AN ILLUSTRATED KEY TO COMMON DIATOM GENERA FROM SOUTHERN AUSTRALIA

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An illustrated key to common diatom genera from southern Australia

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Front Cover:
Top left: *Cymbella tumida* (Brebisson in Kutzing) Grunow in Van Heurck
Middle left: *Gomphonema* cf. *contraturris* Lange-Bertalot & Reichardt
Bottom left: *Rhopalodia gibba* (Ehrenberg) O. Muller
Top right: *Surirella ovalis* Brebisson
Middle right: *Eunotia serpentina* Ehrenberg
Bottom right: *Pleurosira laevis* (Ehrenberg) Compere

CONTENTS

INTRODUCTION

Compared to other parts of the world, relatively little research has been undertaken on the taxonomy of Australian diatoms. Apart from the descriptions of new species such as those by Foged (1978); John (1980, 1981a,b,c); Haworth & Tyler (1993); Hodgson *et al.* (1996); and Vyverman *et al.* (1997, 1998), most Australian researchers rely heavily upon the comprehensive taxonomic texts produced in the northern hemisphere to identify Australian species. Tyler (1998) has suggested that such force-fitting may in fact be overlooking much endemism in the Australian diatom flora. The recent expansion of diatom research in Australia (itself greatly inflating the checklist of Australian diatoms in Day *et al.* (1995)) has suggested that a great majority of diatom species found in Australia are indeed cosmopolitan if the present taxonomic schemes are used. If Mann & Droop's (1996) suspicions about the substantial hidden diversity within *Sellaphora pupula* are applicable across the entire class, then the number of diatom species across the world could exceed 100,000. Certainly under these circumstances there would be many species/forms to discover here and much to add to the Australian checklist. Fortunately, except in waters of unusual chemistry, the bulk of the diatoms in most samples constitute common species. Despite this, a dataset of 50 samples may yield over 300 species and varieties across 30 or more genera. It would be relatively simple to identify those to generic level, but recent work by Chessman (pers. comm.) in Eastern Australia and Gell (pers. comm.) in Adelaide has demonstrated that identification to genus level reduces ecological and water quality information.

With this in mind we begin with a key to 57 genera. This is by no means comprehensive, and individuals working in particular aquatic bioregions, will frequently encounter some rarer genera which are not included here (eg. *Grammatophora*). The authors believe that a useful first step is to produce such a key and to follow this, firstly with a key to common species, and then more detailed keys to diatom families.

Diatom Taxonomy

In recent years, universal consistency in the identification of freshwater diatoms has been facilitated by the publication of the "*Süßwasserflora von Mitteleuropa*" by Krammer and Lange-Bertalot (1986-91). This comprehensive taxonomic series is now used as the basis for freshwater diatom identification worldwide. However, as with all biotic groups, diatom taxonomy is under regular review. In 1990, Round, Crawford and Mann published "*The Diatoms: Biology and Morphology of the Genera*". This volume presented a revised generic classification in which several genera, notably the large groupings of *Navicula* and *Nitzschia*, were divided into a number of smaller genera. However, the uptake of the new nomenclature has been limited, as many of the characteristics used to distinguish genera are only visible under the electron microscope. Table 1 lists some of the key generic changes made by Round *et al.* (1990). So, where once a sample may have reasonably been made up of *Achnanthes*, *Cymbella*, *Fragilaria*, *Navicula* and *Nitzschia*, the same samples may now be represented by nineteen genera. This potentially provides considerably more ecological information than would have been possible under the previous taxonomic classification.

For example, all *Luticola* spp. are associated with enriched waters, whereas as *Navicula* (as these taxa were formerly classified), the group forms part of a genus with a very broad ecological range.

Table 1. Changes to the common genera proposed by Round *et al.* (1990).

Krammer & Lange-Bertalot (1986-91)	Revised genera - Round *et al.* (1990)
Achnanthes	*Achnanthes, Achnanthidium*
Amphipleura	*Berkeleya*
Amphiprora	*Entomoneis*
Anomoeoneis	*Anomoeoneis, Brachysira*
Biddulphia	*Pleurosira*
Cymbella	*Cymbella, Encyonema, Reimeria*
Fragilaria, Synedra	*Ctenophora, Fragilaria, Pseudostaurosira, Staurosira, Staurosirella, Synedra, Tabularia,*
Navicula	*Craticula, Fallacia, Luticola, Navicula, Sellaphora*
Nitzschia	*Nitzschia, Tryblionella.*
Stauroneis	*Stauroneis, Staurophora*

Diatom taxonomy at this level is complex. Over 10,000 taxa have been identified from Great Britain (see the DIATCODE list under the website of UCL Dept. of Geography), and if Mann & Droop's (1996) suspicions are correct, then there are many new species remaining to be identified and described.

Sampling, Preparation and Identification

Diatoms are widespread and abundant in almost all aquatic ecosystems, in both planktonic and benthic habitats. Diatoms are relatively easy to collect due to their numerical dominance in most algal communities. The increasing use of benthic diatoms to assess water quality/ecological health of streams in Australia has resulted in the need for standardised methods to be used by water industry agencies to ensure consistency in the collection of diatom communities. Chessman *et al.* (1997) have proposed draft methods for field sampling and the laboratory processing of diatom samples (Appendix I). These methods are already being used in the MHRI program to collect diatom samples from south-eastern Australia. Further information on sampling benthic diatom communities, including an instructional video is available at a number of Australian diatom websites (Appendix II). Hötzel and Croome (1998) have also proposed methods for sampling phytoplankton communities in Australian rivers. Similar methods may also be applicable to the sampling of lake and reservoir phytoplankton communities.

Diatoms are microscopic and therefore high resolution microscopy is needed for accurate identification. Structures used to differentiate diatoms even at or above generic level are fine and often difficult to distinguish, even under 400x magnification, particularly when observing living or freshly preserved samples.

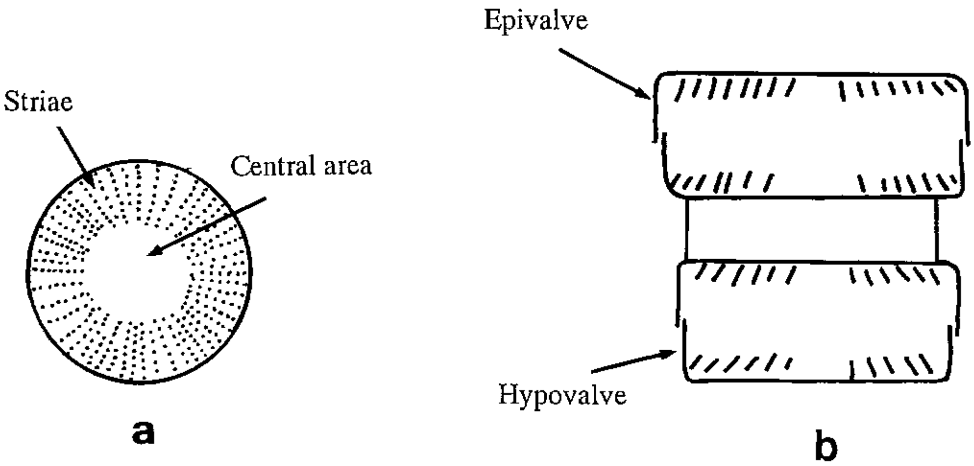


Fig. 1. A schematic diagram of a typical centric diatom (a) valve view; (b) girdle view.

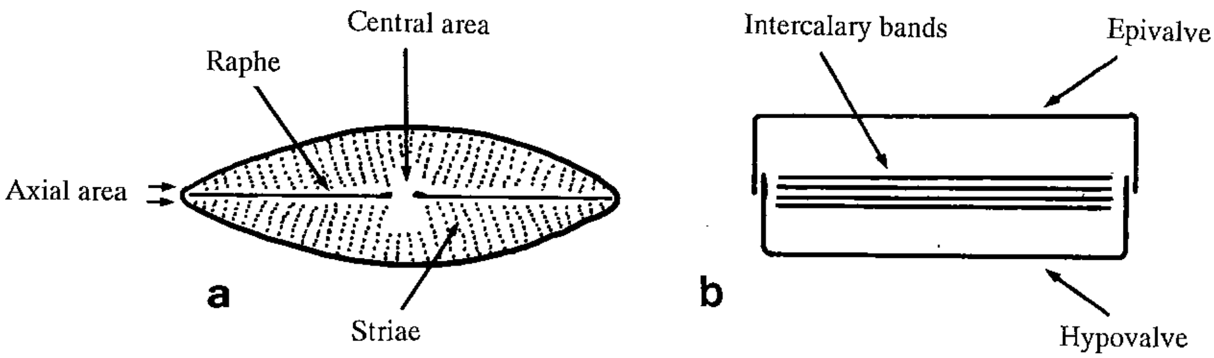


Fig. 2. A schematic diagram of a typical pennate diatom (a) valve view; (b) girdle view.

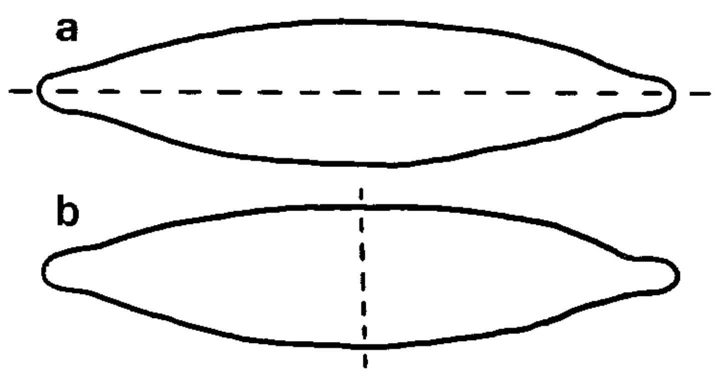


Fig. 3. Planes of the frustle in valve view (a) apical plane; (b) transapical plane.

As such, most diatom identification to genus level is carried out on 'cleaned material'[1] under at least 1000x magnification. Identification to species level and beyond requires high magnification, good optics and microscopical techniques and is virtually impossible unless 1000x magnification with oil immersion is used. Enhancements such as phase and differential interference contrast augment the resolution under such magnification.

One novel method to identify diatoms using chloroplast structure has been proposed by Cox (1996). Cox has produced a key to common diatoms species based on the chloroplast structure in living diatoms. Use of the 'live' key requires unpreserved samples, as chloroplasts typically change size, shape and positioning in response to the addition of preservatives/fixatives.

Morphology of the diatom frustule

The diatom cell is unique amongst the algae as it has a silicified cell wall termed a **frustule**. Diatom taxonomy is almost exclusively based upon features of the frustule, and therefore it is important to understand its basic structure and arrangement.

The basic diatom frustule is made of two overlapping halves termed the valves (Figs 1b, 2b), so that one valve slips inside the other in a similar arrangement to a petri-dish. Each frustule also contains girdle bands which are located between the two valves (Fig. 2b). There are two perspectives from which we can describe a diatom valve, **valve view** - when looking down at the **valve face** from the top (Figs 1a, 2a), and **girdle view** - when looking at the valve from the side, so that the **girdle bands** are visible (Figs 1b, 2b). Diatoms are divided into two major groups based upon the symmetry of the valves: those with valves that are radially symmetrical, the **centric** diatoms (Fig 1); and those that are bilaterally symmetrical, the **pennate** diatoms [except pennate diatoms that are dorsiventral -see below (Fig 2)] . With the exception of a few genera, centric diatoms have round drum shaped frustules (Fig. 1), whereas the pennates are variously shaped (Fig. 4). Descriptions of the shape of pennate diatoms are based upon two principal axes: the **apical axis**, which forms the longest axis parallel to the valve face (Fig. 3a); and the **transapical axis**, which, as the name suggests, runs perpendicular to the apical axis, once again parallel to the valve face (Fig. 3b). With these axes in mind, three key terms are used to describe the symmetry of a pennate diatom: **heteropolar**, meaning that the diatom is asymmetrical about the transapical axis (Figs 4a,b); **isopolar**, meaning that the diatom is symmetrical about the transapical axis (Figs 4c-k); and **dorsiventral**, meaning the diatom is asymmetrical about the apical axis (not shown).

The pennate diatoms are further split into two groups: those without raphes, the **araphid** diatoms; and those with raphes, the **raphid** diatoms. The **raphe** is a slit-like structure running along the longitudinal axis of the valve from which mucilage is exuded. The raphe is a complex structure. It is often interrupted in the centre of the valve by the **central area** (Fig.7), and runs all the way to the **ends** of the valve (Fig. 5). The raphe therefore has **terminal** ends at the valve ends and **proximal** ends at the centre of the valve.

1 Cleaning valves involves dissolving the cell cytoplasm in acid and/or alkali solutions which allows clearer views of the diatom valve patterning.

A spectacular feature of almost every diatom is the delicate ornamentation found on the valve face. Most diatom valves are covered in tiny pores called **punctae**[2]. The punctae are usually organised into lines across the valve face called **striae** (Fig. 6). Each individual puncta may, in turn, consist of many smaller pores, but it is beyond the capacity of light microscopes (**LM**) to resolve these features, so they will not be discussed here. Striae density, structure and arrangement are all critical characteristics used to separate diatom species. The construction of a diatom valve is complex and it is beyond the scope of this guide to outline some of the finer details. Instead, we have summarised many of the important features in the following figures. Please refer to the glossary for explanation of terms not already explained.

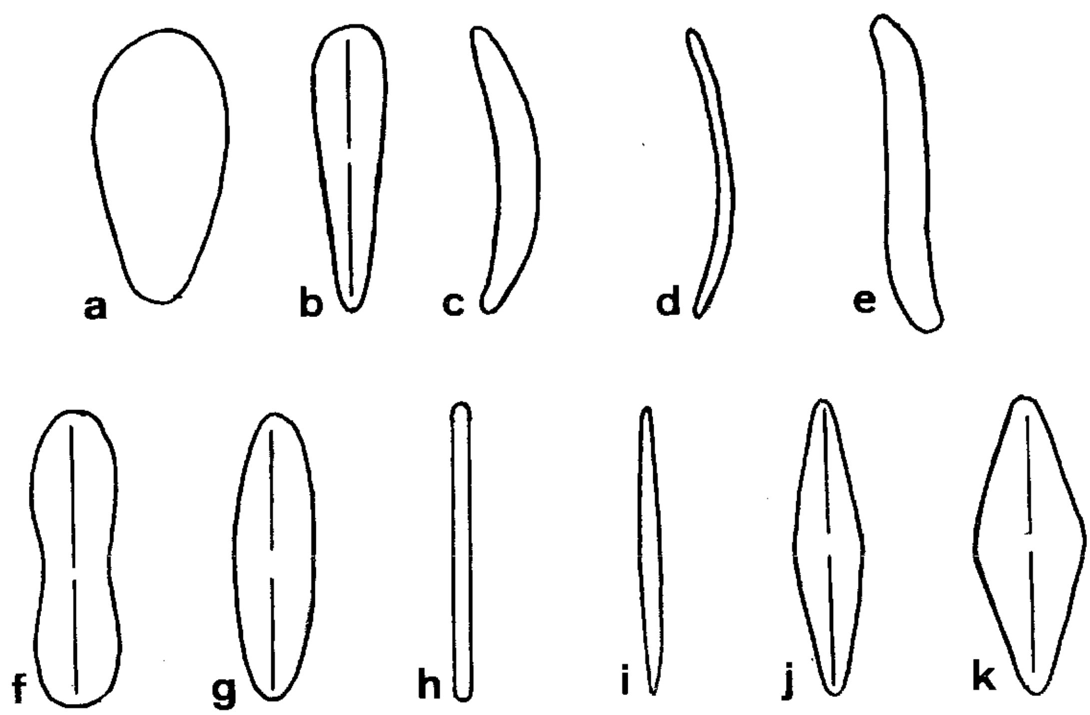


Fig. 4. Valve shapes (a) ovate; (b) clavate; (c) crescentic; (d) arcuate; (e) sigmoid; (f) panduriform; (g) elliptic; (h) linear; (i) acicular; (j) lanceolate; (k) rhombic.

2 The structure of these pores can vary greatly among different diatom groups. This variation is reflected in the different terms that are used to describe these features (punctae, areolae, lineolae). It is rarely possible, however, to reliably distinguish these features using standard light microscopy. For this reason, the term 'punctae' is used generically in this volume to refer to all pore-like structures.

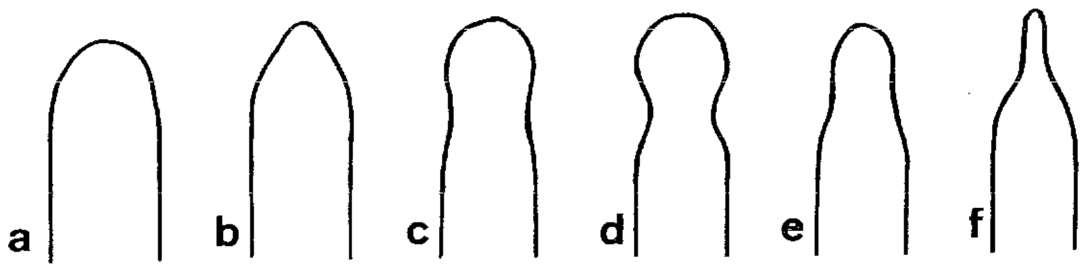


Fig. 5. Valve end types (a) broadly rounded; (b) cuneate; (c) subcapitate; (d) capitate; (e) rostrate; (f) apiculate.

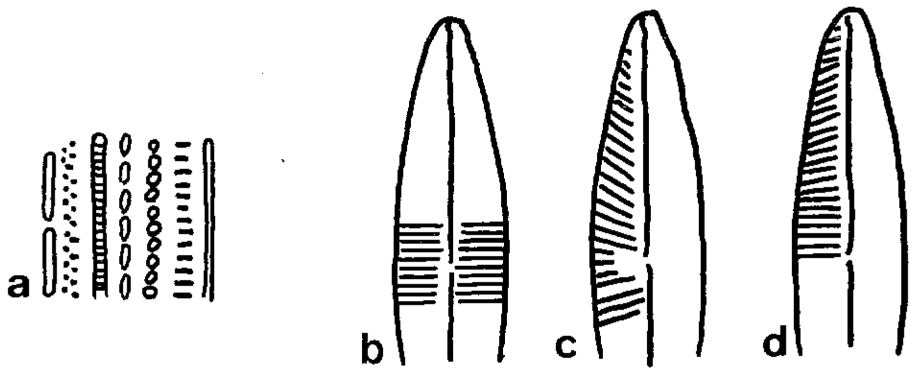


Fig. 6. Striae patterns (a) different types of striae; (b) striae parallel; (c) striae radial; (d) striae parallel tending convergent at ends;.

