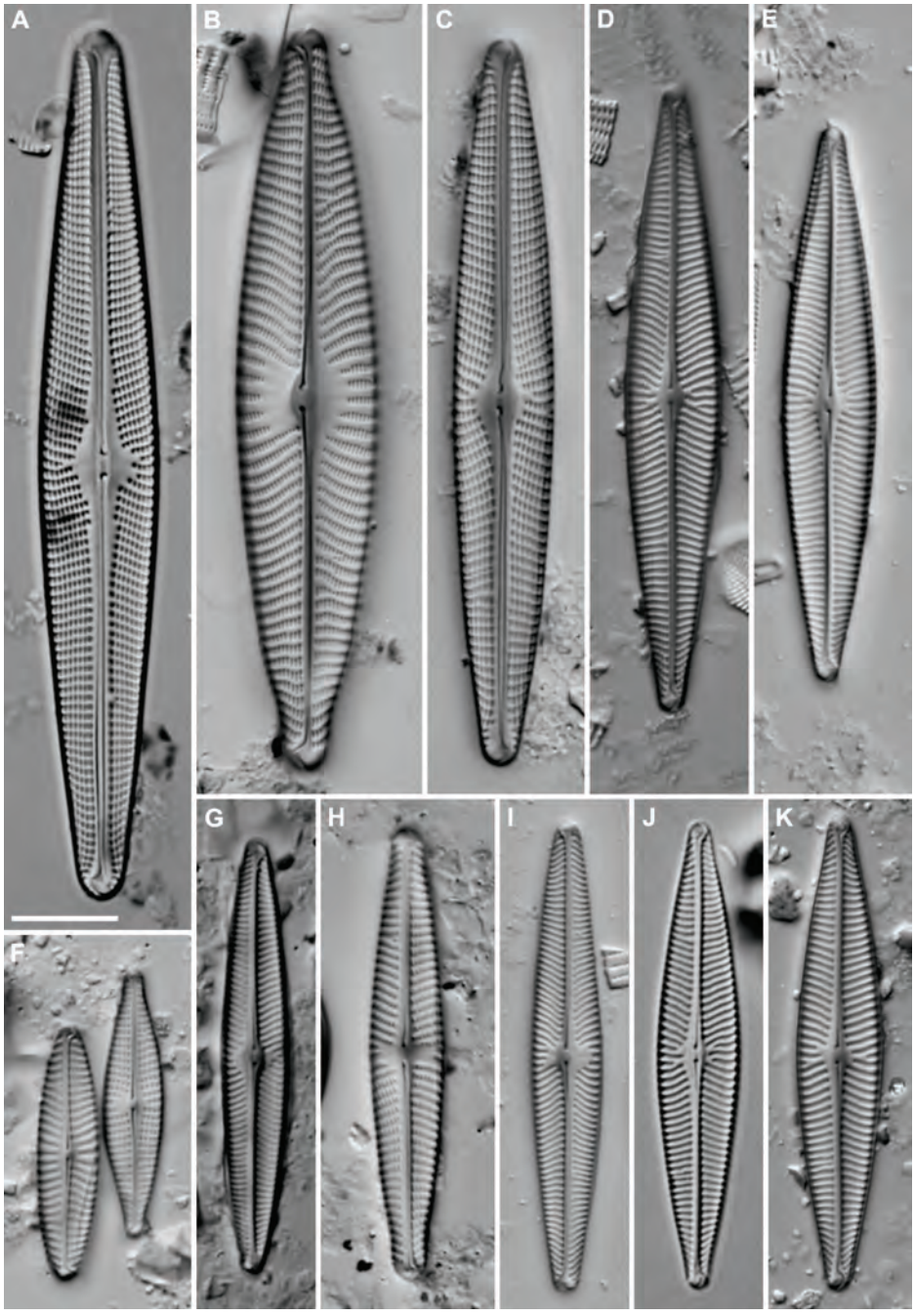


Fig. 145 *Navicula* spp. **A-K.** LM, cleaned valves of various species. **B.** *N. viridula* (Kützing) Ehrenberg. **E.** *N. zanonii* Hustedt. **I.** *Navicula nielsfogedii* J.C. Taylor & Cocquyt.
Scale bar = 10 µm (A-K).

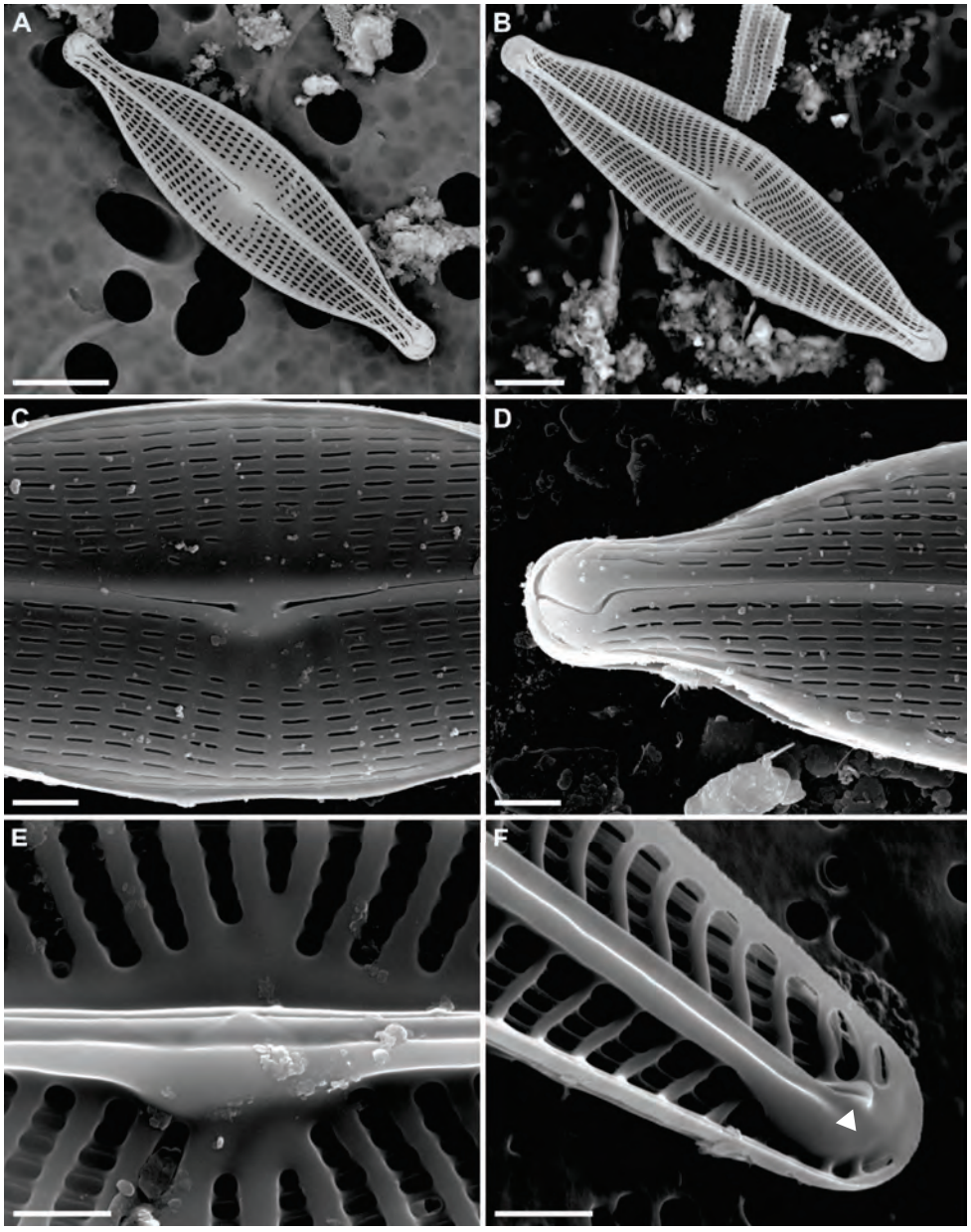


Fig. 146. *Navicula* spp. **A-F.** SEM. **A-D.** External view of valves. **C.** Detail of central raphe endings. **D.** Detail of terminal raphe ending. **E-F.** Internal view of valve. **E-F.** *N. nielsfogedii*, detail of central raphe endings (**E**) and terminal raphe ending (**F**), note helictoglossa (arrow).
Scale bars = 5 µm (A-B), 1 µm (C-F).

Nupela Vyverman & Compère 1991

Type species: *Nupela giluwensis* Vyverman & Compère

SYNONYM:

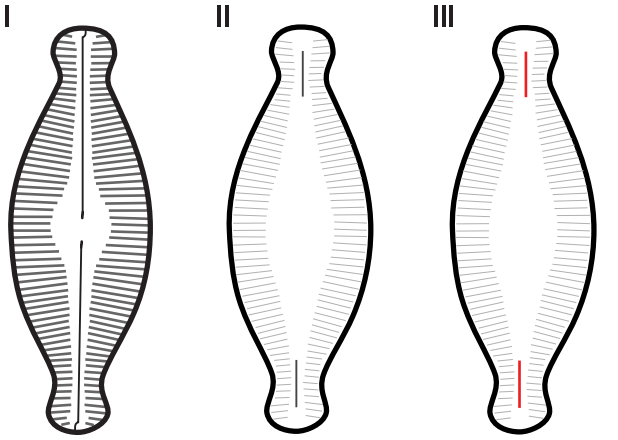
Navicula Bory 1822 pro parte

Characteristics – Cells **isovalvar** or **heterovalvar**, **biraphid**, small, elliptical to linear-elliptical, slightly asymmetric to the apical axis, with broadly rounded or protracted capitate or sub-capitate apices. Striae difficult to discern under LM (Fig. 147: E-R) composed of single rows of round or elongate areolae (Fig. 148: B-F). Raphe straight and simple (I; Fig. 148: C) extending on to the valve mantle, the opposite valve has short or very short and indistinct straight raphe branches which do not extend on to the valve mantle (III). Central area is asymmetrical and may be unilaterally expanded and may or may not reach the valve margins. Axial area often large (Fig. 148: B, D) and may be ornamented with valve face undulations .

Plastid structure – Cells with one plastid with lobes extending under the valve face (Fig. 147: A-D).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, orientation and density of the striae as well as shape of the central and axial areas.

Ecology – Cells solitary, free living and motile. Found in the benthos of slightly acidic to circumneutral waters with low conductivities.



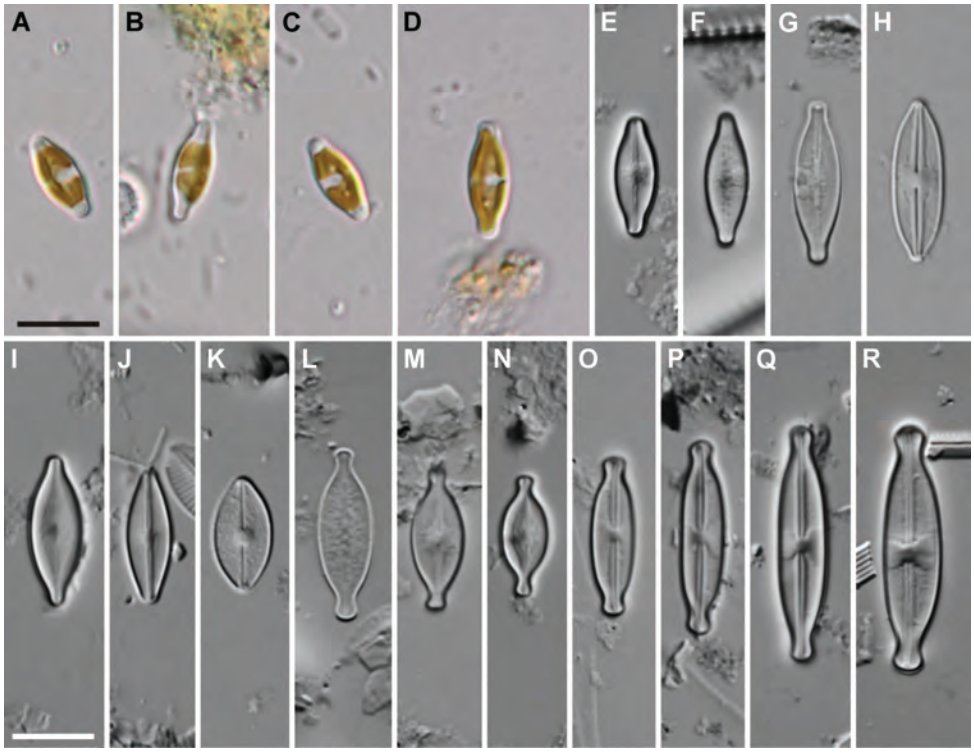


Fig. 147. *Nupela* spp. **A-R.** LM. **A-D.** Living cells. **E-R.** Valve views of cleaned material.
Scale bars = 10 µm (A-R).

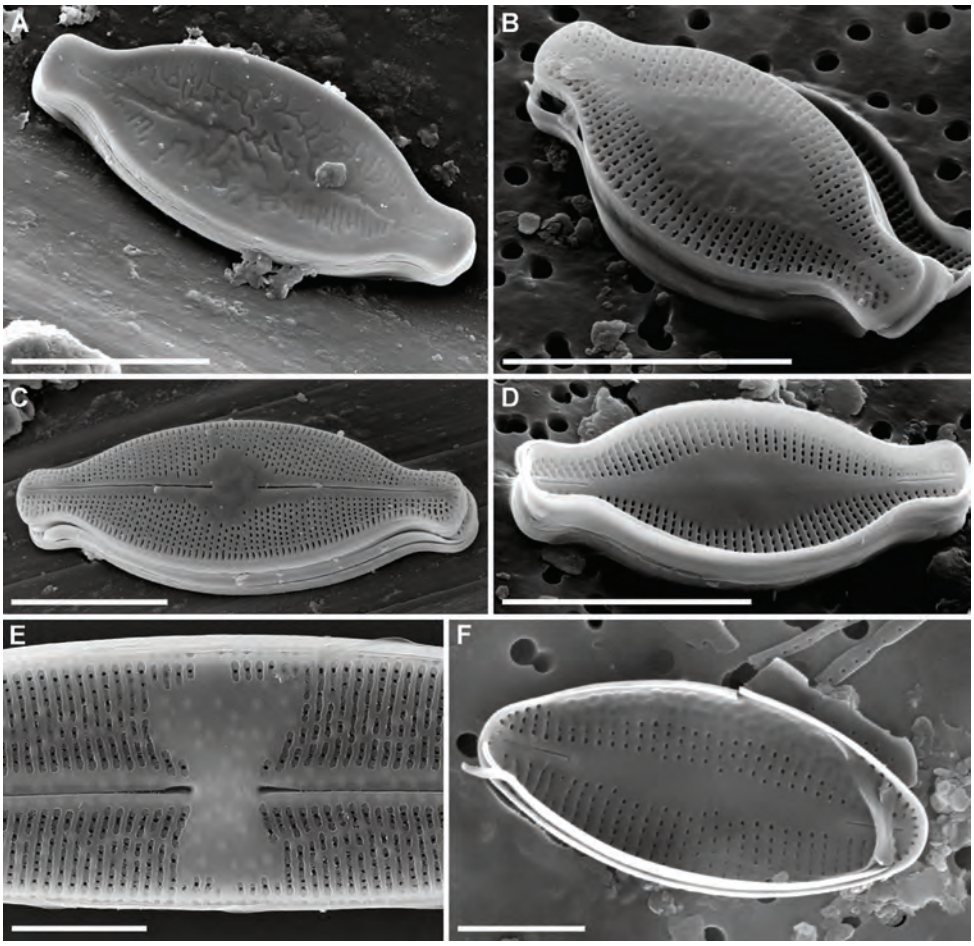


Fig. 148. *Nupela* spp. **A-F.** SEM. **A-C.** External view of valves, note short raphe branches (**B**). **D-F.** Internal view of valves, note short raphe branches (**D, F**). Scale bars = 5 µm (A-D), 2 µm (E-F).

Seminavis D.G. Mann 1990

Type species: *Seminavis gracilenta* (Grunow ex A.W.F. Schmidt) D.G. Mann

SYNONYM:

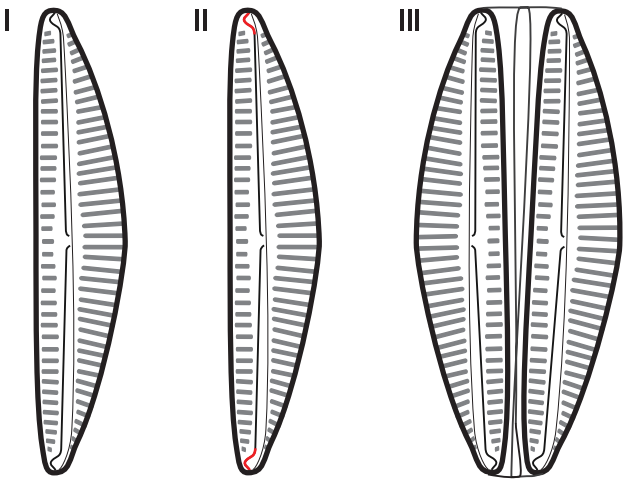
Amphora Ehrenberg ex Kützing 1844 pro parte

Characteristics – Cells **dorsiventral**, **biraphid**, straight ventral margin, curved dorsal margin with rounded apices. Striae discernable under LM (Fig. 149: A-C), composed of linear areolae only possible to resolve with SEM (Fig. 149: D-F). Raphe straight and simple (Fig. 149) carried in a sternum, terminal endings deflected to the dorsal side (II). Axial area and central area of different width and shape on dorsal and ventral sides. Differentiated from *Amphora* by the structure of the areolae and the plastids (naviculoid).

Plastid structure – Cells with 2 plate-like plastids, one along each side of the girdle.

Identification of species – Up till now only one species known from freshwaters of tropical Africa: *Seminavis strigosa* (Hustedt) Danielidis & Economou-Amili.

Ecology – Cells solitary, free living and motile. Found in the benthos of eutrophic waters with moderate to high conductivities.



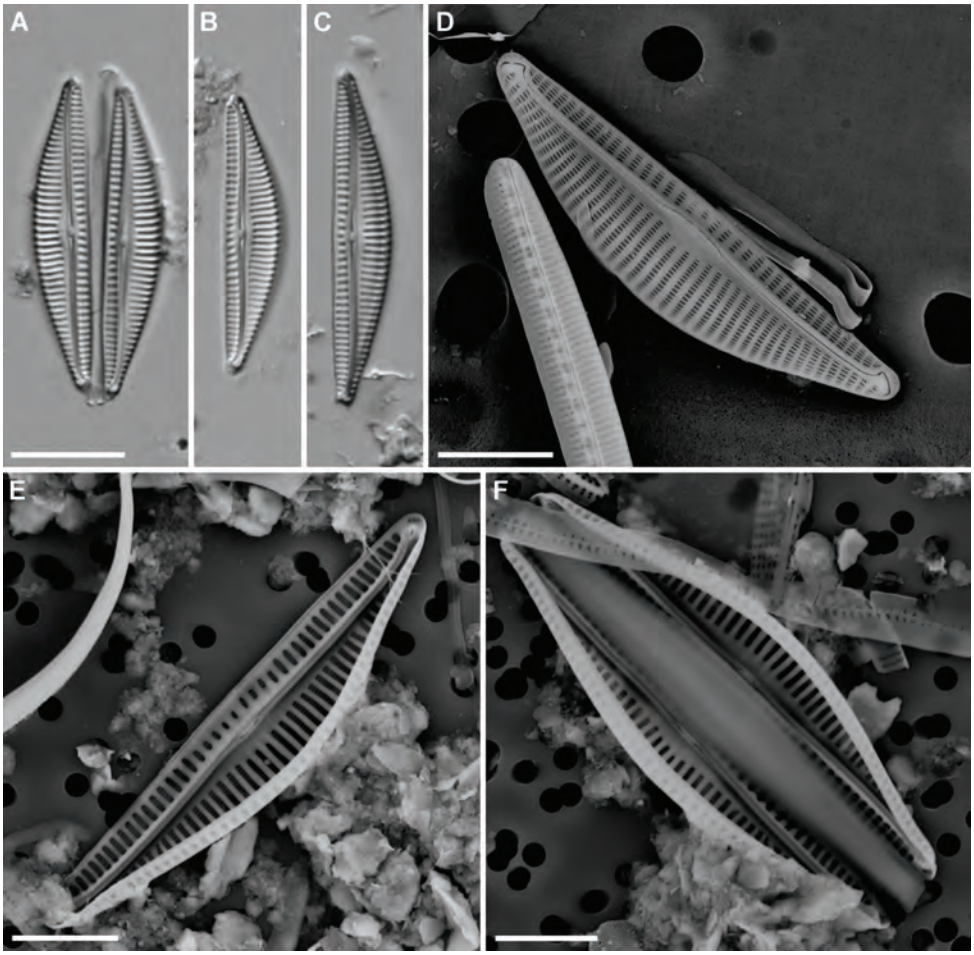


Fig. 149. *Seminavis strigosa.* **A-C.** LM, valve views. **D-F.** SEM. **D**. External view of valve. **E-F.** Internal view of valves.
Scale bars = 10 µm (A-C), 5 µm (D-F).

Gyrosigma Hassall 1845

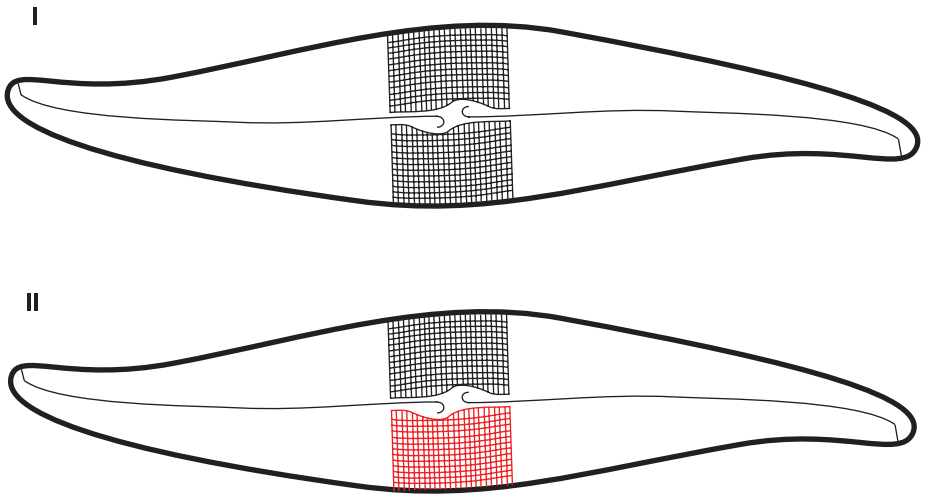
Type species: *Gyrosigma hippocampus* (Ehrenberg) Hassall

Characteristics – Cells **biraphid**, **sigmoid**, large to very large with rounded apices. Striae fine, transapical and longitudinal striae visible at right angles to each other (II; Fig. 151: C-D). Raphe sigmoid and simple (Fig. 150: C-D). Central area small and may contain special structures such as small silica ribs.

Plastid structure – Two plate-like chloroplasts sometimes with lobed margins lie along each side of the girdle (Fig. 150: A-B). Many lipid bodies scattered throughout the cell.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices (degree of sigmoidality), structure and density of the transapical and longitudinal striae, structure of the central area as well as the shape and extent of the central raphe endings.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities.



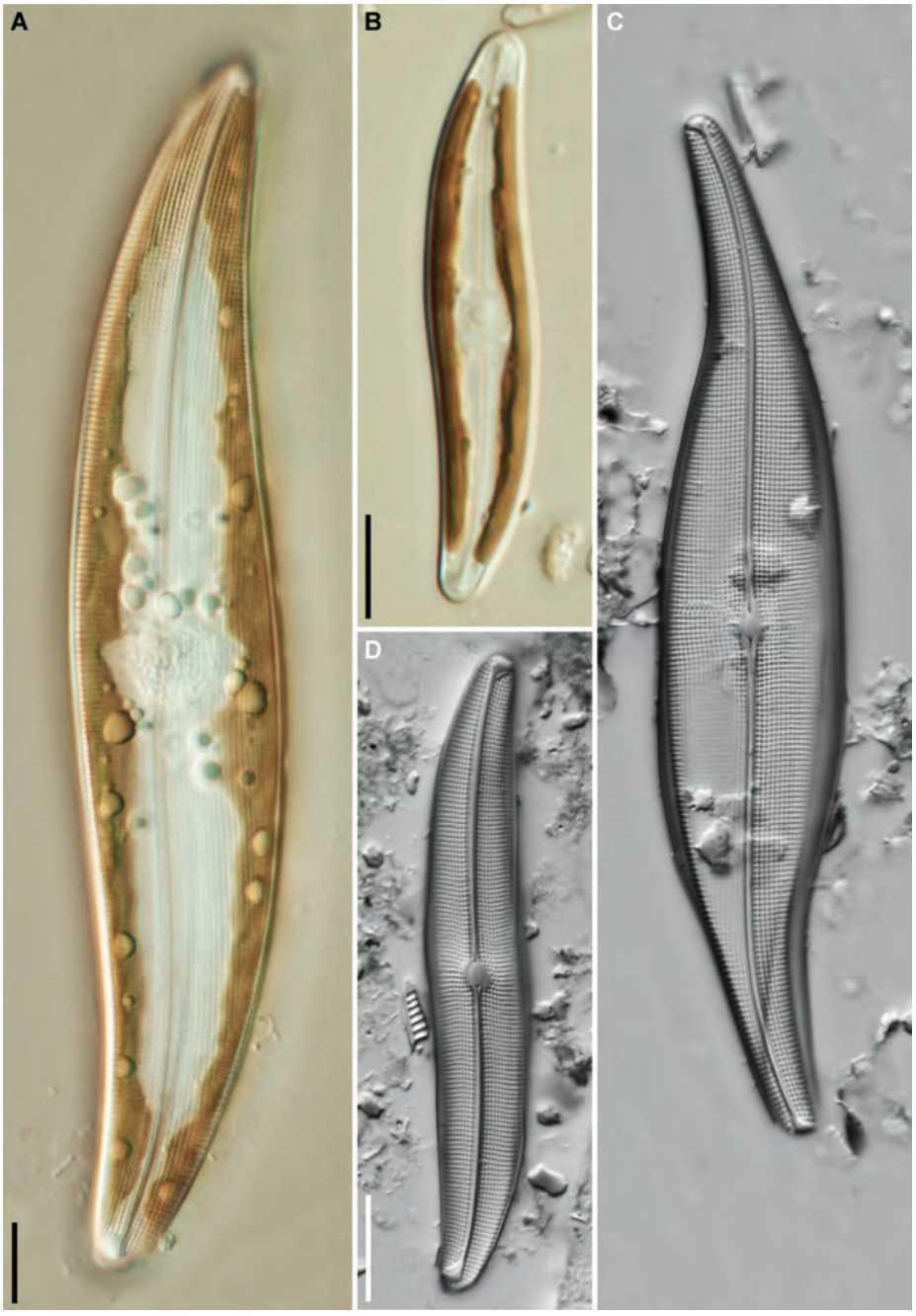


Fig. 150. *Gyrosigma* spp. **A-D.** LM. **A**. Living cell of *G. rautenbachiae* Cholnoky, note many lipd bodies. **B.** Living cell of *G. scalproides* (Rabenhorst) Cleve. **C.** Cleaned valve of *G. parkeri* (Harrison) Boyer. **D.** Cleaned valve of *G. scalproides*. Scale bars = 10 µm (A-D).

