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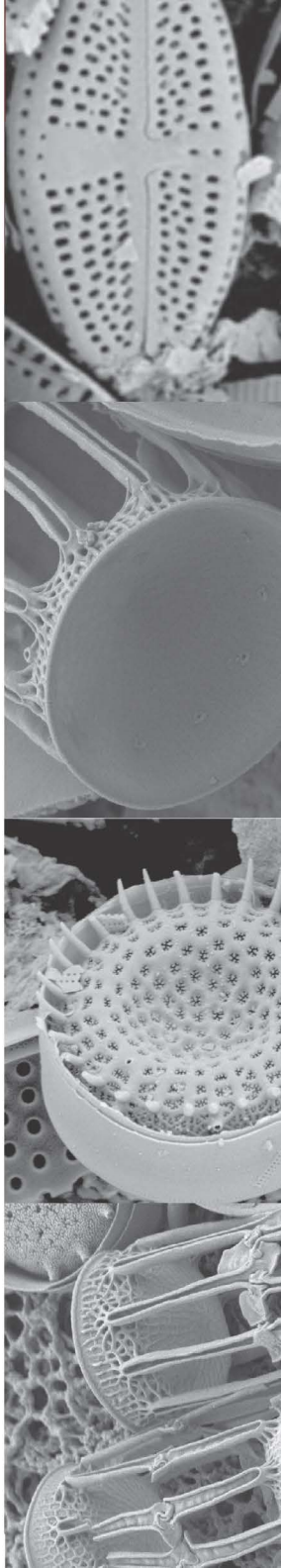
A key to the identification of the species

Gdańsk University Press



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Contents

Introduction

Diatoms are the most widespread group of algae on our planet. They occur in nearly all habitats on Earth. Nevertheless, high environmental selectivity is observed, as manifested in the occurrence of specific species in specific habitats, hence the important role of diatoms as ecological indicators. One of the main ecological conditions to which diatoms are highly sensitive is salinity. This parameter determines the species composition of diatoms occurring in the marine environment, where a significant predominance of centric species is generally observed. However, the brackish waters of the Baltic Sea, including the Gulf of Gdańsk, are dominated by euryhaline species characterized by a wide ecological spectrum in terms of salinity (Kolbe 1927, Hustedt 1953, Simonsen 1962, Ziemann 1971, 1982). Therefore, among the diatoms inhabiting the waters of the southern Baltic Sea, there are many species commonly found in lakes and rivers. For this reason, the presented handbook is not only addressed to those interested in Baltic diatoms, but can also be a good source of knowledge and a useful key in research on algal flora of many coastal and freshwater habitats.

This handbook presents a list of diatom species recorded in the waters of the southern Baltic, the Gulf of Gdańsk and Puck Bay (Namysłowski 1924, Schulz 1926, Rumek 1948, Biernacka 1967, 1968, 1970, Pliński 1975, 1979, Pankow 1976, 1990, Witkowski 1991a, 1991b, 1993, 1994, Witkowski & Lange-Bertalot 1993, 2004, 2004, Witkowski et al. 2000, Dziengo 2003, Łotocka 2006, Li et al. 2018) and in offshore, brackish-water reservoirs, such as the Vistula and Szczecin Lagoons (Brockmann 1954, Szarejko-Łukaszewicz 1957, Zembrzuska 1979, Pliński 1979, Bąk et al. 2004). The list includes plankton species, as well as epilithic and epiphytic forms and those loosely associated with microphytobenthos. Species occurring in other Baltic regions (Hällfors 2004) and those potentially present in the southern Baltic waters have also been considered. The editorial scheme used in this book is typical for this type of publication and consists of two parts – the first being more general and the second one more detailed. Apart from the introduction, the first part presents the purpose of the book, as a short historical overview of the taxonomy of diatoms with a glossary of professional terms used throughout the book (Anonymous 1975, Ross et al. 1979, Round et al. 1990, https://diatoms.org/glossary). The detailed part is written in the form of identification keys for individual taxonomic units, starting from the most