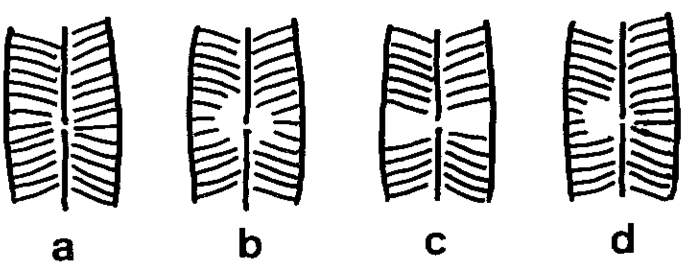


Fig. 7. Central area arrangement (a) absent; (b) circular; (c) stauros; (d) one-sided.

KEY TO THE COMMON GENERA OF FRESHWATER DIATOMS

1a. Radially symmetrical in valve view (valves can appear rectangular if in girdle view) ....[Centrics]........**2**
1b. Not radially symmetrical in valve view ....[Pennates]......**11**

Centrics

2a. Valves with many intercalary bands (barely distinguishable), valves in girdle view appearing rectangular and flattened, weakly silicified, normally planktonic...**10**
2b. Valves appearing otherwise **3**

3a. Valves with two large ocelli (appearing like bubbles at the margin) ....***Pleurosira***
3b. Valves appearing otherwise **4**

Genus ***Pleurosira*** **(Meneghini) Trevison** (Fig. 8)

Description: Cells cylindrical, valve face spherical, with two conspicuous ocelli extending from opposite sides of the valve face. Striae radiating from the centre of the valve face to the margins. Cells often appearing as chains in a zig-zag formation, attached via mucilage pads extruded from the ocelli.

Common species: *Pleurosira laevis* (Ehrenberg) Compère

Remarks: *Pleurosira* is a highly distinctive benthic species. It has been found in large, alkaline lakes such as Lakes Colac and Hindmarsh. It is uncommon and rarely constitutes a large proportion of the total diatom cells in sediment and plankton samples. Occasionally found in slow flowing streams, where it can form visible growths over rocks and water plants.

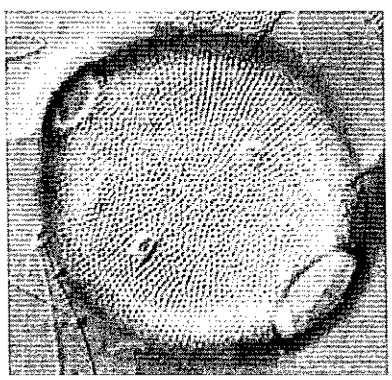


Fig. 8. *Pleurosira laevis* (x300).

4a.	Valves drum to cylinder shaped, usually seen in side view (therefore appear rectangular), cells usually forming chains of varying number	**5**
4b.	Valves disc to drum shaped, valve mantles and girdle mostly reduced, cells generally single	**6**

5a.	Valve mantle and valve face without detail, punctae on the mantle just distinguishable with light microscope	***Melosira* (part)**
5b.	Valve mantle with easily distinguishable punctae	***Aulacoseira* (part)**

Genus ***Melosira*** **Agardh** (Fig. 9)

Description: Cells cylindrical, valve face spherical and appearing either flat or domed. The valve surface contains many small pores that are often not visible under the light microscope (LM), the valve face therefore appears smooth. Cells often forming long filaments, attaching end to end via mucilage attachment pads secreted onto the valve faces.

Common species: *Melosira varians* Agardh

Remarks: *Melosira* previously included species now separated into the genus *Aulacoseira* (see below). Unfortunately, many recently published limnological texts still incorrectly refer to species within the genus *Aulacoseira* as '*Melosira*', giving the impression that *Melosira* is more widespread in freshwater than it really is. In fact, most species retained within *Melosira* are estuarine and marine planktonic, and only one species, *M. varians*, is frequently found in freshwater. This species can be extremely common and is generally associated with mesotrophic (see Appendix III) middle order streams, often fresh-brackish (see Appendix III), and subject to some organic pollution. *Melosira* is easily identified under LM. Frustules equally appear either in girdle and valve view. In girdle view, the valves look like '44 gallon drums' on their side (see Fig. 9b below).

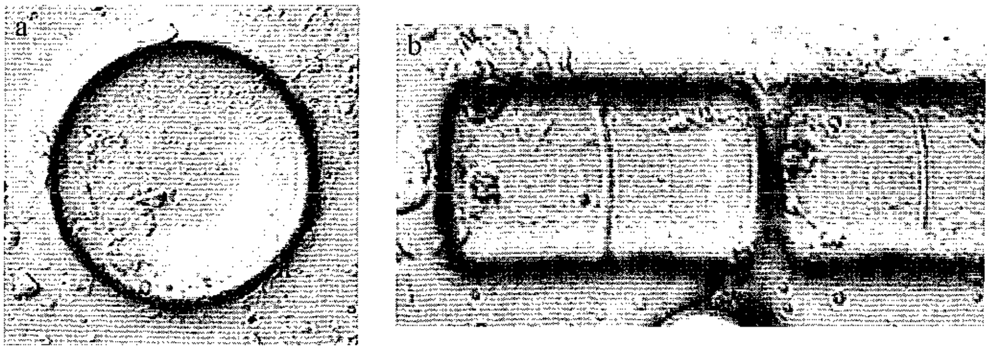


Fig. 9. *Melosira varians* (a) valve view (x1100); (b) girdle view (x830).

Genus *Aulacoseira* **Thwaites** (Fig. 10)

Description: Cells cylindrical with circular valves. Valve faces plain or with scattered punctae near the margins. Valve face/mantle margin with a row of spines that interlink with those of adjacent cells. A thickening inside the margin is also present. This may be hollow in some species. The valve mantle is ornamented with spiralling rows of areolae (large punctae) which may be also straight on some valves. Cells often form long chains/filaments that may be straight, curved or coiled. Filaments often break apart at specialised cells containing separation valves, sometimes revealing large spines.

Common species: *Aulacoseira granulata* (Ehrenberg) Simonsen
Aulacoseira ambigua (Grunow) Simonsen
Aulacoseira distans (Ehrenberg) Simonsen
Aulacoseira italica (Ehrenberg) Simonsen

Remarks: *Aulacoseira* is perhaps the most common and widespread centric diatom genus encountered in south-eastern Australia. *Aulacoseira* consists of mostly planktonic species that are abundant in most lowland waterbodies. They are frequently associated with riverine environments and, as a group, the species *Aulacoseira granulata, A. italica, A. ambigua* and *A. distans*[3] constitute the most abundant algal group in the river plankton of large inland rivers such as the Murray and lower Goulburn Rivers (Hötzel 1996, Reid 1997, Sincock 1997).

In the northern hemisphere, *Aulacoseira* is generally associated with meso-eutrophic waterbodies, however in Australia *Aulacoseira* may dominate even in waters classed as hypereutrophic (see Appendix C). Such waters would, in the northern hemisphere, be dominated by the members of the cyclostephanoid group (*Cyclostephanos* & *Stephanodiscus*). The predominance of the *Aulacoseira* in Australia may relate to the fact that so many lakes and ponds in Australia are shallow, turbid and frequently ephemeral. *Aulacoseira* cells are heavily silicified. This means that, despite their capacity to form chains, the chains have a rapid sinking rate in still water (and so are often the dominant genus in the benthos). *Aulacoseira*, therefore, rely on a turbulent water column to maintain position within the photic zone and are adapted to low light conditions.

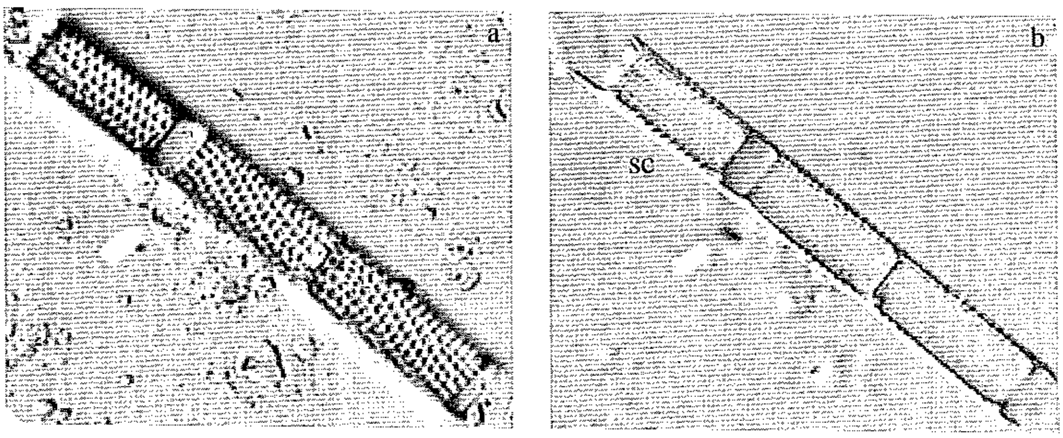


Fig. 10. *Aulacoseira granulata* chain showing: (a) areolae; (b) separation cell (sc) (x600).

3 The diatom identified here as *A. distans* has been variously identified as *A. distans* (Hotzel 1996) and *A.* aff. *alpigena* (Reid 1997 Tibby 1998); however, recent discussions with European researchers have convinced the authors that this taxon is *A. subarctica v. subborealis* a variety of A. subarctica that may be worthy of elevation to species rank (K. Muylaert pers. comm. 1998).

6a. Valves with a sulcus (a distinct ring when focussed through) ..***Aulacoseira* (part)**
6b. Valves without a sulcus **7**

7a. Valves without distinctive features ....***Melosira* (part)**
7b. Valves appearing otherwise...**8**

8a. Areolae arranged radially around the valve margin, usually not extending to the centre of the valve; central area distinct...***Cyclotella***
8b. Central area appearing otherwise...**9**

Genus ***Cyclotella*** **Kützing ex Brébisson** (Fig. 11)

Description: Cells disc or drum-shaped, with spherical valve face and shallow mantle. Valve face with rows of areolae radiating from the centre to the outer margins. Here they group into fasicles, creating a ridge-like appearance around the margin of the valve face. The central area may be plain or undulating, and ornamented with scattered areolae and small wart-like projections. The valve mantle is not ornamented.

Common species: *Cyclotella stelligera* Cleve & Grunow
Cyclotella psuedostelligera Hustedt
Cyclotella atomus Hustedt
Cyclotella meneghiniana Kützing
Cyclotella distinguenda Hustedt

Remarks: *Cyclotella* is a common planktonic diatom genus. It includes *Cyclotella stelligera*, a widely distributed species that is frequently encountered in sediment and planktonic samples from freshwaters, but is most abundant in oligotrophic (see Appendix C) lakes (J. Tibby pers. comm.). Although the genus is widely associated with oligotrophic freshwater lakes, species of this genus may also be found in saline (*C. caspia* Grunow, *C. striata* (Kützing) Grunow), and eutrophic and organically polluted waters (*C. atomus* and *C. meneghiniana*).

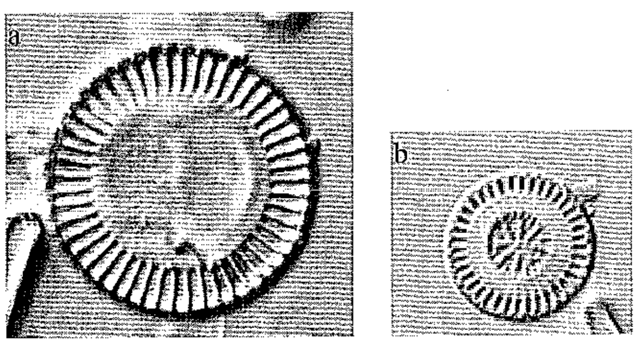


Fig. 11. (a) *Cyclotella meneghiniana* (x875); *Cyclotella stelligera* (x800).

9a. Areolae arranged in clear radial lines extending to valve centre .... **Cyclostephanoid group (*Stephanodiscus*, *Cyclostephanos*)**

9b. Areolae arranged otherwise .... ***Actinocyclus*, *Thalassiosira***

Cyclostephanoid group (Fig. 12)

Description: Valves disc-shaped, valve mantles shallow (saucer-like). Valve face flat or concentrically undulate. A single row of spines is present around the valve margin. A row of fultoportulae is also present on the valve margin below the spines. The valve face is ornamented with radial rows of small punctae. Struts (ribs) are present between the radial rows in *Cyclostephanos*. Cells solitary or as short chains.

Common species: *Cyclostephanos tholiformis* Stoermer, Håkansson & Theriot
Cyclostephanos invisitatus (Hohn & Hellerman) Stoermer, Håkansson & Theriot
Cyclostephanos dubius (Fricke) Round
Stephanodiscus parvus Stoermer & Håkansson
Stephanodiscus hantzschii Grunow (in Cleve & Grunow)

Remarks: *Cyclostephanos* and *Stephanodiscus* are difficult to distinguish using light microscopy as the diagnostic features can only reliably be viewed using SEM. Indeed, it is generally easier to treat the two genera as one and to identify species directly. Both genera are planktonic, and are associated with highly eutrophic conditions. As noted above, these genera appear to be less common in Australia than in the northern hemisphere, but they will dominate in deeper eutrophic waterbodies.

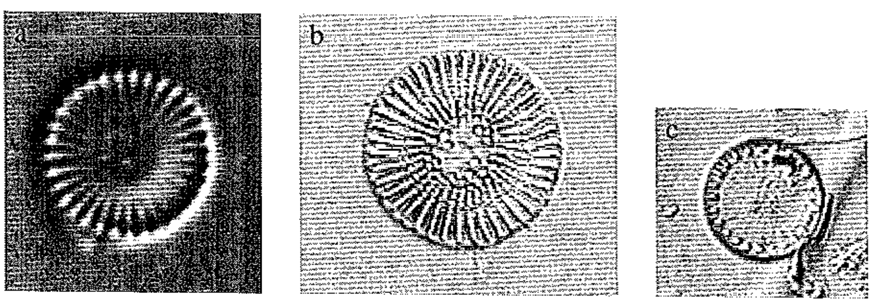


Fig. 12. (a) *Cyclostephanos tholiformis* (x3000); (b) *Cyclostephanous dubius* (x2000); (c) *Stephanodiscus* cf. *hantzschii* (x2500).

Genus *Actinocyclus* **Ehrenberg** (Fig. 13)

Description: Valves circular with shallow mantles (disc-shaped). Valve face flat or domed, ornamented by radial rows of large punctae that almost appear striate.

Common species: *Actinocyclus normanii* (Gregory) Hustedt

Remarks: *Actinocyclus* is a large centric diatom largely restricted to marine and estuarine environments. However one species, *A. normanii,* may be encountered, in fresh and brackish waters, but generally in low numbers.

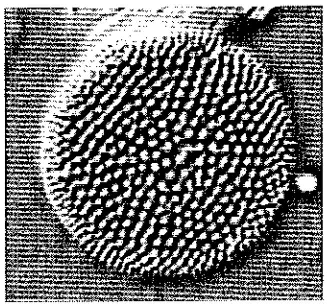


Fig. 13. *Actinocyclis normanii* (x330).

Genus ***Thalassiosira*** **Cleve** (Fig. 14)

Description: Valves circular with shallow mantle (disc-shaped). Valve flat to slightly concave, ornamented with radial rows of large punctae (areolae) spanning from the centre to the margins. A row of fultoportulae (short tubes) are present around the valve margin. Cells may occur solitarily or joined to each other via threads to form chains.

Common species: *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle

Remarks: *Thalassiosira* is primarily a planktonic marine genus, with a few freshwater representatives. They are most ornately decorated. The most common in fresh to brackish (even saline) systems is *T. weissflogii* (syn. *T. fluviatilis*) which can become quite common in lagoons and lakes, particularly those receiving effluent (eg. East Basin near Colac, where it became dominant after the lake was used for dairy effluent disposal).

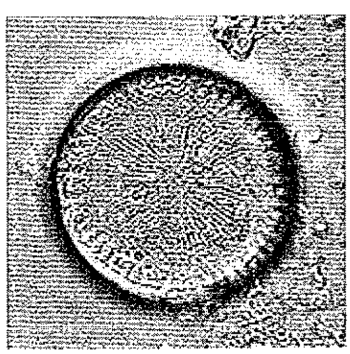


Fig. 14. *Thalassiosira weisflogii* (x1100).

10a. Valves with one long bristle/seta at both ends ....***Urosolenia***
10b. Valves with two long bristles at both ends ....***Acanthoceras***

Genus *Urosolenia* **Round & Crawford** (Fig. 15)

Description: Frustules cylindrical extending into one long spine on either valve. Each valve covered with irregular punctae (feature not visible under LM). Valves separated by many 'collar-like' copulae (girdle bands).

Common species: *Urosolenia eriensis* (H.L. Smith) Round & Crawford

Remarks: Refer to remarks under *Acanthoceras.*

Fig. 15. *Urosolenia eriensis* (x1900).

Genus *Acanthoceras* **Honigmann** (Fig. 16)

Description: Frustules rectangular in girdle view, with a cap-like valve at either end bearing two hollow spines. Each valve is covered with longitudinal rows of fine punctae, but not extending onto spines (feature not visible under LM). Valves are separated by many 'collar-like' copulae (girdle bands).

Common species: *Acanthoceras zachariasii* (Brun) Simonsen

Remarks: *Urosolenia* and *Acanthoceros* are relatively large planktonic diatoms that are commonly found in standing freshwaters. Both genera are very lightly silicified and are characterised by long terminal spines (two for *Urosolenia* and four for *Acanthoceros*). The delicate structure of the frustules of these diatoms means that they are rarely observed in planktonic samples, and even less well preserved in sediments. Nevertheless, the spines of the frustules are distinctive and are more readily preserved, so these features should alert researchers to the likely presence of these genera in samples.