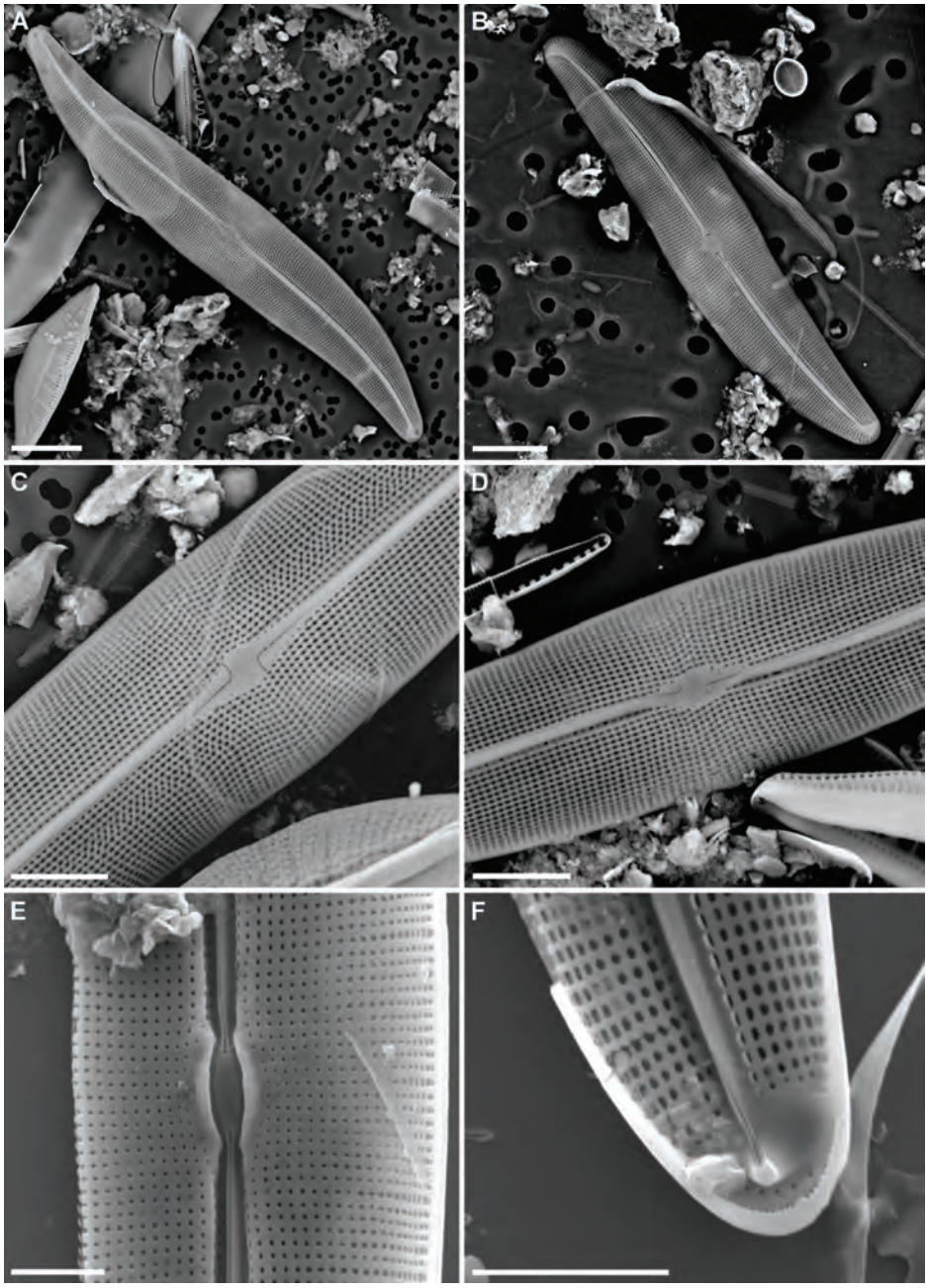


Fig. 151. *Gyrosigma* spp. **A-F.** SEM. **A-D.** External view of valves. **B.** *G. scalproides.* **C-D.** Detail of central raphe endings. **E-F.** Internal view of valves. **E.** *G. rautenbauchiae*, detail of internal central raphe endings. **F.** Detail of internal terminal raphe ending and helictoglossa.
Scale bars = 10 µm (A-B), 5 µm (C-F).

Pleurosigma W. Smith 1852

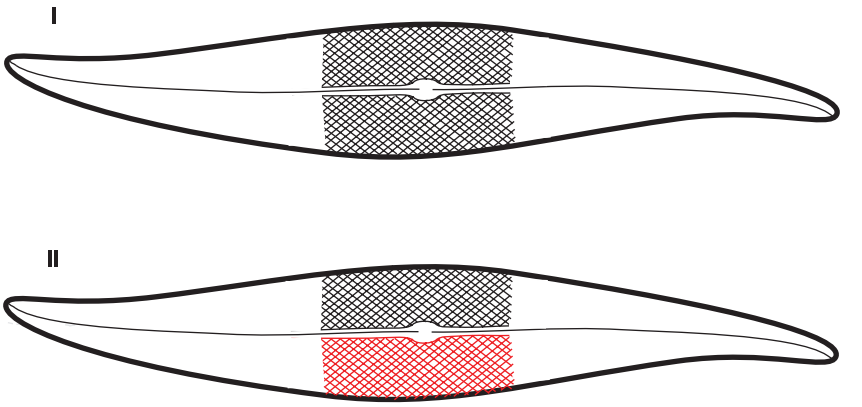
Type species: *Pleurosigma angulatum* (E.J. Quekett) W. Smith

Characteristics – Cells **biraphid**, **sigmoid**, large to very large with acutely rounded apices. Striae fine, transapical and longitudinal striae run diagonal to each other (II). Raphe sigmoid and simple (Fig. 152). Central area small, axial area very narrow.

Plastid structure – Two plate-like plastids, sometimes with lobed margins, lying along each side of the girdle (Fig. 152: A).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central area and the relative angle of the diagonal striae.

Ecology – Cells solitary, free living and motile. Found in the benthos of alkaline mesotrophic to eutrophic waters in moderate to high conductivities.



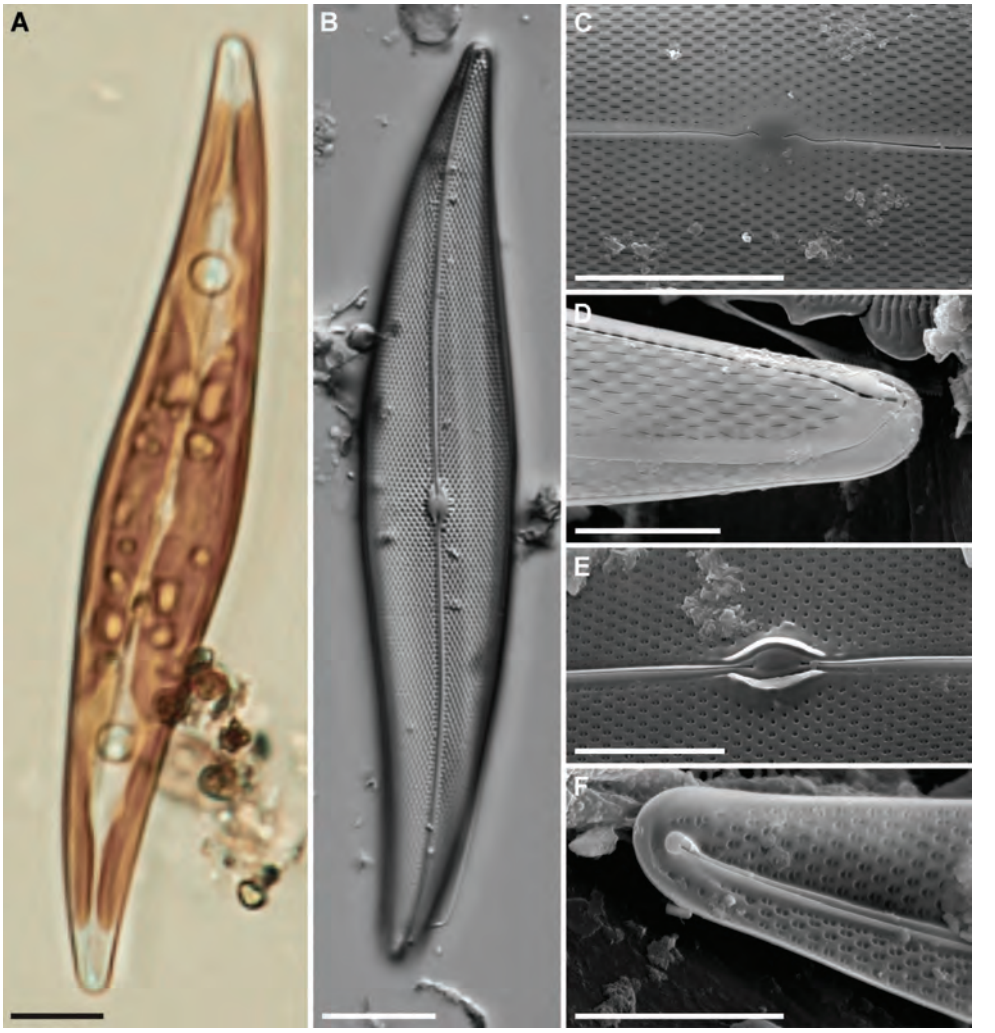


Fig. 152. *Pleurosigma salinarum* Grunow. **A-B.** LM. **A**. Living cell. **B.** Cleaned valve**. C-F.** SEM. **C-D.** External view of valve, detail of central raphe endings (**C**) and apex (**D**). **E-F.** Internal view of valve, detail of central raphe endings (**E**) and terminal raphe ending with helictoglossa (**F**).
Scale bars = 10 µm (A-B), 5 µm (C-F).

Craticula Grunow 1868

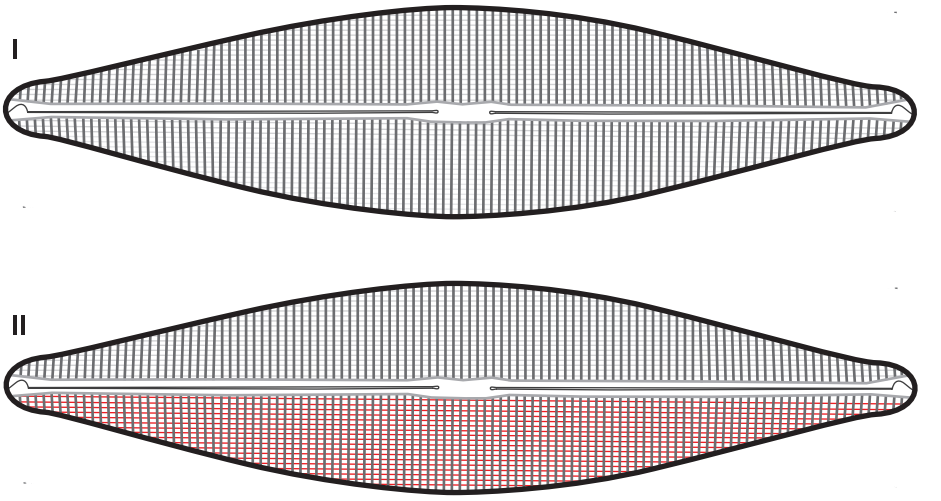
Type species: *Craticula perrotettii* Grunow

Characteristics – Cells **biraphid**, lanceolate with rostrate, capitate or broadly rounded apices. Striae parallel through the length of the valve. Areolae regularly arranged, very small and difficult to observe under LM (Fig. 154: A, B, D) but forming longitudinal striae (II). Cells of different species vary dramatically in size. Under certain conditions the cell forms a craticula (Fig. 1543: C), internal silica thickenings composed of a central rib and transverse ribs.

Plastid structure – Cells with one or two plastids on either side of the nucleus on each side of the girdle (clearly visible in large cells). Typically several small lipid droplets occur in the cytoplasm linking the plastids with one large droplet near to each pole (Fig. 153: C).

Identification of species – Species in this genus are distinguished based on cell size and shape as well as longitudinal and transverse striae density. The structure and shape of the central area can also be a useful characteristic.

Ecology – Cells solitary and motile. Found in the benthos of oligotrophic acidic water and extending into alkaline waters with high conductivity as well as very hard waters. Craticulae are formed when cells are exposed to high osmotic pressure.



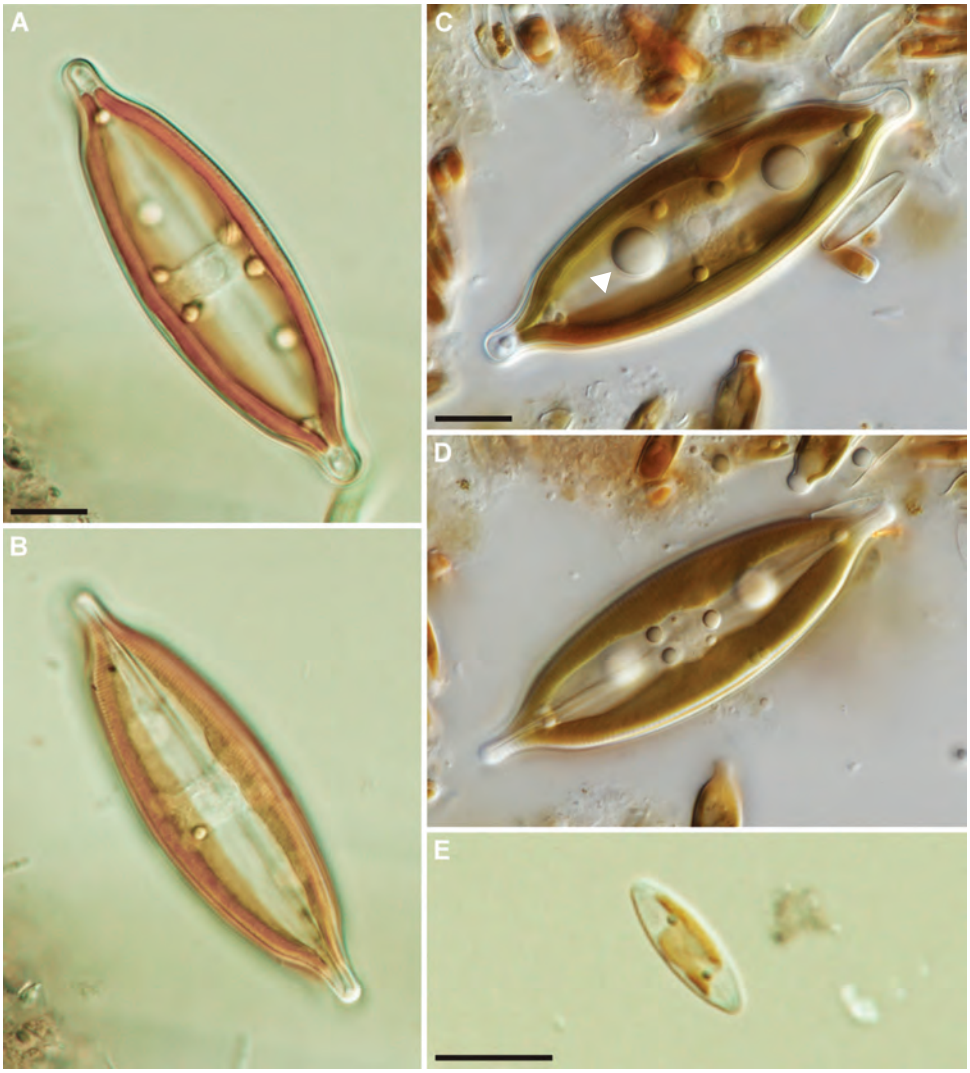


Fig. 153. *Craticula* spp. **A-E.** LM. **A-B.** Living cell of *Craticula ambigua* (Ehrenberg) D.G. Mann, valve view, different foci of same cell. **C-D.** Living cell of *Craticula ambigua*, valve view, different foci of same cell, note large lipid droplets (arrow). **E.** *Craticula molestiformis* (Hustedt) Mayama valve view. Scale bars = 10 µm.

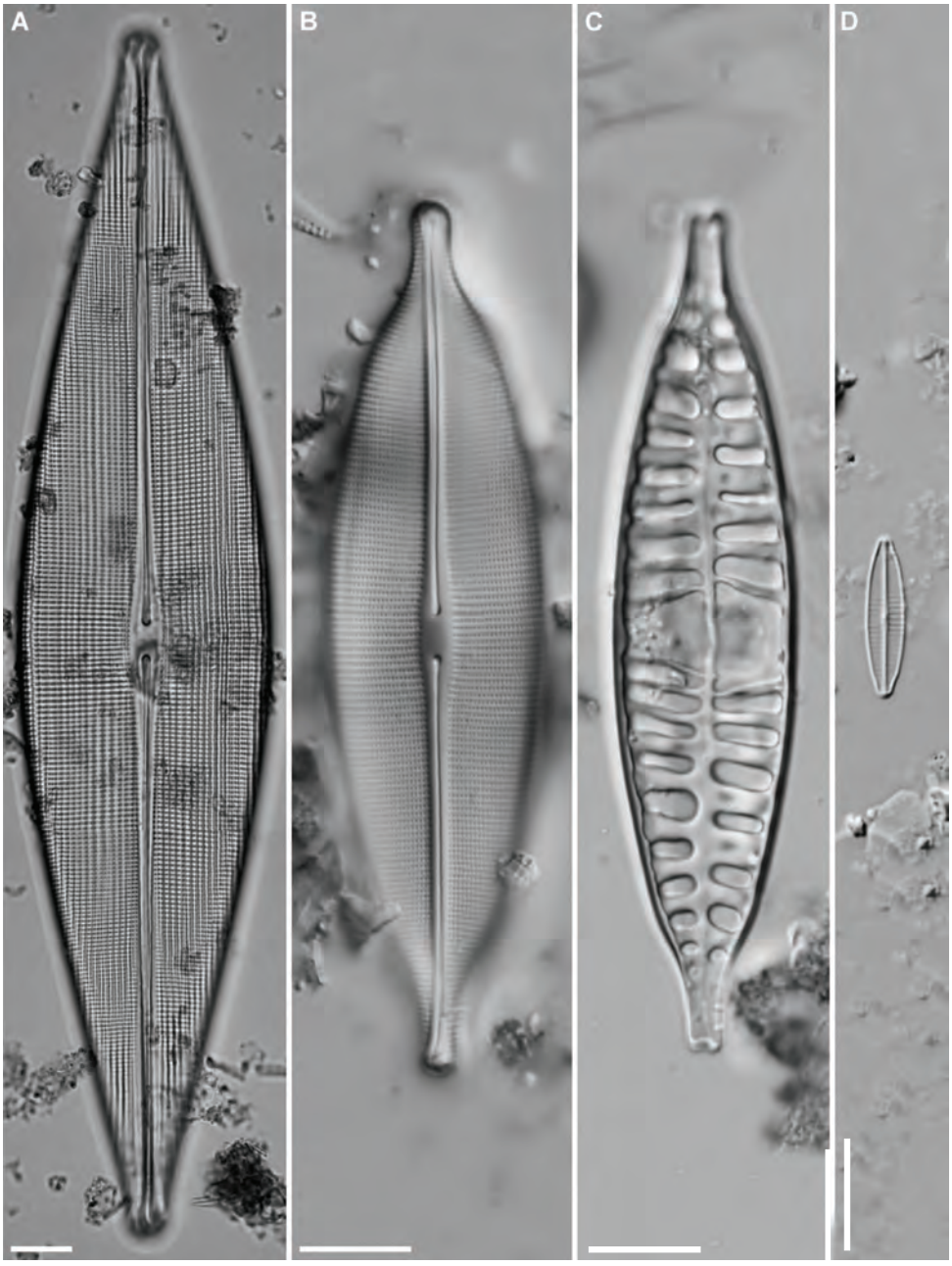


Fig. 154. *Craticula* spp. **A-D.** LM. **A.** Valve view of *Craticula perrotettii.* **B.** Valve view of *C. ambigua*. **C.** *Craticula* sp., a craticula. **D.** Valve view of *Craticula submolesta* (Hustedt) Lange-Bertalot.
Scale bars = 10 µm.

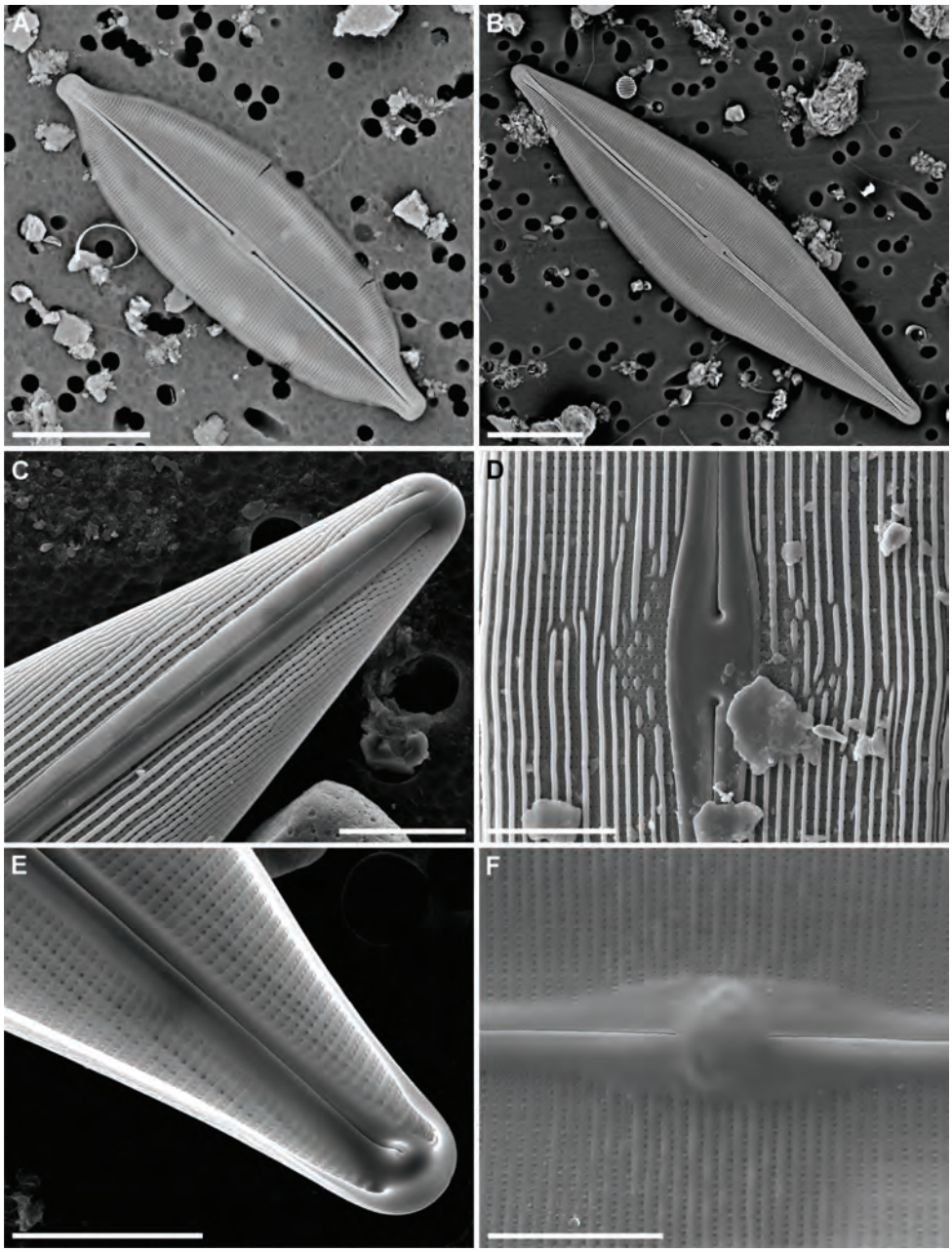


Fig. 155. *Craticula* spp. **A-F.** SEM. **A.** Valve view of *Craticula ambigua*. **B.** Valve view of *C. cuspidata* (Kützing) D.G. Mann . **C-F.** *C. perrotettii,* external view of terminal raphe ending (**C**), external view of central raphe endings (**D**), internal view of terminal raphe ending (**E**), internal view of central raphe endings (**F**). Scale bars = 20 µm (A-B), 10 µm (C-F).

Stauroneis Ehrenberg 1843

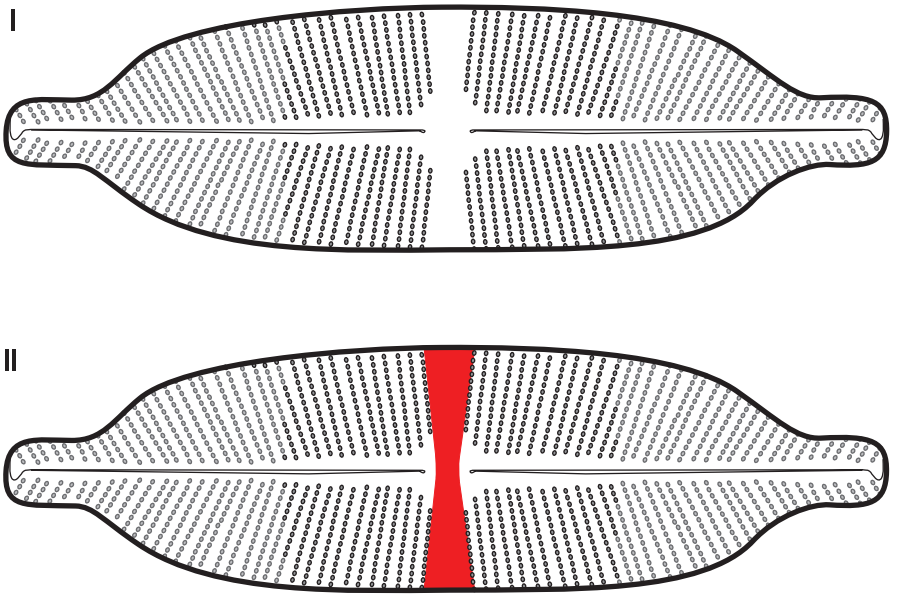
Type species: *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg

Characteristics – Cells **biraphid**, cell may be large, elliptical to linear-elliptical and sub-capitate to capitate apices. Striae easily discernable under LM (Fig. 157) composed of a single row of round or elongate areolae (Fig. 158: A). Raphe carried in a sternum. **Stauros** present (II; Fig. 157; Fig. 158: D-E). **Pseudosepta** may be present at the apices (Fig. 158: C).

Plastid structure – 2 plate-like plastids extending under each valve (Fig. 156).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae, structure of the central raphe endings as well as structure of the central stauros and the presence/absence of pseudosepta.

Ecology – Cells solitary, free living and motile. Found mostly in the benthos of oligotrophic standing waters with low conductivities and also found in streams and sub-aerial habitats.



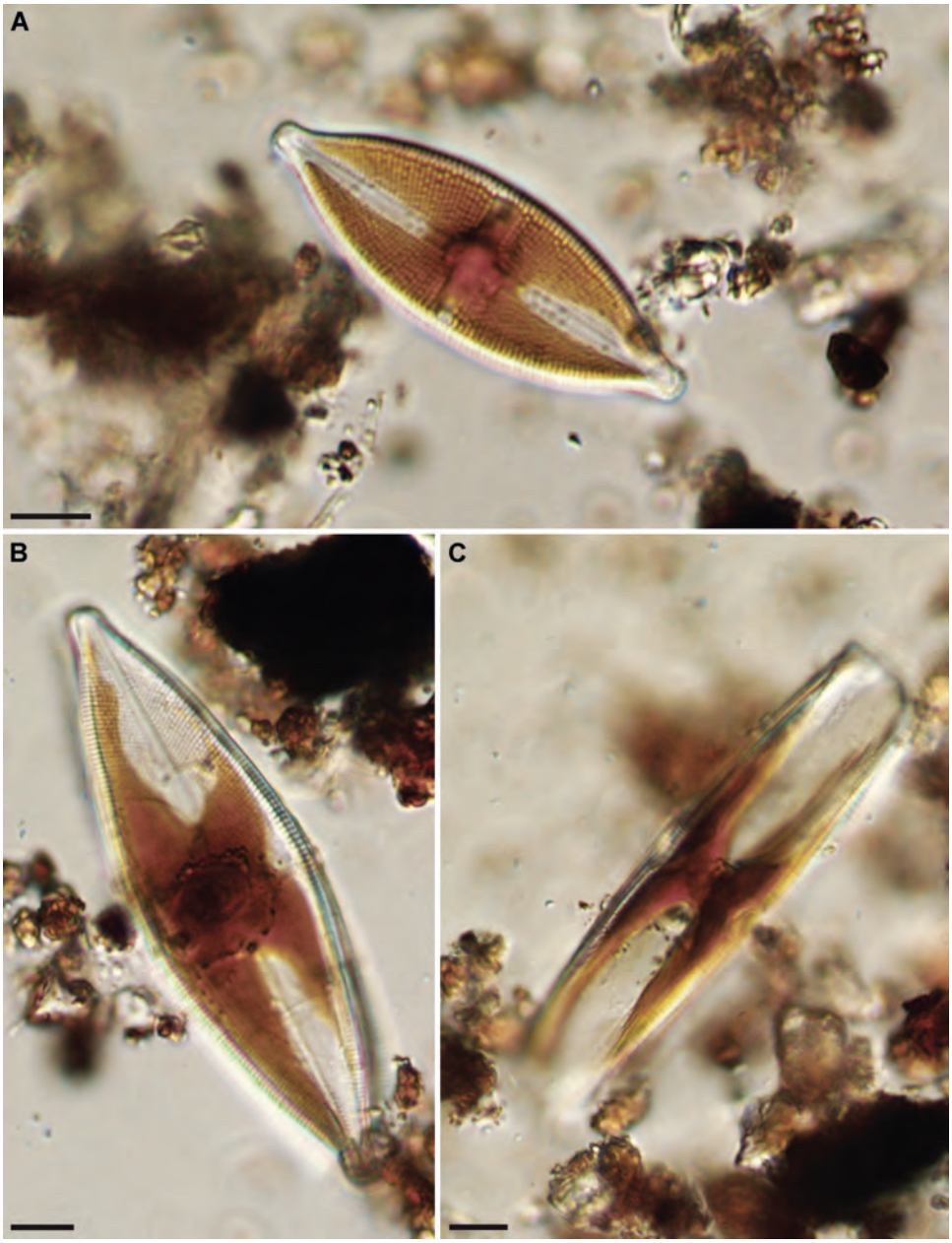


Fig. 156. *Stauroneis* spp. **A-C.** LM, living cells. **A-B.** Valve views. **C.** Girdle view. Scale bars = 10 µm.