general ones, i.e. classes, through orders, families, genera and finally species. All essential diagnostic characters are included in the keys relevant to a given taxonomic level, while the identification key for species provides data on size measurements for specific species. The most important part of this handbook is the tables with drawings and images of species. Some drawings come from historical sources as well as from the latest taxonomic publications on diatoms (e.g. Li et al. 2018). The work is provided with original photographs of selected taxa from samples collected in the Gulf of Gdańsk and adjacent regions of the Baltic Sea. We thus present our readers with a modern key enabling the identification of these diatoms.

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Classification of diatoms

Biologists have been interested in diatoms ever since it was possible to analyse life under a microscope due to the characteristic shape of their siliceous frustules. The oldest diatom classification systems were based on the shape of cells and the form of colony formation; the number of chloroplasts and their shape were also taken into account (Agardh 1830–32, Kützing 1834, Rabenhorst 1853, W. Smith 1853–56, Ehrenberg 1854: after Siemińska 1964). Some of these characters, however, are very variable and depend on the environmental conditions of the habitat in which diatoms live, while others depend on their cell cycle stage. More detailed research on the morphology of frustules showed that the specificity of the structure and ultrastructure of frustules is very diverse and reproducible, especially in terms of their ornamentation. The structure and ultrastructure of frustules was used in the development of classification systems by later researchers (Kützing 1844, Grunow 1860, van Heurck 1896, Schütt 1896, Hustedt 1930, 1962, Siemińska 1964, Hustedt 1953, Cleve-Euler 1951-1953, Simonsen 1979, Krammer and Lange-Bertalot 1986, 1988, 1991a, b, Round et al. 1990). Schütt (1896) was the first to distinguish the two main groups, namely centric and pennate diatoms based on a detailed analysis of principles of symmetry of frustules. Hustedt based his classification on the principles observed by Schütt. Hustedt claimed that his system is a natural classification, because phylogenetically centric diatoms are older than pennate diatoms and are the oldest fossil diatoms found in the geological record.

In recent years, Hustedt's system has been thoroughly revised due to new data on the ultrastructure of frustules obtained from observations carried out using electron microscopy (Simonsen 1979, Krammer and Lange-Bertalot 1986–1991, Round et al. 1990, Stoermer and Julius 2003). The discovery of many new details in the ultrastructure of frustules prompted the need for a different interpretation of the relationships between specific taxa of higher rank. Three classes are currently distinguished in the division of Bacillariophyta diatoms: Coscinodiscophyceae, Fragilariophyceae and Bacillariophyceae (Round et al. 1990). Following the taxonomic concepts mentioned above, the taxonomic system for the genera included in this book is presented below. The system presented here is mainly based on the classification proposed by Round et al. (1990) with further modifications published in later works (i.e. Stoermer and Julius

2003, Kaczmarska et al. 2006, Hofmann, Werum and Lange-Bertalot 2011, Li et al. 2018):

- Class: Coscinodiscophyceae
  - Subclass: Thalassiosirophycidae
    - Order: Thalassiosirales
      - Family: Thalassiosiraceae
        - Genus: Thalassiosira
      - Family: Skeletonemataceae
        - Genus: Skeletonema, Detonula
      - Family: Stephanodiscaceae
        - Genus: Cyclotella, Cyclostephanos, Stephanodiscus
      - Family: Lauderiaceae
        - Genus: Lauderia, Porosira
    - Order Melosirales
      - Family: Melosiraceae
        - Genus: Melosira
      - Family: Hyalodiscaceae
        - Genus: Hyalodiscus, Podosira
    - Order: Paraliales
      - Family: Paraliaceae
        - Genus: Ehrenbergiulva, Ellerbeckia, Paralia
    - Order: Aulacoseirales
      - Family: Aulacoseiraceae
        - Genus: Aulacoseira
    - Order: Orthoseirales
      - Family: Orthoseiraceae
        - Genus: Orthoseira
  - Subclass: Coscinodiscophycidae
    - Order: Coscinodiscales
      - Family: Coscinodiscaceae
        - Genus: Coscinodiscus, Stellarima
      - Family: Hemidiscaceae
        - Genus: Actinocyclus
      - Family: Aulacodiscaceae
        - Genus: Aulacodiscus
      - Family: Heliopeltaceae
        - Genus: Actinoptychus
  - Sublass: Biddulphiophycidae
    - Order: Triceratiales
      - Family: Triceratiaceae
        - Genus: Triceratium, Odontella, Pleurosira