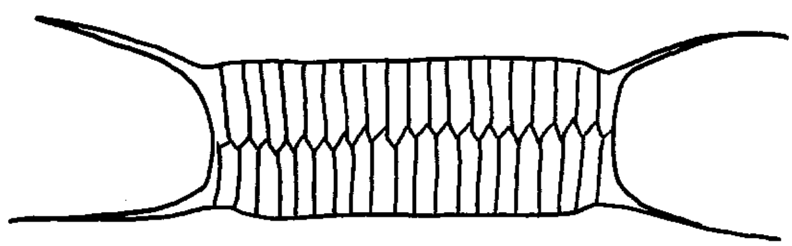


Fig. 16. *Acanthoceras zachariasii* (x650).

Pennates

11a. Valves without raphes..**[Araphid diatoms]** **12**
11b. Valves with raphes...**20**

Araphid diatoms (no raphe present)

12a. Valves without striae ....*Diatoma*
12b. Valves with striae...**13**

Genus ***Diatoma*** **Bory de St.-Vincent** (Fig. 17)

Description: Valves linear to linear-elliptical, with bluntly rounded to capitate ends. Striae finely punctate, parallel in the centre to slightly radial at ends, interrupted along the 'axial area' by a narrow, central sternum. Valves with conspicuous internal transverse ribs (costae) that are a prominent feature when seen under LM. Cells often forming ribbon-like or 'zig-zig' shaped colonies.

Common species: *Diatoma tenuis* Agardh
Diatoma moniliformis Kützing

Remarks: *Diatoma* can be common in fresh to oligo-saline waters which are circumneutral. The clear transverse ribs are a distinct feature of this genus and *Meridion*. These genera can be differentiated under LM on the basis of valve and colony shape.

Fig. 17. (a) *Diatoma tenuis* (x650); (b) *Diatoma monoliformis* (x875).

13a. Valves heteropolar (may only be slightly so) **14**
13b. Valves isopolar...**15**

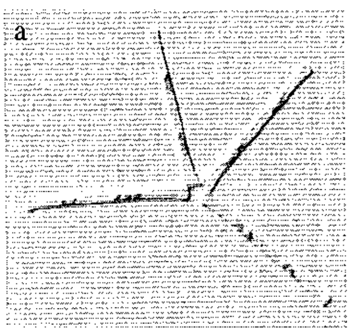
14a. Valves swollen at both ends .... ***Asterionella***
14b. Valves swollen at head end only .... ***Meridion***

Genus *Asterionella* **Hassall** (Fig. 18)

Description: Elongate linear valves with inflated capitate ends. Transverse striae finely punctate, interrupted by a narrow central sternum (not usually visible under LM). Cells attached by mucilage pads secreted at one of the ends, forming distinct stellate colonies.

Common species: *Asterionella formosa* Hassall

Remarks: *Asterionella* are lightly silicified, planktonic, freshwater diatoms. The most commonly encountered species in south-eastern Australia is *A. formosa.* Whilst this species is widely distributed and is common in meso-eutrophic lakes in the temperate northern hemisphere, it has rarely been recorded as very abundant in Australia. Though generally regarded as a lake species (Denys 1991), *Asterionella* has also been recorded in the plankton of the middle and lower Murray (Shiel *et al.* 1982; Hötzel and Croome 1996). Harper (1994) has suggested, based on the absence of this species from fossil records in Australia and New Zealand, that this diatom may have been introduced to Australasia by Europeans. However, its generally low abundance and delicate structure mean that fossil records would be expected to be rare in any case.



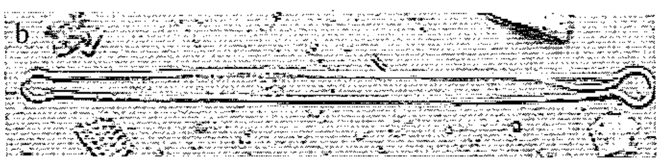


Fig. 18. *Asterionella formosa* (a) stellate colony (x275); (b) singe valve (x1050).

Genus *Meridion* **Agardh** (Fig. 19).

Description: Valves club-shaped 'cuneate' (ie. one end larger than the other) with broadly rounded-capitate ends. Striae finely punctate, interrupted centrally by a narrow sternum. Valves with coarse, thickened, transverse ribs (costae). Cells attach face to face to form characteristic fan shaped colonies.

Common species: *Meridion circulare* (Greville) Agardh

Remarks: *Meridion* is a monotypic genus exclusively found in freshwater. *M. circulare* is easily recognised under LM on the basis of valve and colony shape. The valve structure of *M. circulare* is also superficially similar to *Diatoma*. Occasionally found in benthic algal communities.

Fig. 19. *Meridion circulare* (x).

15a. Valve swollen centrally and at ends, with septa inside frustule................***Tabellaria***
15b. Valve appearing otherwise **16**

Genus ***Tabellaria*** **Ehrenberg** (Fig. 20)

Description: Valves with notably inflated central region and swollen capitate ends. Axial area centrally widened, striae transverse and irregularly spaced. Multiple girdle bands may be present consisting of either complete or incomplete septa. Cells often forming distinctive zig-zag chains in both the plankton and benthos.

Common species: *Tabellaria flocculosa* (Roth) Kützing

Remarks: *Tabellaria* is a planktonic diatom typical of acidic waters (*T. fenestrata* was used as an indicator of lake acidification in the northern hemisphere), even in peat swamps where the pH can extend below 3.0. However, the species most frequently encountered in Australia, *T. flocculosa*, can also occur in circumneutral to slightly acidic waters. The genus is characterised by the presence of septa within the girdle bands. These are clearly visible in girdle view and can also be seen in valve view if girdle bands remain attached to the valves. The robust nature of the girdle bands means that they generally maintain their original outline even after they have separated from the valves. As such, the girdle bands may be mistaken for the actual valve. The girdle bands can be readily distinguished, however, by the absence of valve-face ornamentation (ie, striae).

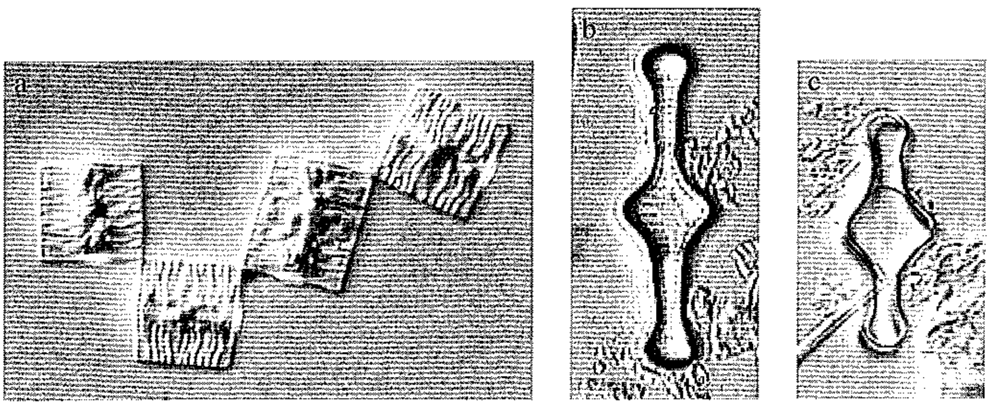


Fig. 20. *Tabellaria flocculosa* (a) 'zig-zag' shaped colony (x230); (b) valve view (x700); (c) valve with internal septa visible (x500).

16a. Clearly punctate striae, distinct hyaline central area.............................***Ctenophora***
16b. Valve appearing otherwise **17**

Genus *Ctenophora* **(Grunow) Williams & Round** (Fig. 21)

Description: Valves linear to linear-lanceolate with rounded to sub-capitate ends. Striae transverse, notably punctate and extending to valve ends. Axial area narrow, generally not visible. Central area large, expanding to valve margin.

Common species: *Ctenophora pulchella* (Ralfs ex Kützing) Williams & Round

Remarks: *Ctenophora* is a monotypic genus created to separate *C. pulchella* from all other *Synedra*-type fragilarias. *C. pulchella* is generally attached to benthic surfaces as tufts, and is reflective of brackish conditions. Its clearly punctate striae and swollen central area make it quite a distinctive type.

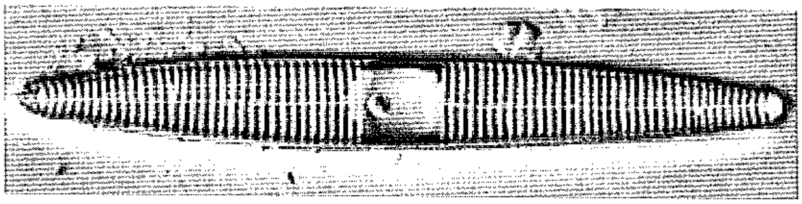


Fig. 21. *Ctenophora pulchella* (x900).

17a. Shortened striae (<half of valve width) **18**
17b. Striae appearing otherwise **19**

18a. Valves longer than 20 µm .... ***Tabularia***
18b. Valves shorter than 20 µm .... ***Staurosira* group (part)**
....**(*Staurosira, Psuedostaurosira, Staurosirella*)**

Genus *Tabularia* **(Kützing) Williams & Round** (Fig. 22)

Description: Valves linear to linear-lanceolate. Striae transverse. Axial area notably wide, often referred to as a pseudoraphe. Central area not present.

Common species: *Tabularia fasciculata* (Agardh) Williams & Round

Remarks: *Tabularia* is also a new genus created to separate *T. fasciculata* and *T. parva* from other *Synedra*-like fragilarias on the basis of the broad pseudoraphe (the wide axial area). It is common in fresh to brackish waters and may be both planktonic or periphytic.

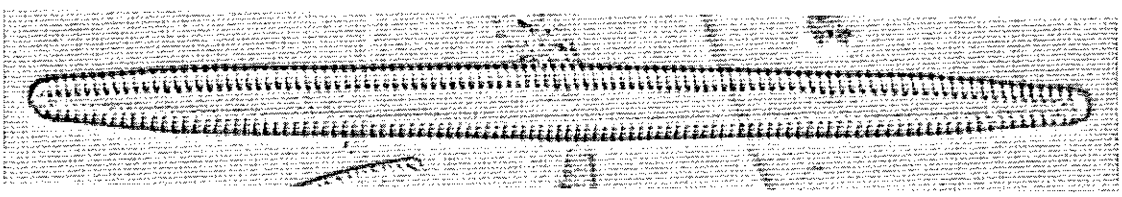


Fig. 22. *Tabularia fasciculata* (x900).

19a. Valves >20μm; if shorter then with clearly defined central area .... ***Fragilaria/Synedra***

19b. Valves shorter ....***Staurosira*** **group (part) (*Staurosira, Psuedostaurosira, Staurosirella*)**

[Note: It is very difficult to separate *Fragilaria/Synedra* and *Staurosira* 'group' in cleared material]

Fragilaria/Synedra/Staurosira complex

The status of the *Fragilaria/Synedra* group is subject to some debate. Traditionally the separation of *Synedra* and *Fragilaria* has been made on the basis of whether or not the diatom is capable of forming ribbon-like colonies (*Fragilaria*) or not (*Synedra*). This protocol has been challenged by Krammer & Lange-Bertalot (1980) who argued that this feature was insufficient to separate species within the *Fragilaria/Synedra* group in the absence of consistent distinguishing structural features. In contrast, Round *et al.* (1990) have not only separated *Fragilaria* and *Synedra*, but have further separated groups within each genus. Unfortunately, several of the features used by Round *et al.* (1990) to distinguish among these genera are not readily observed using even advanced light microscopes. As a consequence we have taken a compromised approach in this key and combined several of the typically smaller genera described by Round *et al.* (1990) (*Staurosira, Pseudostaurosira, Staurosirella*). In addition to their similar appearance, diatoms within these genera share similar ecologies and are frequently co-dominant in lake assemblages. This group will be dealt with in greater detail in a subsequent key.

Genus ***Fragilaria*** **Lyngbye** (Fig. 23)

Description: Valves linear to linear-lanceolate, sometimes tending elliptical, ± capitate ends, ± swollen at centre. Striae transverse, clearly areolate, central area often swollen to one side. Axial region linear to lanceolate. Cells often forming long ribbons.

Common species: *Fragilaria capucina* Desmazières
Fragilaria tenera (W. Smith) Lange-Bertalot
Fragilaria famelica (Kützing) Lange-Bertalot

Remarks: *Fragilaria* is an extremely diverse genus including species that occur both as attached forms in streams and lakes, as well as in the plankton of lakes. *Fragilaria* species tend to be associated with circumneutral to slightly alkaline, fresh to fresh-brackish waters. Although they are ostensibly distinguished from the *Synedra* on the basis of their capacity to form chains, they are typically smaller and less robust than the *Synedra*. *Fragilaria* valves can be extremely difficult to identify under the light microscope as they are often orientated in girdle view.

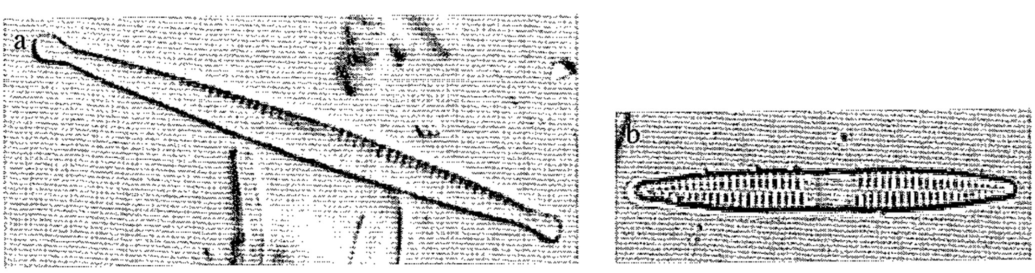


Fig. 23. *Fragilaria capucina* (a) var. *rumpens* (x1200); (b) var. *capucina* (x1200).

Genus *Synedra* **Ehrenberg** (Fig. 24)

Description: Valves long, relatively narrow, usually distinctly linear in outline, sometimes tending linear-lanceolate, ± capitate ends,. Striae transverse, distinctly areolate, axial area narrow, ± central area. Cells grow as radiate colonies attached to a common mucilage pad.

Common species: *Synedra ulna* Ehrenberg
Synedra acus Kützing

Remarks: *Synedra* spp. mostly occur attached to substrates but may occasionally be found in the plankton. While *S. ulna* and *S. acus* (which are distinguished primarily on the basis of striae density) appear to tolerate a broad range of water quality conditions, including eutrophic and organic-rich waters, they are principally restricted to fresh or oligosaline waters.

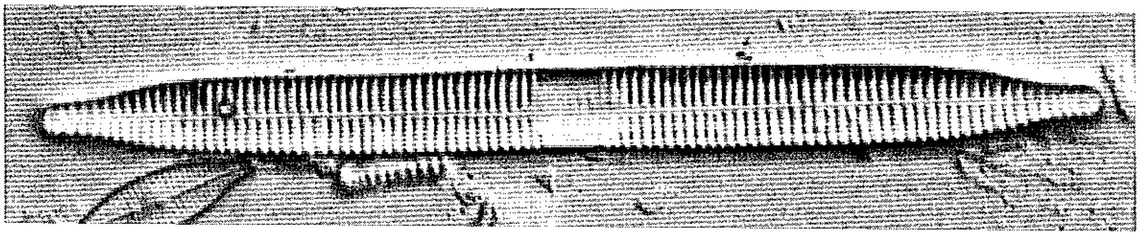


Fig. 24. *Synedra ulna* (x700).

Staurosira **group** (Fig. 25)

Description: Valves variously shaped, linear, oval, elliptical, cruciform, often with undulate margins, with rounded to capitate ends.

Staurosira: Striae with circular-elliptical punctae, transverse to radial, interrupted centrally by a sternum. Apical pore fields ± present consisting of a few isolated pores to several rows (Round *et al.* 1990).

Pseudostaurosira: Coarse striae with a few large, elongate areolae restricted to the margins, transverse to radial, interrupted centrally by a broad sternum. Apical pore fields ± present consisting of a few isolated pores (Round *et al.* 1990).

Staurosirella: Striae with large slit-like punctae, transverse to radial, interrupted centrally by a broad sternum. Thick 'ribs' separating punctae within the striae are characteristic of this genus. Apical pore fields present consisting of several to many rows of fine pores (Round *et al.* 1990).

Common species: *Psuedostaurosira brevistriata* (Grunow in Van Heurck) Williams & Round
Staurosira construens (Ehrenberg) Williams & Round
Staurosira elliptica (Schumann) Williams & Round
Staurosirella pinnata (Ehrenberg) Williams & Round

Remarks: The group defined here as '*Staurosira* group' includes several genera formerly included within *Fragilaria.* They are relatively small diatoms which can generally be distinguished from the smaller members of the *Fragilaria* by their small length-width ratios and the absence of a clearly defined central area. Species within this group appear to display morphological plasticity. They are generally elliptical to rhombic elliptical, although several species include cruciform morphotypes. They share a facultative planktonic habit and frequently form long ribbon-like chains which ensure that they are mostly seen in girdle view. Species within this group are frequently abundant and often dominant, usually as a suite of two to four taxa, in relatively clear, shallow meso- to eutrophic lakes associated with river-floodplain systems. They have been recorded in lakes from the upper Murray and Goulburn Rivers and extending downstream to large dune-barrier lakes such as Lake Alexandrina (Murray mouth, S.A.) and Lake Wellington (Gippsland Lakes, Victoria).

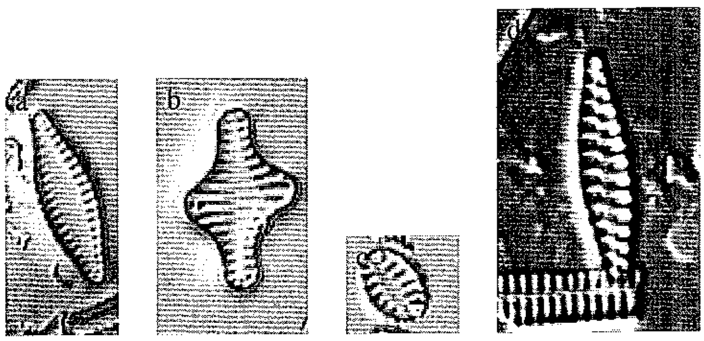


Fig. 25. (a) *Psuedostaurosira brevistriata* (x650); (b) *Staurosira construens* (x1200); (c) *Staurosira* cf. *elliptica* (x730); (d) *Staurosirella leptostauron* (Ehrenberg) Williams & Round (x1050).

