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THE DIATOMS (BACILLARIOIDEAE) OF NEBRASKA

BY

CLARENCE J. ELMORE

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE COLLEGE IN THE UNIVERSITY OF NEBRASKA IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY, DEPARTMENTS OF GEOLOGY AND BOTANY

Lincoln, Nebraska

1921

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THE DIATOMS (BACILLARIOIDEAE) OF NEBRASKA

BY CLARENCE J. ELMORE

OCCURRENCE

Diatoms are found practically in all places where there is water—in lakes, rivers, creeks, ponds, tubs, troughs, tanks; and on damp ground, rocks, walls, or boards. All water, from the ocean to the smallest puddle caused by the tracks of cattle's feet, provided the puddles persist for a few days, is almost certain to contain diatoms. When unmixed with other substances they present a brownish color. Often the entire bottom of a stream may be covered to a thickness of an inch or more with a brown mass of diatoms. But the greater number occur mixed with other algae, in which case their brown color is hidden by the green of the algae.

Diatoms are also found in the fossil state. In this condition they are called Diatomite by geologists, or Kieselguhr in commerce. The name Infusorial Earth has also been applied to them, but this is incorrect, for diatoms are not Infusoria.

Diatoms differ from other plants in that their cell walls are thoroughly infiltrated with silica, or quartz of the opal variety. The form of the cell is often likened to a pill box or a telescope, one-half fitting over the other. The statement made in practically all of the textbooks is that when a cell divides the two valves, ends of the cell, separate slightly and a new valve grows inside of each, thus forming two new cells. Thus each new cell has one of the original valves of the mother cell and a new valve formed inside of the girdle of the old one. Hence it would appear that one of the new cells is the exact size of the mother cell and the other slightly smaller, the reduction in size going on with each cell division. This process continues until a certain minimum size is reached, when an auxospore is formed. The necessity for auxospore formation arises from the fact that the cell walls of diatoms are silicified and so can not grow, together with the fact that they become smaller with each division.

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The simplest manner of auxospore formation is by the protoplasmic contents of a cell escaping from its siliceous shell and growing to the normal size for the species and then secreting a new shell about itself. Or in some cases two cells are formed in this way from a single mother cell. Another method is for the contents of two cells to escape and conjugate, forming in some cases one, and in other cases two, auxospores.

Since diatoms multiply with great rapidity, the diminution in size ought to require the very frequent formation of auxospores. But the actual condition is that they are of comparatively rare occurrence. The discrepancy arises from the fact that the foregoing description of a diatom is only partly true. In some cases the girdle of the old valve inside of which the new valve is formed enlarges so that the new valve is as large as, or larger than, the old one. In *Lysigonium* (*Melosira*), a genus in which the cells adhere together, long filaments are formed which are practically uniform in size. Otto Müller, *Die Zellhaut und das Gesetz der Zellteilungs folge von Meloseira arenaria Moore,* has shown that in this species the girdle is enlarged according to a regular law, so that the minimum size is very seldom reached. And according to this law only one auxospore is formed, where, if the diminution in size took place regularly, 1,052,100,000,000 would be formed. This easily accounts for the infrequent occurrence of auxospores in this species.

In *Fragilaria,* another genus in which the cells adhere in bands, the girdles can be seen meeting, but not overlapping, and in this genus, too, there is no apparent diminution in size of the filaments.

Diatomite, when pure, is a white or grayish substance so light that it floats on water. It is often mixed with other substances. In Nebraska it usually contains more or less calcium carbonate, the amount varying from a slight trace to so much that it becomes a hard limestone with comparatively few diatoms. The deposit from Greeley County, however, is practically pure. In our region, at least, it is not often mixed with other substances than calcium carbonate. Conditions favorable to the growth of diatoms were favorable to the growth of the organisms producing the carbonate, and conditions under which inorganic sediment was formed were

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unfavorable to the growth of diatoms. It is likely, however, that some diatoms were growing when inorganic sediment was being formed, but in the large amount of this sediment they have been overlooked.

COLLECTING AND PRESERVING

Few directions are needed for collecting diatoms. Any vegetable growth in water or in damp places is likely to contain them. All that is necessary is to get the material in any way that is most convenient and to carry it in whatever may be at hand for the purpose.