Order: Biddulphiales
Family: Biddulphiaceae
Genus: Biddulphia, Terpsinoë
Order: Hemiaulales
Family: Hemiaulaceae
Genus: Cerataulina
Subclass: Lithodesmiophycidae
Order: Lithodesmiales
Family: Lithodesmiaceae
Genus: Ditylum
Subclass: Rhizosoleniophycidae
Order: Rhizosoleniales
Family: Rhizosoleniaceae
Genus: Rhizosolenia, Guinardia, Dactyliosolen, Pseudosolenia, Proboscia, Urosolenia
Subclass: Chaetocerotophycidae
Order: Chaetocerotales
Family: Chaetoceraceae
Genus: Chaetoceros
Family: Acanthocerataceae
Genus: Acanthoceros
Family: Attheyaceae
Genus: Attheya
Order: Leptocylindrales
Family: Leptocylindraceae
Genus: Leptocylindrus
Class: Fragilariophyceae
Subclass: Fragilariophycidae
Order: Fragilariales
Family: Fragilariaceae
Genus: Meridion, Opephora, Neosynedra, Staurosira, Fragilariforma, Diatoma, Ctenophora, Fragilaria, Staurosirella, Ulnaria, Asterionella, Pseudostaurosiropsis, Tabularia, Synedra, Pseudostaurosira, Plagiostriata
Order: Tabellariales
Family: Tabellariaceae
Genus: Tetracyclus, Tabellaria
Order: Licmophorales
Family: Licmophoraceae
Genus: Licmophora

Order: Thalassionematales
Family: Thalassionemataceae
Genus: Thalassionema
Order: Rhabdonematales
Family: Rhabdonemataceae
Genus: Rhabdonema
Order: Striatellales
Family: Striatellaceae
Genus: Grammatophora

Class: Bacillariophyceae
Subclass: Eunotiophycidae
Order: Eunotiales
Family: Eunotiaceae
Genus: Eunotia
Subclass: Bacillariophycidae
Order: Achnanthales
Family: Achnanthaceae
Genus: Achnanthes
Family: Achnanthidiaceae
Genus: Achnanthidium, Eucocconeis, Astartiella, Karayevia, Lemnicola, Planothidium, Psammothidium, Rossithidium, Pauliella
Family: Cocconeidaceae
Genus: Anorthoneis, Cocconeis
Order: Lyrellales
Family: Lyrellaceae
Genus: Lyrella, Petroneis
Order: Mastogloiales
Family: Mastogloiaceae
Genus: Mastogloia, Aneumastus
Order: Cymbellales
Family: Rhoicospheniaceae
Genus: Rhoicosphenia, Gomphonemopsis
Family: Anomoeoneidaceae
Genus: Anomoeoneis, Staurophora
Family: Cymbellaceae
Genus: Placoneis, Brebissonia, Cymbopleura, Cymbella, Encyonema, Encyonopsis, Navicymbula
Family: Gomphonemataceae
Genus: Gomphonema, Gomphoneis, Reimeria