20a. Valves with only vestigial raphes at distal ends on ventral side .... **[Pseudoraphid diatoms]**.....***Eunotia***

20b. Valves with at least one true raphe **21**

Pseudoraphid diatoms

Genus *Eunotia* Ehrenberg (Fig. 26)

Description: Valves lunate-arcuate, often strongly dorsiventral with broadly rounded, rostrate to capitate ends. The dorsal margin may be undulate in some species. Striae finely punctate, parallel to slightly radial. A short, narrow, vestigial raphe is located near the ventral margin on the valve mantle.

Common species: *Eunotia bilunaris* (Ehrenberg) Mills
Eunotia incisa Gregory
Eunotia minor (Kützing) Grunow
Eunotia naegeli Migula
Eunotia pectinalis (Dyllwyn) Rabenhorst
Eunotia serpentina Ehrenberg

Remarks: *Eunotia* is principally an epiphytic genus, although species such as *E. naegeli* and some of the long, narrow forms of *E. bilunaris* may occur in the plankton. The genus is most easily recognised by its arcuate shape (though several taxa are only barely so) but it is distinctive structurally by its vestigial raphe at the ventral margins (a feature it shares with *Peronia* - not illustrated here). While several species can be found in neutral or even alkaline, brackish waters, *Eunotia* is most commonly found in acidic waters.

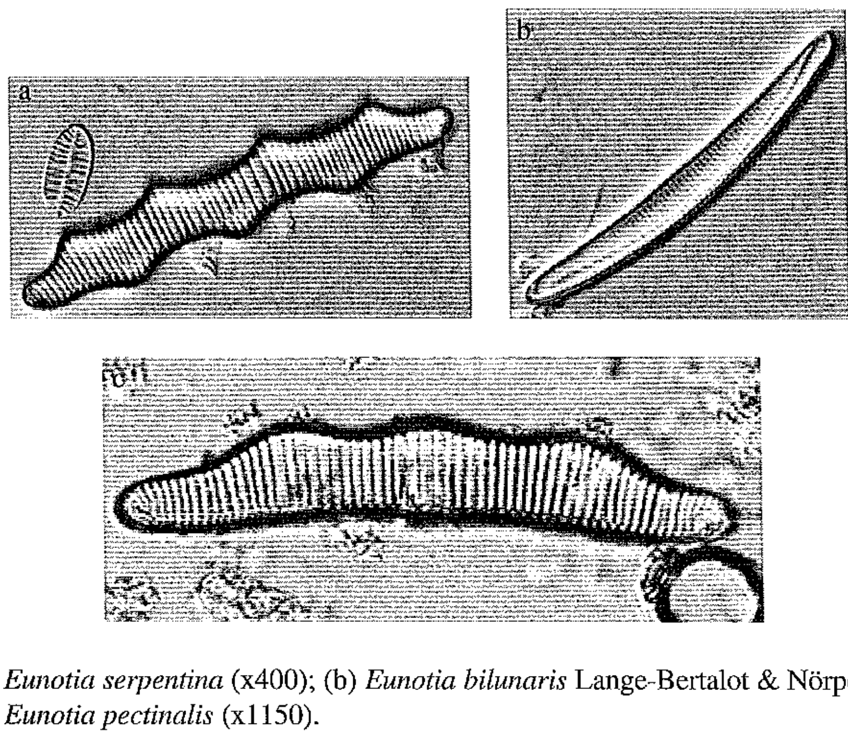


Fig. 26. (a) *Eunotia serpentina* (x400); (b) *Eunotia bilunaris* Lange-Bertalot & Nörpel (x1040); (c) *Eunotia pectinalis* (x1150).

21a. Valves with raphes on one valve only .... **[Monoraphid diatoms].....22**
21b. Valves with raphes on both valves .... **[Biraphid diatoms].....24**

Monoraphid diatoms

22a. Valves bent in girdle view **23**
22b. Valves (flat so rarely seen in girdle view .... ***Cocconeis***

Genus ***Cocconeis*** **Ehrenberg** (Fig. 27)

Description: Valves circular-elliptic with broadly rounded ends, appearing flat in girdle view. Valve curved along the transapical axis. Striae fine to coarsely punctate, parallel tending radial at the ends. Raphe within a slightly raised axial area. Central area small and circular. Rapheless valve with central pseudoraphe (rapheless axial area), often exhibiting different striae density and structure.

Common species: *Cocconeis placentula* Ehrenberg

Remarks: Of the common Monoraphidae, *Cocconeis* is easily recognised by its disc shape and flat profile in girdle view (it shares this with *Anorthoneis* - not illustrated here). Many *Cocconeis* species have distinctly different striae arrangement on the raphid and rapheless valves. *Cocconeis placentula* is one of the most abundant attached diatoms in neutral and alkaline waters. It is a species that is frequently one of the first to colonise newly submerged surfaces in lakes and streams.

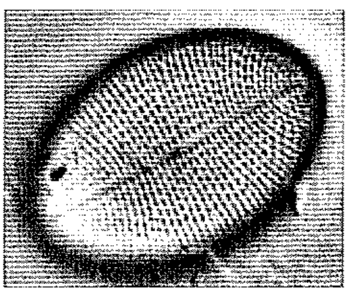


Fig. 27. Araphid valve of *Cocconeis placentula* (x850).

23a. Coarsely punctate, brackish water forms .... ***Achnanthes***
23b. Most finely punctate, generally freshwater .... ***Achnanthidium***

Genus *Achnanthes* Bory de St.-Vincent (Fig. 28)

Description: Valves linear to linear-lanceolate with broadly rounded to cuneate ends. In girdle view, valves curved along the apical axis. Striae appear somewhat coarsely punctate, parallel tending slightly radial at ends. Raphe lies in a central axial area, central area usually forming a fascia or stauros. Psuedoraphe on rapheless valve often displaced towards one margin. Many girdle bands present in the mantle, some of which are ornamented with fine punctae (not visible under LM).

Common species: *Achnanthes brevipes* Agardh

Remarks: Refer to remarks under *Achnanthidium.*

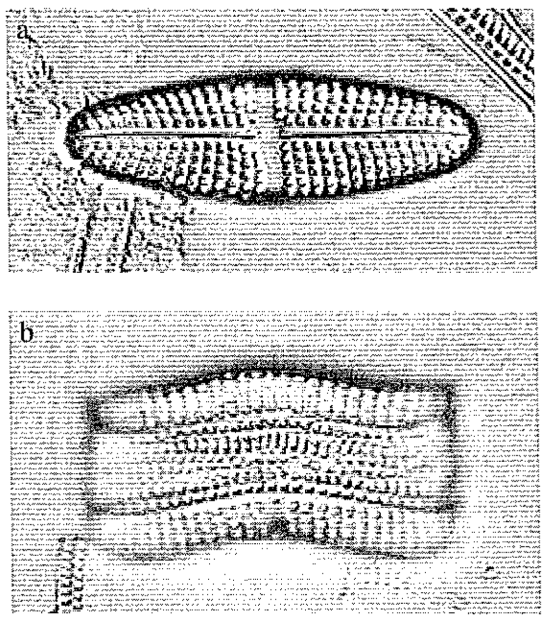


Fig. 28. *Achnanthes brevipes* (a) valve view (910); (b) girdle view (x910).

Genus *Achnanthidium* **Kützing** (Fig. 29)

Description: Valves linear, linear-lanceolate, elliptic with broadly rounded to sub-capitate ends. In girdle view, valves curved along the apical axis. Striae fine to coarsely punctate, generally parallel to slightly radial. Axial area narrow, central area small and circular, often forming a stauros or markedly one sided in some species. Rapheless valve often with wide psuedoraphe and with different striae density and alignment. Girdle bands often present, but not ornamented with fine punctae as in *Achnanthes*. Cells often found joined together as a linear chain.

Common species: *Achnanthidium clevei* Grunow in Cleve & Grunow[4]
Achnanthidium hungaricum Grunow
Achnanthidium lanceolata (Brébisson) Grunow[5]
Achnanthidium linearis (W. Smith) Grunow[6]
Achnanthidium minutissima Kützing

Remarks: *Achnanthidium* has been separated from the original genus *Achnanthes* on the basis of its striae (punctae coverings), raphe and girdle structure, features that are extremely difficult to determine under LM.

Achnanthidium is generally restricted to freshwater to brackish habitats, whereas *Achnanthes* is primarily marine with a few freshwater species. Many stream samples are dominated by a suite of *Achnanthidium* species. The genus is generally more diverse in oligo- to mesotrophic conditions; however some taxa, such as *A. lanceolata* occur in abundance in eutrophic and organic-rich waters. One of the problems encountered in identifying *Achnanthidium* valves is the similarity of raphe valves to those of small *Navicula* species. Fortunately, the small size of many of these diatoms means that the frustules frequently remain intact (ie. the valves and girdle bands do not separate). This means that the existence or absence of a rapheless valve can be determined by altering the focal plane so as to observe the upper and lower valve when the frustule is in valve view. A further feature that can also be used to distinguish *Navicula* and *Achnanthidium* is whether the valve is bent (*Achnanthiduim*) or flat (*Navicula*) in girdle view. In valve view this may appear as the central area being blurred when the ends are in clear focus.

Although many common *Achnanthidium* species have been transferred out this genus [see Round and Bukhtiyarova (1996)], we have retained them within *Achnanthidium* to avoid confusion in using this key.

The very coarse *Achnanthes* have affinities with marine forms and in continental situations are most commonly experienced in salt lakes with high sodium. *A. brevipes* is the most commonly encountered species, usually in estuarine environments.

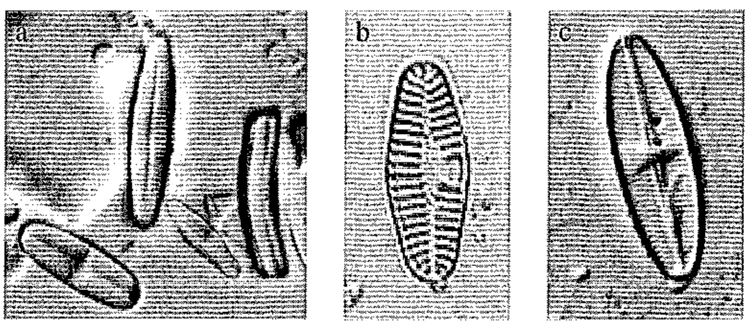


Fig. 29. (a) *Achnanthidium* cf. *linearis* (x700); (b) *Achnanthidium lanceolata* (x1150); (c) *Achnanthidium hungaricum* (x1000).

4 Round and Bukhtiyarova (1996) have transferred this species to a new genus *Karayevia* Round and Bukhtiarova.
5 Round and Bukhtiyarova (1996) have transferred this species to a new genus *Planothidium* Round and Bukhtiarova.
6 Round and Bukhtiyarova (1996) have transferred this species to a new genus *Rossithidium* Round and Bukhtiarova.

Biraphid diatoms

24a. Valves bent in girdle view, heteropolar, vestigial raphe on one valve .... ***Rhoicosphenia***
24b. Valves straight **25**

Genus *Rhoicosphenia* Grunow (Fig. 30)

Description: Valves linear-lanceolate, clavate (club-shaped) with broadly-pointedly rounded ends. Valve curved in girdle view. Striae coarse and parallel. Axial area straight on both valves, central area small. Valves vary in raphe structure, one valve has a complete raphe, whilst the other has a vestigial raphe (raphe very short at either end). A distinct pseudosepta (thickened valve margins) is present at the ends.

Common species: *Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot

Remarks: *Rhoicosphenia abbreviata* (syn. *R. curvata*) is a distinctive species commonly found in circumneutral to alkaline streams. It is often attached to rocks and plants, and appears to favour elevated nutrient levels.

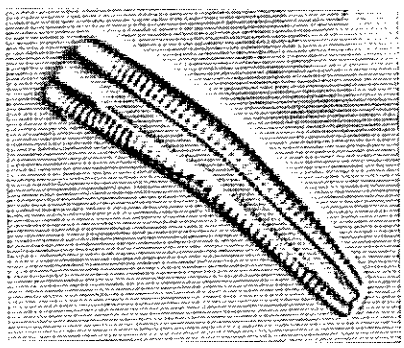


Fig. 30. *Rhoicosphenia abbreviata* (x830)

25a. Valves with heavy costae **26**
25b. Valves without costae **31**

26a. Valves completely crossed by costae **27**
26b. Valves not completely crossed by costae **29**

27a. Valves dorsiventral **28**
27b. Valves appearing otherwise .... ***Denticula***

Genus ***Denticula*** **Kützing** (Fig. 31)

Description: Valves linear-lanceolate to lanceolate with bluntly rounded to sub-rostrate ends. Striae fine to coarsely punctate, parallel. Raphe often within a centrally positioned wide, low keel, often eccentric. Transverse fibulae are present internally within each valve (highly visible under LM). Cells either solitary or forming small chains.

Common species: *Denticula subtilis* Grunow

Remarks: *Denticula* is the only member of the Epithemiaceae which does not have a dorsiventral shape. It is infrequently encountered relative to *Epithemia* and *Rhopalodia*.

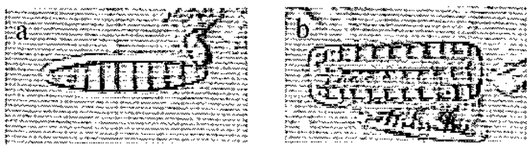


Fig. 31. *Denticula subtilis* (a) valve view (x1400); (b) girdle view (x1400).

27a. Raphe lying along ventral side rising dorsally at centre .... ***Epithemia***
27b. Raphe lying along dorsal side .... ***Rhopalodia***

Genus ***Epithemia*** **Kützing** (Fig. 32)

Description: Valves strongly dorsiventral, arcuate (similar to an orange segment), with rounded, rostrate to sub-capitate ends. Ventral margin often straight or slightly concave, dorsal margin distinctly convex. Striae coarse, highly punctate, bounded by transapical costae (thickened ridges). Raphe narrow, running along ventral margin and curving dorsally near valve centre. In some species, the raphe may almost touch the dorsal margin.

Common species: *Epithemia sorex* Kützing
Epithemia adnata (Kützing) Brébisson

Remarks: *Epithemia* is a common periphytic genus primarily confined to alkaline freshwaters (rarely encountered above 3 g/L), occasionally found in brackish waters. Most species known to contain small endosymbiotic cyanophytes. An easy genus to identify under LM.

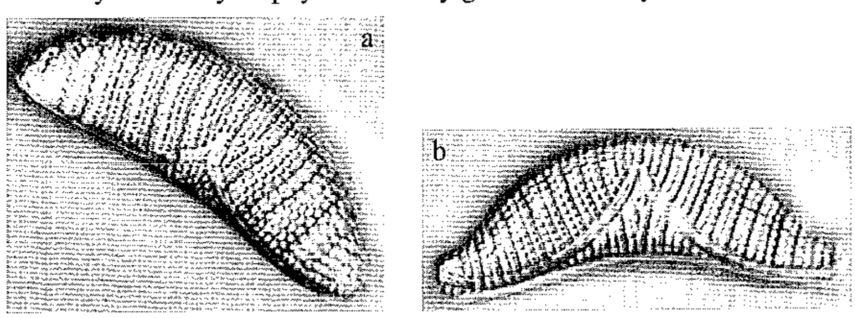


Fig. 32. (a) *Epithemia adnata* (x450); (b) *Epithemia sorex* (x1040).

Genus ***Rhopalodia*** **Müller** (Fig. 33)

Description: Valves distinctly dorsiventral, linear to arcuate (similar to an orange segment), often with turned down ends. Valves often elliptical in girdle view. Striae coarse, highly punctate, bounded by transapical costae (thickened ridges). Raphe narrow, generally present along the dorsal margin, sometimes forming a raised keel. Many girdle bands often present.

Common species: *Rhopalodia brebissonii* Krammer
Rhopalodia gibba (Ehrenberg) Müller
Rhopalodia gibberula (Ehrenberg) O. Müller
Rhopalodia musculus (Kützing) Müller

Remarks: *Rhopalodia* is found mostly in the benthos of brackish to saline (and even hypersaline) waters. One species, however, *R. gibba*, avoids even brackish waters. Some *Rhopalodia* species are known to contain small endosymbiotic cyanophytes. An easy genus to identify under LM. Many saltwater specimens were assigned previously to *R. gibberula* but Krammer's (1988) review clearly distinguished types, foremost on the basis of shape and punctae density.

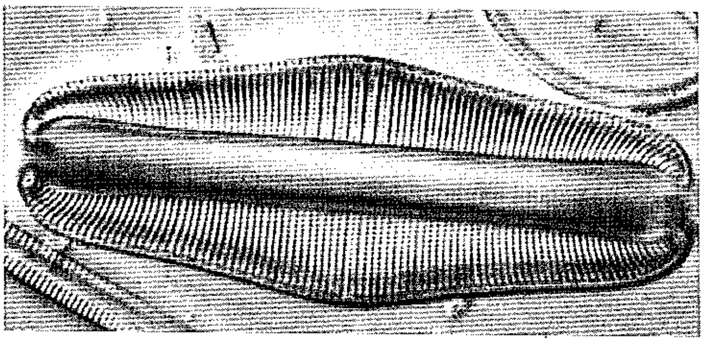


Fig. 33. *Rhopalodia gibba* (x410).

29a.	Valves saddle-shaped	***Campylodiscus***
29b.	Valves appearing otherwise	**30**

Genus ***Campylodiscus* Ehrenberg ex Kützing** (Fig. 34)

Description: Valves circular-orbicular, valve face concave along the apical axis, 'saddle-shaped' and narrow in girdle view. Striae finely punctate, radial from centre, bordered by thickened 'ribs' (costae). The raphe is indistinct and is positioned on a keel that runs around the entire margin of the valve.

Common species: *Campylodiscus clypeus* Ehrenberg
Campylodiscus echineis Ehrenberg

Remarks: *Campylodiscus* is a large benthic diatom thatwhich is widely, although infrequently, encountered in brackish waters (eg. Lake Hindmarsh, The Coorong). Its 3-dimensional shape leaves it susceptible to breakage on mounting and so often only fragments are seen. It this case, the fragments are counted to allow for an estimation of valve numbers.