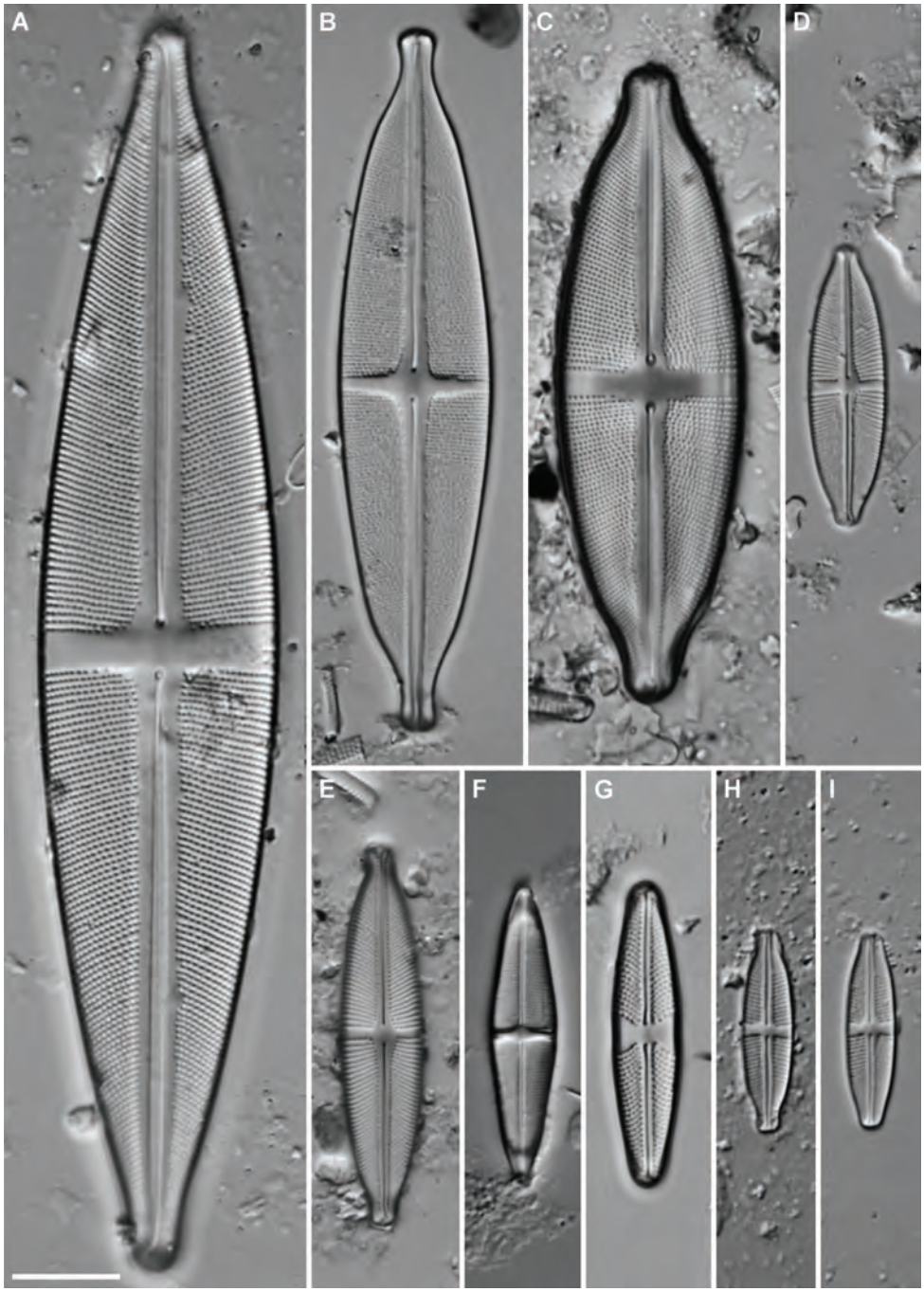


Fig. 157. *Stauroneis* spp. **A-I.** LM, cleaned valves. **B.** *Stauroneis gracilior* E. Reichardt. **H-I.** *Stauroneis kriegeri* R.M. Patrick.
Scale bar = 10 µm (A-I).

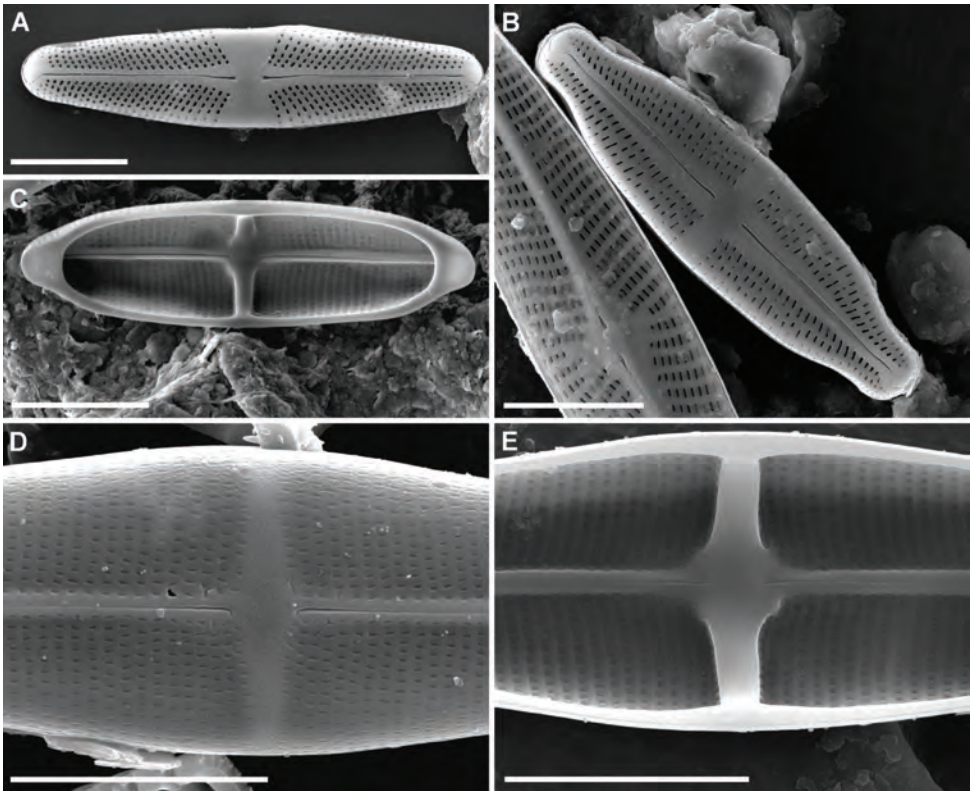


Fig. 158. *Stauroneis* spp. **A-E.** SEM. **A-B, D.** External view of valves. **B.** *Stauroneis kriegeri*. **C.** Internal view of valve, note the pseudosepta at both apices. **E.** Internal view of valve, detail of stauros. Scale bars = 5 µm (A-E).

Envekadea Van de Vijver, Gligora, F. Hinz, Kralj & Cocquyt 2009

Type species: *Envekadea hedinii* (Hustedt) Van de Vijver, Gligora, F. Hinz, Kralj & Cocquyt

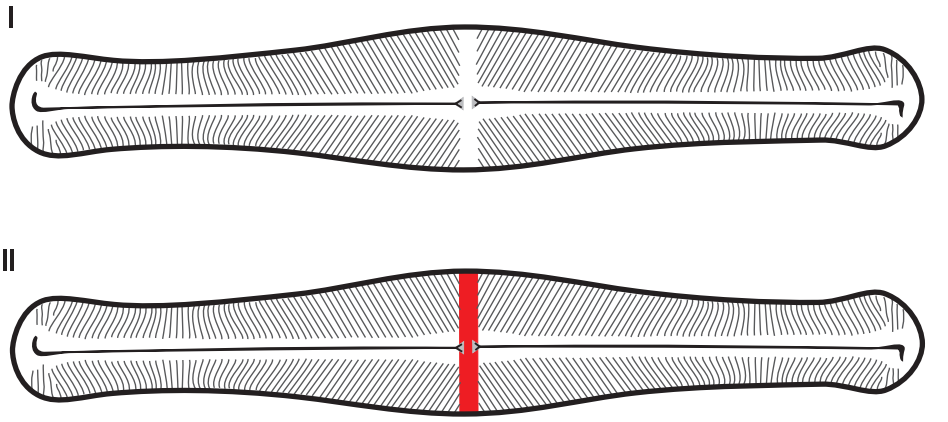
SYNONYM:
Navicula Bory 1822 pro parte
Stauroneis Ehrenberg 1843 pro parte

Characteristics – Cells **biraphid**, usually with expanded apices and expanded central region. Striae fine, strongly radiate in the mid-valve becoming strongly convergent near the apices. Raphe sigmoid, terminal raphe endings curved in opposite direction, golf club shaped under SEM, central raphe endings delta-shaped. Stauros may be present (II; Fig. 159).

Plastid structure – Cells with one H-shaped plastid.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure of the central area.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to mesotrophic waters in both low and moderate conductivities.



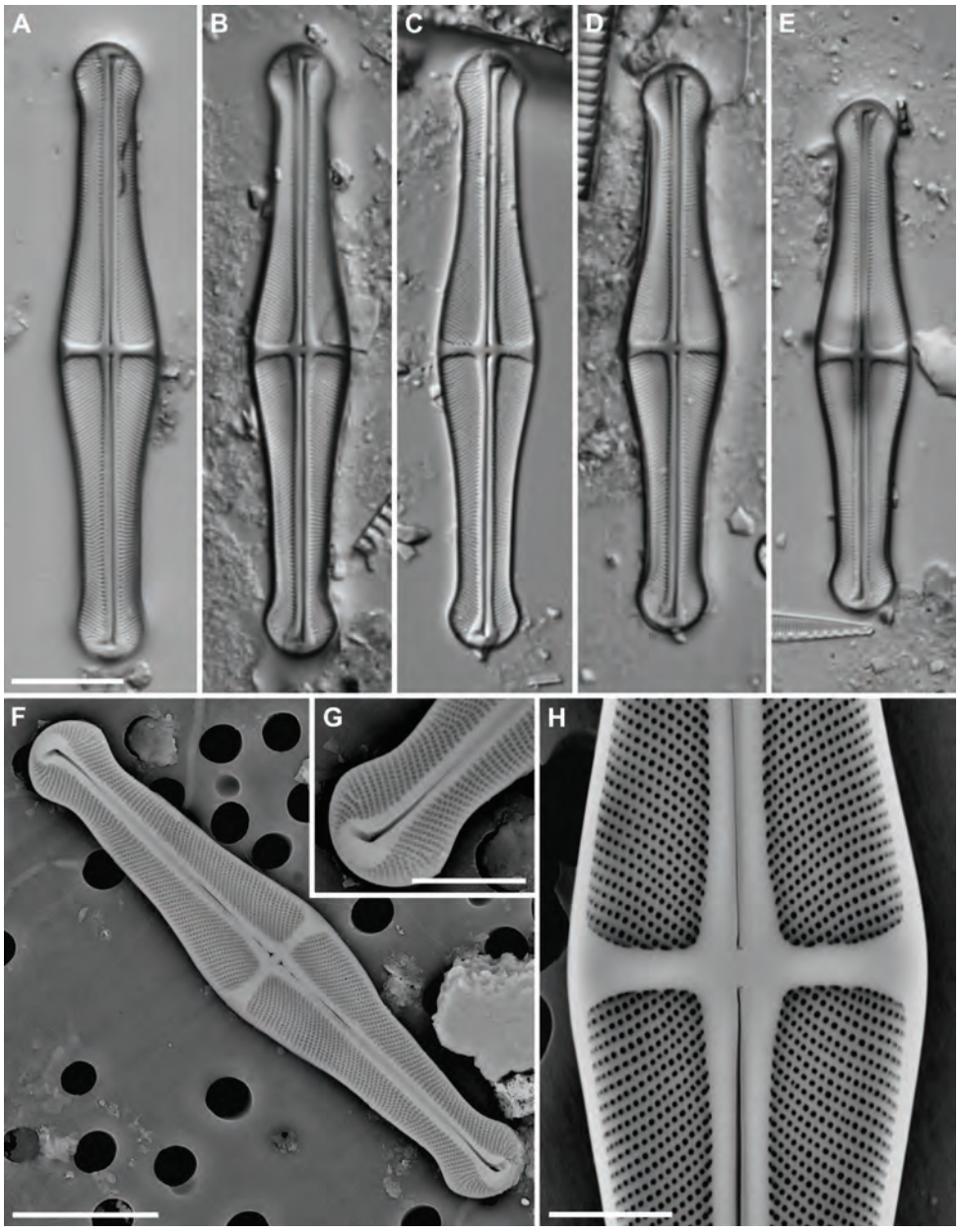


Fig. 159. *Envekadea* sp. **A-E.** LM, valve views. **F-H.** SEM, internal view of valve. **G.** Detail of apex, note golf club shaped terminal raphe ending. **H.** Detail of stauros, note delta-shaped central raphe endings.
Scale bars = 10 µm (A-F), 5 µm (G), 3 µm (H).

Amphora Ehrenberg ex Kützing 1844

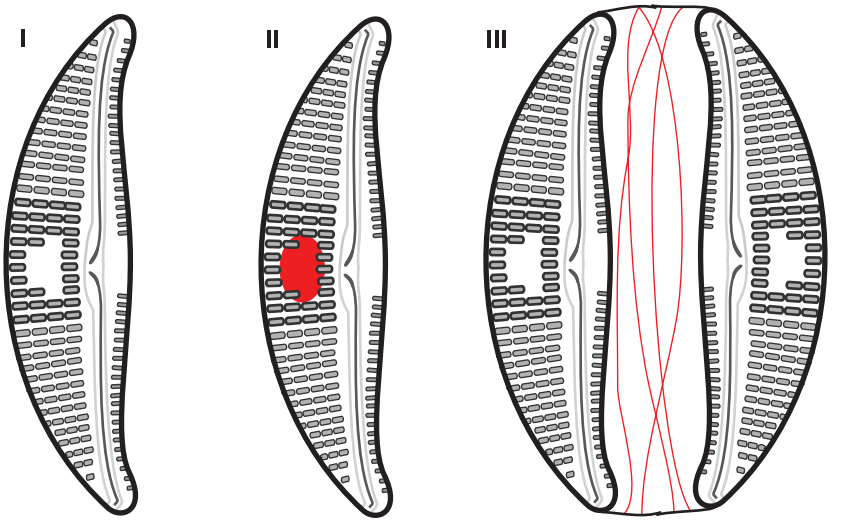
Type species: *Amphora ovalis* (Ehrenberg) Kützing

Characteristics – Cells **biraphid**, variable in terms of size and shape. Intact cells (i.e. both valves still joined by the girdle) are similar in shape to an orange segment, with the diatom valve faces being comparable to the faces of the orange segment, this is because cells have many more girdle bands on the dorsal side than on the ventral side (III; Fig. 161: A). The dorsal central striae are often separated by a thickened area of the valve known as a **semi-stauros** (II; Fig. 160: G-H; Fig. 161: D) absent in *Halamphora* Levkov. The striae on the ventral side of the valve are very short, composed of only a few areolae. In some species the areolae are clearly discernable under LM. Differentiated from *Halamphora* by the structure of the areolae (only visible under SEM).

Plastid structure – Single H-shaped plastid (Fig. 160: A). Lipid droplets (2-4) found towards the apex of each lobe of the plastid.

Identification of species – Species in this genus are distinguished based on cell size and shape and the shape of the apices. Striae density and angle relative to the **transapical axis** are also important characteristics to consider along with the size of individual areolae. The number of areolae on the ventral side of the valve is also important (IV) as well as the distance between the raphe and the ventral margin.

Ecology – Cells solitary, free living in the benthos of alkaline waters and occurring in a range of conductivities and trophic levels.



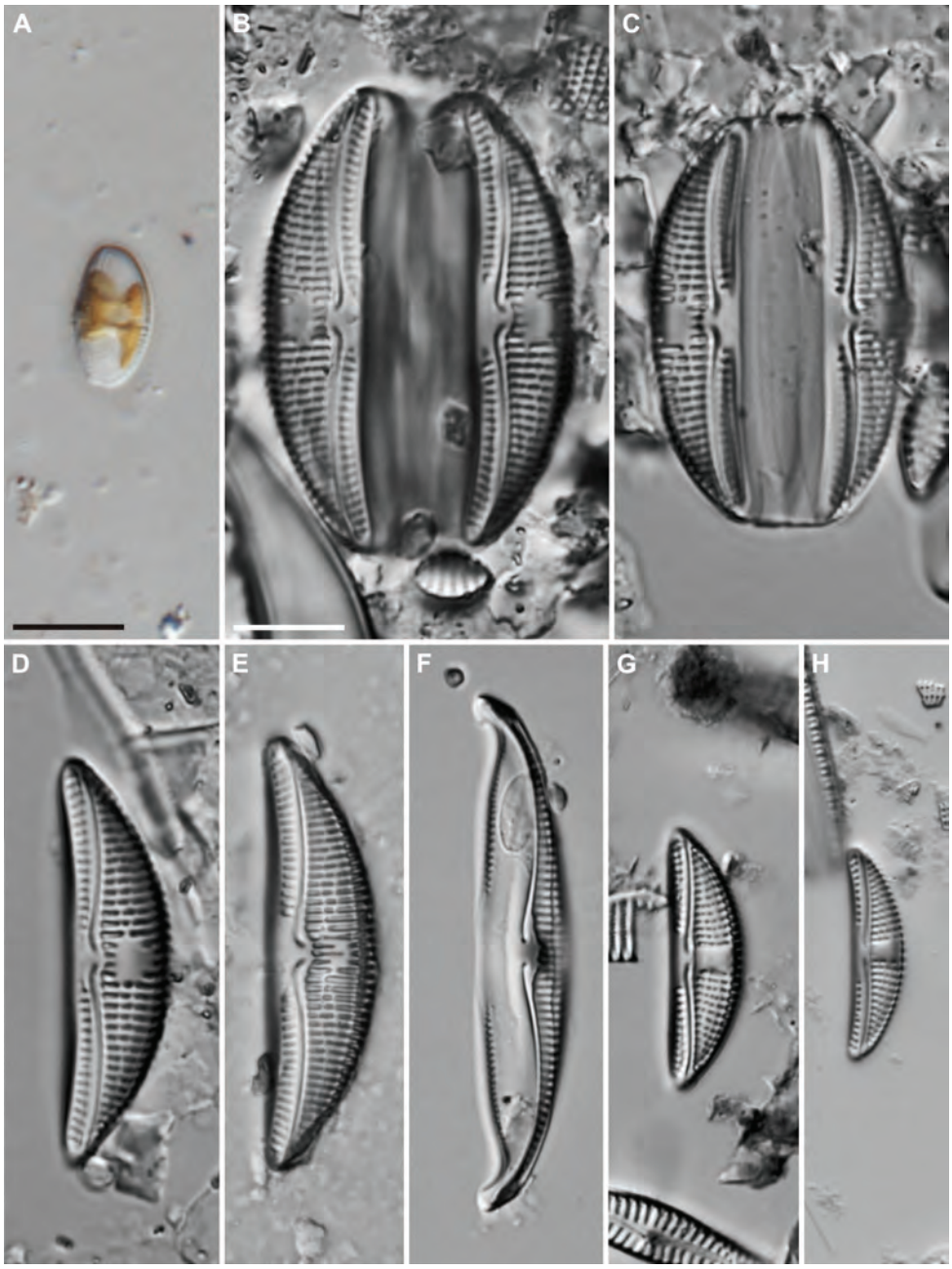


Fig. 160. *Amphora* spp. **A-H.** LM. **A.** Living cell. **B-H.** Cleaned valves. **B-D.** *Amphora copulata* (Kützing) Schoeman & R.E.M. Archibald. **E.** *Amphora ovalis*. Scale bars = 10 µm (A-H).

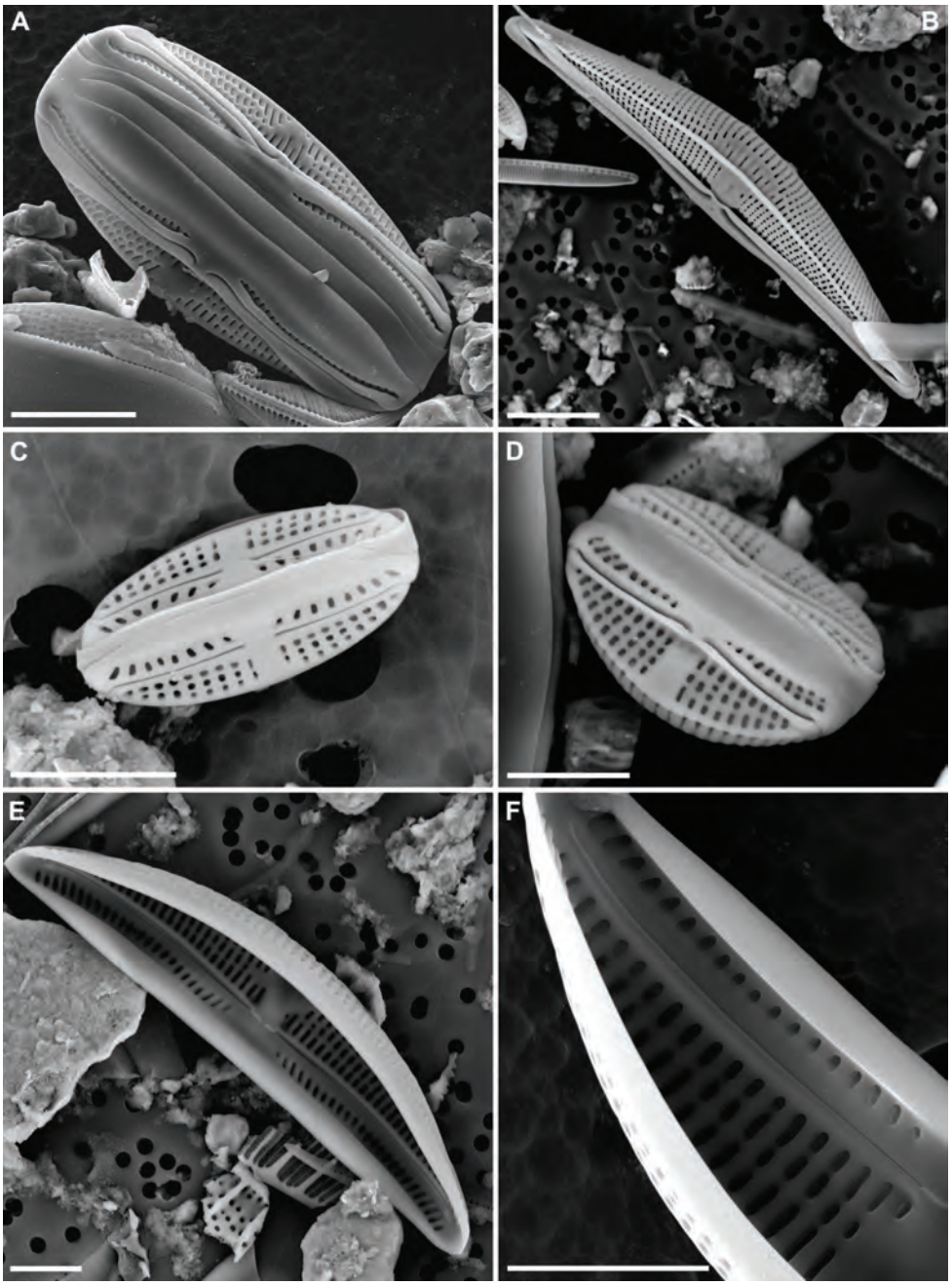


Fig. 161. *Amphora* spp. **A-F.** SEM. **A-D.** External view of valves. **C-D.** *Amphora pediculus* (Kützing) Grunow**. E-F.** Internal view of valve.
Scale bar = 10 µm (A-B), 5 µm (C-F).

Halamphora (Cleve) Levkov 2009

Type species: *Halamphora coffeaeformis* (C. Agardh) Levkov

SYNONYM:

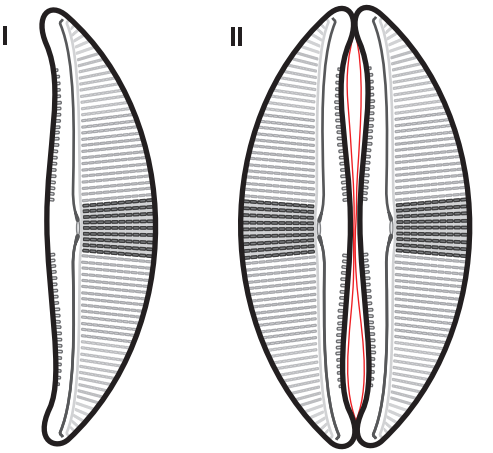
Amphora Ehrenberg ex Kützing 1844 pro parte

Characteristics – Cells **biraphid**, variable in terms of size and shape. Intact cells (i.e. both valves still joined by the girdle) are similar in shape to an orange segment, with the diatom valve faces being comparable to the faces of the orange segment, this is because cells have many more girdle bands on the dorsal side than on the ventral side (II; Fig. 163: A). Dorsal **semi-stauros** is absent. The striae on the ventral side of the valve are very short, composed of only a few areolae (Fig. 162: D, F-H; Fig. 163: C, E). In some species the areolae are clearly discernable under LM. Differentiated from *Amphora* by the structure of the areolae (only visible under SEM).

Plastid structure – Single H-shaped plastid (Fig. 162: A-B). Lipid droplets (2-4) found towards the apex of each lobe of the plastid (Fig. 162: A).

Identification of species – Species in this genus are distinguished based on cell size and shape and the shape of the apices. Striae density and angle relative to the **transapical axis** are also important characteristics to consider along with the size of individual areolae. The number of areolae on the ventral side of the valve is also important as well as the distance between the raphe and the ventral margin.

Ecology – Cells solitary, free living in the benthos. Occurs in a range of water quality with most species found at moderate conductivity and some species being specifically associated with high conductivity.



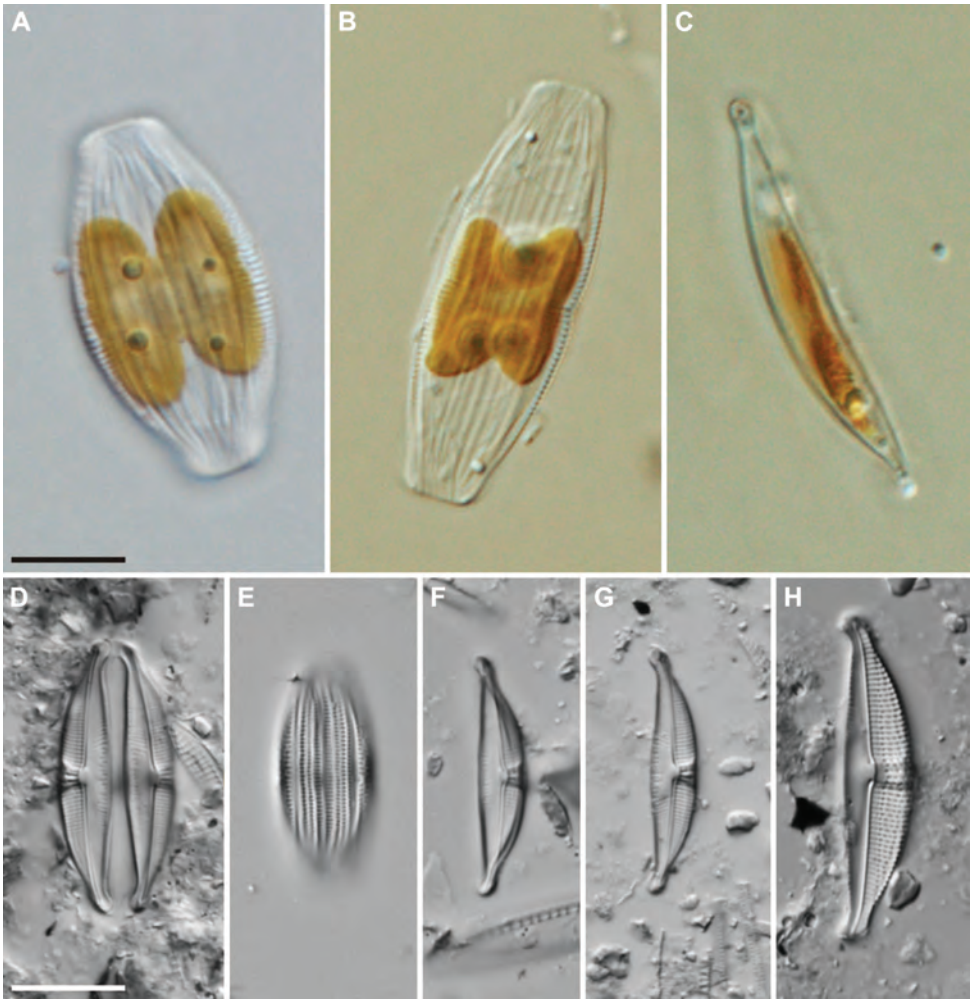


Fig. 162. *Halamphora* spp. **A-H.** LM. **A-B.** Living cells, girdle view. **C.** Living cell, valve view. **D-H.** Cleaned valves. **D, F, G.** *Halamphora submontana* Hustedt, valve view. **E.** *H. submontana*, girdle view.
Scale bars = 10 µm (A-H).