Order: Naviculales
Suborder: Neidineae
Family: Berkeleyaceae
Genus: Berkeleya, Lunella, Dickieia, Parlibellus
Family: Amphipleuraceae
Genus: Amphipleura, Frustulia
Family: Diadesmidaceae
Genus: Luticola
Family: Cavinulaceae
Genus: Cavinula
Family: Cosmioneidaceae
Genus: Cosmioneis
Family: Neidiaceae
Genus: Neidium
Suborder: Diploneidineae
Family: Diploneidaceae
Genus: Diploneis
Suborder: Sellaphorineae
Family: Sellaphoraceae
Genus: Sellaphora, Fallacia
Family: Pinnulariaceae
Genus: Pinnularia, Caloneis
Suborder: Naviculineae
Family: Pleurosigmataceae
Genus: Pleurosigma, Gyrosigma
Family: Plagiotropidaceae
Genus: Plagiotropis
Family: Naviculaceae
Genus: Navicula, Haslea, Fogedia, Hippodonta, Fistulifera, Amicula, Pinnunavis, Geissleria, Mayamaea, Adalfia, Chamaepinnularia, Eolimna, Biremis, Stauronella
Family: Stauroneidaceae
Genus: Stauroneis, Craticula
Family: Proschkiniaceae
Genus: Proschkinia
Order: Thalassiophysales
Family: Catenulaceae
Genus: Catenula, Amphora
Order: Rhopalodiales
Family: Rhopalodiaceae
Genus: Denticula, Epithemia, Rhopalodia

Order: Bacillariales
- Family: Bacillariaceae
  - Genus: Cylindrotheca, Bacillaria, Hantzschia, Nitzschia, Tryblionella

Order: Surirellales
- Family: Entomoneidaceae
  - Genus: Entomoneis
- Family: Surirellaceae
  - Genus: Campylodiscus, Stenopterobia, Cymatopleura, Surirella, Petrodictyon

Glossary of terms used in the handbook

alar canals (**portulae**) – tube-shaped connections between the raphe canal and the cell lumen in canal raphe bearing diatoms, e.g. *Surirella* and *Stenopterobia*

alveolae – transapical striae in the form of an elongated chamber with external surface perforated by numerous small areolae and internally open to the cell lumen (cf. species in *Pinnularia*)

aperture – gap between cells in the colonies of the genus *Chaetoceros*; the shape of this gap is one of the important identification characters of species from the genus *Chaetoceros*

apical axis – axis connecting two poles of the valve of pennate diatoms

areola (pl. areolae) **–** arranged in rows, polygonal or circular pores in the siliceous layer of the valve, closed from the inside or outside by a finely ornamented siliceous membrane; a row of areolae forms a transapical stria.

axial area – longitudinal hyaline area in pennate diatoms, developed on both sides of the apical axis; see also raphe sternum

canopeum (also conopeum) – thin, very finely perforated siliceous lamina attached to the raphe sternum, which may completely cover the valve face, known inter alia in species from the genus *Fallacia*

carinoportulae (sing. carinoportula) – connecting elements located on the surface of the valve in some species of the genus *Cyclotella*

central area – middle part of the valve, usually composed of solid silica (without ornamentation)

central nodule – thickening of the valve within the central area in raphid diatoms of varying thickness and range, and separating the proximal raphe ends

cingulum (also called **girdle**) – part of the frustule between the epivalve and hypovalve, composed of a series of siliceous bands so that both valves form

a closed system isolated from the ambient environment; the cingulum consists of copulae (= girdle bands)

collar – ring-like projection located outside the valve at its edge, e.g. in *Melosira nummuloides*

collum – very short (without areolae) distal part of the valve mantle in *Aulacoseira* species

copulae (girdle bands) – elements of the cingulum

cribrum (pl. cribra) – type of areolae occlusion with regularly arranged pores, which can be flat or domed and observed only in electron microscopy. Cribra occur in *Thalassiosira* and *Stephanodiscus.*

fascia – in some pennate forms, a hyaline area of thickened silica extending from the central area. A transverse fascia is formed by secondary deposition of silica into depressions on the valve present in some e.g. *Luticola* species.