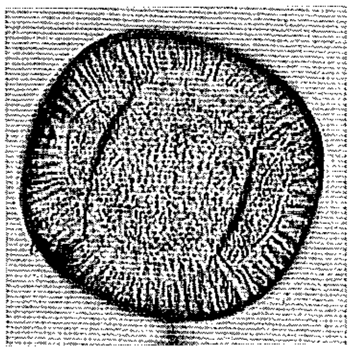


Fig. 34. *Campylodiscus clypeus* (x310).

30a. Valves transapically undulate .... ***Cymatopleura***
30b. Valves appearing otherwise .... ***Surirella***

Genus *Cymatopleura* W. Smith (Fig. 35)

Description: Valves linear, elliptic to panduriform (constricted in the centre), with rounded or apiculate ends. Valve narrow in girdle view, valve face undulate (often appearing as transverse shadows). Striae extremely fine, generally parallel. A narrow raphe is located on a shallow keel that runs around the margin of the valve, and is supported by thickened ribs that extend onto the valve face.

Common species: *Cymatopleura solea* (Brébisson) W. Smith

Remarks: *Cymatopleura* is a large, benthic diatom thatwhich is infrequently encountered. Its size, general shape and undulate surface are characteristic of the genus. *Cymatopleura* is generally found in highly conductive waters.

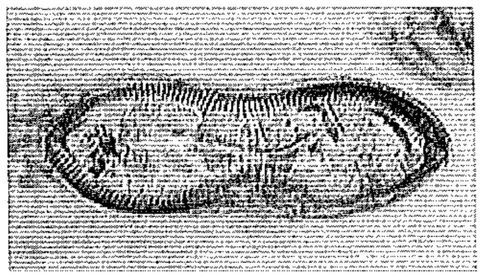


Fig. 35. *Cymatopleura solea* (x350).

Genus *Surirella* Turpin (Fig. 36)

Description: Valves linear, elliptical to broadly ovate, with broadly rounded to apiculate ends. Valves often linear in girdle view. Valve face flat to concave, often undulating. Striae finely punctate, transverse, often not able to be resolved under LM. Striae often bordered by large thickened marginal ribs. The raphe is located within a raised wing that follows the circumference of the valve.

Common species: *Surirella angusta* Kützing
Surirella brebissonii Krammer & Lange-Bertalot
Surirella robusta Ehrenberg

Remarks: *Surirella* is a distinctive and diverse genus. They are common in the benthos of hard waters and some taxa (eg. *S. brebissonii*) can tolerate quite saline, and nutrient-rich conditions. An easy genus to identify under LM.

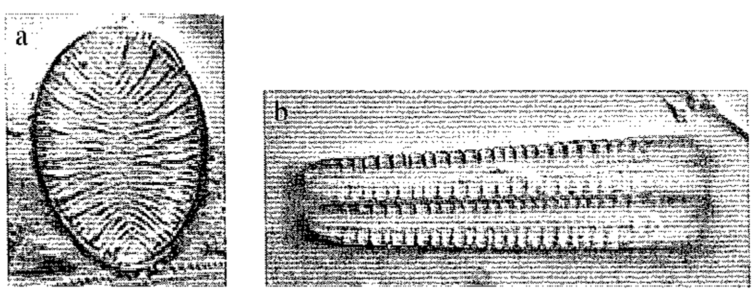


Fig. 36. (a) *Surirella brebissonii* (x550); (b) *Surirella angusta* in girdle view (x960).

31a. Raphe in a canal crossed by fibulae **32**
31b. Raphe appearing otherwise **36**

32a. Raphe canal spiralling down length of valve .... ***Cylindrotheca***
32b. Raphe straight **33**

Genus ***Cylindrotheca*** **Rabenhorst** (Fig. 37)

Description: Valves long linear 'strips' with drawn out ends. Striae not present. Valves twisted around each other to form a spirally formed cell. The raphe appears as a spiral down the length of the cell.

Common species: *Cylindrotheca gracilis* (Brébisson) Grunow

Remarks: *Cylindrotheca* is a poorly silicified diatom which is often difficult to resolve under LM. Its spiralling raphes are most characteristic. It is rarely common and largely restricted to brackish, alkaline waters.

Fig. 37. *Cylindrotheca gracilis* (x1100).

33a. Raphe canal central .... ***Bacillaria***
33b. Raphe usually lateral **34**

Genus *Bacillaria* Gmelin (Fig. 38)

Description: Valve linear to linear-lanceolate, with drawn out rostrate or capitate ends. Striae finely punctate, parallel, difficult to distinguish under LM. Raphe canal central to eccentric, with conspicuous irregularly spaced fibulae. Cells are often arranged in linear colonies via attachment of the raphes. Colonies exhibit a unique movement as cells slide alongside each other.

Common species: *Bacillaria paradoxa* Gmelin

Remarks: *Bacillaria* is one of the more heavily silicified and distinctive diatoms within the family Nitzschiaceae. The heavy, central raphe canal with irregularly spaced fibulae are a useful identification characteristic. It is associated with fresh-brackish, meso-to eutrophic water and will tolerate moderate levels of organic pollution. Accordingly, it is occasionally abundant in the lower reaches of urban streams.

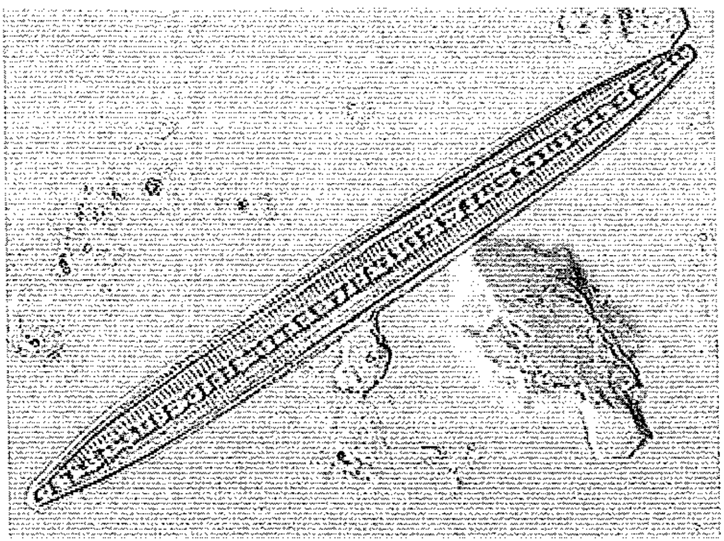


Fig. 38. *Bacillaria paradoxa* (x875).

34a.	Valve with longitudinal hyaline fold	***Tryblionella***
34b.	Valve appearing otherwise	**35**

Genus ***Tryblionella*** **W. Smith** (Fig. 39)

Description: Valves linear, linear-lanceolate to elliptical, sometimes with central constriction, ends broadly rounded to apiculate. Valve narrow in girdle view. Valve face flat to undulate. Striae finely punctate, bordered by thick conspicuous transverse fibulae extending from the raphe keel. Striae may be interrupted by one or two hyaline bands (thin longitudinal bands with no punctae). The raphe is eccentric, running along the valve margin.

Common species: *Tryblionella apiculata* Gregory
Tryblionella calida (Grunow in Cleve & Grunow) Mann
Tryblionella debilis Arnott
Tryblionella hungarica (Grunow) Mann
Tryblionella levidensis (W. Smith) Grunow

Remarks: *Tryblionella* (previously within *Nitzschia*) is common in estuarine systems and appears to prefer saline waters. The raphe canal is marginal and often difficult to detect but the longitudinal fold in the valve surface, often seen as a hyaline band, is highly characteristic of the genus.

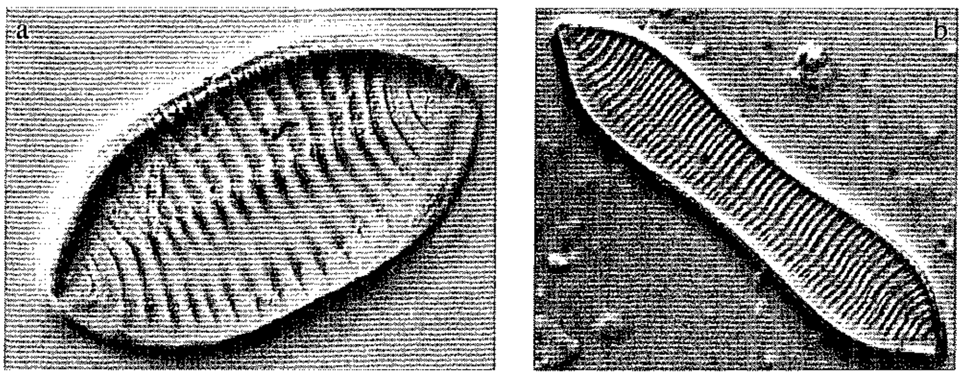


Fig. 39. (a) *Tryblionella levidensis* (x1300); (b) *Tryblionella calida* (x920).

35a. Raphe canals on same side of each valve .... ***Hantzschia***
35b. Raphe canals on opposite side of each valve .... ***Nitzschia***

Genus *Hantzschia* Grunow (Fig. 40)

Description: Valves linear to linear-lanceolate, slightly dorsiventral-sigmoid (asymmetrical about the apical plane) with rounded capitate ends. Striae fine, finely punctate and parallel. The raphe is highly fibulate and is located within a canal on the ventral (concave) margin of both valves (ie. same side, cf. *Nitzschia*).

Common species: *Hantzschia amphioxys* (Ehrenberg) Grunow

Remarks: *Hantzschia* is closely aligned to *Nitzschia*. At various divisional stages, the raphe canal on the hypervalve directly overlays that of the hypovalve. This genus is ecologically versatile. They are aerophilous (able to live out of water on wet surfaces)and as such, their presence in benthic samples may reflect sediment input to a system.

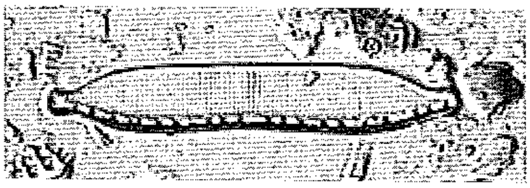


Fig. 40. *Hantzschia amphioxys* (x675).

Genus *Nitzschia* Hassall (Fig. 41)

Description: Valves linear, linear-lanceolate, lanceolate, sigmoid or elliptic, with rounded, capitate, rostrate or apiculate ends. Striae may be extremely fine to coarsely punctate (in many species not visible under LM), parallel to slightly radial. The raphe is highly fibulate and is located in a canal that runs along the margin on opposite sides of the valve, however in some species, the raphe may be located on the same side (ie. as in *Hantzschia*). A central node (an area of the raphe without fibulae) is present in some species.

Common species: *Nitzschia acicularis* (Kützing) W. Smith
Nitzschia acidoclinata Lange-Bertalot
Nitzschia amphibia Grunow
Nitzschia closterium (Ehrenberg) W. Smith
Nitzschia desertorum Hustedt
Nitzschia dissipata (Kützing) Grunow
Nitzschia draveillensis Coste & Ricard
Nitzschia filiformis (W. Smith) Van Heurck
Nitzschia frustulum (Kützing) Grunow
Nitzschia inconspicua Grunow
Nitzschia lacuum Lange-Bertalot
Nitzschia leibetruthii Rabenhorst
Nitzschia linearis (Agardh) W. Smith
Nitzschia microcephala Grunow
Nitzschia palea (Kützing) W. Smith
Nitzschia sigma (Kützing) W. Smith

Remarks: *Nitzschia* is a large, diverse and ecologically versatile genus. They are mostly benthic but include some planktonic taxa (*N. acicularis*). *Nitzschia* is abundant in most circumneutral to alkaline systems where as many as 30 species may be recognised in any sample. They are also frequently present in oligotrophic waters, but they are rarely a major component of these assemblages. Identification to species requires consideration of numerous characters (valve shape, striae and fibulae density, presence or absence of a central node) that are not always clearly visible. The genus does however yield much ecological information as several taxa (eg. *N. desertorum* and *N. palea*) are reflective of nutrient enrichment, whilst others (eg. *N. etoshensis*) are useful indicators of elevated salinities. Several finely silicified types such as *N. closterium* may be overlooked. This genus will be dealt with in greater detail in a subsequent key.

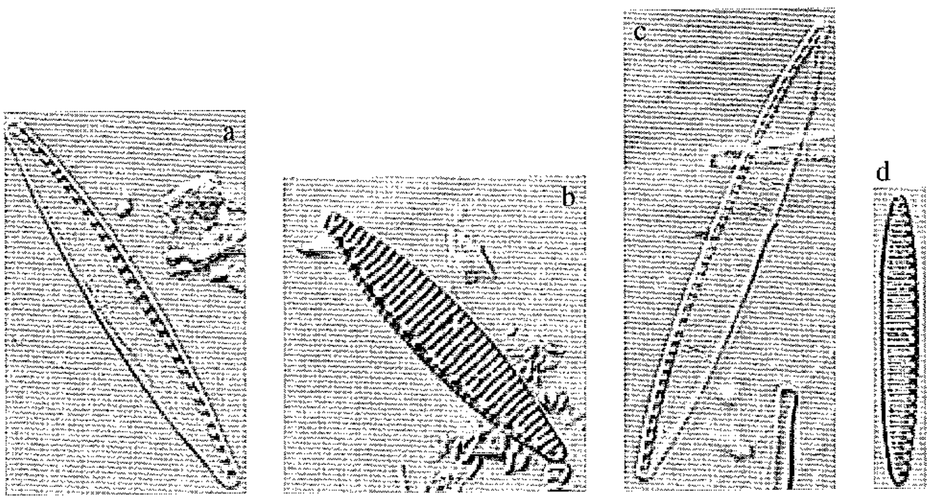


Fig. 41. (a) *Nitzschia filiformis* (x900); (b) *Nitzschia amphibia* (x1200); (c) *Nitzschia palea* (x920); (d) *Nitzschia frustulum* (x1200).

36a.	Valve heteropolar	***Gomphonema***
36b.	Valve isopolar	**37**

Genus *Gomphonema* **Ehrenberg** (Fig. 42)

Description: Valves clavate (club-shaped) to linear-lanceolate, with round, rostrate to capitate ends. Striae usually coarsely punctate and radial. Axial area narrow, raphe straight to undulate, central area rounded, fasciate to one-sided, usually with one or more prominent stigmata. Cells often attached to substrates via mucilaginous stalks secreted from the base end (Round *et al.* 1990).

Common species: *Gomphonema angustatum* Kützing
Gomphonema angustum Agardh
Gomphonema gracile Ehrenberg
Gomphonema parvulum Kützing
Gomphonema truncatum Ehrenberg

Remarks: *Gomphonema* is a distinctive genus primarily found in freshwater. Species within *Gomphonema* have a tendency to display a high degree of morphological variability which can make reliable identification to species level difficult. It is not clear whether this apparent morphological plasticity reflects a response to environmental variables or the existence of several distinct morphotypes. Several species are reflective of elevated nutrients eg. *G. augur* Ehrenberg. Generally an easy genus to identify under LM.

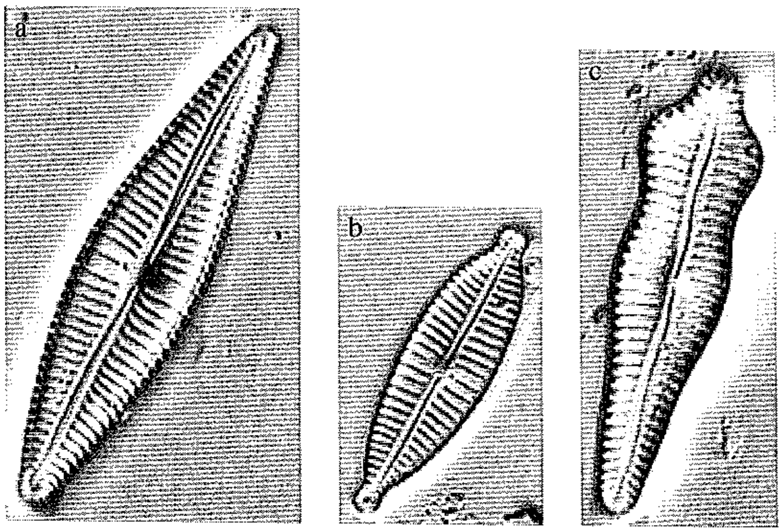


Fig. 42. (a) *Gomphonema* cf. *affine* (x930); (b) *Gomphonema parvulum* (x1050); (c) *Gomphonema accuminatum* (x580).

37a.	Valve dorsiventral	**38**
37b.	Valve appearing otherwise	**41**

38a.	Ventral side with swollen central area	***Reimeria***
38b.	Ventral side appearing otherwise	**39**

Genus *Reimeria* Kociolek & Stoermer (Fig. 43)

Description: Valves linear to linear-lanceolate, slightly dorsiventral, with rounded ends tending to sub-capitate. Central area is noticeably one-sided on ventral side of valve (side with central swelling). A conspicuous stigma is present between the raphe ends or displaced slightly to the dorsal side. Striae parallel, density quite low. The raphe is generally straight but is occasionally offset towards the ventral side.

Common species: *Reimeria sinuata* (Gregory) Kociolek & Stoermer

Remarks: Kociolek and Stoermer (1987) separated *Reimeria* from *Cymbella* on the basis of valve shape and the ventrally displaced apical pore field (not visible under LM). *Reimeria sinuata* is easily recognised under LM due to the valve shape and one-sided central area. It is infrequently encountered, but is generally found growing in epilithic habitats in streams.

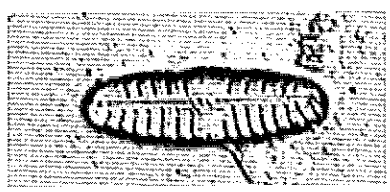


Fig. 43. *Reimeria sinuata* (x1500)

39a.	Valve mantle usually much wider at dorsal side often with many intercalary bands	***Amphora***
39b.	Dorsal side only slightly wider	**40**

Genus *Amphora* **Ehrenberg ex Kützing** (Fig. 44)

Description: Valves dorsiventral, semilanceolate, crescentic (shaped like an orange segment) with rounded, rostrate to capitate ends. Striae variable from fine to coarsely punctate, parallel to radial, often interrupted by a hyaline area on the dorsal side of the raphe, reduced on the ventral margin. The raphe is located near the ventral margin, proximal ends may be either straight or curved towards either margin. The raphes on each valve are located to the ventral side of the frustule. Numerous girdle bands (copulae) are present on the dorsal margin of the frustule.