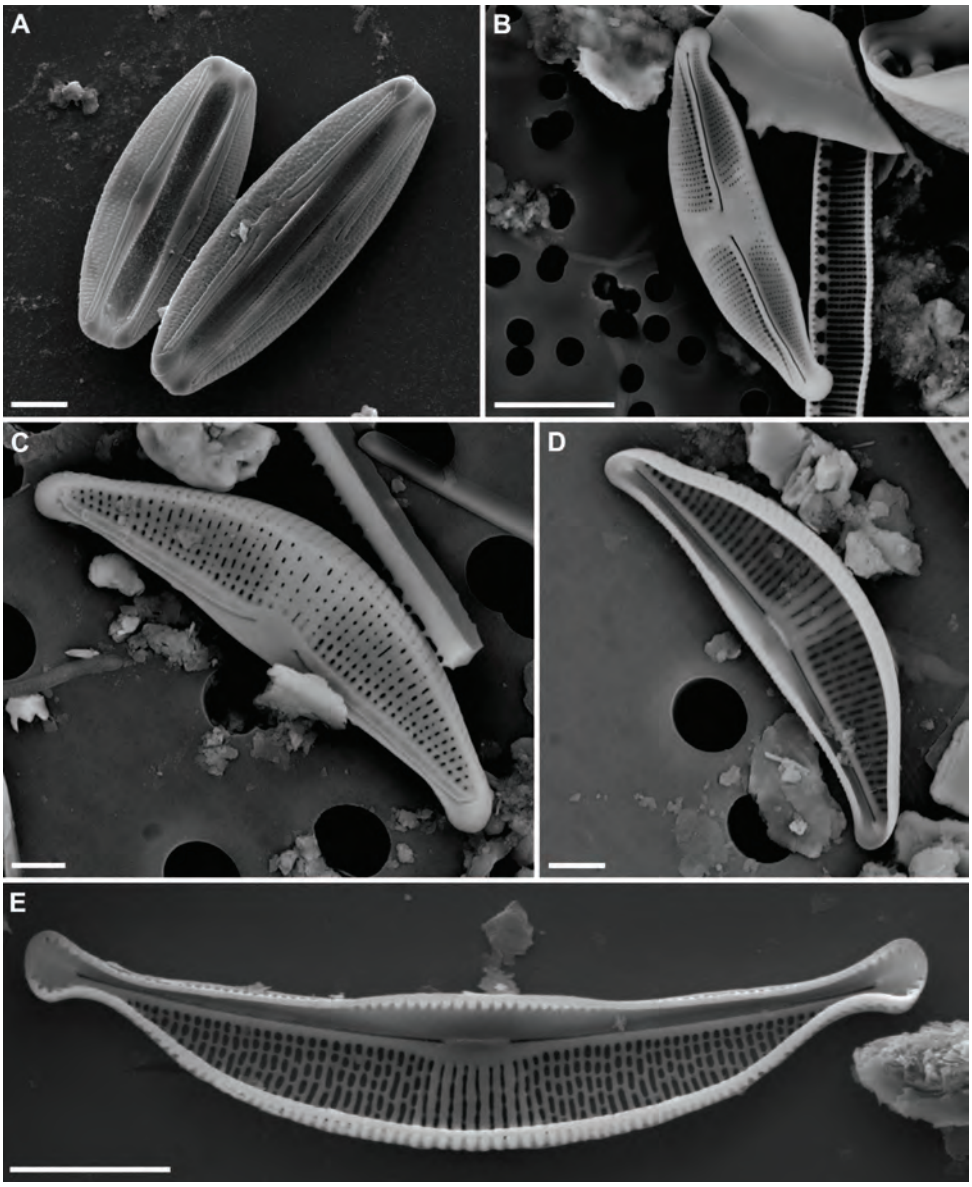


Fig. 163. *Halamphora* spp. **A-E**. SEM. **A-C.** External view of valves. **B.** *Halamphora submontana*. **D-E.** Internal view of valves. Scale bar = 5 µm (A-B, E), 2 µm (C-D).

Bacillaria J.F. Gmelin 1791

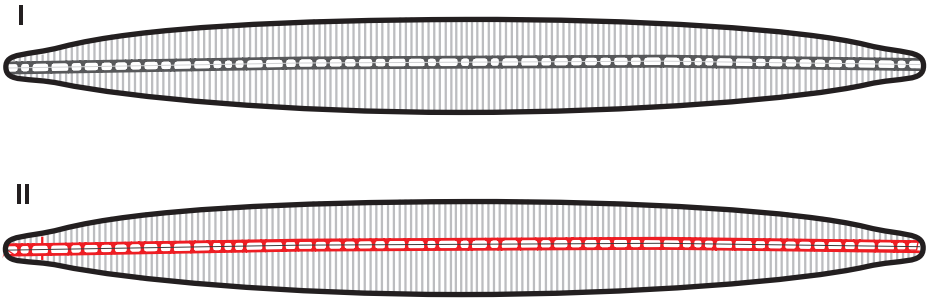
Type species: *Bacillaria paradoxa* J.F. Gmelin

Characteristics – Cells **biraphid**, large and rather robust, valve shape **linear**. Raphe located close to the center of the valve supported by robust **fibulae** (II; Fig. 164: A-B, E-F). Striae are coarse and easily discernable in LM but the areolae are indistinct.

Plastid structure – Two plate-like plastids on either side of the nucleus.

Identification of species – Up till now only one species occurs commonly in the inland waters of the tropics: *Bacillaria paradoxa.*

Ecology – Cells colonial, benthic. Found in tropical waters with high conductivity, usually in brackish to marine waters.



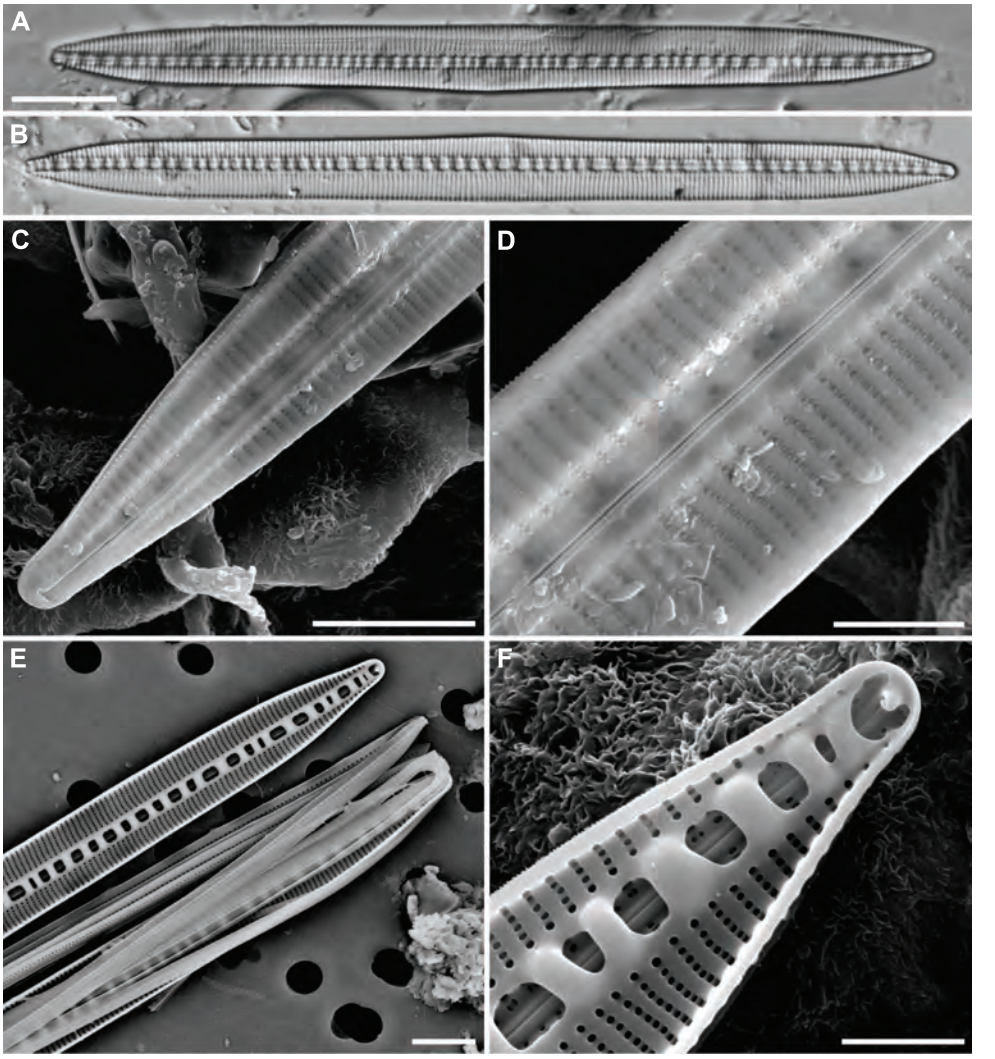


Fig. 164. *Bacillaria paradoxa*. **A-B.** LM, cleaned material, valve view. **C-F.** SEM. **C**. External view of valve showing detail of the terminal raphe ending. **D**. External view of valve showing detail of raphe slit. **E-F.** Internal view of valve showing structure of the fibulae and the copulae (**E**).
Scale bars = 10 µm (A-B), 5 µm (C, E), 2 µm (D, F).

Denticula Kützing 1844

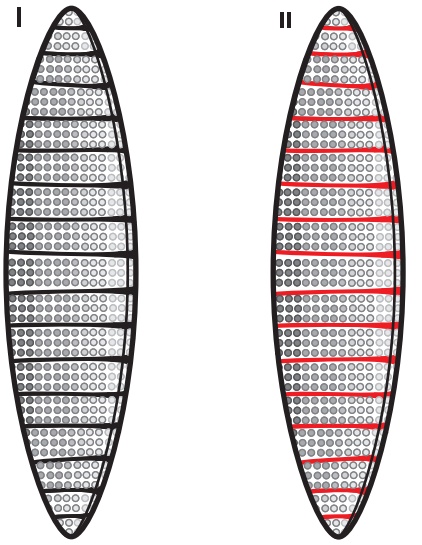
Type species: *Denticula elegans* Kützing

Characteristics – Cells **biraphid**, of variable size with prominent ribs or **transapical costae** (II) stretching across the valve face; these costae are extensions of the **fibulae**. Striae may be coarse and easily discernable or rather fine and in this case only the costae are readily discernable (Fig. 165: C-D). Costae are also clearly visible under LM in girdle view (Fig. 165: B). Raphe, not visible under LM, located at the junction of the valve face and valve mantle above the fibulae.

Plastid structure – Cells with 2 lobed plastids, each one extending from mid-valve to each apex (Fig. 165: A-B). Several small lipid droplets scattered throughout the cell (Fig. 165: B).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices and structure and density of the **costae** and striae as well as the structure and density of the areolae.

Ecology – Cells solitary and motile. Found in the benthos of hard waters with medium conductivity.



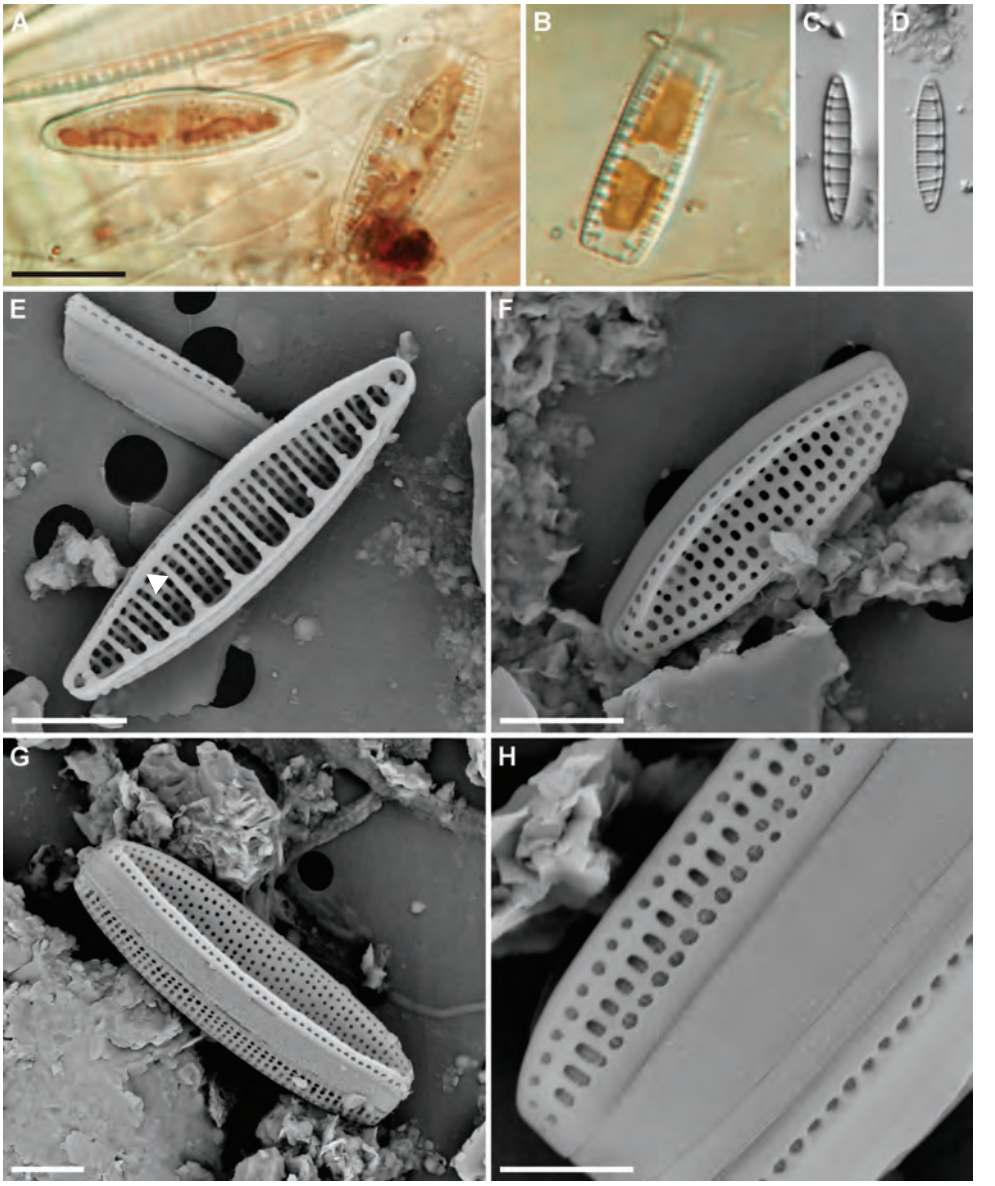


Fig. 165. *Denticula* spp. **A-D.** LM. **A-B**. Living cells of *Denticula kuetzingii* Grunow. **A**. Valve view (left), girdle view (right). **B**. Girdle view. **C-D.** *D. elegans*, valve views. **E-H**. SEM, *D. kuetzingii*. **E**. Internal view of valve, note costae (arrow). **F-G**. External view of valves. **H**. External view of girdle. Scale bars = 10 µm (A-D), 5 µm (E-G), 3 µm (H).

Gomphonitzschia Grunow 1868

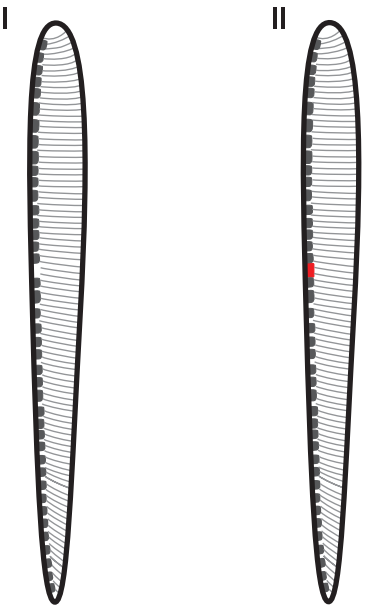
Type species: *Gomphonitzschia ungeriana* Grunow

Characteristics – Cells **biraphid**, **heteropolar**, head pole broadly rounded with a narrow foot pole. Marginal raphe supported by fibulae, central gap (II; Fig. 166: A-I, L) between the fibulae present. Striae fine, radiate, slightly curved near the head pole, composed of single rows of areolae which are discernable under LM.

Plastid structure – Cells with 2 plastids, each one extending from mid-valve to each apex.

Identification of species – Up till now only one species known from tropical Africa: *Gomphonitzschia ungeriana*.

Ecology – Cells solitary, free living and motile. Found in the plankton and benthos of alkaline waters with moderate conductivity.



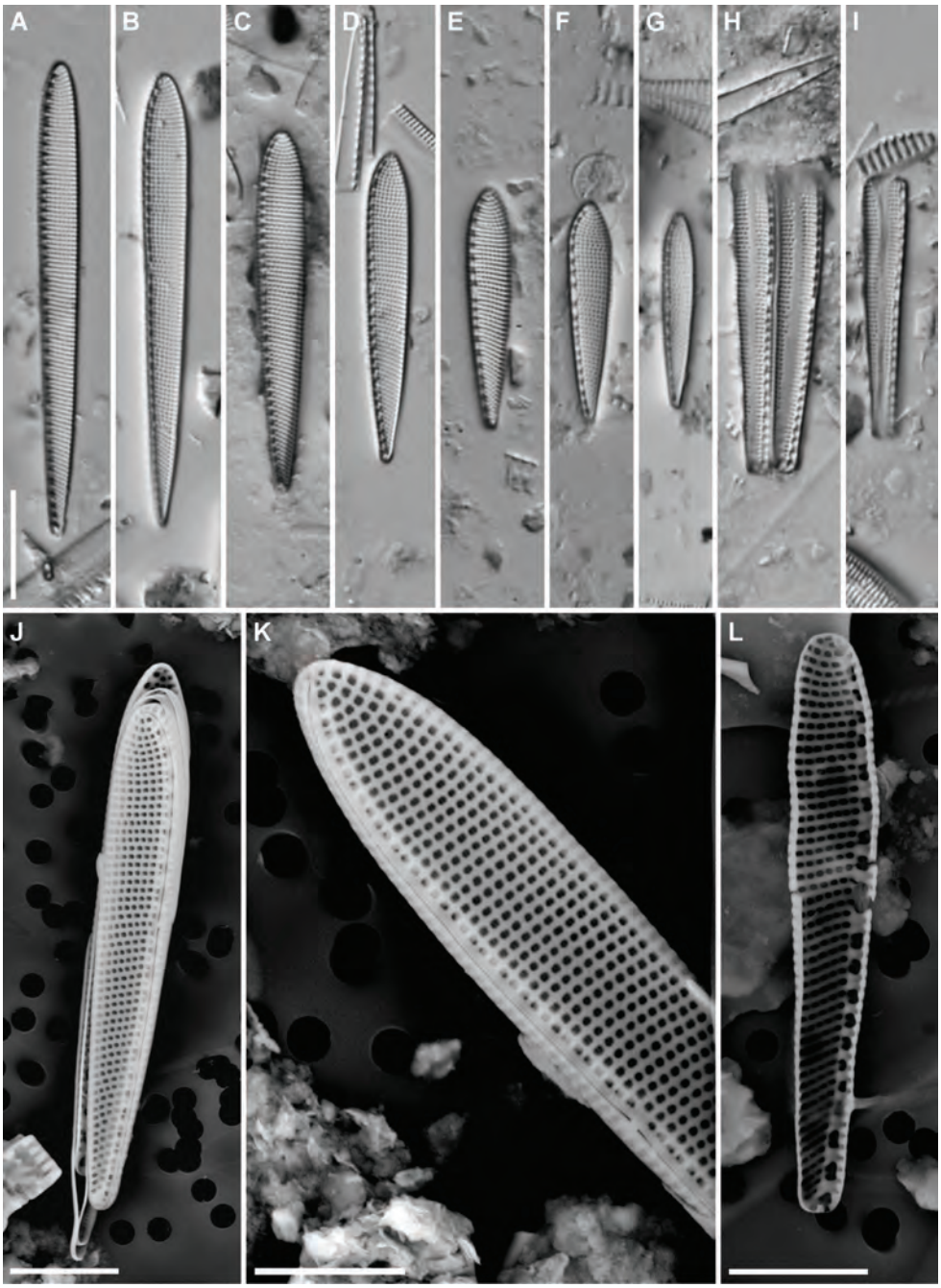


Fig. 166. *Gomphonitzschia ungeriana*. **A-I.** LM. **A-G.** Valve views. **H-I.** Girdle views. **J-L.** SEM. **J-K.** External view of valve. **L.** Internal view of valve. Scale bars = 10 µm (A-D), 5 µm (J-L).

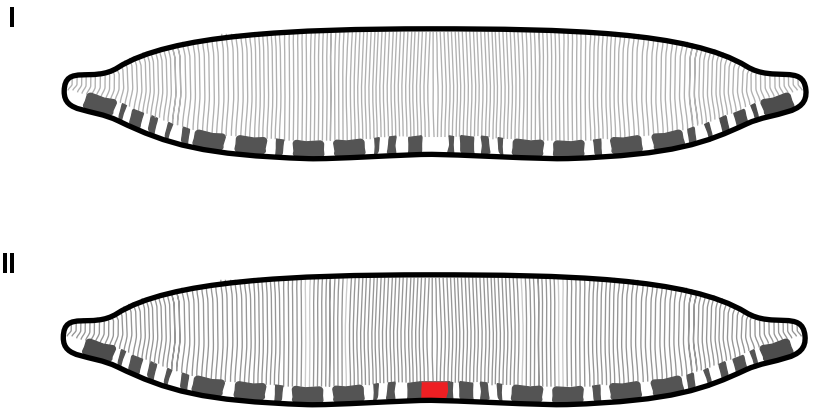
Hantzschia Grunow 1877

Type species: *Hantzschia amphioxys* (Ehrenberg) Grunow

Characteristics – Cells **biraphid**, weakly **dorsiventral**, ventral valve margin slightly concave and dorsal margin slightly convex. Rostrate apices. Raphe on the junction of valve face and mantle. Striae vary from fine to coarse, composed of single rows of areolae which may or may not be discernable under LM. Fibulae robust, easily discernable, with a central gap (I; Fig. 167: A-G) and carried on the ventral margins of both valves (**hantzschioid symmetry**).

Plastid structure – Two simple or complexly lobed plastids (Fig. 167: A-B) on either side of the central nucleus against the ventral side of the cell, or two girdle-appressed plates connected by a central pyrenoid (Fig. 167: A).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae, density and structure of the fibulae as well as structure of the areolae.



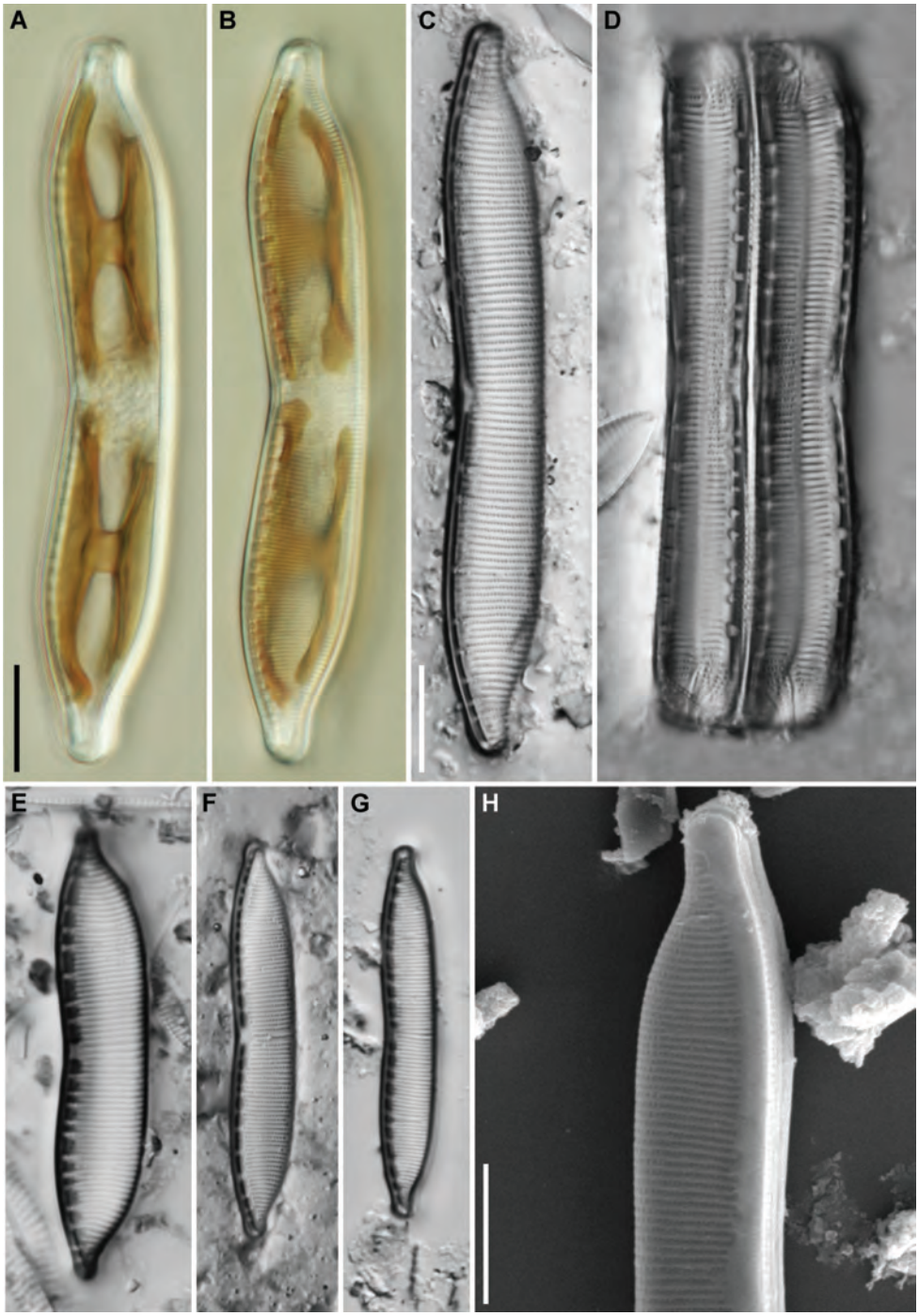


Fig. 167. *Hantzschia* spp. **A-G.** LM. **A-B.** Living cells. **C, E-G.** Cleaned valves. **D.** Girdle views. **H.** SEM, detail of external view of valve. Scale bars = 10 µm (A-G), 5 µm (H).

Nitzschia Hassall 1845

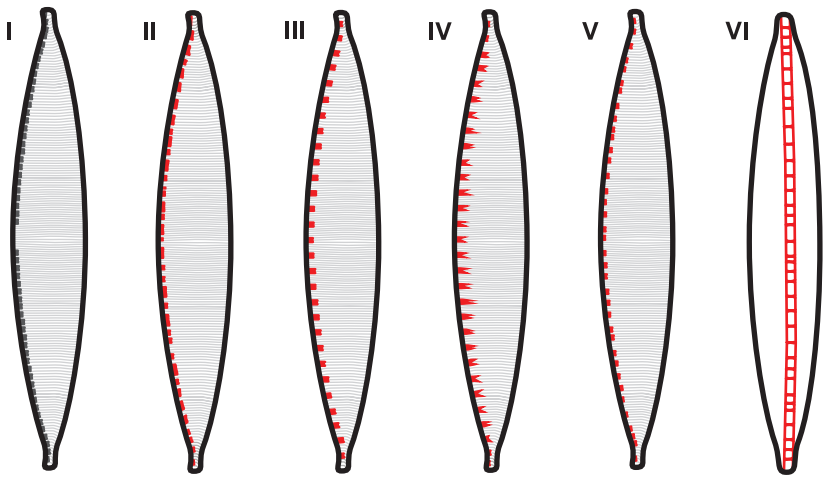
Type species: *Nitzschia elongata* Hassall

Characteristics – Cells **biraphid**, raphe eccentric, usually found at the junction of the valve face and mantle. Raphe keel is supported internally by **fibulae** (Fig. 170: H). Raphe may be continuous through the length of the valve or interrupted mid-valve (Fig. 170: D). The raphe is not discernable under LM but the presence of central raphe endings is indicated by a central gap in the fibulae (Fig. 169: A). The fibulae are variable in terms of shape (II), size (width) (III), extent across the valve face (IV) as well as the spacing between them (V). *Nitzschia dissipata* (Kützing) Rabenhorst and allied taxa are characterised by a raphe which is eccentric but not located at the junction of the valve face and mantle but more toward the valve centre (VI). This group also has an external conopeum covering the raphe (Fig. 170: G). Striae composed of single rows of round areolae which may or may not be discernable under LM, individual areolae may be discernable under LM.

Plastid structure – Cells with 2 plastids, each one extending from mid-valve to each apex (Fig. 168: F). Several small lipid droplets scattered throughout the cell (Fig. 168: A-C).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as structure and arrangement of the fibulae and the presence or absence of a central gap.