fibulae (sing. fibula) – internal siliceous bridges of various shapes, from narrow ribs to flat sheets or more complex structures supporting the raphe bearing canal and extending transapically from the raphe canal to the valve face; present in e.g. *Bacillaria*, *Denticula*, *Hantzschia* and *Nitzschia*; in the older literature referred to as keel puncta

frustule – external part of the cell in diatoms saturated with silica, which consists of two overlapping halves; the outer part is called the epitheca and the inner one – hypotheca; the frustule can be isopolar when both ends are similar or heteropolar, and one end is wider than the other

fultoportulae (sing. fultoportula) – tubular processes on the valve present in Thalassiosiraceae species

girdle view – view of the diatom frustule with the girdle positioned perpendicularly to the observer

horseshoe – U-shaped siliceous thickening present inside the sternum (SV) or raphe (RV) valve in some monoraphid species

hyaline area – part of the valve face without ornamentation, e.g. axial area, central area, lateral area, apical area

hymen – very delicate, finely perforated siliceous membrane occluding the areolae of some pennate diatoms

keel – structural element elevated above the valve surface in e.g. *Nitzschia*, *Surirella*, *Entomoneis* species

labiate process (rimoportula) – tubular or similarly shaped process through the valve in some diatoms, the outer end of which is a simple opening or a short tube extending above the valve surface and the inner end has a structure similar in shape to the human mouth (lips)

lateral area – hyaline area developed in raphid diatoms positioned between the raphe and the valve margin, which is usually parallel to the axial area; frequent in conjunction with the central nodule and the central area in e.g. *Fallacia*, *Fogedia*, *Lyrella*; unilateral in many *Amphora* species

longitudinal canal – apically elongated chamber with a tubular shape, present within the valve centre (*Diploneis*) or along the valve margin (*Neidium*)

lineolae (sing. lineola) – special kind of dash-like areolae, forming transapical striae distinguished only in *Navicula* sensu stricto as typified with *N. tripunctata*.

macrolabiate process – large rimoportula (labiate process) occurring only in some *Coscinodiscus* species

mantle – marginal part of the valve surrounding the valve face, visible in the girdle view, in many cases ornamented differently than the surface of the valve, or is hyaline

ocellus – isolated grouping of small pores on the poles of some centric forms, surrounded by a delicate ring of silica

orbiculus – apical structure on the sternum, devoid of areolae commonly found in sternum valves of *Achnathes* sensu stricto, e.g. *Achnanthes longipes*

partecta (sing. partecum) – ring of chambers on the inside of the valvocopula in *Mastogloia* species, arranged in rows on each side of the valvocopula; "divided into camera" septa present at the valve margin visible in *Mastogloia* species

pervalvar axis – axis of the valve perpendicular to the centre of the valve face

pseudocellus – aggregation of small areolae, which is not distinctly separated from the surrounding valve as is the case with ocellus

pseudonodulus – small structure, usually a depression, circular or irregular, devoid of ornamentation (hyaline area) within the valve surface

pseudosepta (sing. pseudoseptum) – siliceous plates developed internally in the apical part of the valve; part of the valve in e.g. *Gomphonema*, *Cuneolus* and *Stauroneis*

raphe – longitudinal slit within the valve face, usually parallel to the apical axis; exceptions are Enotiophycidae, where raphe is not parallel to the valve margin and occurs on the mantle and valve face, e.g. *Eunotia* species

raphe-sternum – longitudinal, usually thickened and structureless element in valves of raphid diatoms, containing the raphe slit. The raphe-sternum is usually positioned along the apical axis (e.g. *Navicula*), but in *Eunotia* partly along the valve margin and partly along the valve mantle. In some genera, the sternum corresponds to the axial area.

rib – solid, elongated thickening of the valve surface, usually parallel to the transapical striae; Latin = costa (pl. costae)