Common species: *Amphora coffeaeformis* (Agardh) Kützing
Amphora holsatica Hustedt
Amphora pediculus (Kützing) Grunow
Amphora veneta Kützing

Remarks: In 3-dimensions an *Amphora* cell is likened to several intact orange segments. As such, when entire, the valve surfaces are not clearly seen and the intercalary bands of the mantle are the most obvious feature. Its variable valve surface and raphe-form are the basis for generic classification. *A. coffeaeformis* is most common in saline and even hypersaline waters while the diminutive (8-12 (µm long). *A. pediculus* and *A. veneta* are characteristic of the epilithon of freshwaters.

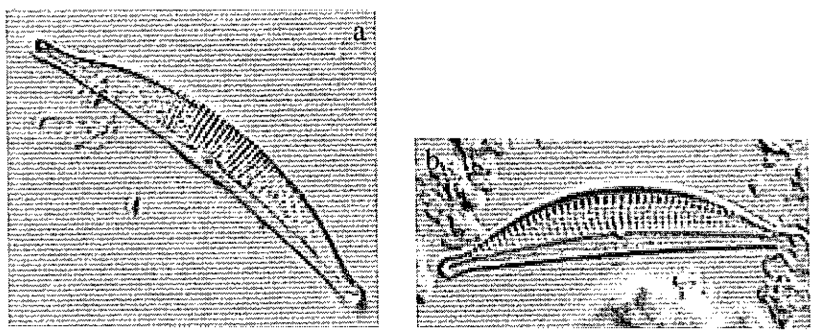


Fig. 44. (a) *Amphora* cf. *veneta* (x1100); (b) *Amphora coffeaeformis* (x850).

40a. Raphe rising from ends to valve centre; distal raphe ends deflected dorsally .... ***Cymbella***

40b. Raphe ± parallel with ventral side not rising to centre; distal raphe ends deflected ventrally .... ***Encyonema***

Genus ***Encyonema* Kützing** (Fig. 45)

Description: Valves dorsiventral, strongly arcuate, with rounded to sub-rostrate. Ventral margins straight to slightly convex, dorsal margin convex. Striae often coarsely punctate (slit-like), radiate on the dorsal margin, reduced on the ventral margin. The raphe is positioned along the centre of the valve, and is generally orientated parallel to the ventral margin. The terminal raphe fissures are always deflected to the ventral margin. One or more conspicuous stigmata are often present on the ventral margin of the central area. True stigma not present, punctae near the central area may be variously modified.

Common species: *Encyonema gracilis* Ehrenberg
Encyonema minuta Hilse in Rabenhorst
Encyonema silisiacum (Bliesch in Rabenhorst) Mann

Remarks: *Encyonema* was recently re-instated as a separate genus from *Cymbella. Encyonema* species are restricted to freshwaters. They are, however, encountered in most freshwater benthic and periphytic samples, including those taken from waters with elevated nutrients.

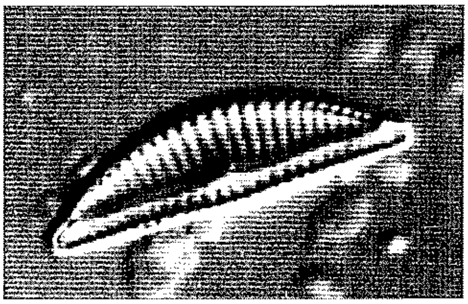


Fig. 45. *Encyonema minuta* (x2040).

Genus ***Cymbella* Agardh** (Fig. 46)

Description: Valves dorsiventral, strongly arcuate, with rounded, sub-rostrate to sub-capitate ends. Ventral margins straight to slightly convex or concave. Striae often coarsely punctate (slit-like), radiate on the dorsal margin, reduced on the ventral margin. The raphe is positioned along the centre of the valve and may be curved, sinuous or straight. The terminal raphe fissures are always deflected to the dorsal margin. One or more conspicuous stigmata are often present on the ventral margin of the central area.

Common species: *Cymbella aspera* (Ehrenberg) Peragallo
Cymbella cistula (Ehrenberg) Kirchner
Cymbella pusilla Grunow
Cymbella tumida (Brébisson) Van Heurck

Remarks: *Cymbella* is a diverse genus, largely restricted to freshwaters, although *C. pusilla* is typical of brackish waters. It includes some spectacular species which may be greater than 100-200μm in length (eg. *C. lanceolata* (Ehrenberg) Kirchner). An easy genus to identify under LM.

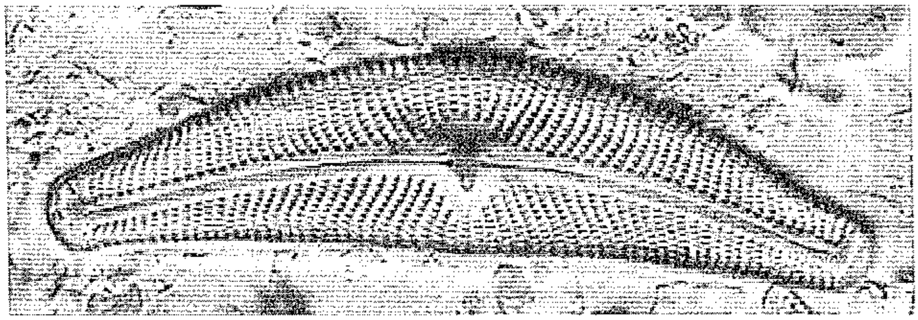


Fig. 46. *Cymbella tumida* (x800).

41a.	Valve in S-shape	**42**
41b.	Valve appearing otherwise	**43**

42a.	Transverse and longitudinal striae cross at right angles	***Gyrosigma***
42b.	Valve with diagonal striae	***Pleurosigma***

Genus *Gyrosigma* Hassall (Fig. 47)

Description: Valves sigmoid (s-shaped) to linear-lanceolate, with rounded to drawn out ends. The striae consist of very fine punctae appearing as longitudinal lines orientated both parallel and transverse to the raphe (ie. the striae cross at right angles). The axial area is narrow and with a small central area. The raphe is narrow and sigmoid.

Common species: *Gyrosigma attenuatum* (Kützing) Rabenhorst
Gyrosigma salinarum Grunow
Gyrosigma spencerii (W. Smith) Cleve

Remarks: Refer to remarks under *Pleurosigma.*

Fig. 47. *Gyrosigma attenuatum* (x670).

Genus *Pleurosigma* **W. Smith** (Fig. 48)

Description: Valves sigmoid (s-shaped), linear-lanceolate to rhombic with pointed ends. The striae consist of very fine punctae and run obliquely to the raphe (ie. in a decussate pattern). The axial area is narrow with a small central area. The raphe is narrow and sigmoid.

Common species: *Pleurosigma elongatum* W. Smith

Remarks: *Gyrosigma* and *Pleurosigma* are large, s-shaped naviculoid diatoms that are easily recognised under LM. The longitudinal and transverse striae in *Gyrosigma* cross at right angles whereas the striae run obliquely to the main axis in *Pleurosigma.* Both genera have marine affinities and are most commonly found in brackish to saline systems, although several species of *Gyrosigma* (eg. *G. spencerii, G.attenuatum*) and one of *Pleurosigma* (*P. elongatum*) are widely encountered, albeit in low numbers, in freshwaters. Striae density (in both directions), the arrangement of the central area, and the associated raphe ends are amongst the features used to separate species within each genus.

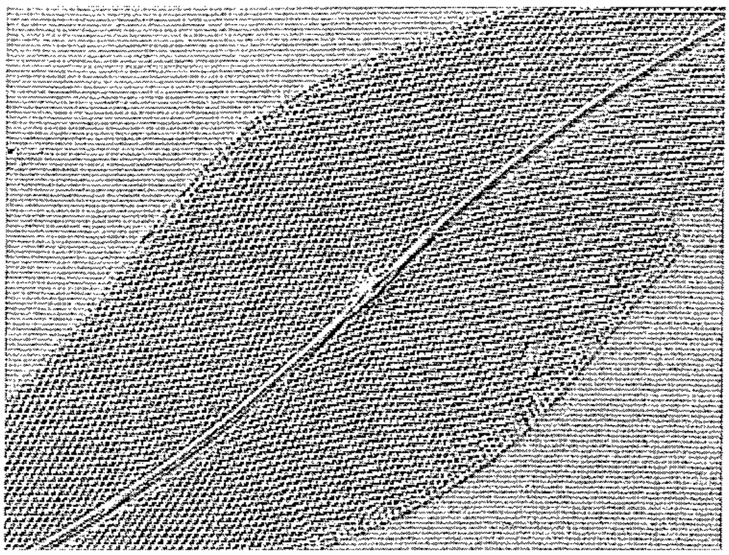


Fig. 48. *Pleurosigma angulatum* (Quekett) W. Smith (x1250).

43a. Valve apically twisted with raphe along margins of 'wings' .... ***Entomoneis***
43b. Valve appearing otherwise **44**

Genus *Entomoneis* Ehrenberg (Fig. 49)

Description: Valves lanceolate to linear with pointed ends. Each valve with a narrow upright keel that is constricted at the central area. Striae fine and generally not visible under LM. Axial area and raphe largely obscured by keel. Numerous intercalary bands generally present.

Common species: *Entomoneis alata* (Ehrenberg) Ehrenberg
Entomoneis costata (Hustedt) Reimer
Entomoneis paludosa (W. Smith) Reimer

Remarks: *Entomoneis* is primarily a marine and brackish water genus, with only a small number of species found in freshwater. The three most commonly encountered taxa reflect a broad cline in salinities from fresh (*E. costata*) to brackish (*E. alata*) and saline (*E. paludosa*).

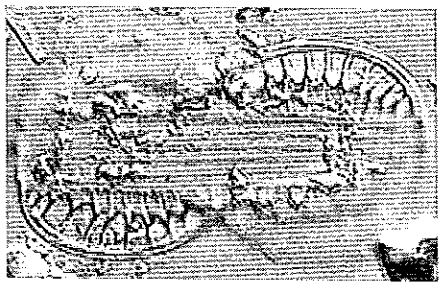


Fig. 49. *Entomoneis costata* (x1300).

44a. Locules (chambers) on valve margin usually evident (also wavy raphe <u>and</u> punctate striae) .... ***Mastogloia***
44b. Locules never present **45**

Genus *Mastogloia* **Thwaites ex W. Smith** (Fig. 50)

Description: Valves elliptical to linear-lanceolate, with rounded to sub-capitate ends. Striae variable from fine to coarsely punctate, parallel to slightly radiate. Axial area central and narrow, central area narrow. The raphe may be straight or occasionally sinuous. A row of internal chambers (locules) is present along the valve margins (easily visible under LM).

Common species: *Mastogloia elliptica* Agardh
Mastogloia pumilla (Cleve & Möller) Cleve
Mastogloia smithii Thwaites

Remarks: While the striae of most *Mastogloia* are usually coarsely punctate and the raphe wavy, it is the marginal chambers which are characteristic of this genus. *Mastogloia* is principally found in marine and estuarine waters and has been associated with the building of stromatolites. It is generally found in waters with elevated salinity levels.

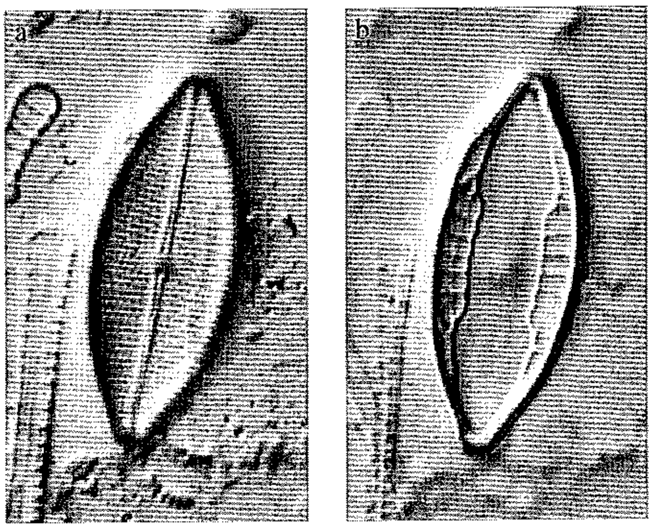


Fig. 50. *Mastogloia elliptica* (a) Valve view (x1000); (b) Internal locules (x1000).

45a. Most valves < 20 µm; isolated stigma in central area .... ***Luticola***
45b. Stigma never present **46**

Genus *Luticola* **Mann in Round, Crawford & Mann** (Fig. 51)

Description: Valves linear, linear-lanceolate to linear-elliptical, with broadly rounded to capitate ends. The striae are heavily punctate, often with only several punctae per stria, and radiate. The axial area is narrow and expands into a broad central area (stauros) which almost extends to the margins. A single conspicuous stigma is located on one side of the central area. Cells usually occur solitary or occasionally as short chains.

Common species: *Luticola goepeppertiana* (Bleisch in Rabenhorst) Mann
Luticola mutica (Kützing) Mann

Remarks: *Luticola* was recently separated from *Navicula* on the basis of its punctate striae and isolated stigma which are easily seen under LM. It is also somewhat ecologically distinct, being largely aerophilous (soils and subaerial habitats) and common in enriched waters.

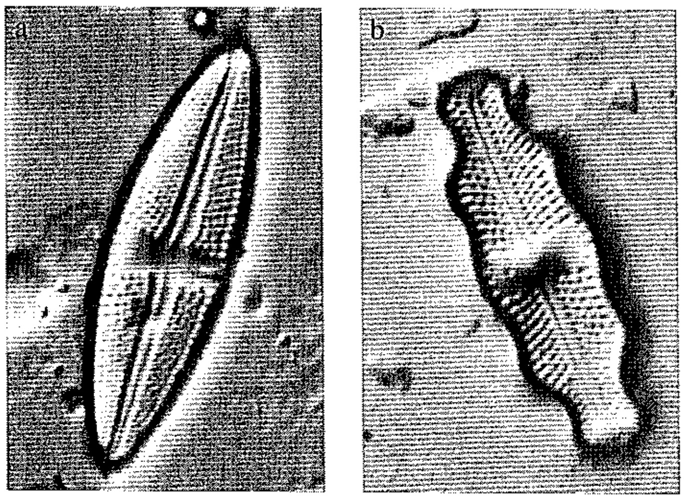


Fig. 51. (a) *Luticola goepeppertiana* (x880); (b) *Luticola nivalis* (Ehrenberg) Mann (x1380).

46a.	Raphe in heavy rib, ending in an "arrow"	**47**
46b.	Axial area may be wide but not with rib	**48**

47a.	Proximal raphe ends widely separated	***Berkeleya***
47b.	Raphe otherwise formed	***Frustulia***

Genus *Berkeleya* Greville (Fig. 52)

Description: Valves linear to linear-lanceolate, with broadly rounded to sub-capitate ends. The striae are extremely fine and parallel, and may be sub-radially orientated towards the ends. The axial area is narrow and does not appear (under LM) to reach the ends. The raphe is straight and the proximal ends may or may not closely meet at the central area.

Common species: *Berkeleya rutilans* (Trentepohl ex Roth) Grunow

Remarks: The most common *Berkeleya* found in freshwaters is *B. rutilans*, a salt tolerant species. *B. rutilans* is often lightly silicified, and is characterised by widely spaced proximal raphe ends, that are often difficult to determine when seen in girdle view. *Berkeleya* is superficially very similar to *Frustulia*, but the two genera may be separated (using LM) on the basis of valve shape and the appearance of the axial area.

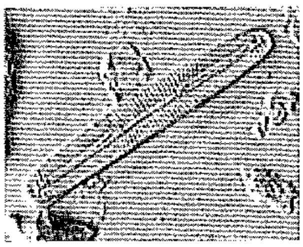


Fig. 52. *Berkeleya rutilans* (x1080).

Genus *Frustulia* Rabenhorst (Fig. 53)

Description: Valves linear-lanceolate, lanceolate to rhombic, with pointed to occasionally subcapitate ends. The striae are extremely fine, parallel, and orientated transversely. The axial area is bounded by prominent internal ribs running along either side of the raphe, often giving the axial area a raised 'ridge-like' appearance. The central area is normally thinner than the axial area, although it is sometimes rounded.

Common species: *Frustulia rhomboides* (Ehrenberg) De Toni
Frustulia vulgaris (Thwaites) De Toni

Remarks: *Frustulia* can be distinguished from naviculoid genera based upon the high striae density and the distinct appearance of the axial area in *Frustulia*. *Frustulia vulgaris* is often found in alkaline waters while *F. rhomboides* is more typical of acid conditions where pH values are often less than 3.0. It is often found growing within epipelic habitats in streams, but is rarely encountered in high numbers.

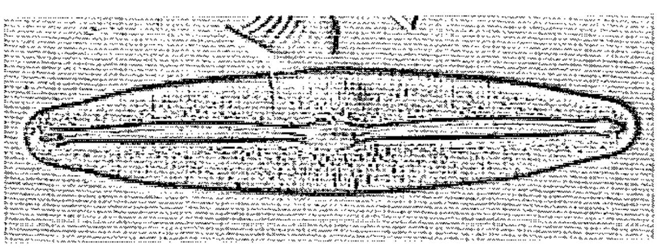


Fig. 53. *Frustulia vulgaris* (x1250).

48a. Striae interrupted forming longitudinal lines **49**
48b. Striae complete without longitudinal lines **53**

49a. Longitudinal lines hyaline, centrally constricted .... ***Fallacia***
49b. Longitudinal lines otherwise formed **50**

Genus *Fallacia* Stickle & Mann in Round, Crawford & Mann (Fig. 54)

Description: Valves linear to lanceolate to elliptical, with broadly rounded ends. Striae fine and parallel. The striae are interupted by distinct lateral thickenings (sterna) on the valve face that appear lyre shaped (H-shaped). The axial area is narrow and straight, and the central area is often slightly enlarged.