Ecology – Cells usually solitary, usually free living and motile but do form colonies within mucilage tubes. Found in the plankton and benthos of acidic to alkaline, oligotrophic to hypereutrophic waters in low to high conductivities.



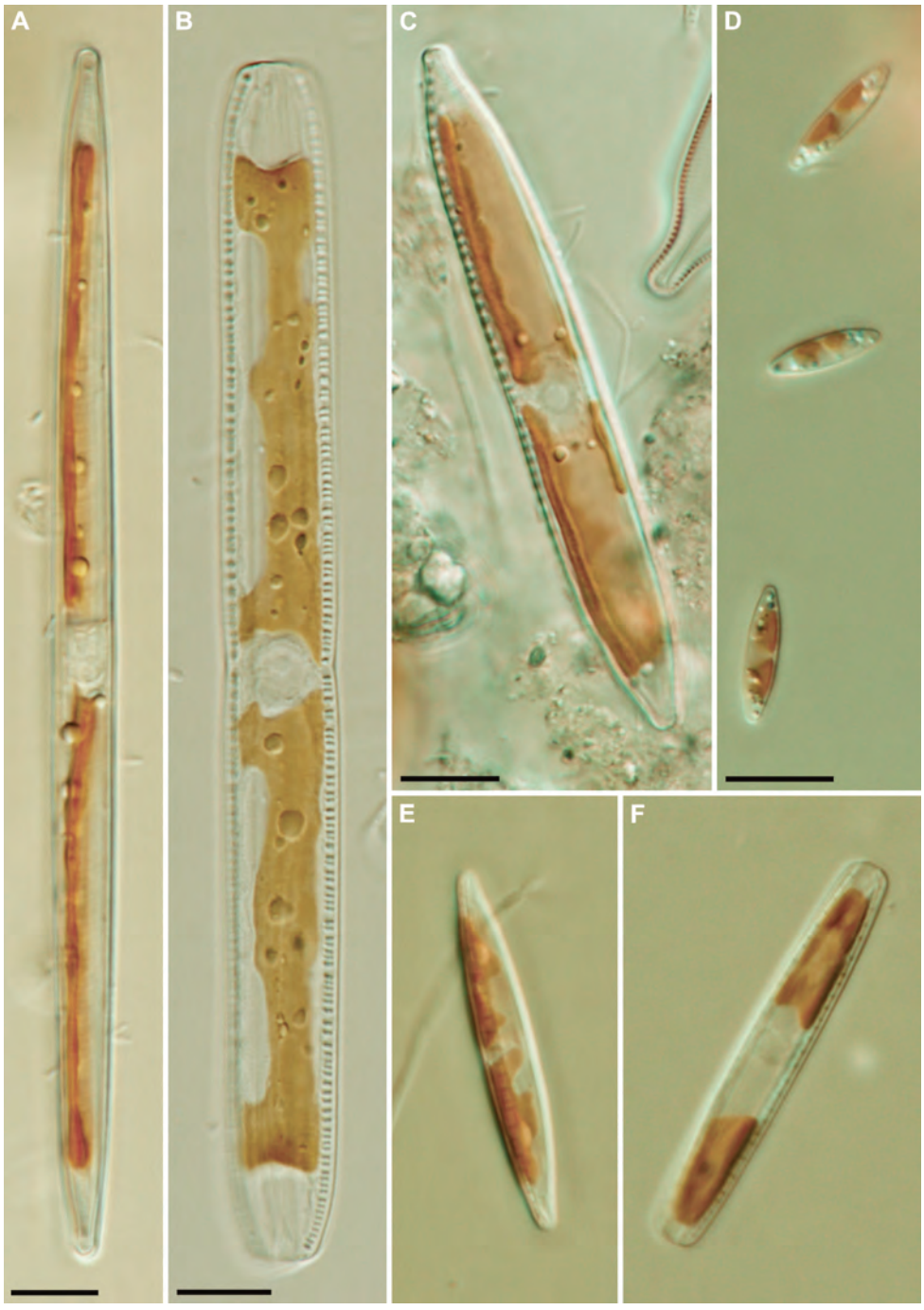


Fig. 168. *Nitzschia* spp. **A-F.** LM, living cells. **A, C-E.** Valve views, note lipid bodies. **B, F.** Girdle view, note lipid bodies.
Scale bars = 10 µm (A-F).

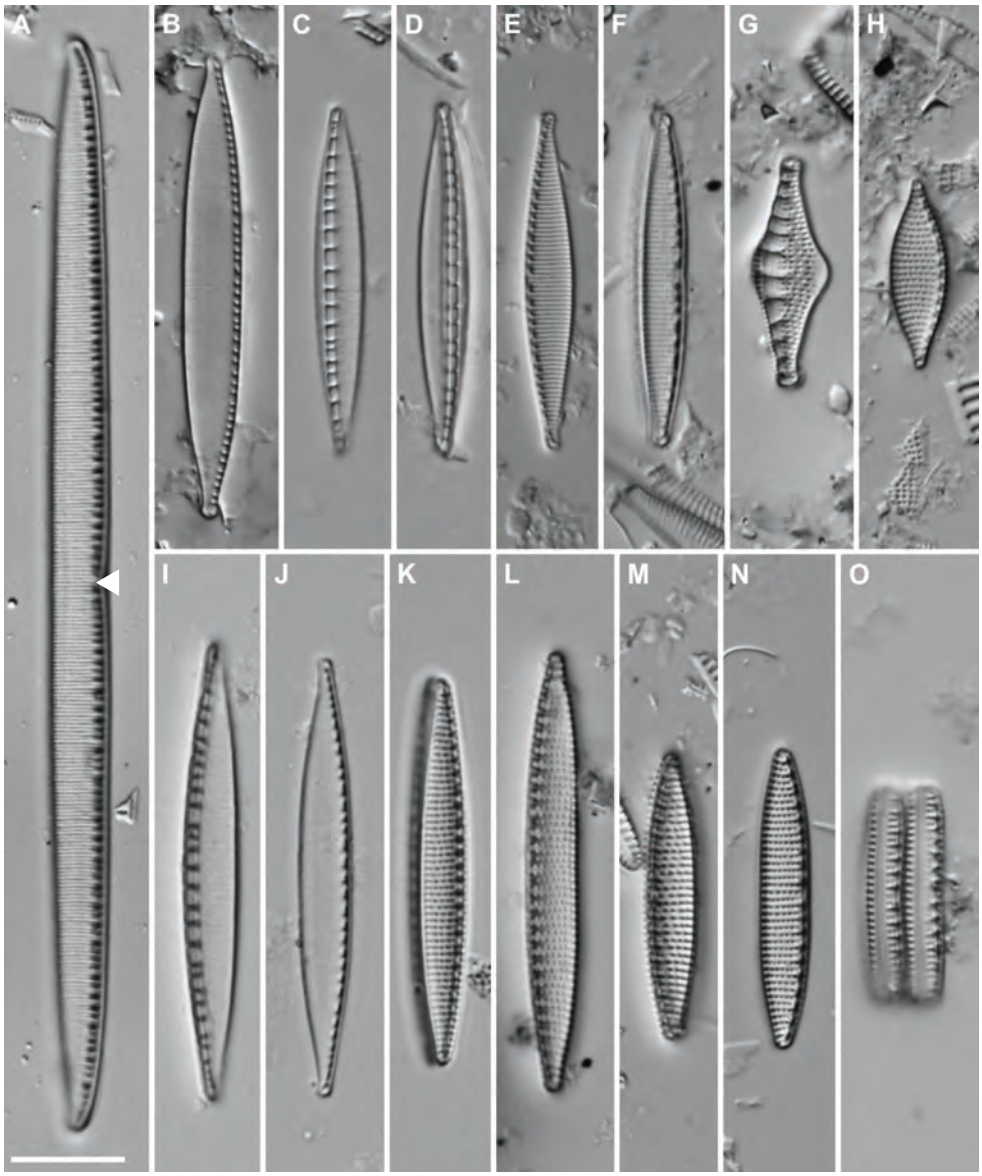


Fig. 169. *Nitzschia* spp. **A-O.** LM, cleaned valves. **A-N.** Valve views. **A.** *N. linearis* (C. Agardh) W. Smith, note central gap in the fibulae (arrow). **C-D.** *N. dissipata*. **G.** *N. sinuata* var. *tabellaria* (Grunow) Grunow. **H.** *N. lancetulla* O. Müller. **M-N.** *N. amphibia* Grunow. **I.** *N. recta* Hantzsch ex Rabenhorst. **O.** Girdle view. Scale bar = 10 µm (A-O).

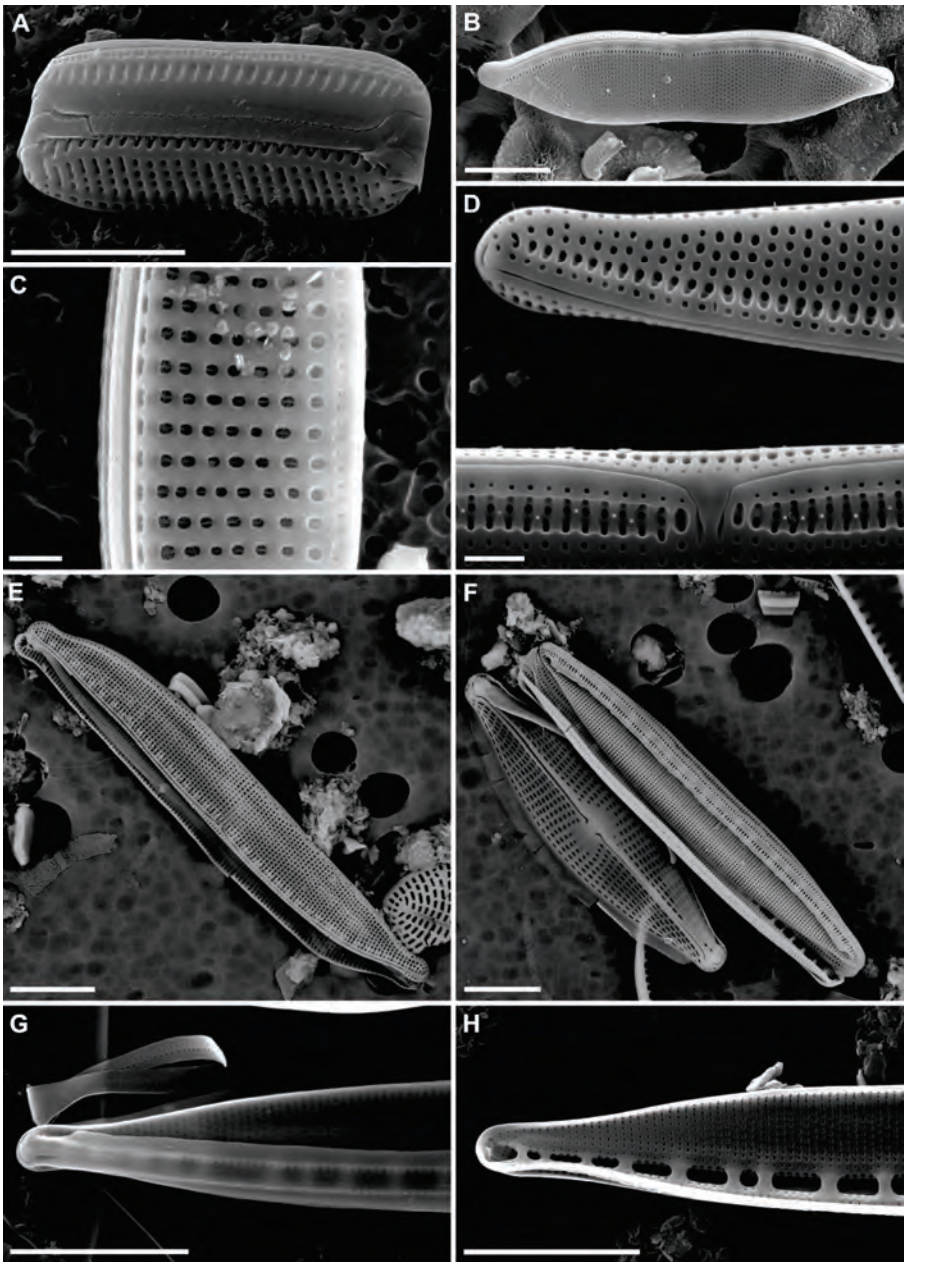


Fig. 170. *Nitzschia* spp. **A-H.** SEM. **A-E.** External view of valves. **A.** Oblique view showing the valve mantle and girdle bands. **D.** Detail of terminal raphe ending and central raphe endings. **F-G.** *N. dissipata,* detail of terminal raphe ending (**G**), note the external conopeum covering the raphe. **H.** Internal view of valve of *N. dissipata*, note the fibulae.
Scale bars = 5 µm (A-B, E-H), 1 µm (C-D).

Simonsenia Lange-Bertalot 1979

Type species: *Simonsenia delognei* (Grunow) Lange-Bertalot

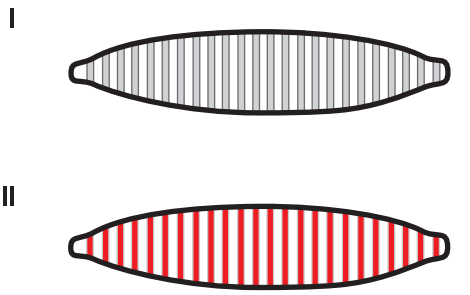
SYNONYM:
Nitzschia Hassall 1845 pro parte

Characteristics – Cells **biraphid**, very small, elliptical to linear elliptical with narrow rostrate apices. Striae fine, parallel, composed of double rows of areolae which are not discernable under LM. Raphe carried on a keel at the junction of one side of the valve face and mantle, supported by **costae** (II) which traverse the width of the valve face (Fig. 171: F-H). **Costae** are the only structure clearly discernable in LM. Cells similar in appearance to *Nitzschia* but **fibulae** are absent (Fig. 171: F-H).

Plastid structure – Cells with 2 plastids, each one extending from mid-valve to each apex (see *Nitzschia*).

Identification of species – Up till now only one species known: *Simonsenia delognei.*

Ecology – Cells solitary, free living and motile. Found in the benthos of waters with moderate conductivities.



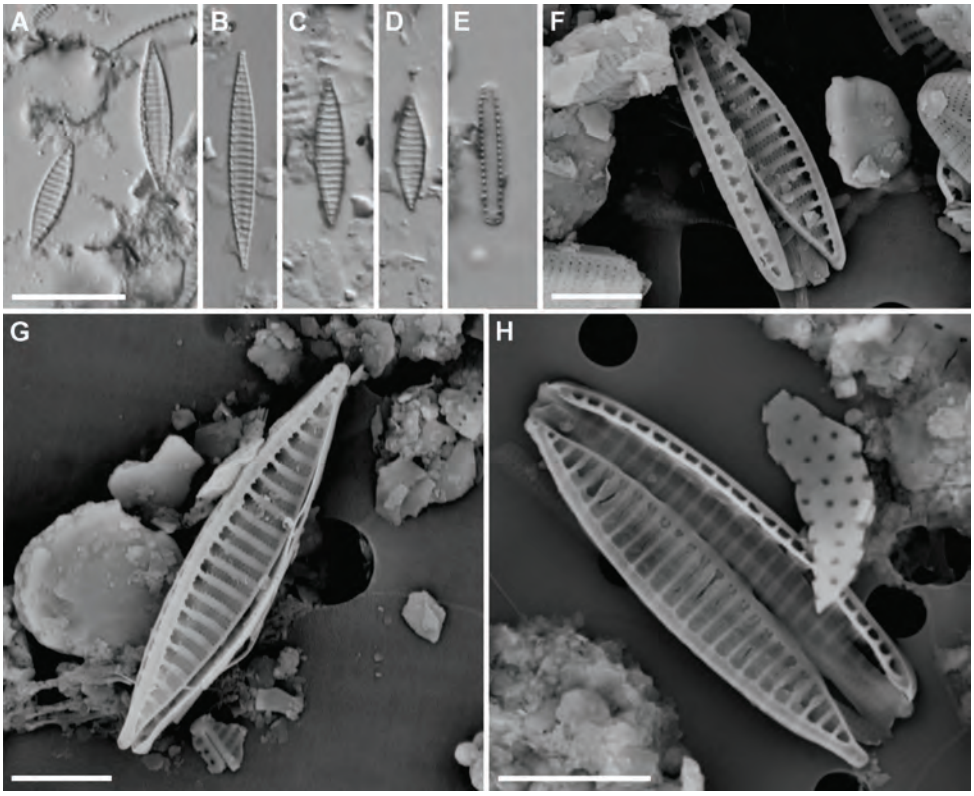


Fig. 171. *Simonsenia delognei*. **A-E.** LM, cleaned valves. **F-H.** SEM. **F** Internal view of valve. **G-H**. External view of valves.
Scale bars = 10 µm (A-E), 3 µm (F-H).

Tryblionella W. Smith 1853

Type species: *Tryblionella acuminata* W. Smith

SYNONYM:

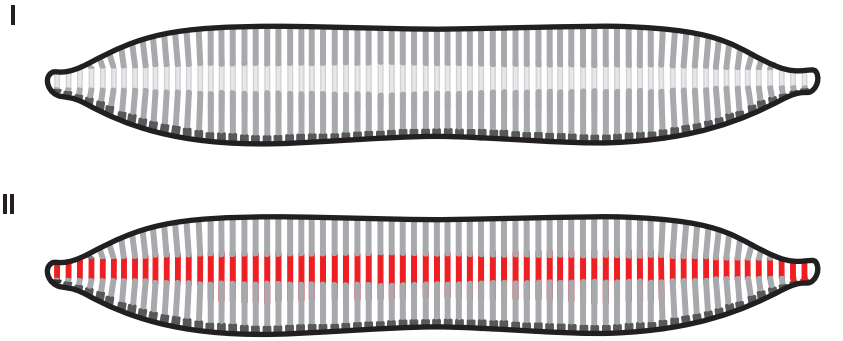
Nitzschia Hassall 1845 pro parte

Characteristics – Cells **biraphid**, elliptical to linear elliptical with cuneate and occasionally subrostrate apices. Marginal raphe carried in canal at junction of valve face and valve mantle. Raphe difficult to discern, supported by fibulae (Fig. 173), interrupted mid-valve. Striae very fine composed of rows of small round areolae which are not discernable under LM. Valve face strongly longitudinally undulated (II; Fig. 173: A-C, E-G). **Costae** cross the valve face. Occasionally silica granules may be scattered on the valve face (Fig. 174: B).

Plastid structure – Cells with 2 large plastids, each one extending from mid-valve to each apex (Fig. 172: A-B). Several small lipid droplets scattered throughout the cell (Fig. 172: A-C).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae as well as the degree of the constriction mid-valve.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both moderate to high conductivities.



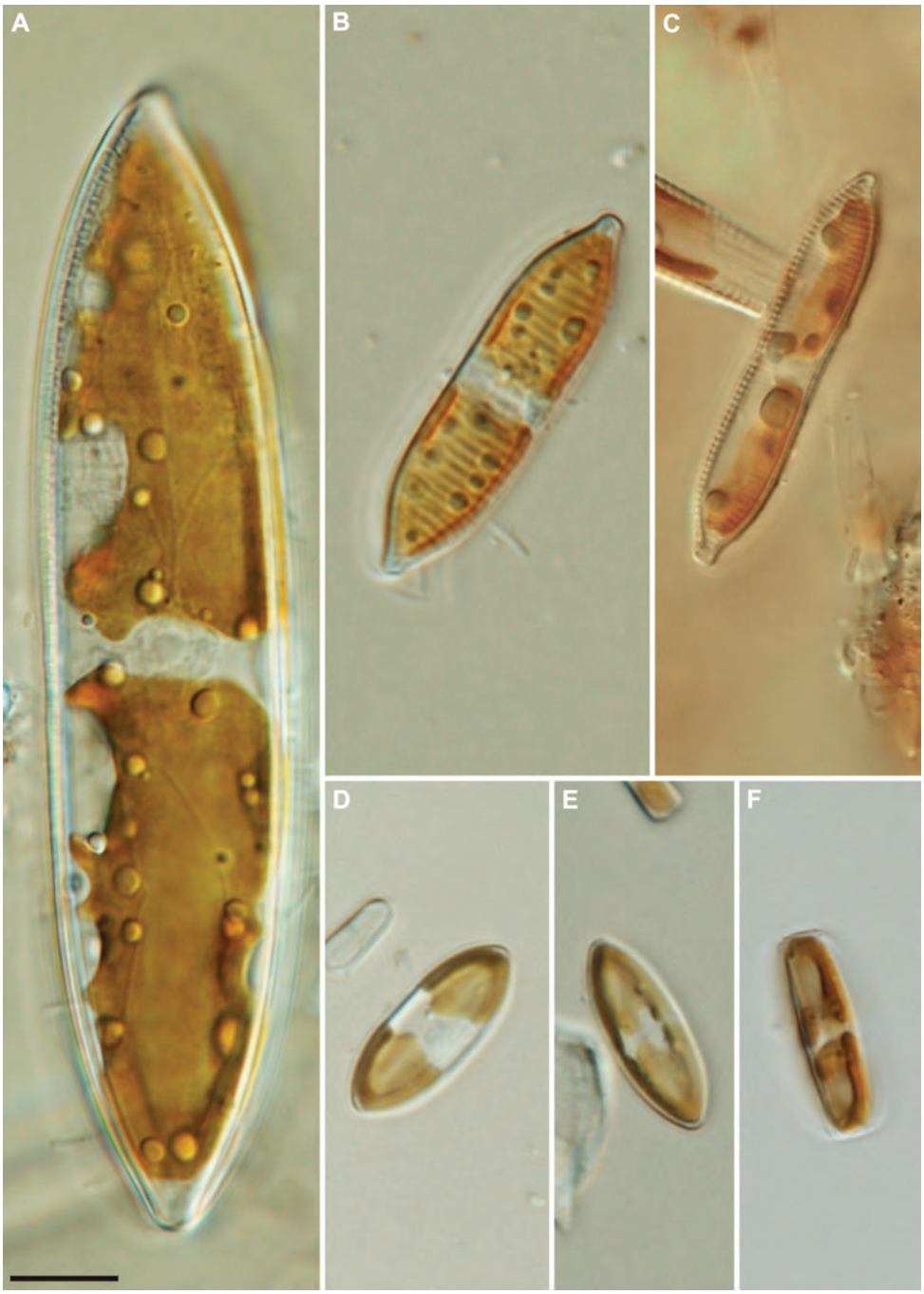


Fig. 172. *Tryblionella* spp. **A-F.** LM, living cells, note two 2 large plastids, each one extending from mid-valve to each apex, and several small lipid droplets. **A.** *T. littoralis* (Grunow) D.G. Mann. **B.** *T. calida* (Grunow) D.G. Mann. **C.** *T. apiculata* (W. Gregory) D.G. Mann. **D-F.** *T. debilis* Arnott. Scale bar = 10 µm (A-F).

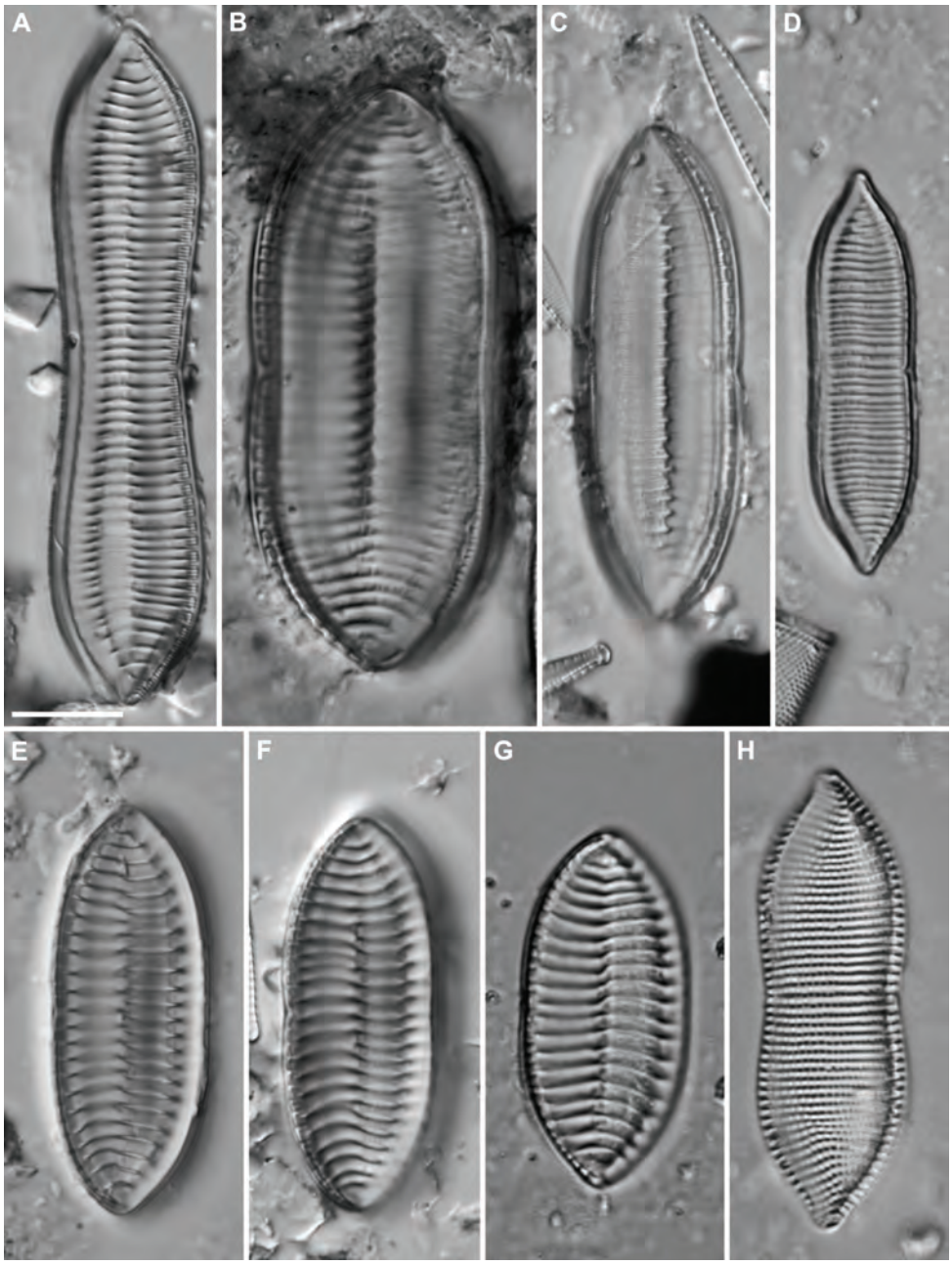


Fig. 173. *Tryblionella* spp. **A-H.** LM, cleaned valves. **C.** *T. littoralis*. **D.** *T. calida*. **E-F.** *T. levidensis* W. Smith. **H.** *T. coarctata* (Grunow) D.G. Mann. Scale bar = 10 µm (A-H).

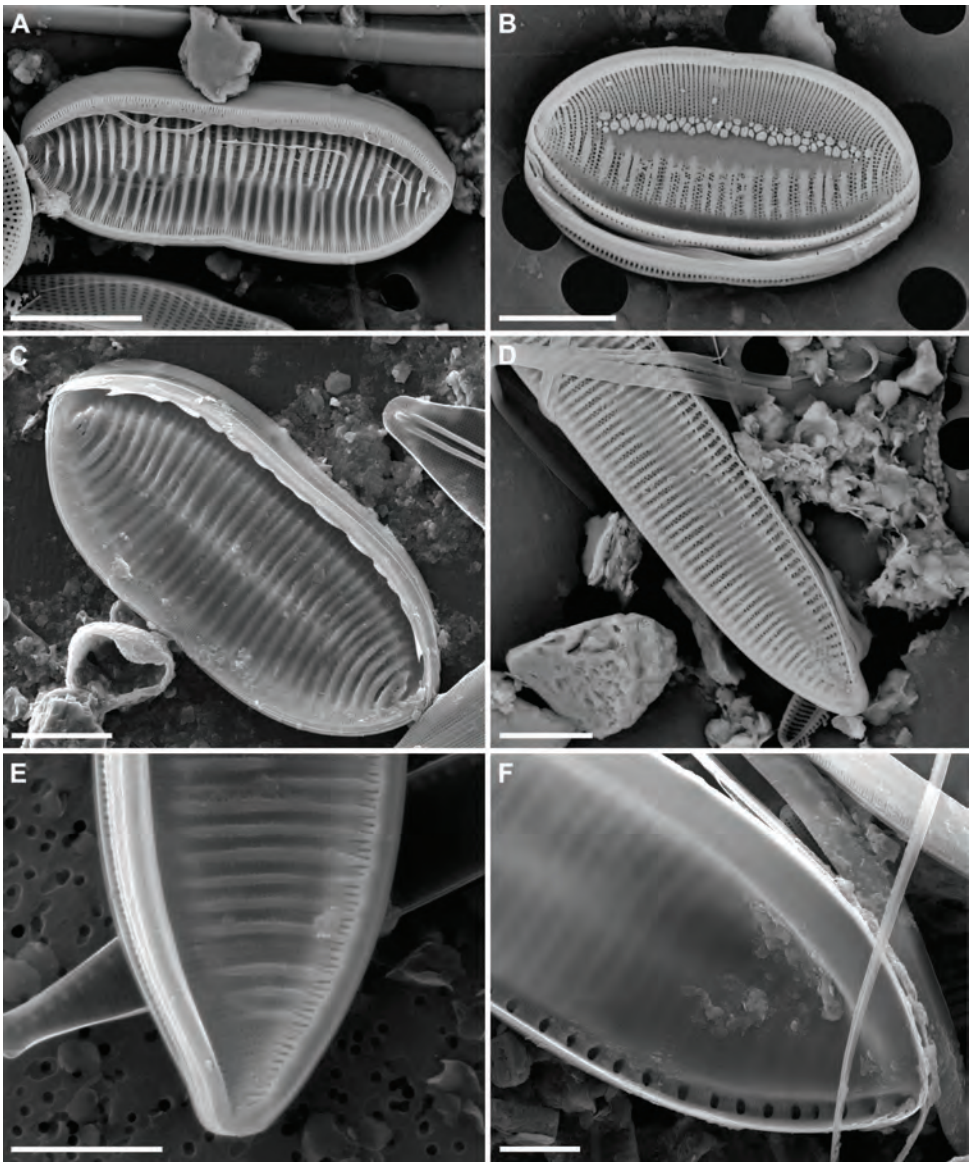


Fig. 174. *Tryblionella* spp. **A-F.** SEM. **A-E.** External view of valves. **B.** *T. debilis*, note scattered silica granules on valve face. **C.** *T. levidensis*. **D.** *T. hungarica* (Grunow) Frenguelli. **E.** *T. calida.* **F.** Internal view of valve, note fibulae.
Scale bars = 10 µm (A, C), 5 µm (B, D-F).