RV (= raphe valve) – valve with raphe in monoraphid diatoms

septa (sing. septum) – siliceous flaps, straight or repeatedly bent, parallel to the surface of the valve, which develop from the copulae, e.g. *Grammatophora*, *Rhabdonema*

stauros – transverse hyaline thickening in the central area of the valve in *Stauroneis* species

sternum – hyaline thickening in pennate diatoms located in the middle of the valve, positioned along the apical axis; in the older literature the term "pseudoraphe" was used

stigma (pl. stigmata) – opening or perforation through the central area, differing in terms of structure from the striae forming areolae; externally usually of round or oblong shape, whereas internally either slit-like or complex

striae (sing. stria) – the most characteristic element of ornamentation in diatoms, consisting of different types of pores; striae can be perpendicular, radiate, convergent or oblique to the apical axis of a given valve

strutted processes (**fultoportulae**) – in centric diatoms, tubular processes through the valve consisting of the tubular process surrounded by two or more satellite pores. Externally, the fultoportula appears as either a tube or a simple pore in the valve surface (singular = fultoportula).

SV (= sternum valve) – in monoraphid diatoms, a valve without raphe, with sternum

transapical axis – short axis parallel to the surface of the valve face in pennate diatoms, perpendicular to the apical axis.

umbilicus – flat area in the centre of the watch glass-shaped valve present e.g. in *Hyalodiscus.*

valve – either flat or convex siliceous unit constituting the epitheca or hypotheca of a given frustule, which is connected by girdle bands.

valve view – the valve is seen in the "face view" and the valvar plane is positioned perpendicularly to the observer

valvocopula – one of the copulae of a given frustule's girdle, which directly adheres to the valve mantle.

velum (sing. vela) – type of areolae occlusions composed of a porous layer of silica with ultrastructure resolvable only by electron microscopy.

Keys for the identification of the species

Key to the classes:

1. Frustules with centric symmetry. . . . . **Coscinodiscophyceae** (p. 20)
1a. Frustules with bilateral symmetry (pennate) 2
2. Frustules without raphe . . . . . **Fragilariophyceae** (p. 45)
2a. Frustules with raphe . . . . . **Bacillariophyceae** (p. 58)

Class: **Coscinodiscophyceae** Round et Crawford *in* Round et al. 1990

Key to the subclasses:

1. Cells discoid, lenticular or shortly cylindric; valves circular in valve view; the structure of the frustule radial, usually coarse 2
1a. Cell structure differs from the above 3
2. Cells discoid, usually connected into chain-like colonies with one to a few rings of strutted processes (fultoportulae) and with one to a few labiate processes (rimoportulae). . . . . **Thalassiosirophycidae**
2a. Cells usually shortly cylindric, solitary; ornamentation composed of areolae occluded with external cribra; processes without external tubes . . . . . **Coscinodiscophycidae**
3. Cells cylindric, elongate 4
3a. Cells barrel-shaped, valves elliptic or circular to polyangular. 5
4. Cells solitary rectangular in girdle view; valves tri-, rarely bipolar or quadrangular . . . . . **Lithodesmiophycidae**
4a. Cells cylindrical, length a few times longer than width; valves flat, slightly convex or conical in shape . . . . . **Rhizosoleniophycidae**
5. Valves more or less circular, triangular or polyangular, with two to many poles, at each pole present one ocellus or pseudocellus; frustule structure distinct in a form of more or less coarse areolae. . . . . **Biddulphiophycidae**
5a. Valves ellipsoid to circular with 1–2 or numerous long setae . . . . . **Chaetocerotophycidae**

This handbook presents a concise list of diatom species recorded in the waters of the southern Baltic, the Gulf of Gdańsk, the Puck coastline and in offshore brackish-water systems, such as the Vistula and Szczecin Lagoons. Importantly this work includes a well set out key for ease of their identification. This will provide a very useful baseline for future comparisons of changing environmental conditions in this region of the world.

The key is set out in an unambiguous structure for each genus that has been encountered in the material and as such is an important contribution to the advancement of our knowledge of diatoms in general. It is also backed up with a glossary of terms which clarifies the detail of taxonomic attributes. The experienced authors have demonstrated and shared their fundamental knowledge of this group of diatoms in a most presentable manner in this handbook.

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