Common species: *Fallacia pygmaea* (Kützing) Stickle & Mann
Fallacia tenera (Hustedt) Mann

Remarks: *Fallacia* is a recently created genus that has been separated from the naviculoid group. It includes several freshwater species of which *F. pygmaea* and *F. tenera* are the most frequently encountered. They are probably aerophilous, although they are often found in epipelic and epilithic habitats and are tolerant of a large range of water quality conditions.

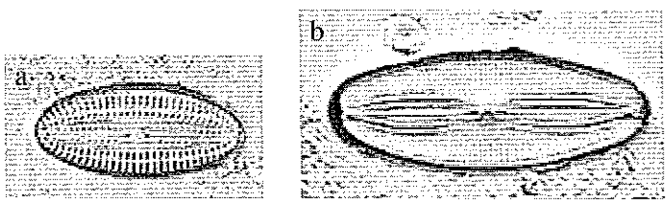


Fig. 54. (a) *Fallacia tenera* (x1080); (b) *Fallacia pygmaea* (x840).

50a. Raphe lying in thickened axial area .... ***Diploneis***
50b. Raphe appearing otherwise **51**

Genus *Diploneis* **Ehrenberg ex Cleve** (Fig. 55)

Description: Valves linear to elliptical, rhombic, occasionally constricted in the centre (panduriform), with broadly rounded ends. Valve face flat to undulate. Striae extremely variable, punctae size changing transapically across valve face. Punctae at margin large tending smaller towards axial area. Axial area extremely broad, bounded by a row of punctae on either side (longitudinal canals). Central area small, bounded by axial area.

Common species: *Diploneis ovalis* (Hilse) Cleve
Diploneis parma Cleve
Diploneis smithii (Brébisson) Cleve

Remarks: Whilst *Diploneis* is primarily marine, there are also several smaller, freshwater species. These are primarily separated primarily on the basis of striae arrangement and structure. *Diploneis* is occasionally found in the epipelic and epilithic habitats.

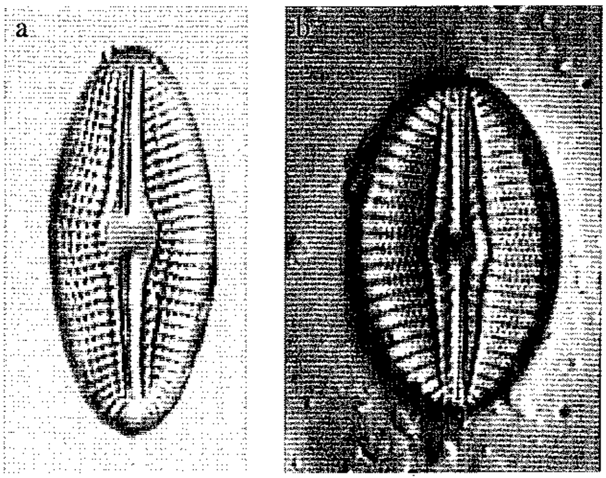


Fig. 55. (a) *Diploneis* cf. *subovalis* Cleve (x1060); (b) *Diploneis* cf. *smithii* (x750).

51a. Striae punctate and incomplete forming several wavy longitudinal lines .... ***Anomoeoneis***

51b. Striae appearing otherwise **52**

Genus ***Anomoeoneis*** **Pfitzer** (Fig. 56)

Description: Valves lanceolate to elliptic-rhombic, with rounded, rostrate to capitate ends. Striae extremely fine, parallel, punctae arranged in irregular longitudinal lines due to uneven spacing of the punctae in each stria (striae appear 'dashed'). Axial area straight and narrow, sometimes broad, central area small and elliptic.

Common species: *Anomoeoneis sphaerophora* (Ehrenberg) Pfitzer

Remarks: *Anomoeoneis* is most frequently represented by the ornate *A. sphaerophora* which can be abundant in alkaline, carbonate-rich mesosaline conditions. The related genus *Brachysira*, which was recently separated from *Anomoeoneis*, is more common in acidic waters. A commonly encountered genus.

A recently re-established genus, *Brachysira* Kützing, includes many species that were previously placed in the genus *Anomoeoneis*. Two species that are often encountered: *B. styriaca* (Grunow) Round & Mann (syn: *Anomoeoneis styriaca* (Grunow) Hustedt) and *B. vitrea* (Grunow) Round & Mann (syn: *Anomoeoneis vitrea* (Grunow) Ross).

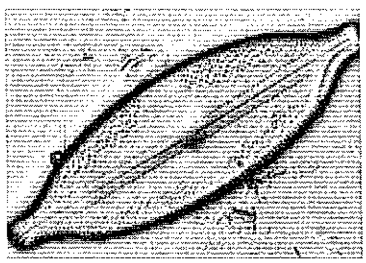


Fig. 56. *Anomoeonies sphaerophora* (x600).

52a. Striae generally clearly punctate and proximal raphe ends usually deflected in opposite directions .... ***Neidium***
52b. Striae appearing otherwise ....***Pinnularia* & *Caloneis* (Part)**

Genus ***Neidium*** **Pfitzer** (Fig. 57)

Description: Valves linear, lanceolate to elliptic, with blunt rounded, rostrate to sub-capitate ends. Striae fine, orientated straight, slightly radial or occasionally across the valve at a slight angle (oblique) to the transapical axis. Axial area narrow, central area often rounded or elliptic. The raphe is fine (almost thread-like), and the proximal raphe ends either straight or deflected in opposite directions.

Common species: *Neidium affine* (Ehrenberg) Pfitzer
Neidium ampliatum (Ehrenberg) Krammer

Remarks: *Neidium* is exclusively a freshwater genus that is primarily found in epipelic and epilithic habitats. It is widely distributed throughout a range of water types, but is infrequently encountered.

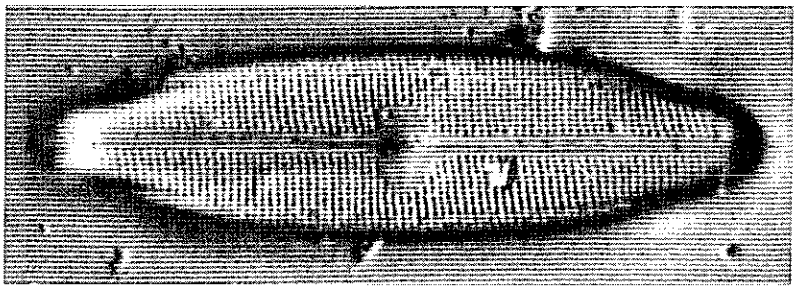


Fig. 57. *Neidium iridis* (Ehrenberg) Cleve (x1300).

Genus ***Pinnularia* Ehrenberg** (Fig. 58)

Description: Valve linear, lanceolate to elliptical, ends broadly rounded, capitate or rostrate. Striae fine to coarsely areolate, usually radial in the centre tending to convergent at the ends. The axial area is variable, often wide with a broad central area that reaches the margin. The raphe may be straight or curved, with the proximal raphe ends turned to the same side. The raphe forms distinctive hooked terminal fissures at the ends which can often be seen in large specimens under the LM.

Common species: *Pinnularia borealis* Ehrenberg
Pinnularia divergentissima (Grunow) Cleve
Pinnularia gibba Ehrenberg
Pinnularia microstauron (Ehrenberg) Cleve
Pinnularia subcapitata Gregory
Pinnularia viridis (Nitzsch) Ehrenberg

Remarks: *Pinnularia* has heavy striae in which the ultrastructure is rarely evident under light microscope. The presence of a compound raphe, striae which change direction down the length of the valve, or of strongly hooked terminal fissures usually differentiate *Pinnularia* from the other similar genera (cg. *Navicula*). *Pinnularia* is primarily a freshwater genus. It is common is most streams living in epipelic and epilithic habitats. It may dominate samples collected from acidic waters.

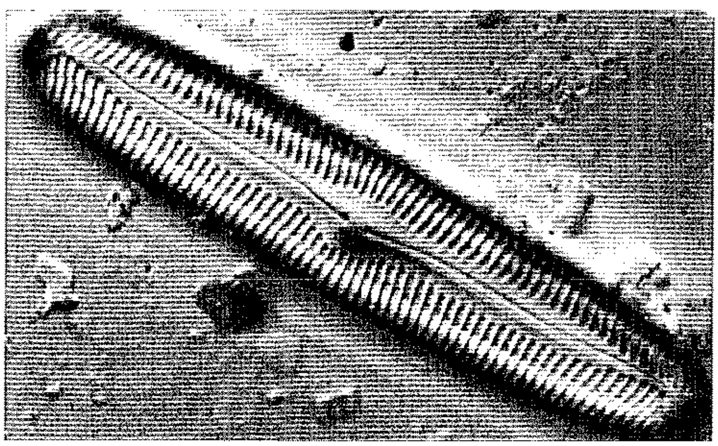


Fig. 58. *Pinnularia viridis* (x830).

Genus *Caloneis* **Cleve** (Fig. 59)

Description: Valves linear, lanceolate to elliptic, with rounded to sub-capitate ends. Striae finely alveolate, interupted by one or two longitudinal lines along the valve margin. The axial area variable, central area elliptic, round or forming a fascia. Raphe usually straight with the proximal ends turned to the same side.

Common species: *Caloneis bacillum* (Grunow) Cleve
Caloneis molaris (Grunow) Krammer
Caloneis silicula (Ehrenberg) Cleve

Remarks: *Caloneis* is a relatively common genus, that is found in a wide range of freshwaters. There is some debate within the literature as to whether in fact *Caloneis* is justified as a genus. For example, Round *et al.* (1990) noted that they were unable to find a satisfactory basis for the traditional separation of *Caloneis* from *Pinnularia*. The axial margin of the striae often appears ragged and the striae are usually parallel.

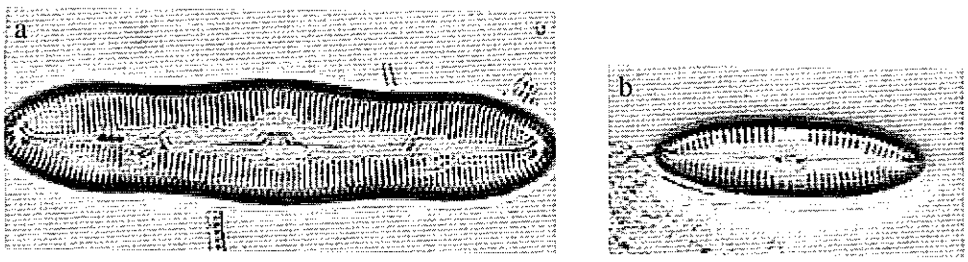


Fig. 59. (a) *Caloneis silicula* (Ehrenberg Cleve) (x720); (b) *C. bacillum* (x1170).

53a.	Valve with clear central area extending to margin	**54**
53b.	Valve appearing otherwise	**56**
54a.	Striae punctate, sometimes not obviously so	**55**
54b.	Striae appearing otherwise	***Pinnularia* & *Caloneis* (part)**
55a.	Cells rounded, often appearing on their side	***Staurophora***
55b.	Valve face relatively flat	***Stauroneis***

Genus ***Staurophora*** **Mereschkowsky** (Fig. 60)

Description: Valves linear to linear-lanceolate with rounded to rostrate ends. Valve face gently curved. Striae finely punctate, parallel to slightly radial, shortened centrally to form a narrow-transverse to acute-angled stauros. Axial area narrow and straight.

Common species: *Staurophora salina* (W. Smith) Mereschkowsky
Staurophora wislouchii (Poret & Anisimova) Mann

Remarks: *Staurophora* is generally restricted to marine and brackish waters, but is also found in some inland waters with high conductivity. It is distinguished from *Stauroneis* by the plastid structure and arrangement, and the raphe ultrastructure. making it very difficult to distinguish under LM. However, *Staurophora* is most readily separated from *Stauroneis* on the basis of its round, rather than flat valve face. *Staurophora* are also distinctive ecologically, favouring brackish to hypersaline conditions.

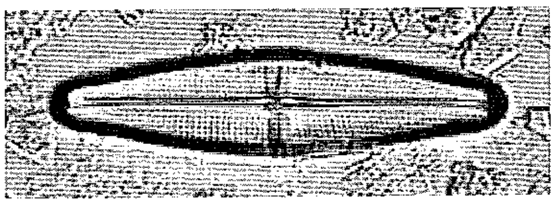


Fig. 60. *Staurophora wislouchii* (x1700).

Genus ***Stauroneis*** **Ehrenberg** (Fig. 61)

Description: Valves lanceolate to elliptical-lanceolate with rounded to capitate ends. Valve face flat. Striae finely punctate, parallel to sometimes slightly radial. Axial area narrow to broad, central area extending to margins to form a distinctive narrow-transverse to acute-angled stauros. Valve margin may be thickened at the ends to form a psuedosepta.

Common species: *Stauroneis anceps* Ehrenberg

Remarks: *Stauroneis* is an exclusively freshwater genus found in a range of water types. It is often found in the epipelon, but may also exist in aerophilous habitats. The genus can be easily identified by LM by the presence of the stauros and the flat valve face.

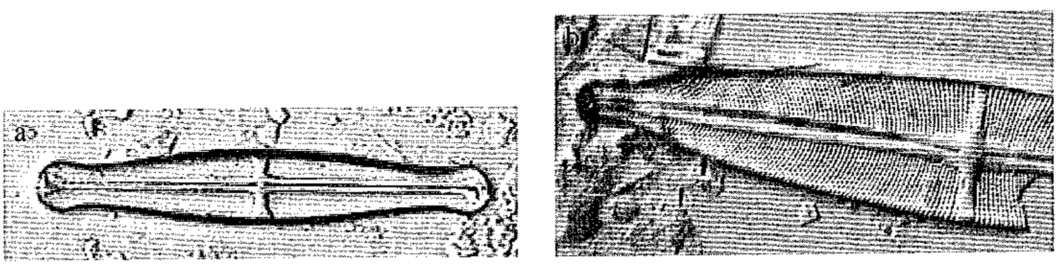


Fig. 61. (a) *Stauroneis* cf. *kriegerii* Patrick (x2500); (b) *Stauroneis anceps* (x1250).

56a. One valve with craticulum, usually with parallel striae extending to axial area .... ***Craticula***
56b. Valve appearing otherwise **57**

Genus *Craticula* Grunow (Fig. 62)

Description: Valves lanceolate with rostrate to capitate ends. Striae finely punctate and strictly parallel. Punctae are generally aligned longitudinally so that they often appear as longitudinal lines. Axial area straight and narrow, central area absent or small and ovoid.

Common species: *Craticula accomoda* (Hustedt) Mann
Craticula cuspidata (Kützing) Mann
Craticula halophila (Grunow ex Van Heurck) Mann

Remarks: *Craticula* was recently split from *Navicula* on the basis of an internal siliceous structure, the craticulum (not always evident). The parallel striae and small central area are often useful surrogate characters. *Craticula* may be found in brackish to freshwater, and is mainly found in the epipelon.

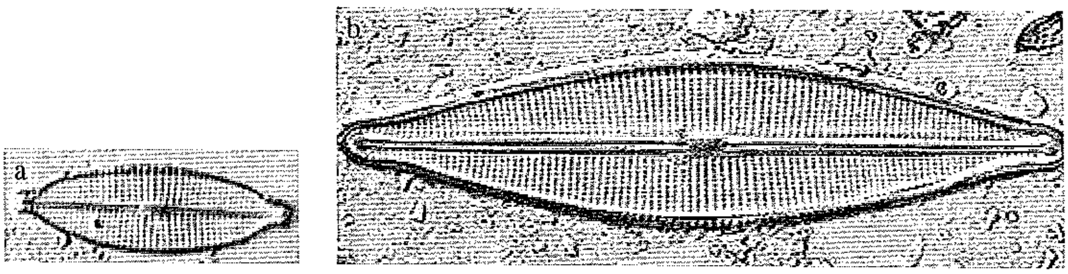


Fig. 62. (a) *Craticula accomoda* (x1400); (b) *Craticula cuspidata* (x1500).

57a. Valve apices hyaline, extending to valve margin .... ***Sellaphora***
57b. Valve appearing otherwise **58**

Genus **Sellaphora Mereschkowsky** (Fig. 63)

Description: Cells generally small (10-80μm length), valves linear to lanceolate, elliptical, with broadly rounded to sub-capitate ends. Striae finely areolate, either parallel or radial from the centre. Axial area narrow, central area round, elliptic to rectangular. Terminal thickenings occur at the ends in some species.

Common species: *Sellaphora minima* (Grunow in Van Heurck) Mann
Sellaphora pupula (Kützing) Mereschkowsky
Sellaphora seminulum (Grunow) Mann

Remarks: *Sellaphora* has recently been separated from *Navicula* on the basis of plastid, areola and raphe, features which are not usually resolveable under LM, making correct identification of this genus difficult. Apart from the small size of most *Sellaphora* species, one useful characteristic that is present in many of the common species, is the presence of the terminal thickenings, which appear as an abrupt end to the striae before the terminal fissures. The saprophilous taxa *S. minima* and *S. seminulum* are now included within this genus.

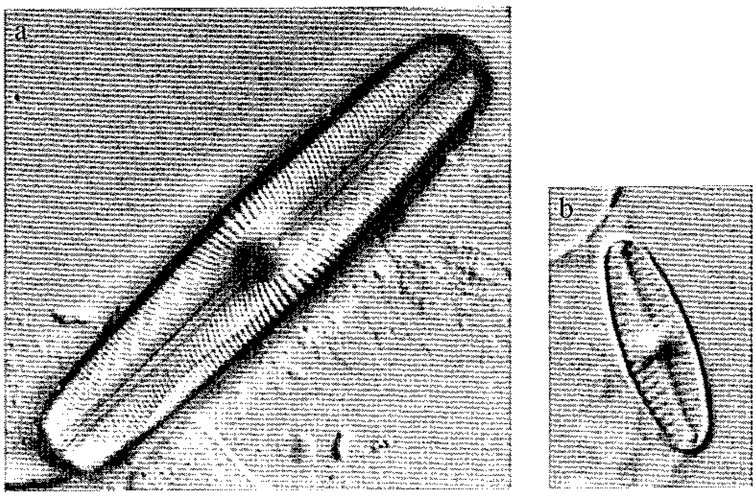


Fig. 63. (a) *Sellaphora bacillum* (x1500); (b) *Sellaphora seminulum* (x1500).