Epithemia Kützing 1844

Type species: *Epithemia turgida* (Ehrenberg) Kützing

Characteristics – Cells **biraphid**, **dorsiventral**, robust and heavily silicified. **Costae** (I) traverse the valve face in the transapical plane. Striae are easily discernable and composed of complex areolae (Fig. 176; Fig. 177: D). Raphe (II) supported by **fibulae** (III; Fig. 177: F) and located in a canal close to the ventral margin near the apices, each branch of the raphe is arched towards the dorsal valve margin. Septum like extensions found on the valvocopula (first girdle band next to the valve mantle) (Fig. 177: B).

Plastid structure – Cells with single, many-lobed plastid (Fig. 175: A-C). Many scattered lipid droplets.

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the striae and costae as well as shape and degree of arching of the raphe.

Ecology – Cells solitary, free living and motile. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities. Cells can contain endosymbiotic prokaryotes which are able to fix nitrogen.

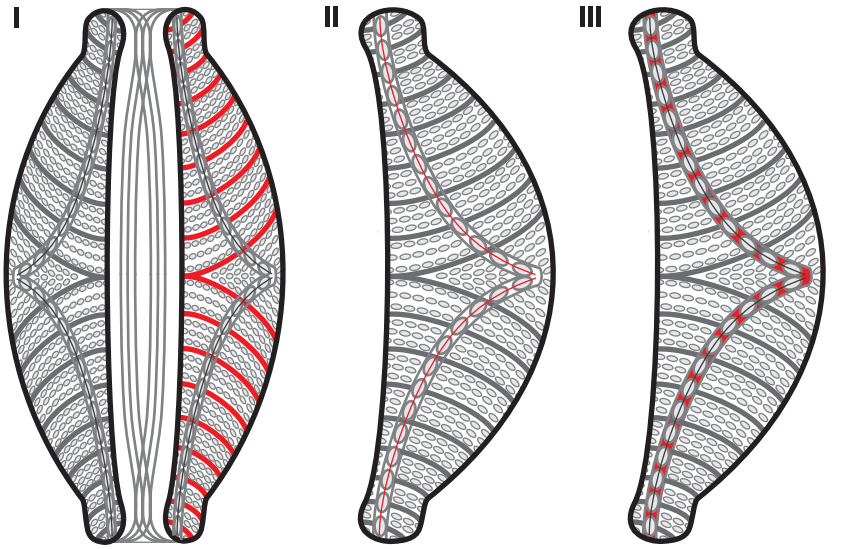


Fig. 175. *Epithemia* spp. **A-C.** LM. **A.** Living cell, girdle view (left) and valve view (right). **B-C.** Living cells of *Epithemia adnata* (Kützing) Brébisson, girdle view showing highly lobed plastid (**B**) and valve view (**C**).
Scale bar = 10 µm.

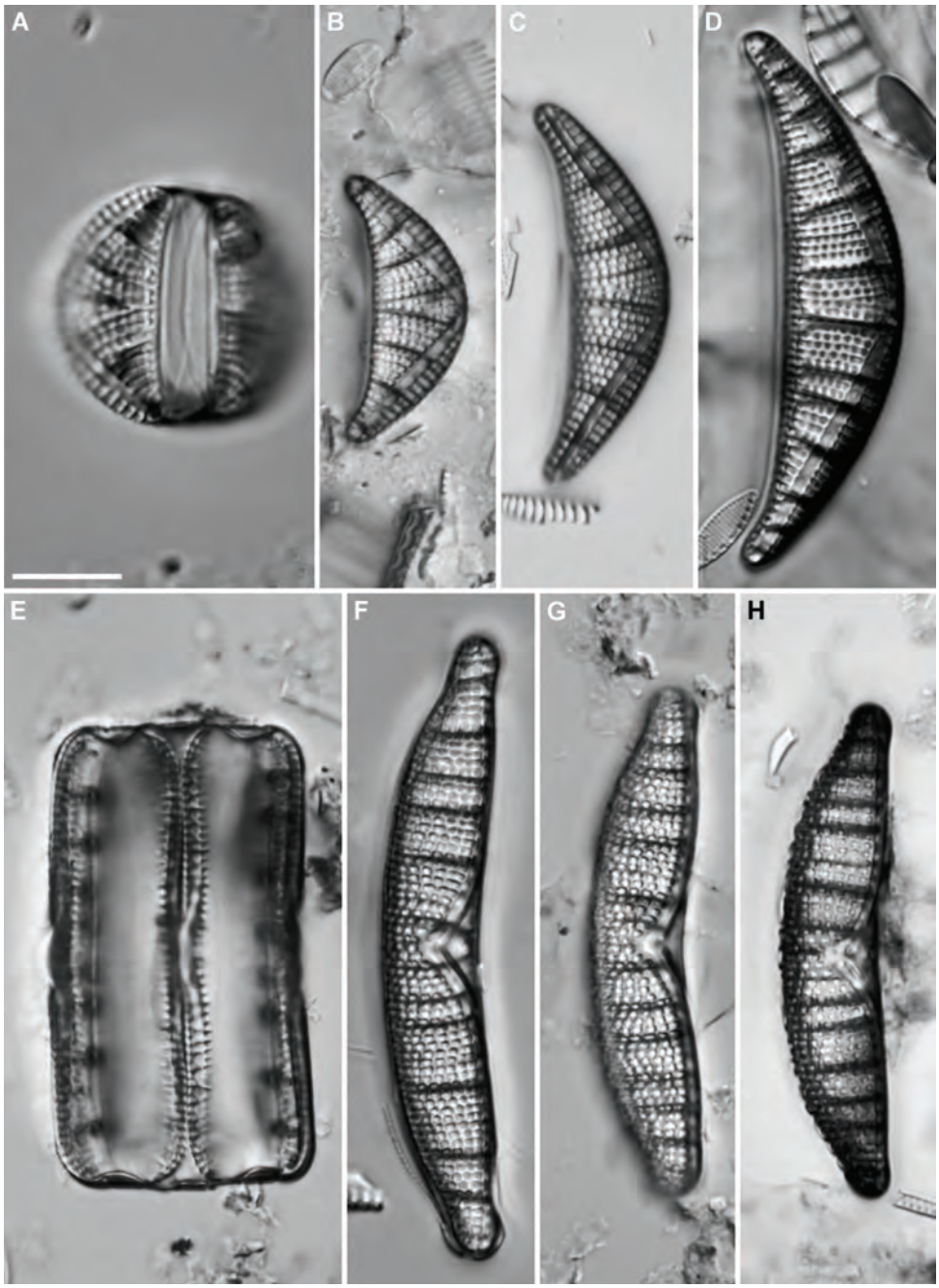


Fig. 176. *Epithemia* spp. **A-H.** LM. **A-D.** *Epithemia* sp., valve view. **E.** *E. adnata*, girdle view of cell undergoing asexual reproduction. **F-H.** *E. adnata* valve view. Scale bar = 10 µm.

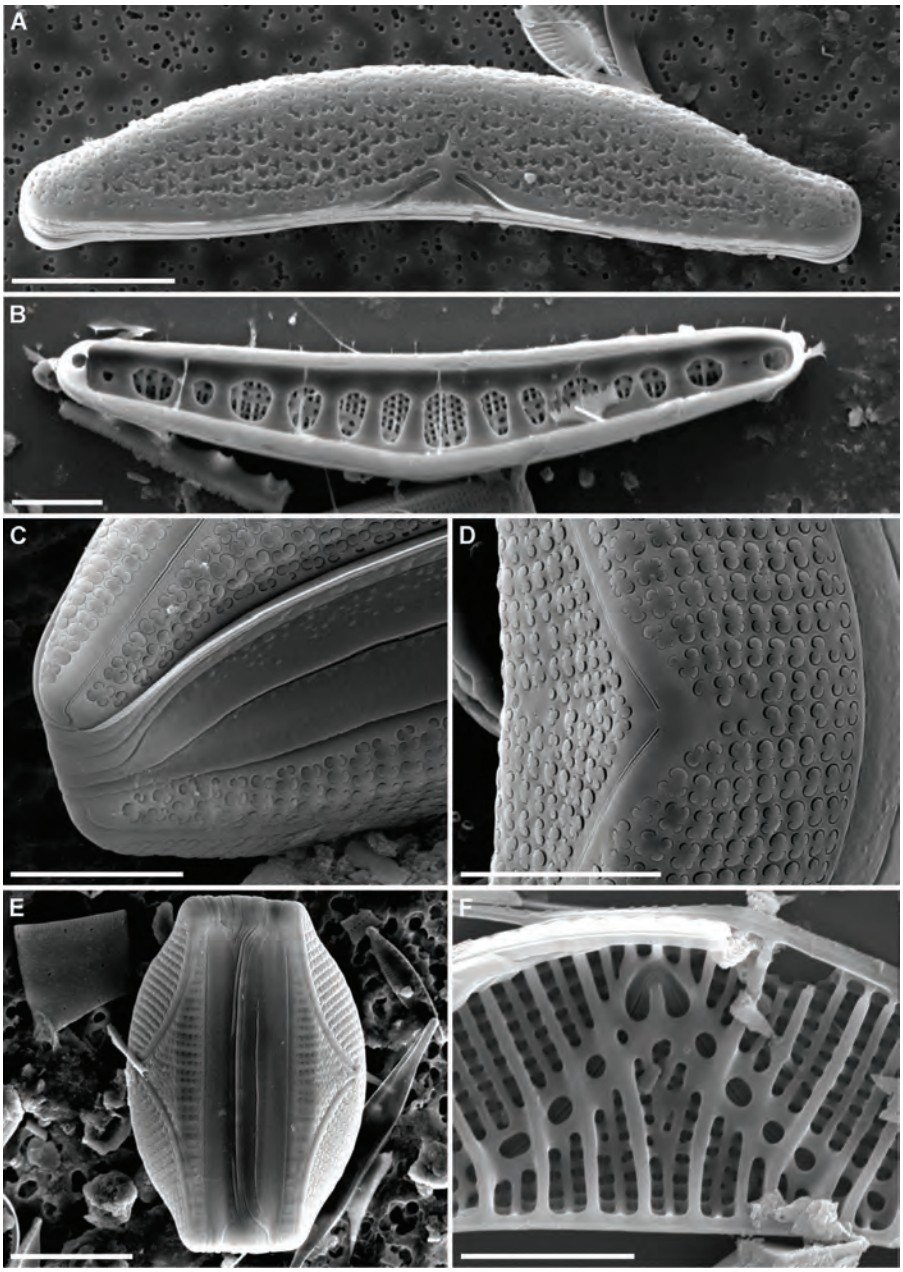


Fig. 177. *Epithemia* spp. **A-F.** SEM. **A.** *E. adnata*, external view of valve. **B.** Internal view of valve showing septum like extensions from the valvocopula. **C-F.** *E. sorex* Kützing. **C.** External view of terminal raphe endings. **D.** External view of central raphe endings. **E.** External view of ventral margin of intact cell. **F.** Internal view of valve showing heavily silicified costae. Scale bars = 10 µm (A-B, E), 5 µm (C-D, F).

Rhopalodia O. Müller 1897

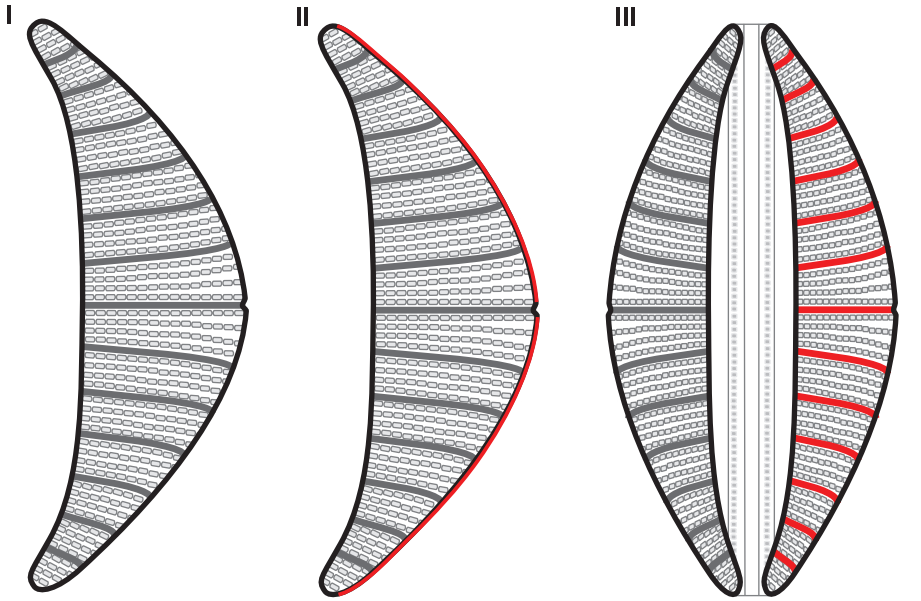
Type species: *Rhopalodia gibba* (Ehrenberg) O. Müller

Characteristics – Cells **biraphid**, **dorsiventral** with often straight ventral side, sometimes **heteropolar**, robust and heavily silicified. Cells large to extremely large. **Costae** traverse the valve face in the transapical plane (III; Fig. 180: E-I). Striae are easily discernable and composed of complex areolae (Fig. 181: F). Raphe (II) is very difficult to discern in LM, located in a canal on the dorsal valve margin, each branch of the raphe follows the curvature of the margin and is usually indented at the central nodule (Fig. 181: C). Girdle bands not complex such as those found in *Epithemia*.

Plastid structure – Single plate-like plastid lying along the ventral side of the girdle with highly lobed margins extending under the valve faces (Fig. 178: A-D).

Identification of species – Species can be identified by cell size, cell shape, shape and curvature of the apices, structure and density of the striae and costae as well as the degree of heteropolarity.

Ecology – Cells solitary, free living and motile or attached with mucilage stalks. Found in the benthos of oligotrophic to eutrophic waters in both low and moderate conductivities. Cells can contain endosymbiotic prokaryotes which are able to fix nitrogen.



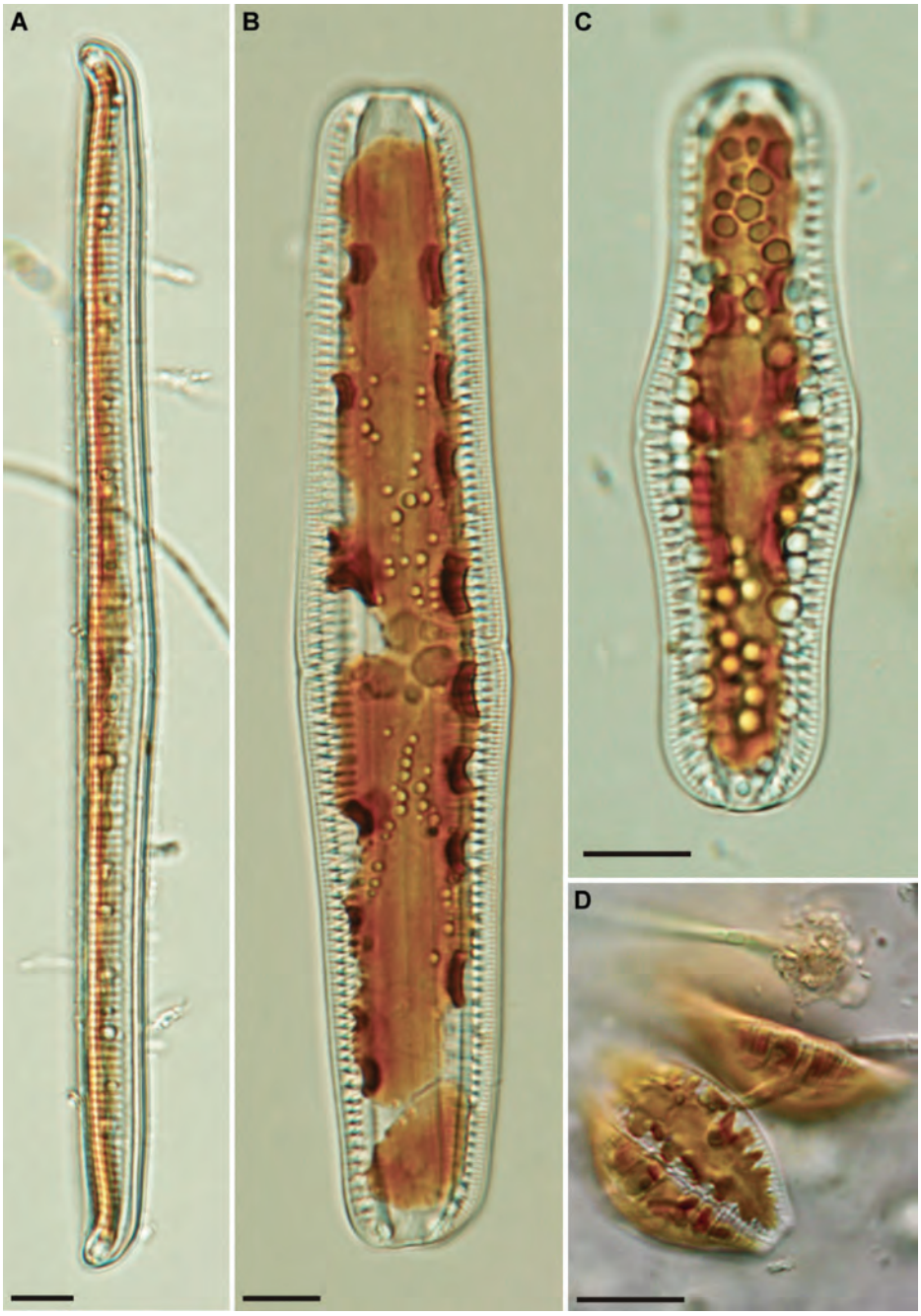


Fig. 178. *Rhopalodia* spp. **A-D.** LM, living cells. **A.** *Rhopalodia gibba*, valve view. **B-C.** *Rhopalodia gibba*, girdle view. **D.** *Rhopalodia* sp., girdle view, showing highly lobed plastid.
Scale bars = 10 µm.

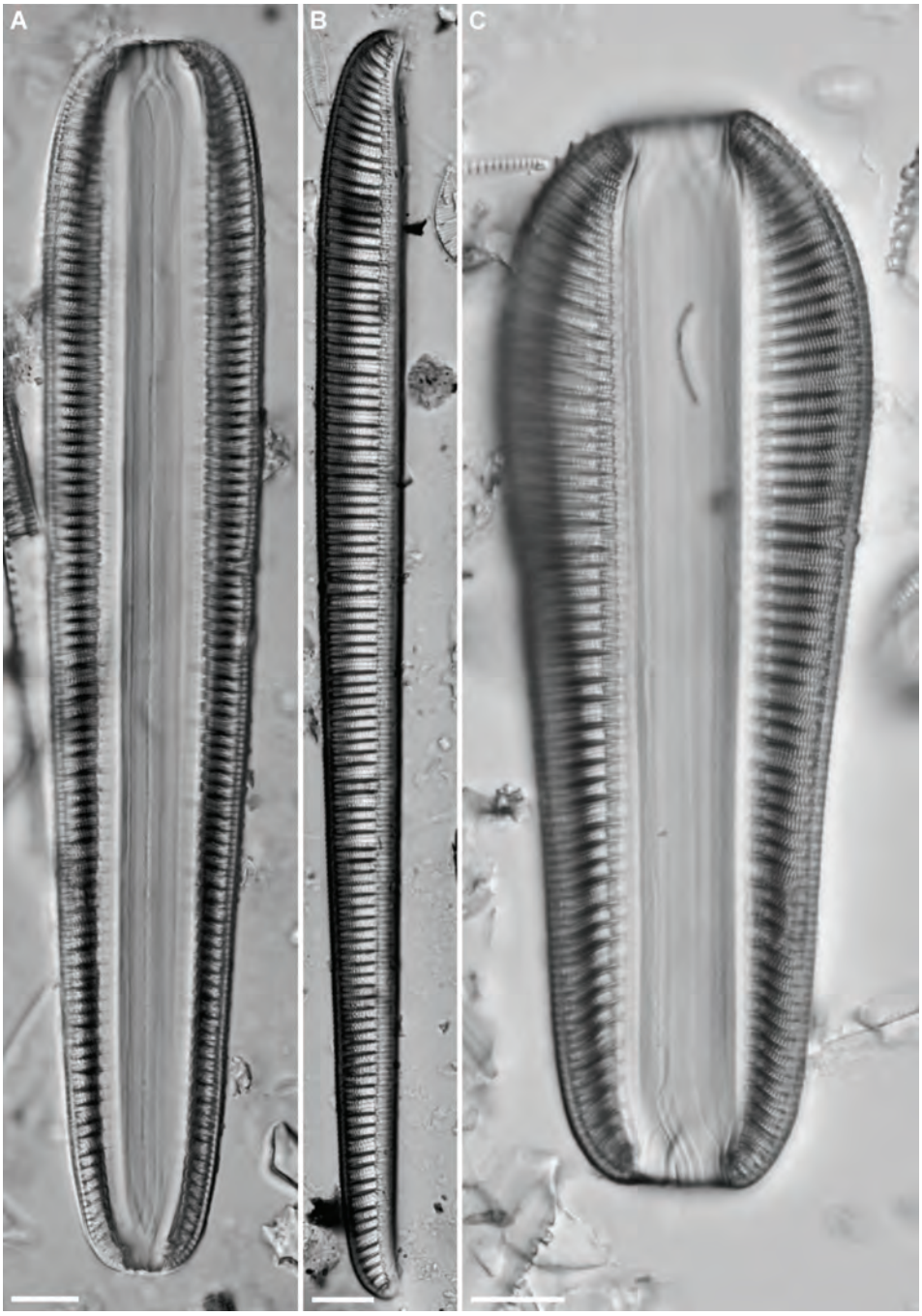


Fig. 179. *Rhopalodia hirudiniformis* O. Müller. **A-C.** LM, cleaned valves. **A, C.** Girdle view. **B.** Valve view.
Scale bars = 10 µm.

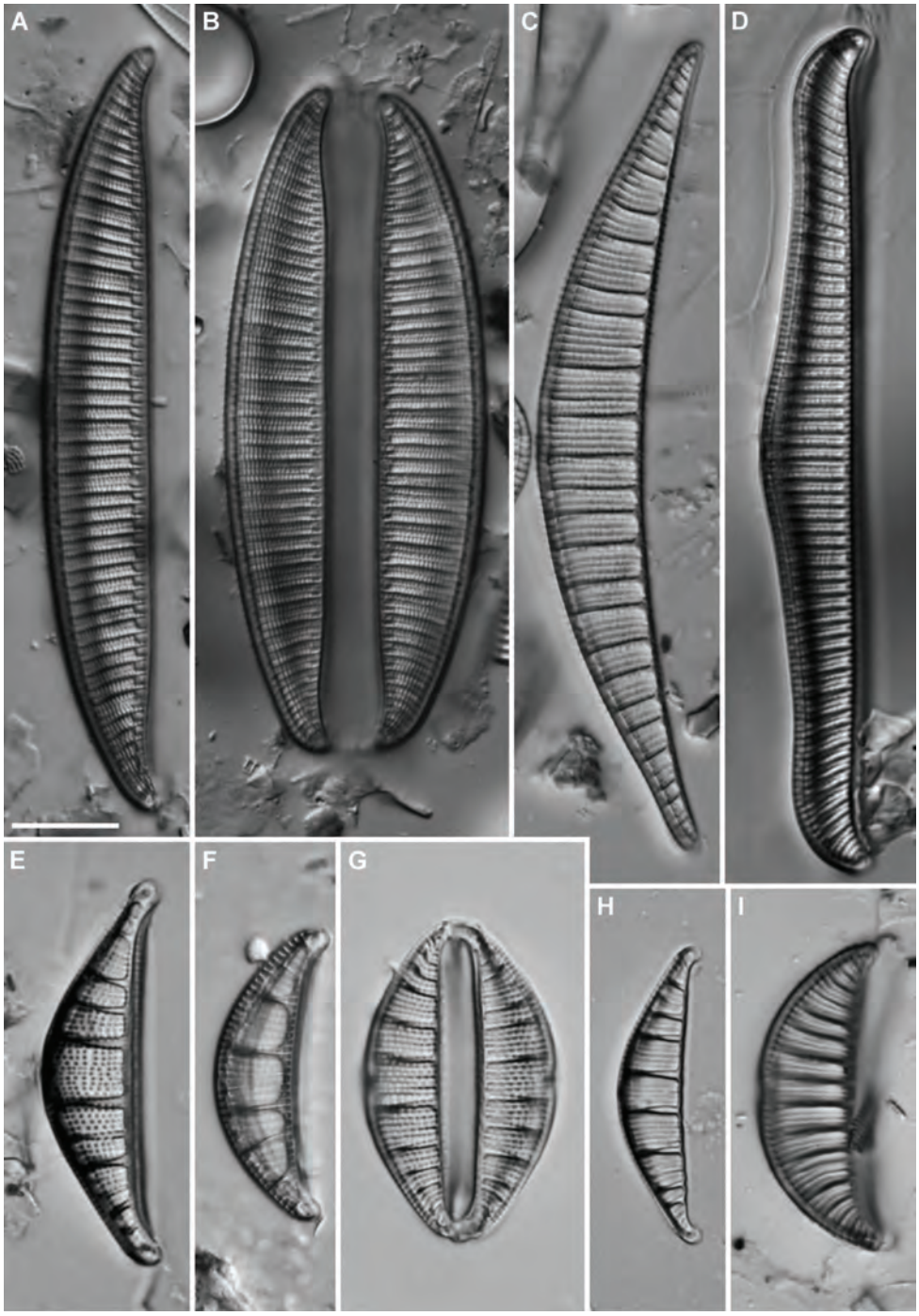


Fig. 180. *Rhopalodia* spp. **A-I.** LM, cleaned valves. **A.** Valve view. **B.** *Rhopalodia* sp., girdle views. **C.** *Rhopalodia* sp., valve view. **D.** *R. gibba*, valve view. **E-F.** *Rhopalodia* sp., valve views. **G.** *Rhopalodia* sp., girdle view. **H.** *R. gibberula* var. *vanheurckii* O. Müller, valve view. **I.** *Rhopalodia* sp., valve view. Scale bar = 10 µm.

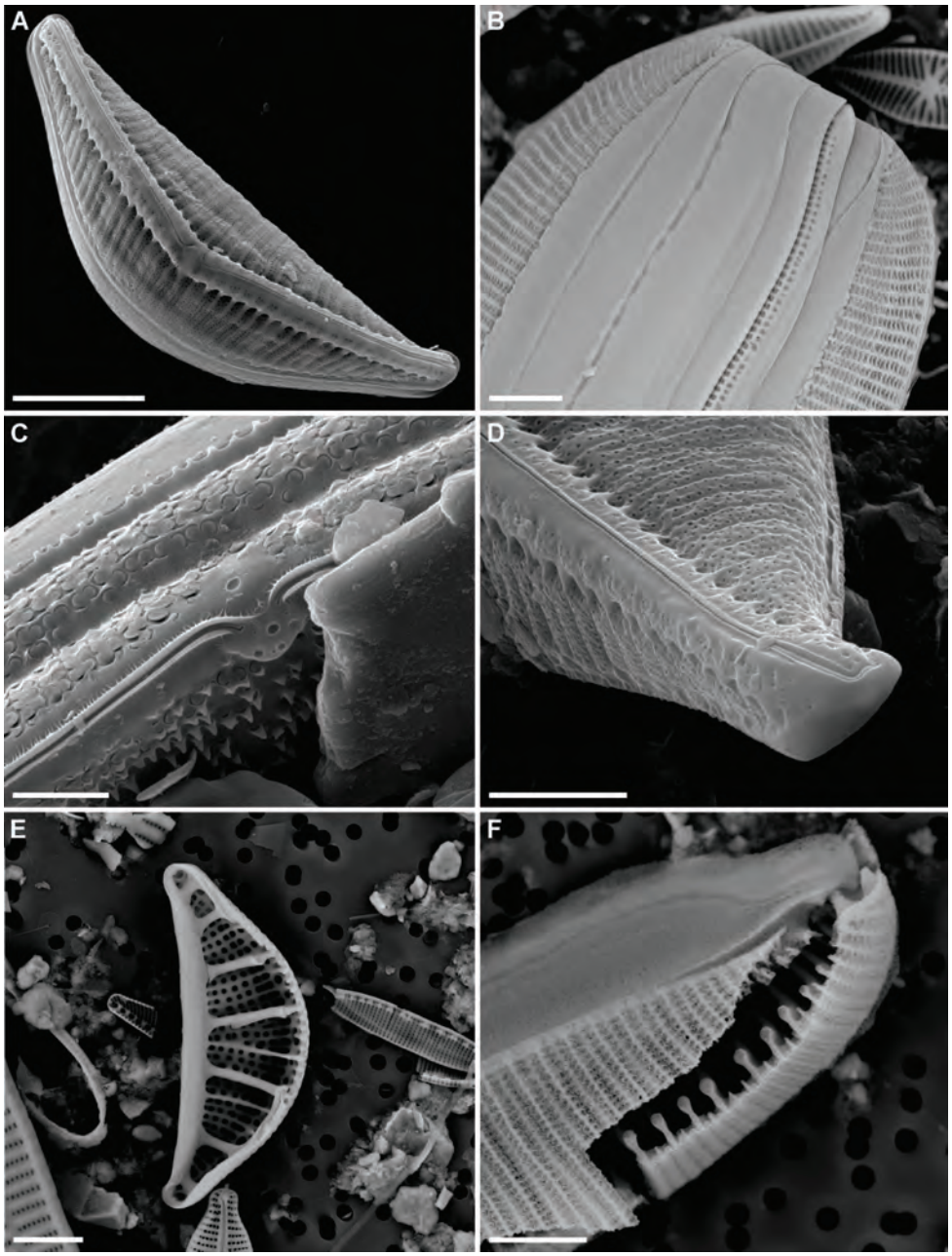


Fig. 181. *Rhopalodia* spp. **A-F.** SEM. **A-D, F.** External views. **B.** *Rhopalodia hirudiniformis*, detail of girdle bands. **C.** Detail of central raphe endings. **D.** Detail of terminal raphe ending. **E.** Internal view of valve. **F.** broken valve showing the complex structure of the areolae.
Scale bar = 10 µm (A), 5 µm (B, E-F), 2 µm (C-D).

Crucicostulifera J.C. Taylor & Lange-Bertalot 2010

Type species: *Crucicostulifera areolata* (Hustedt) J.C. Taylor & Lange-Bertalot

SYNONYM:

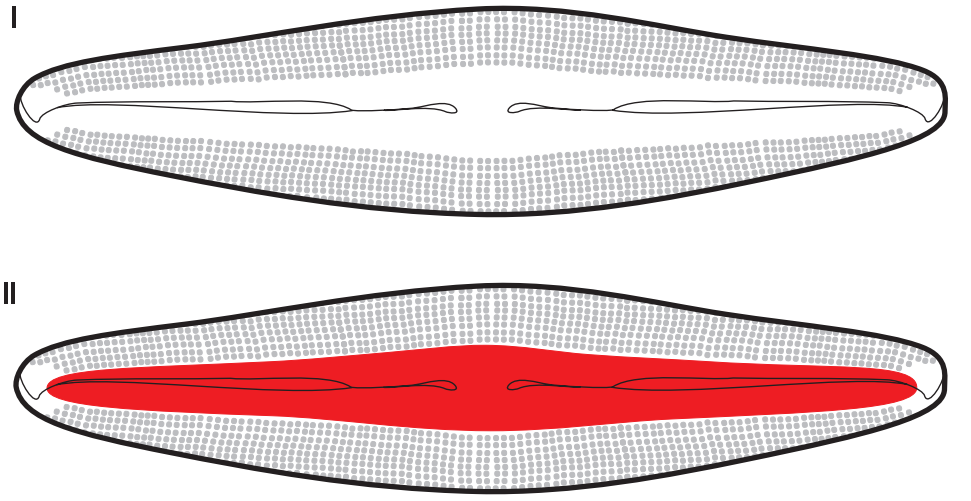
Navicula Bory 1822 pro parte

Characteristics – Cells **biraphid** with parallel striae through the length of the valve, areolae large, regularly arranged and easily observed under LM (Fig. 183: A-B). **Axial area** very broad (II; Fig. 183: A-B). Areolae have a typical X-shape when observed under SEM and are separated by transapical costae (Fig. 183: C-D).

Plastid structure – Cells with one H-shaped plastid and a large pyrenoid in the central area against one girdle. Several small lipid droplets scattered throughout the cell (Fig. 182).

Identification of species – Up till now only one species known from tropical Africa: *Crucicostulifera areolata.*

Ecology – Cells solitary and motile. Found in the benthos of oligotrophic slightly acidic water and extending into moist habitats such as splash zones near waterfalls.



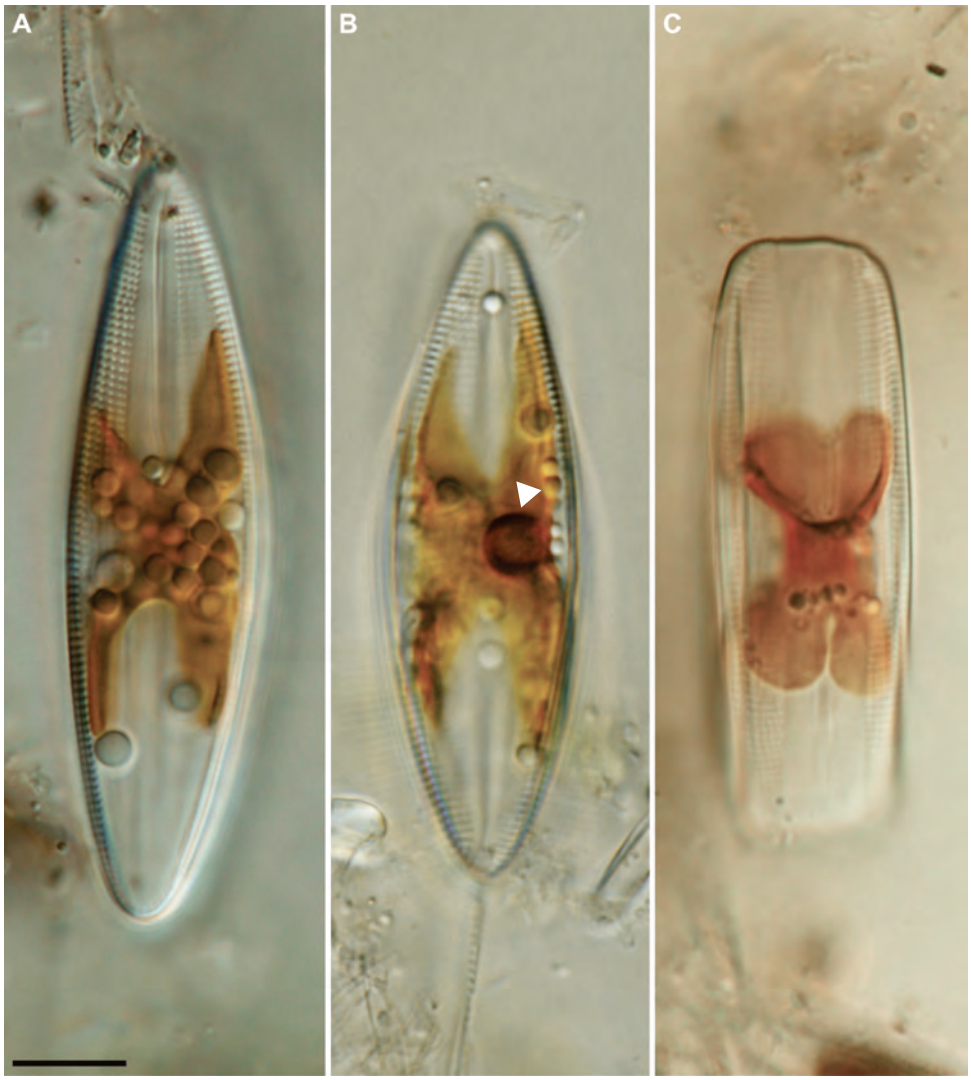


Fig. 182. *Crucicostulifera areolata*. **A-C.** LM, living cells, note H-shaped plastid and large pyrenoid (arrow - **B**).
Scale bars = 10 µm (A-C).

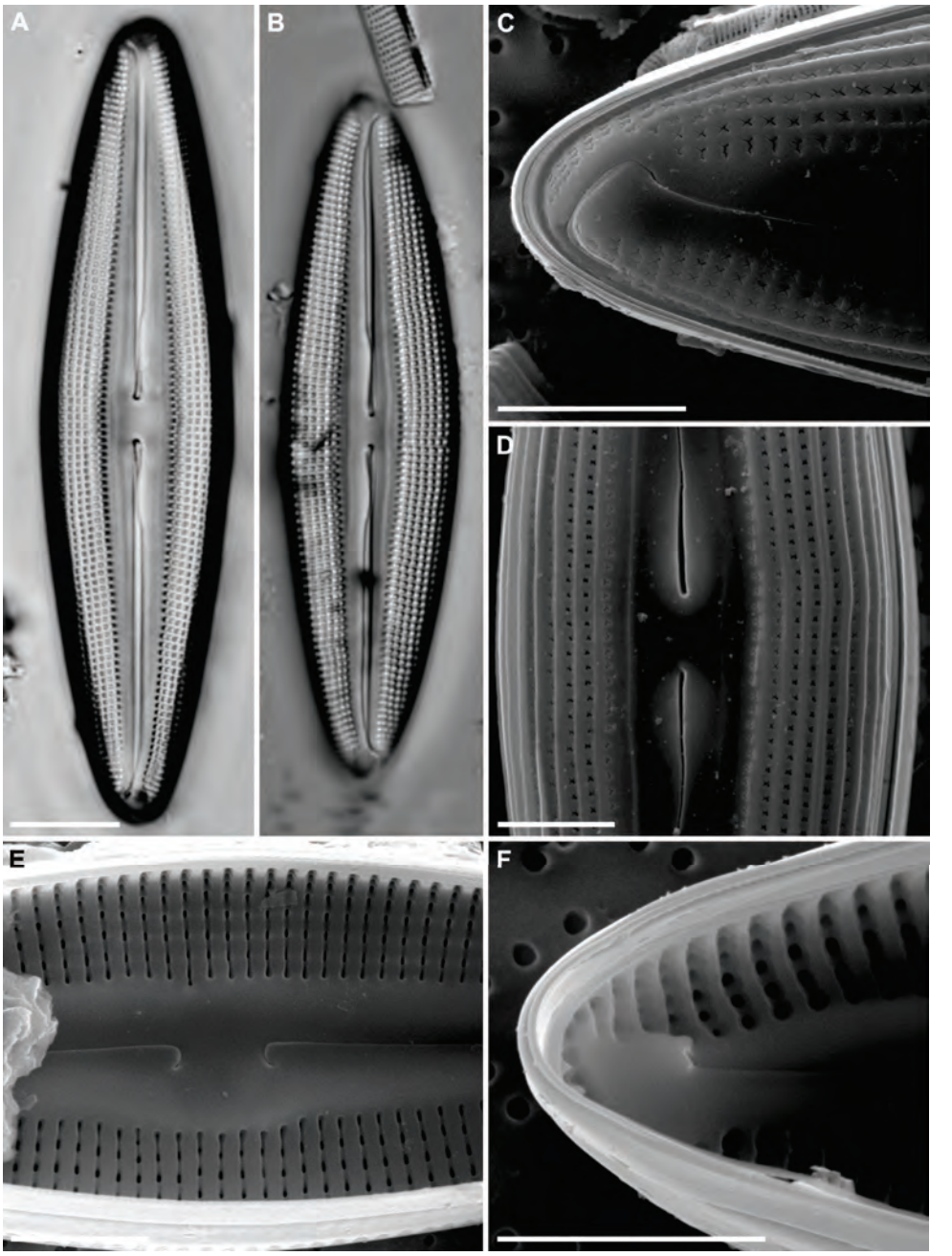


Fig. 183. *Crucicostulifera areolata*. **A-C.** LM, cleaned valves. **C-F.** SEM. **C.** Detail of external terminal raphe ending, note X-shaped areolae. **D.** Detail of external central raphe endings. **E.** Detail of internal central raphe endings. **F.** Detail of internal terminal raphe ending
Scale bars = 10 µm (A-B), 5 µm (C-F).

Campylodiscus Ehrenberg ex Kützing 1844

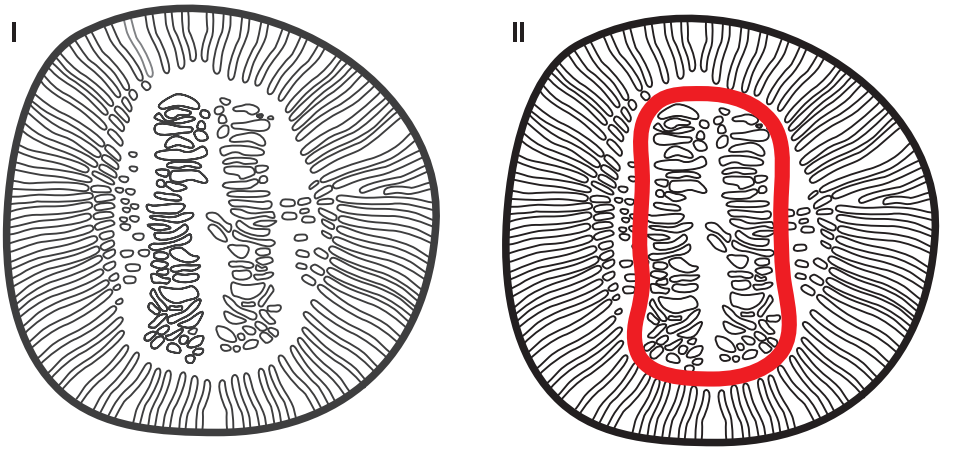
Type species: *Campylodiscus clypeus* (Ehrenberg) Ehrenberg ex Kützing

Characteristics – Cells **isopolar**, **biraphid**, saddle-shaped and very large. Concentric transapical valve undulations run parallel to the valve outline enclosing a (semi)circular area. Striae interrupted by a hyaline area (II). Raphe in a canal, raised on a keel above the valve (Fig. 184 F). This keel may be significantly higher than the valve face forming a wing. Open fenestrae sometimes present on the wing and in line with the depressions of the transapical valve undulations.

Plastid structure – Cells with one large lobed plastid.

Identification of species – Species can be identified by cell size, structure and density of the striae, and structure of the central region.

Ecology – Cells solitary, benthic, re-suspended in the plankton. Found in waters with moderate to high conductivity.



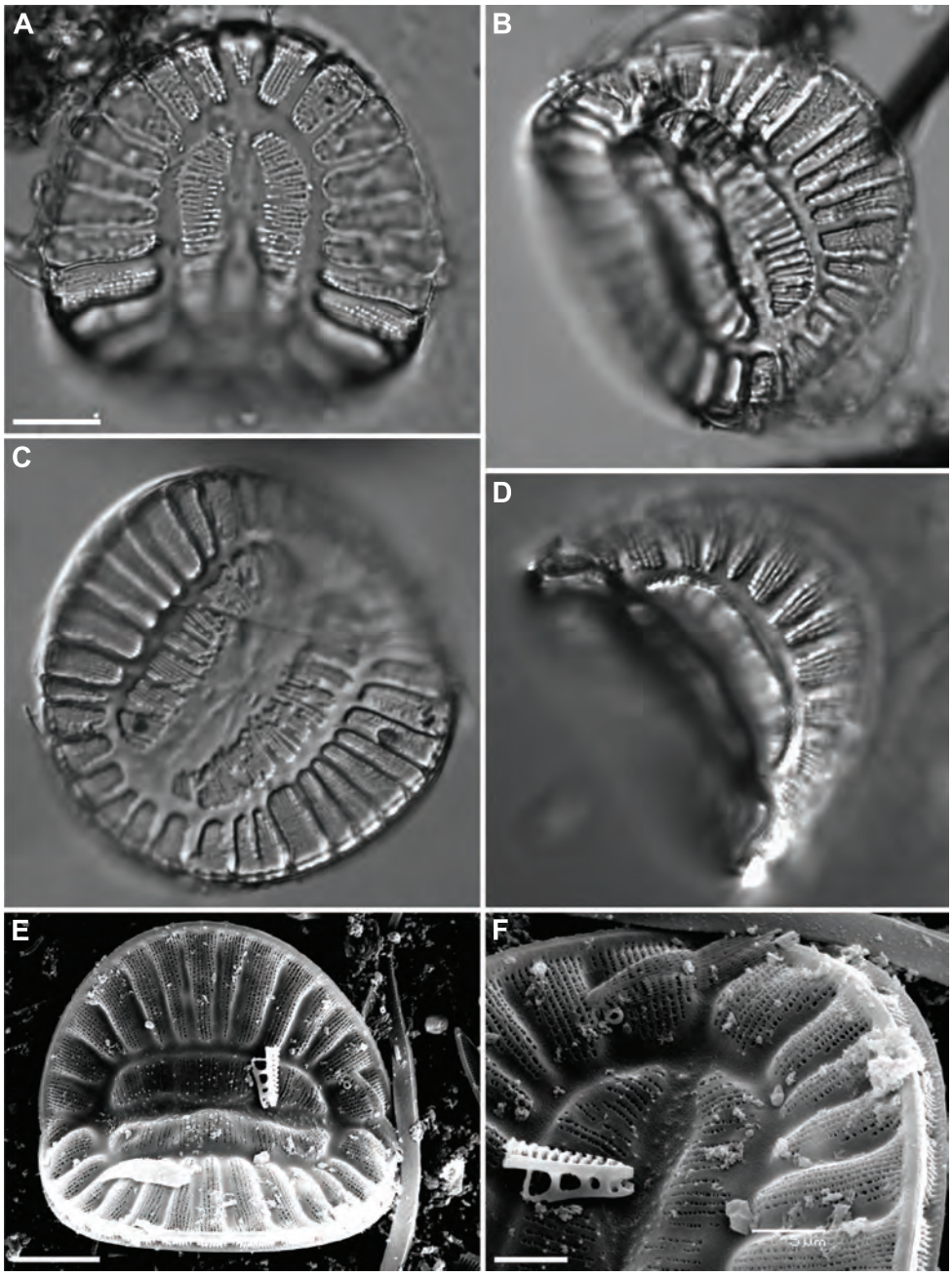


Fig. 184. *Campylodiscus clypeus*. **A-D.** LM. Cells at various angles and foci. **E-F.** SEM, external view of valve, note elevated keel bearing the raphe slit (arrow - **F**).
Scale bars = 10 µm (A-F).

Cymatopleura W. Smith 1851

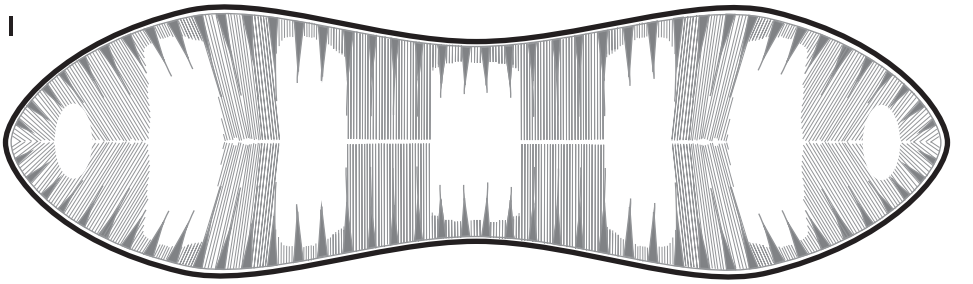
Type species: *Cymatopleura solea* (Brébisson) W. Smith

Characteristics – Cells **isopolar**, **biraphid**, large, elliptical, panduriform or linear with valve margins straight or constricted mid-valve. **Raphe** in a shallow **keel** on the entire circumference of the valve face supported by robust **fibulae** (Fig. 185: B-D; Fig. 186: D). Striae radiate, very fine, composed of small areolae which cannot be resolved using LM. Valve undulates in the transapical plane (Fig. 185: C, D).

Plastid structure – Cells with one large many lobed plastid (Fig. 185: A).

Identification of species – Cell shape, shape of the apices and size, number and position of the transapical valve undulations, structure and density of the fibulae.

Ecology – Cells benthic or planktonic, motile. Found in alkaline waters of low to moderate conductivity.



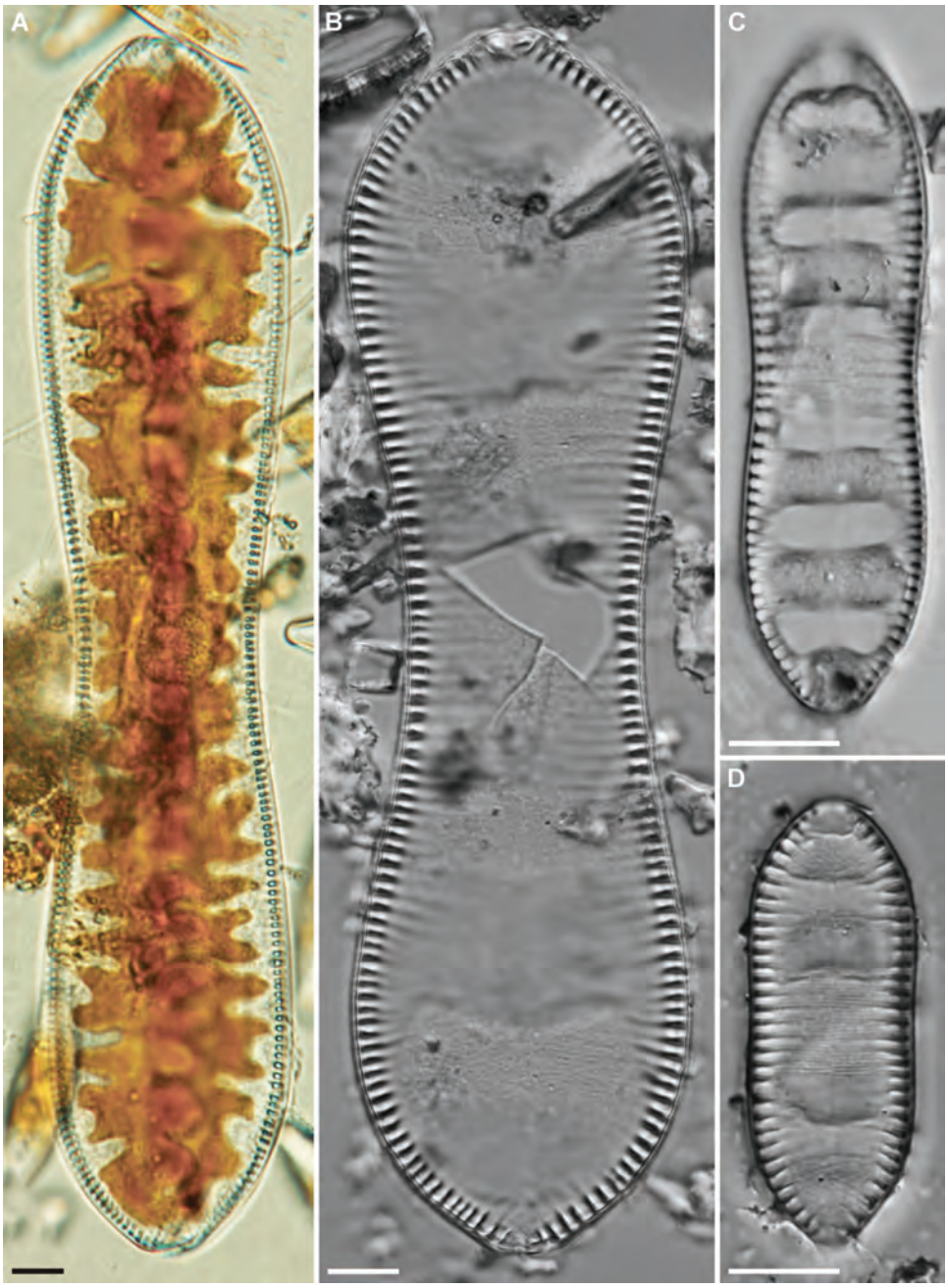


Fig. 185. *Cymatopleura* spp. **A-D.** LM. **A.** Living cell of *Cymatopleura clavata* (O. Müller) Cocquyt & R. Jahn, valve view, note highly lobed plastid. **B-D.** Cleaned material, valve view. **C-D.** *C. comperei* Cocquyt & R. Jahn, note undulations on valve face.
Scale bars = 10 µm (A-D).

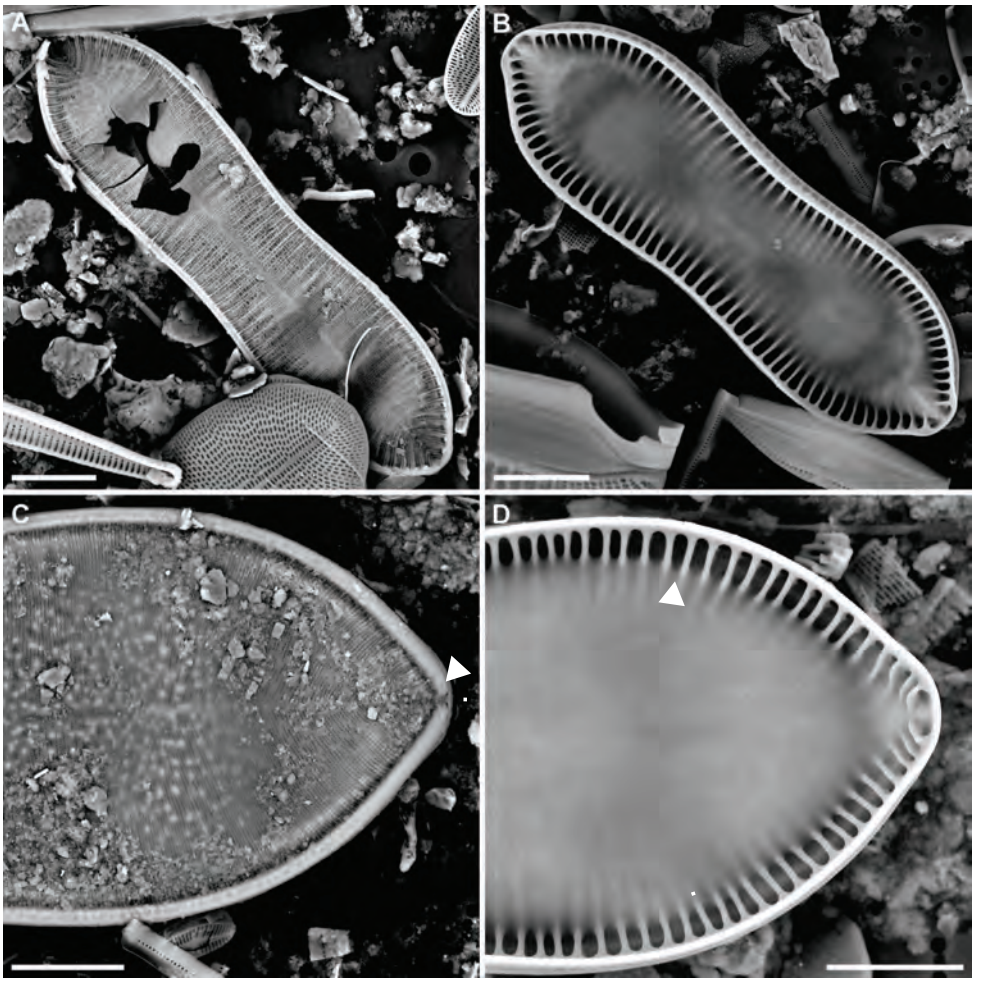


Fig. 186. *Cymatopleura* spp. **A-D.** SEM. **A-B.** *C. comperei.* **A.** View of valve exterior. **B.** View of valve interior. **C.** Valve exterior showing cell apex and raphe endings (arrow). **D**. Valve interior showing fibulae (arrow).
Scale bars = 10 µm (A-D).