58a. Striae alveolate .... ***Pinnularia & Caloneis* (part)**
58b. Striae not alveolate .... ***Navicula***

Genus *Navicula* **Bory de St.-Vincent** (Fig. 64)

Description: Valves linear to lanceolate, with blunt-rounded to capitate or rostrate ends. Striae consisting of linear or rounded punctae, often forming longitudinal lines (curved or straight) along the central axis of the valve. Striae may be parallel or radially orientated, convergent or divergent at the ends. The axial area is thickened, often more so on one side (occasionally causing the raphe to look slightly curved). The structure of the central area can be extremely variable. It may be absent, rounded or noticeably one-sided. Cells may occur solitary or as colonies within mucilaginous tubes.

Common species: *Navicula atomus* (Kützing) Grunow
Navicula cryptocephala Kützing
Navicula elegans W. Smith
Navicula elginensis (Gregory) Ralfs
Navicula erifugia Lange-Bertalot
Navicula gregaria Donkin
Navicula incertata Lange-Bertalot
Navicula radiosa Kützing
Navicula schroeterii Meister
Navicula veneta Kützing
Navicula viridula (Kützing) Ehrenberg

Remarks: *Navicula* is an enormously diverse genus, morphologically and ecologically. Over twenty species of the genus may be identified from any one sample. Features such as valve size and shape, striae density, size and shape of the central area and the form of the ends are used to differentiate hundreds of species. There have been several recent attempts to divide the genus (for example, Round *et al.* 1990) into smaller genera (see *Luticola, Sellaphora, Fallacia* in this guide), but it is evident from the large suite of species remaining that further revision of this group is required. *Navicula* is one of the most common diatom genera encountered in benthic algal communties. Several small forms such as *N. incertata* and *N. salinicola* Hustedt are principally saline, benthic forms whereas others such as *N. angusta* Grunow inhabit less saline conditions. There is also a suite of small *Navicula* species (eg. *N. atomus* and *N. subminuscula*) that are characteristically found in eutrophic, organically polluted waters. This genus will be dealt with in greater detail in a subsequent key.

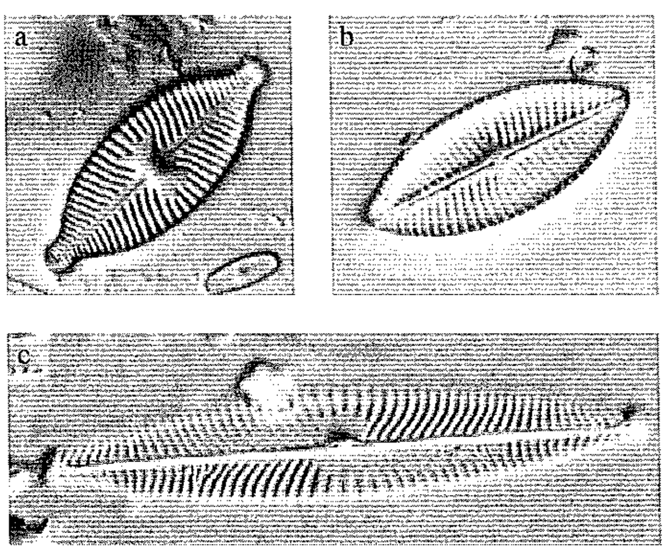


Fig. 64. (a) *Navicula elginensis* (x950); (b) *Navicula* sp. (x1500); (c) *Navicula viridula* (x720).

GLOSSARY

Araphid - term used to describe pennate diatom taxa lacking a raphe.
Areola - an alternative term for puncta; usually used to refer to larger pore-like structures.
Aerophilous - able to live in marginal aquatic environments, for example, on moist surfaces or in the soil.
Bristle/Seta - needle-like spines projecting from the body of the diatom frustule.
Centric - informal term referring to diatom taxa that exhibit radial symmetry in valve view (Class: Coscinodiscophyceae).
Copulae - see 'Girdle".
Costae - thickened internal ribs, usually visible under LM.
Dorsiventral - term used to describe pennate valves that are asymmetrical about the apical axis (eg *Eunotia, Cymbella, Encyonema, Reimeria, Amphora, Epithemia, Rhopalodia*).
Dorsal side - the most convex side of the valve for valves described as 'dorsiventral'.
Fibula - struts that link the outer margins of the raphe canal in genera such as *Nitzschia, Hantzschia* and *Bacillaria.*
Frustule - collective term to describe the siliceous components of the diatom cell wall (hypovalve, epivalve, girdle bands).
Girdle - a series of siliceous bands that link the epi- and hypovalves of the frustule. Girdle bands are added as the individual cell grows, causing the volume of the cell to increase in a single plane.
Heteropolar - term used to describe pennate valves that are asymmetrical about the transapical axis. That is, with differently shaped poles (eg. *Gomphonema, Asterionella, Meridion, Rhoicosphenia*).
Head end - the broader of the two poles in a heteropolar valve.
Foot end - the narrower of the two poles in a heteropolar valve.
Fultoportulae - short tube-like structures extending internally and externally from the valve face. found in several centric genera.
Intercalary bands - see 'girdle'.
Isopolar - term used to describe pennate valves that are symmetrical to the apical axis.
Mantle - the portion of the valve extending away from the valve face to form a 'skirt' that meets the girdle bands.
Ocelli - a clearly defined circular to elliptical area, usually near the valve margin covered by distinctly smaller pores (termed 'porelli'). Often seen as smooth in LM (cf. *Pleurosira*).
Pennate - informal term referring to diatom taxa that exhibit a form of symmetry other than radial (usually bilateral).
Pseudoraphe - a clear area forming a longitudinal line along the apical axis in the absence of a true raphe.
Puncta - small pore-like structures on the valve face, usually extending to the mantle; frequently arranged in lines (striae - see below) across the valve face.
Raphe - a slit-like structure that runs for a varying distance more or less along the apical axis of the valves of several diatom groups. It is believed to facilitate the movement of diatom cells through the secretion of mucilage.
Septum - an internal plate extending from the girdle into the interior of the valve.
Sternum - a thickened and sometimes raised area running along the apical axis of pennate valves.
Striae - lines formed by the linear arrangement of punctae across the valve
Sulcus - furrow (indentation) running around the valve margin of several species of *Aulacoseira.*
Valve - the upper (epivalve) or lower (hypovalve) portion of the diatom frustule excluding the girdle bands.
Ventral side - the least convex of the valve for valves described as 'dorsiventral'. May be concave, straight or convex (but always less convex than the dorsal side).

ACKNOWLEDGEMENTS

The first Australian Diatom Taxonomic Workshop was held at Warrnambool in February 1997 with the aim of bringing together a number of diatomists working alone or in small groups in laboratories around south-eastern Australia. It was quickly recognised that the uptake of diatoms as ecological indicators in Australia was hindered by taxonomic difficulties and lack of research support. As such, the theme of subsequent workshops has been to facilitate the adoption of diatom research by developing a simplified taxonomy for adoption by schools, universities and industry.

The generic key is the product of the deliberations of participants at the 4^{th} Australian Diatom Workshop in Adelaide in July 1998. Here, a consensus-moderated working key to the genera was generated, reinforced by the principal taxonomic texts used universally. It is therefore, hopefully, a functional key that will be useful in the laboratory.

The authors of this document acknowledge the contribution of colleagues Nina Bate, Jennie Fluin, Peter Newall and John Tibby. We would also like to thank all of the participants at the Australian Diatom Workshops for contributing to our better understanding of Australian diatom floras. In particular we would like to thank, Peter Tyler for the use of his image capturing equipment, Deakin University, The University of Adelaide, Monash University/CRC for Freshwater Ecology, La Trobe University, Environment Protection Authority and Murray Darling Freshwater Research Centre/CRC for Freshwater Ecology for their support.

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APPENDIX I

DRAFT PROTOCOL FOR SAMPLING AND LABORATORY PROCESSING OF DIATOMS FOR THE MONITORING AND ASSESSMENT OF STREAMS

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Introduction

This protocol provides a set of standard methods for the sampling of diatoms for bioassessment and biomonitoring of streams. The methods described here are those used in the collection of several large data sets across south-eastern Australia (Chessman unpublished data, Gell unpublished data, Newall unpublished data, Sonneman unpublished data), covering several hundred sites.

It is anticipated that most or all of these data sets will be combined and form the basis of a national diatom data base. Consequently, researchers using this protocol will be able to compare their results with the national data base and its accompanying environmental data. Similarly, gathering diatom data using this protocol will enable that data to be added to the data base.

Diatom samples for the data bases have generally focussed on natural substrates, wherever available. Future additions to the data base may include artificial substrates.

The Protocol

Substrate selection

Wherever possible, two samples should be taken:

i) **hard surface**
ii) **mud/detritus**

Hard surface samples are expected to be the most consistently collected, are faster to analyse and less likely to be contaminated with dead cells than the mud/detritus samples. It is anticipated that hard surface samples will be the most readily used in the development of transfer functions and in general site assessment. Therefore, if it is at all possible to get a hard substrate sample, it is important to do so.

Hard Surface Samples:

The most preferable substrate is a rock that is big enough to have remained stable under most flows, yet small enough to be picked out of the water (eg approx 10-30 cm diameter). The key will be to "make do" where the preferred situation doesn't exist. So, if there are not the right sized rocks, use larger or smaller ones. If there are no rocks, then the preferred substrates are logs, other woody debris, and macrophytes (in that order). The type of substrate used should be recorded.

Wherever possible, these samples should be from riffle or run sections of the streams. It is preferable to sample near the middle of the stream. The sample should be a composite of scrapings from three rocks (or logs, etc) at the site, with each individual substrate being at least 1 metre apart from the others being sampled.

Diatoms are collected from the hard surface by scraping with a blade (eg from a pocket knife) or from a stick, such as a sharpened ice-cream stick. When a pocket knife is used, it must be thoroughly washed between sites. When sharpened ice-cream sticks are used, a new one should be used for each site.

It is important to scrape from an area of the rock that was exposed to light when it was in the stream (ie. the top or side of the rock). Also, it is preferable to scrape an area that does not have other growths (such as moss, lichen, or filamentous algae). Sometimes the options may be limited and a compromise will be needed on some of these preferences. If there is some detritus on the rock (or other substrate), the sample may actually be part "soft surface" community as well as "hard surface" community. To avoid this contamination of the hard surface sample, ***please shake any hard surfaces (under the water) prior to sampling***. For consistency, a vigorous shake for 3 seconds is recommended.

It is preferable (if possible) to sample from approximately 15 cm depth. This measure is also selected purely for maintaining consistency. ***If the substrate near the middle of the stream is deeper than this, then deeper is fine***. Two exceptions:

1. If the substrate is too deep to sample near the middle, then sample where practical
2. If the water is too turbid to see the bottom of the stream in the middle, then keep to the 15 cm rule.

If the stream has no riffles or runs then slow-flowing sections are all that can be sampled. If there are no hard substrates, then there cannot be a hard substrate sample.

Mud/Detritus Samples:

Wherever possible these should be from the edge of a pool or a protected area (such as behind a large rock or log). The sample may be collected either by dipping a tea-spoon into the detritus layer or by using a pipette. When using a pipette, the sample is simply taken by pressing the bulb of the pipette, then gradually releasing it whilst dragging the nozzle over the surface of the detritus. This should be done at three locations in the stream reach. These three locations may be all within one metre of each other, or they may be on opposite sides of the stream - depending on what is available. If a tea-spoon is used, it should be washed thoroughly between sites. When pipettes are used, a new pipette should be used for each site (plastic disposable pipettes are ideal for this).

The preferred depth of sampling is 5 cm - again this is just for consistency and more shallow is preferable to going deeper.

Two important points to keep in mind when selecting sample points:

1. The soft substrate sampling should be done at a point in the stream that has been inundated for several weeks. In streams where the water depth fluctuates considerably, it is better to sample a little deeper if this means that the sample point is more likely to have been inundated for the required length of time.
2. Although quiet sections of the stream may offer the most suitable habitat for detritus accumulation, diatom assemblages from areas that do not have substantial movement of water over them may reflect the internal nutrient dynamics of that area rather than the water quality of the stream. Therefore isolated pools or backwaters without significant streamflow should not be sampled as stream assessment sites.

As for the hard surface samples, if there is not a suitable place to sample, then there cannot be a sample from that site.

Warnings

1. Diatoms are often sampled as part of a larger biological monitoring program. When macroinvertebrates are also being sampled, this can disturb large areas of the stream site. It is important to collect the diatom samples from undisturbed areas. Because diatom sampling requires only three rocks (or other substrate types) and three sheltered areas it is best to sample the diatoms prior to the invertebrate sampling. Otherwise collect the diatom samples upstream of the macroinvertbrate samples.
2. There is currently some debate as to the best method of preservation of the diatoms and whether the frustules dissolve in the various preservatives. Preservatives most commonly used are ethanol (approx 70%) and lugols iodine solution. Regardless of which preservative is used, it is best to process the samples as soon os possible after collection to minimise the risk of dissolution

Laboratory processing of samples

Processing of diatom samples involves three basic steps:

1. concentration of the periphyton from the sample*
2. clearing of organic matter from the diatom frustules, to enable a clear view of the patterns and features of each diatom for taxonomic purposes; and
3. mounting of the cleared diatoms for microscopic examination

1. Wash the sample into a beaker using distilled water. This is then allowed to settle allowing at least one hour for each centimetre of water depth in the beaker. After settling, the supernatant must be removed, leaving the sedimented diatoms (and other particulates). The sediment is then washed into a test tube, and again allowed to settle for at least one hour per centimetre of water depth in the test tube. For neither of the settling periods should the diatoms be left longer than a day. This is to ensure minimum dissolution of the silica from the frustules.

   At this stage, a scan of the material on a light microscope should be undertaken, and a record made of the approximate percentages of the most common taxa. a note should be made of the numbers of each taxa with organelles (ie. alive at the time of sampling) versus those without organelles. The results of this scan should be compared with the the count of the cleared frustules.

2. Clearing of the frustules requires the removal of the supernatant from the test tube after the diatoms have settled, the addition of hydrogen peroxide to the sediment in the test tube, and the placement of the test tube in a water bath at approximately 60-80°C. Two hours is quoted as the usual amount of time required for the removal of the organic matter from the frustules, although it may in fact take more than a day.

   When clearing the frustules, it is important to keep watch on the test tubes in the water bath, especially for the first half hour. This is because reaction of the hydrogen peroxide on the organic matter may be vigorous, and the mixture may overflow. If the mixture does appear to be about to overflow, the test tube should be removed from the water bath, and the water bath set at a lower temperature for the clearing process. Clearing is complete when effervescence ceases.

Following clearing, the material is again allowed to settle. The supernatant hydrogen peroxide is removed, and the sediment is resuspended in high grade ethanol. This process should be repeated twice, and after the final rinse in ethanol, the sediment can be stored in a vial, ready for mounting

3. Mounting of the cleared diatoms requires the use of a hotplate, warmed to approximately 50°C. Microscope slides and cover slips should be warmed on the hot plate prior to mounting. It is easiest to label the microscope slide prior to mounting, using a small adhesive label, with the site, replicate number, and date of sample. The slides should be placed on the hot plate with label side down.

   When the cover slips have warmed, shake the vial containing the diatoms and ethanol, and use a pipette to place a drop of mixture onto the cover slips. Repeat if necessary (experience will tell you if it is necessary). The aim is to achieve a sufficient number of cleared frustules on the slide, without having them so abundant as to make counting difficult. When the alcohol has evaporated, place a drop of naphrax onto the cover slip and then lower the microscope slide (still with the label side down) above the coverslip, until the surface tension of the naphrax joins the two. Place the slide on the hot plate (this time with the label side up) and allow to dry for a couple of days. Once the naphrax has dried, seal the outside edge of the cover slip by painting the edge with nail polish (this prevents moisture from getting into the mount).

   * Detachment of the diatoms from the substrate is necessary prior to concentration of the sample if the substrate was collected and taken back to the laboratory. This is usually accomplished by scrubbing the substrata with a toothbrush into a petri dish. In our sampling protocol (Chessman, Gell, Newall and Sonneman 1998) we recommend detachment in the field (using a blade or sharpened ice-cream stick), during sampling.

APPENDIX II

FURTHER INFORMATION

Useful Websites

The authors of this key have been working to establish a website entitled "The Australian Diatom Home Page" which is intended to facilitate the use of diatoms by industry and students. At present, this and three others keys have been placed on this site. It will also become the base for a diatom iconograph of common species. Another site based at the University of Adelaide provides background information on the use of diatoms, their preparation and a short video and national protocol on their collection. Some useful diatom websites are:

Australian Diatom Home Page	http://www.geography.monash.edu.au/~diatoms/index.html
University of Adelaide	http://chomsky.arts.adelaide.edu.au/Geography/gell.htm
Diatom Home Page (Indiana)	http://www.indiana.edu/~diatom/diatom.html#14nads
UCL website (DIATCODE)	http://www.geog.ucl.ac.uk/~pmalipha/checklis.html

APPENDIX III

A GUIDE TO THE TERMS USED TO DESCRIBE ECOLOGICAL TOLERANCES OF DIATOMS

pH classification system (Hustedt 1937-39)

- Alkalibiontic - occurring at pH greater than 7.0.
- Alkaliphilous - occurring at pH around 7.0 with widest distribution at pH greater than 7.0.
- Circumneutral - occurring equally at pH around 7.0.
- Acidophilous - occurring at pH around 7.0 with widest distribution at pH less than 7.0.
- Acidobiontic - occurring at pH less than 7.0.

Salinity system (Van Dam *et al.* 1994)

- Fresh - salinity less than 0.2 %
- Fresh brackish - salinity less than 0.9 %
- Brackish fresh - salinity between 0.9- 1.8 %
- Brackish - salinity between 1.8 - 9.0 %

Trophic system (US EPA, Office of Water, URL: http://www.epa.gov/owowwtr1/305b)

- Oligotrophic - Clear waters with little organic matter or sediment and minimum biological activity.
- Mesotrophic - Waters with more nutrients and, therefore, more biological productivity.
- Eutrophic - Waters extremely rich in nutrients, with high biological productivity. Some species may be choked out.
- Hypereutrophic - Murky, highly productive waters, closest to the wetlands status. Many clearwater species cannot survive.
- Dystrophic - Low in nutrients, highly colored with dissolved humic organic matter. (Not necessarily a part of the natural trophic progression.).