Stenopterobia (Brébisson) Van Heurck 1896

Type species: *Stenopterobia sigmatella* (W. Gregory) R. Ross

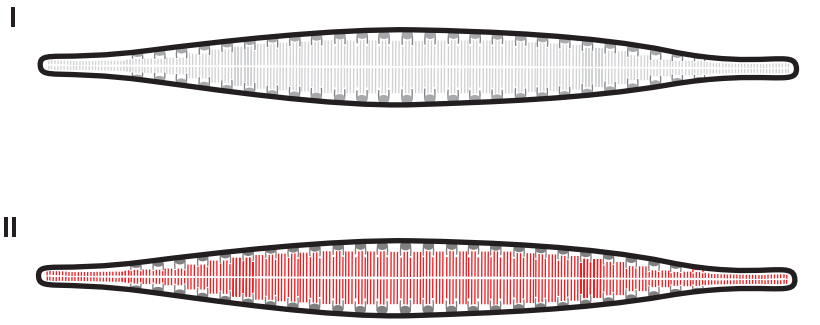
SYNONYM:
Surirella Turpin 1828 pro parte

Characteristics – Cells **isopolar**, **biraphid**, valves narrow lanceolate or sigmoid. Striae fine, parallel composed of 2-3 rows of areolae which are not discernable under LM. **Costae** (Fig. 188: A-D; Fig. 189: A) cross the raphe and interrupted by a narrow axial area (Fig. 189: A-B). Raphe runs the length of the valve on both margins in a canal on a keel raised above the valve (Fig. 189: A-D).

Plastid structure – Cells with one plastid divided into 2 plates (Fig. 187: C, F), one against each valve connected by a narrow isthmus near one pole.

Identification of species – Species can be identified by cell size, cell shape (lanceolate or sigmoid), shape of the apices, structure and density of the costae, density of the striae as well as structure and width of the axial area.

Ecology – Cells solitary, free living and motile. Found in the benthos of acidic, oligotrophic waters in low conductivities.



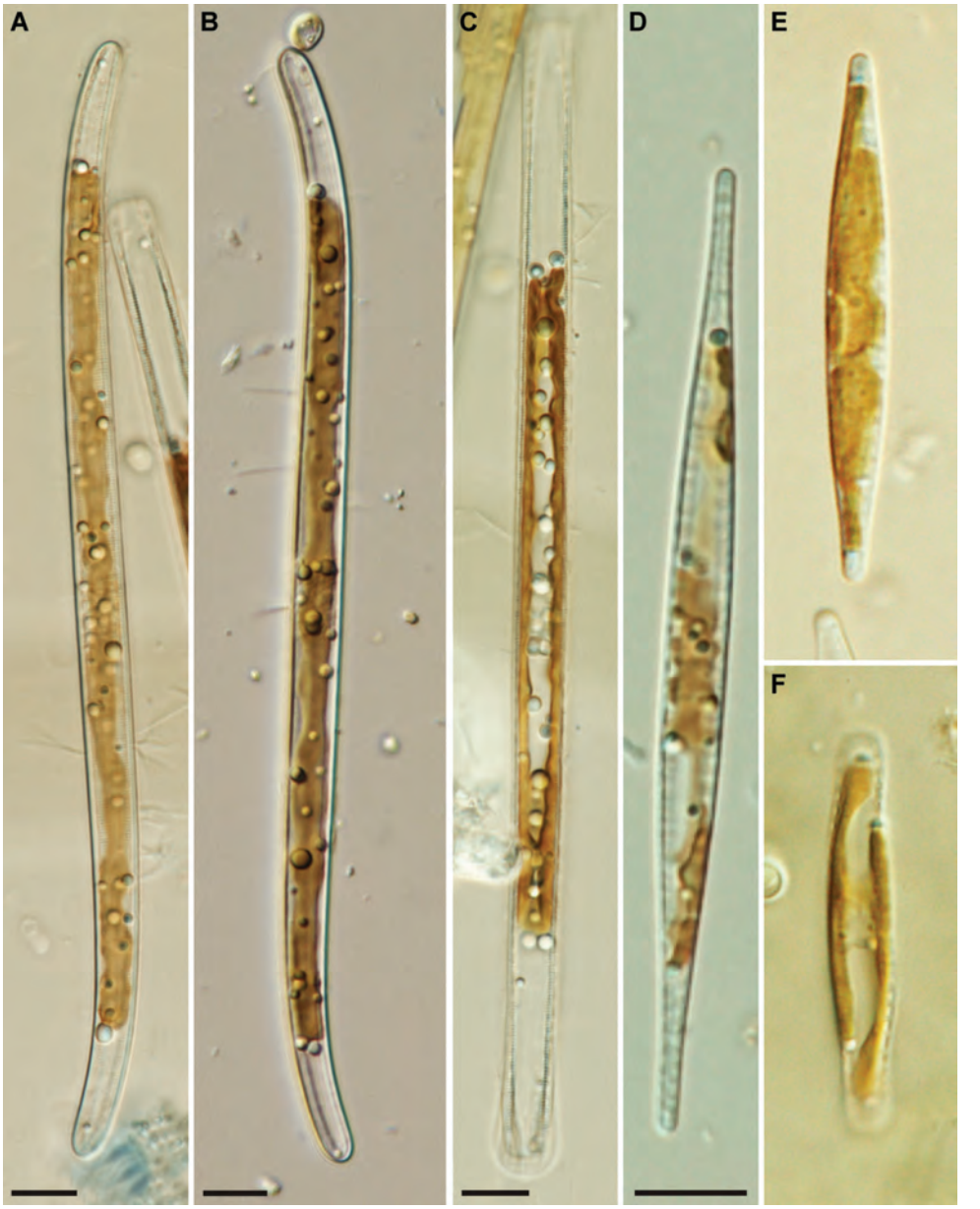


Fig. 187. *Stenopterobia* spp. **A-F.** LM, living cells. **A-B**. *Stenopterobia* sp. valve views. **C.** *Stenopterobia* sp. girdle view. **D-E.** *S. delicatissima* (F.W. Lewis) Brébisson ex Van Heurck, valve views. **F.** *S. delicatissima*, girdle view. Scale bars = 10 µm (A-F).

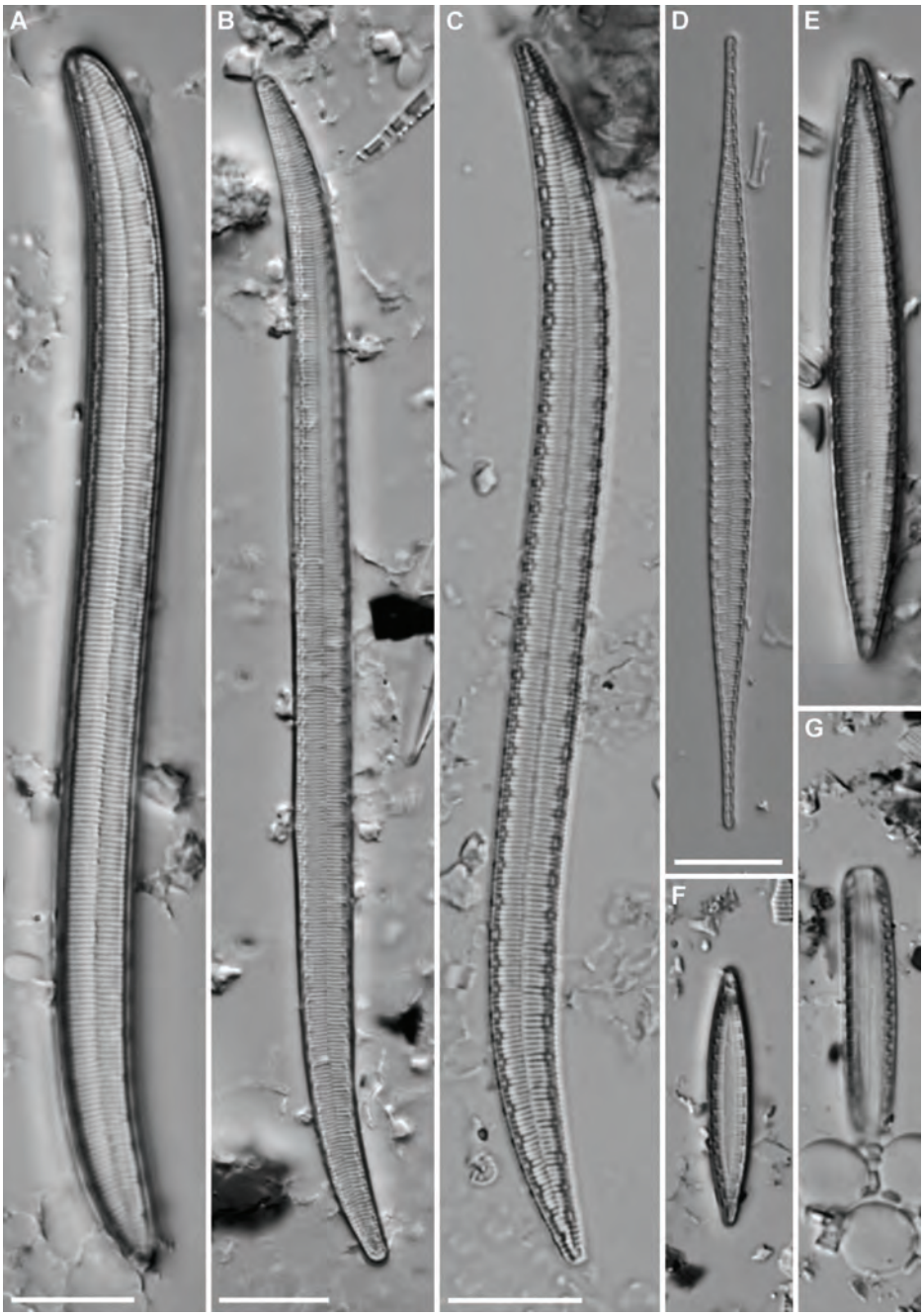


Fig. 188. *Stenopterobia* spp. **A-G.** LM, cleaned valves. **A-C.** *Stenopterobia* spp., valve views. **D.** *S. delicatissima*, valve view. **E-F.** *Stenopterobia* spp., valve views. **G.** *Stenopterobia* sp., girdle view.
Scale bars = 10 µm (A-G).

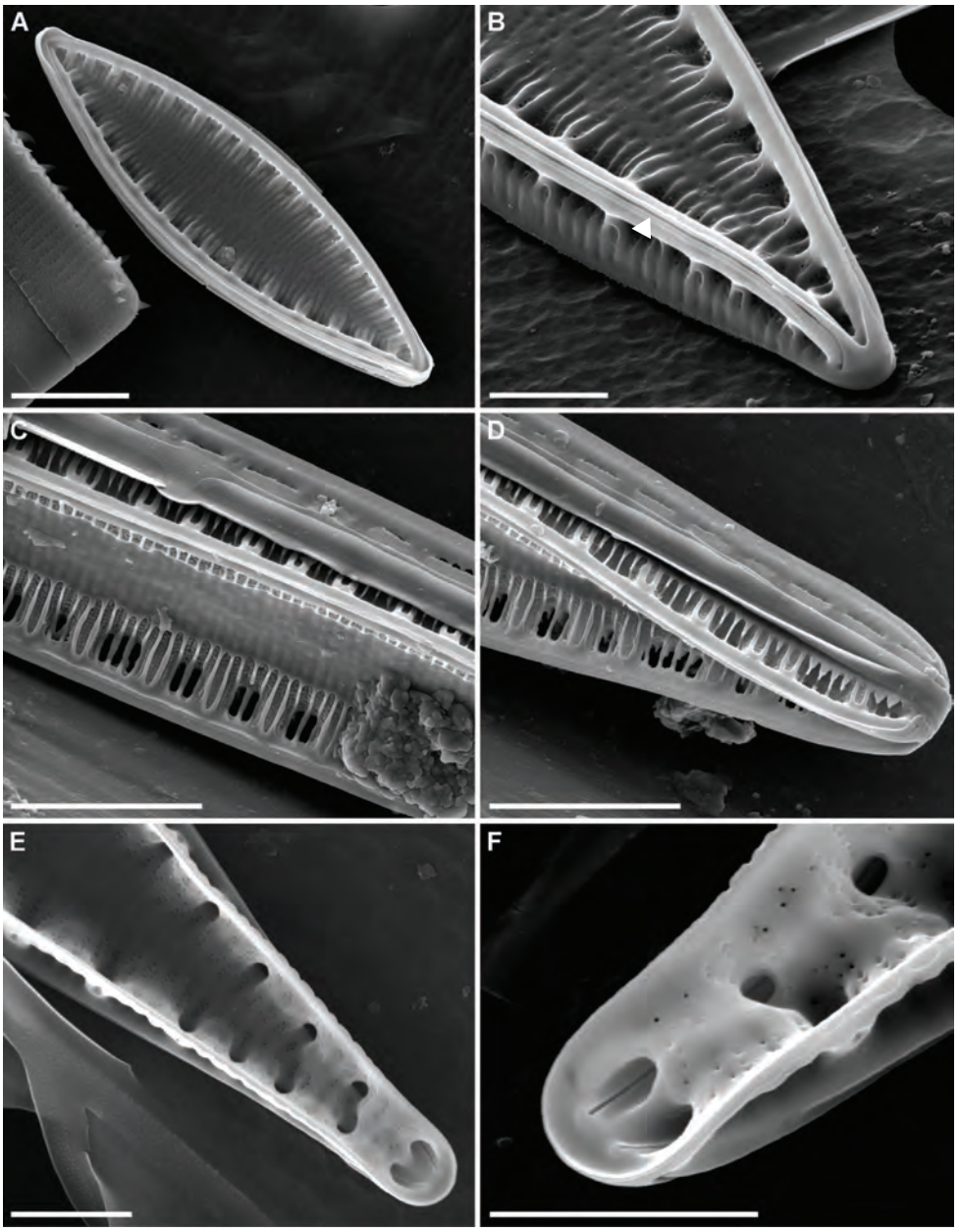


Fig. 189. *Stenopterobia* spp. **A-F.** SEM. **A-B.** *S. delicatissima*, external view of valves, note the raphe keel (arrow - **B**). **C-D.** *Stenopterobia* sp., detail of valve mantle and girdle bands. **E-F.** *S. delicatissima*, internal view of valves, detail of apices and terminal raphe endings..
Scale bars = 5 µm (A, C-D) 2 µm (B, E-F).

Surirella Turpin 1828

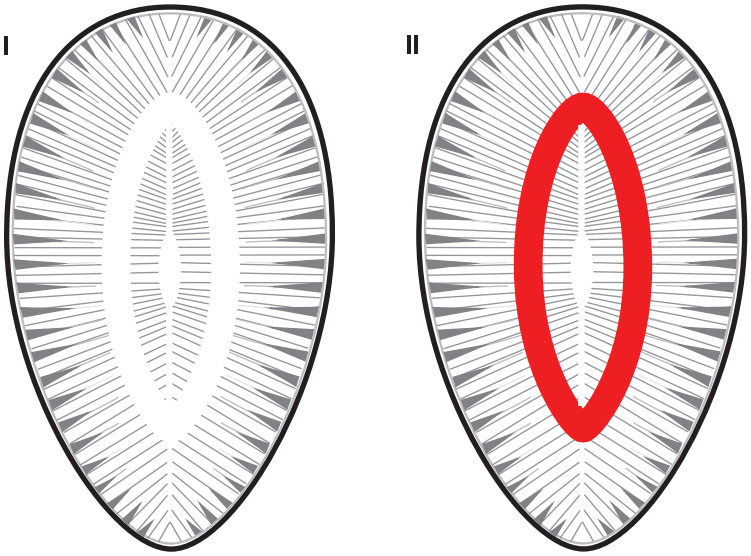
Type species: *Surirella striatula* Turpin

Characteristics – Cells **isopolar** or **heteropolar**, **biraphid**, sometimes constricted mid-valve. Striae fine, parallel to radiate composed of one or several rows of small round areolae which are not discernable under LM (Fig. 191). **Transapical valve undulations** (Fig. 191) cross the valve face, interrupted by the axial area which is variable in width (Fig. 191). Raphe runs around the whole circumference of the valve face, interrupted at the foot pole (Fig. 192: D). Raphe in a canal on both margins which may be raised on a keel above the valve face (Fig. 192: A-B, E-F) forming a wing, **fenestrae** may be present. Valve face may have small scattered spines (Fig. 191: B), granules (Fig. 192: E) or other siliceous structures. Some species have one to several large spines in the axial area (Fig. 192: A).

Plastid structure – Cells with one large lobed plastid divided into 2 plates, one against each valve connected by a very narrow isthmus near one pole (Fig. 190).

Identification of species – Species can be identified by cell size, cell shape, shape of the apices, structure and density of the costae, presence and structure of spines, structure of the axial area, as well as structure of the wings.

Ecology – Cells solitary, free living and highly motile. Found in the benthos and plankton of oligotrophic to eutrophic waters in low to high conductivities.



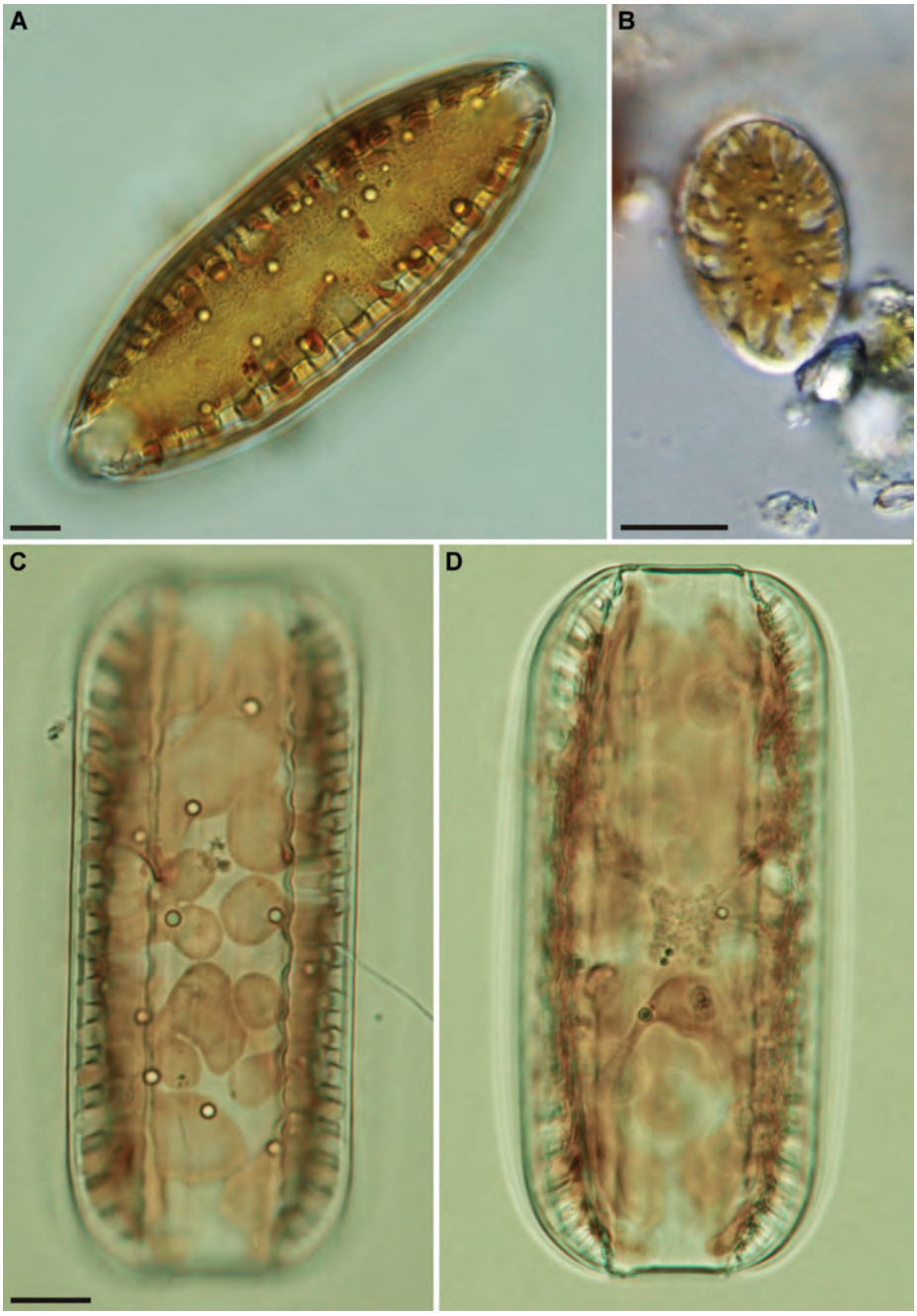


Fig. 190. *Surirella* spp. **A-F.** LM, living cells. **A.** *Surirella* sp., valve view. **B.** *S brebissonii* Krammer & Lange-Bertalot, valve view. **C-D.** *Surirella* sp., girdle view of the same cell taken at different foci.
Scale bars = 10 µm (A-F).

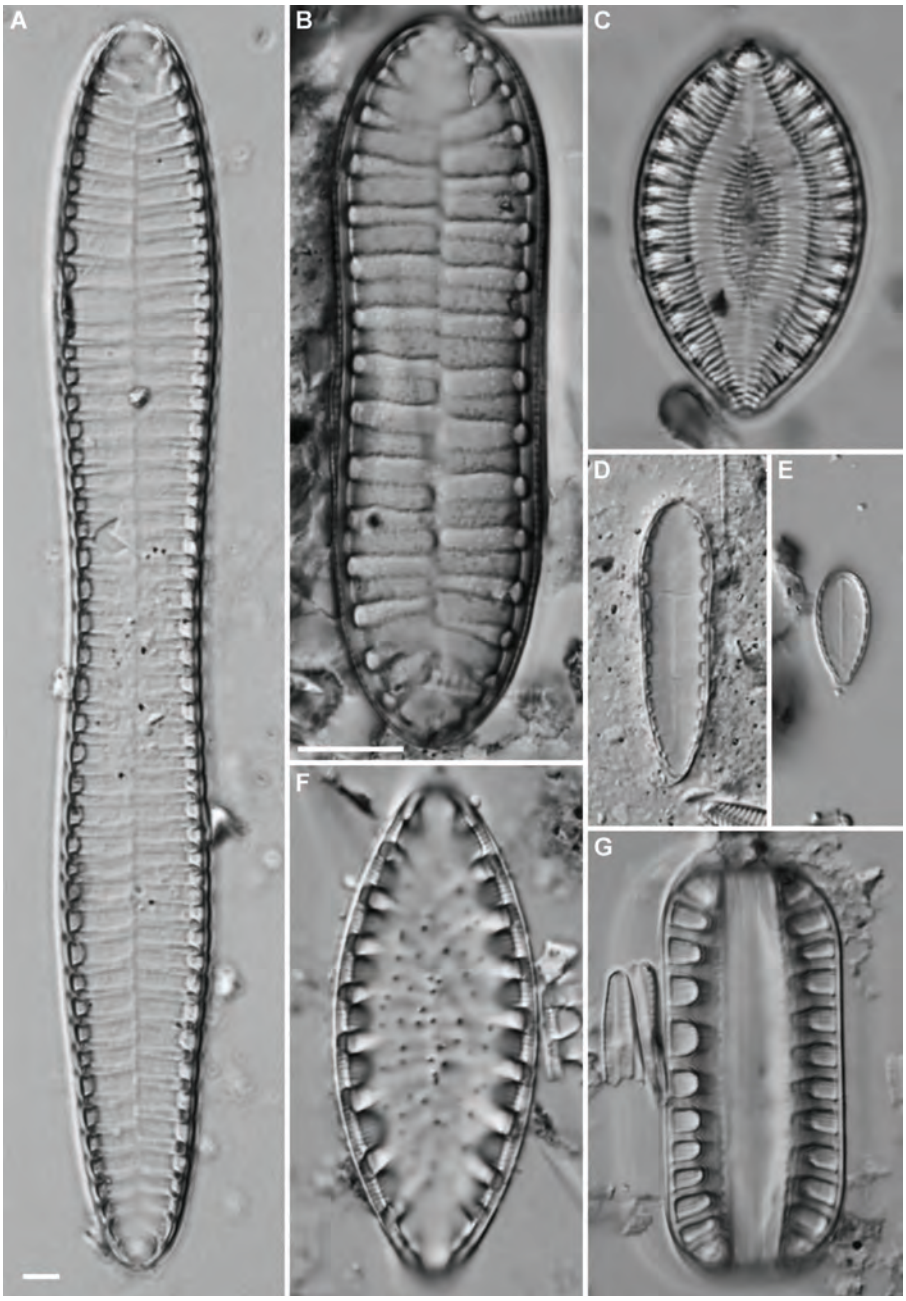


Fig. 191. *Surirella* spp. **A-G.** LM, cleaned valves. **A-F.** Valve views. **B.** *S. ebalensis* Cocquyt & J.C. Taylor. **C.** *S. brebissonii*. **D.** *S. congolensis* Cocquyt & J.C. Taylor. **E.** *S. ostentata* Cholnoky. **F.** *S. bifrons* (Ehrenberg) Ehrenberg. **G**. *Surirella* sp., girdle view.
Scale bars = 10 µm (A-G).

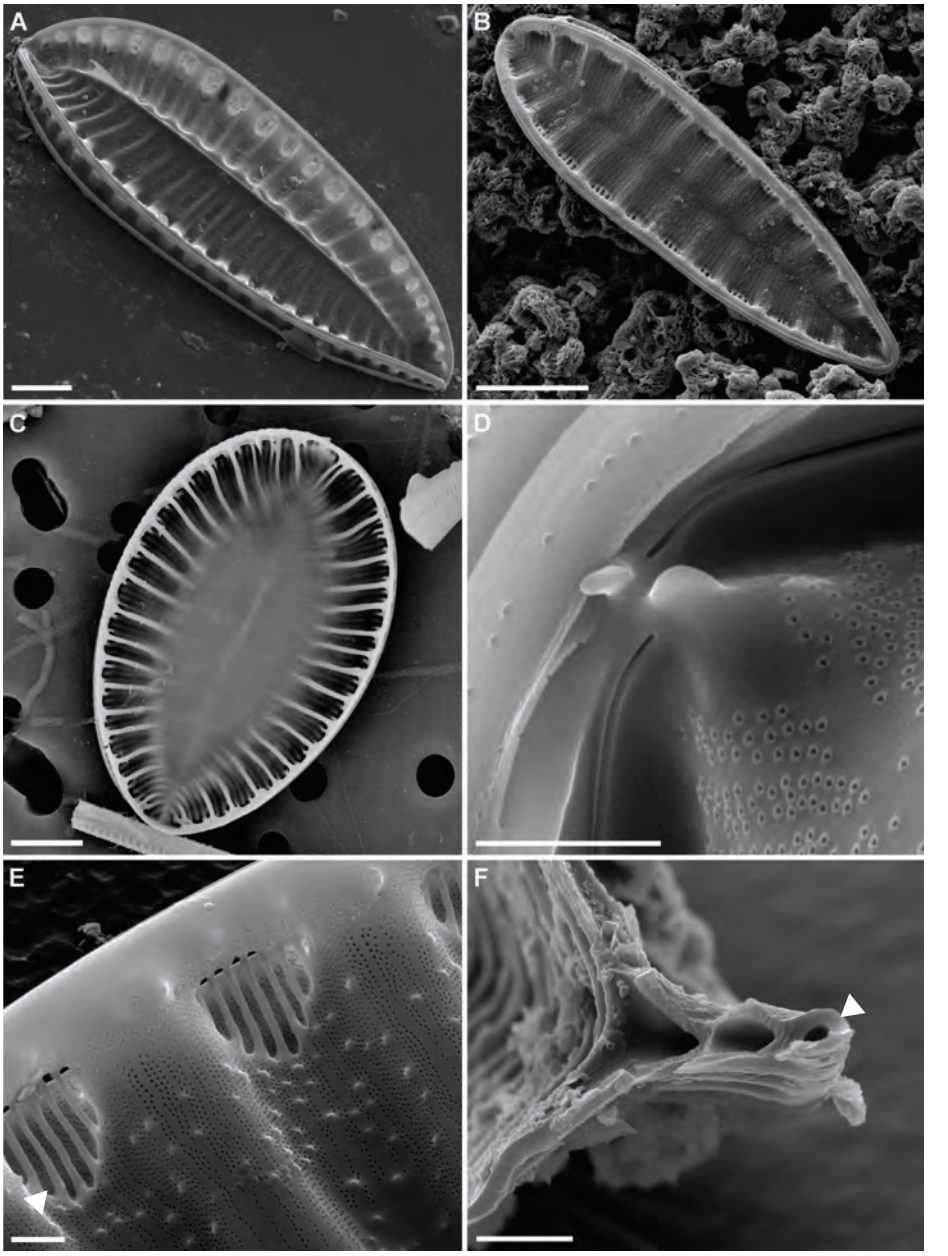


Fig. 192. *Surirella* spp. **A-F.** SEM. **A-B, E.** External view of valves. **A.** *S. nervosa* (A.W.F. Schmidt) Ant. Mayer **B.** *S. congolensis*. **C-D.** Internal view of valves. **C.** *S. brebissonii*. **D.** *S. ebalensis*, detail of internal raphe endings and helictoglossae at the foot pole. **E.** Detail of open fenestrae with fenestral bars (arrow), note the uniseriate striae becoming bi- to triseriate near the keel. **F.** Cross-section of the keel with raphe canal (arrow).
Scale bars = 10 µm (A, C), 5 µm (B), 1 µm (D-F).

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16. Taxonomic index

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