When it is desired to preserve the protoplasmic contents of diatom cells, they may be placed in formaldehyde or other preservative in the same manner as other algae. For careful cytological work they may be killed in hot mercuric bichloride solution, and then, after washing and dehydrating, mounted in balsam.

The determination of species depends mostly on the siliceous shells and when they are collected for that purpose no preservative need be used. The material containing them may be wrapped in paper and allowed to dry. Diatoms preserved in this way are in no way inferior to those preserved by more careful methods for purposes of identification when it is only the shells that are to be examined.

MOUNTING

The markings on the shells are often very delicate and difficult to see. In many of the smaller species they can not be seen when in their natural condition and mounted in water. They are more easily seen when the protoplasm is removed from the shells. This may be removed by boiling in a test tube in nitric acid. This destroys the cell contents, leaving only the siliceous shells. Water is then added, and after the diatoms have settled it is poured off. This process is repeated until the acid is all removed. A drop of the liquid containing them is placed on a coverglass and allowed to dry.

The method usually used by the writer, however, is to dry a small portion of the material containing the diatoms on a coverglass and to heat until all of the organic material has been burned

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out. By this method they may be prepared much more quickly than by treating with acid. When there is sufficient heat, as with a gas flame, the coverglass may be laid on a flat piece of iron (the writer has used the blade of an old table knife) and held in the flame. When first heated the material turns black. It should be heated until the blackness disappears. If the heat of the flame is not sufficient, as is likely to be the case with an alcohol lamp, it may be increased by the use of a blowpipe. If the coverglass is held on a piece of silver, it will heat much more readily, owing to the greater conductivity of the silver. For this purpose the writer has used an old silver quarter dollar with a hole in it, a wire being fixed in the hole for a handle. In using a blowpipe the flame should be directed on the under side of the metal on which the coverglass is lying and not directly on the coverglass.

Nearly all of the fossil diatoms found in Nebraska are mixed with limestone or some form of calcium carbonate. This must be removed, for there is often so much of it that the diatoms are hidden entirely. This may be done by treating with hydrochloric acid. The method is the same as that for using nitric acid except that it is not necessary to heat it.

When dried on the coverglass they may be mounted in Canada balsam, but the markings are seen much more easily if mounted in styrax.[1]

[1] Styrax can be procured only in the crude state and must be prepared for use. The first step in preparing it is to spread a thin coating of it on a pane of glass or a plate and allow it to dry until all of the water has been removed. It is then dissolved in a mixture of equal parts of benzine and alcohol, or sulphuric ether and absolute alcohol. The solution is then filtered through filter paper. If it is so thick that it will not pass through the filter paper readily, more of the alcohol and ether may be added. After filtering it is ready for use. A quantity may be made up at one time since it will keep indefinitely. A drop of the styrax is placed on the coverglass containing the diatoms. If it becomes opaque at first it must be allowed to stand until it becomes clear. This may require several hours. This clearing may be hastened by heating gently. When cleared it is placed on a slide. The slide should then be heated until the volatile portion of the styrax solution is driven off. This will cause bubbles under the coverglass and the heating should be continued until the bubbles cease to form. When cooled the bubbles will disappear.

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The location of individual diatoms on the slide may be indicated by drawing a circle around each specimen on the coverglass. Sanford's Indelible Stamping ink has been found satisfactory for this purpose. It may be applied with a pen and does not run on the glass. When dry it is not much affected by the oil of an oil immersion objective. If there are several specimens marked on one slide, a diagram of the location of each may be drawn on the label, indicating each species by a number.

RELATIONSHIP

The systematic place of diatoms is a matter about which there has been much disagreement. They were formerly regarded as animals and placed among the Infusoria. They are now universally regarded as plants, but there seems to be no general agreement as to their relationship. The placing them among the Brown Algae was based merely on their color, which is probably only an accidental or perhaps a physiological resemblance and has no systematic significance. That they are a derived and not a primitive group is indicated by the fact that they appeared comparatively late in geological time, none being known earlier than the Devonian. And since their appearance very little change has taken place. It is possible that they have evolved through earlier periods without their siliceous cell walls, and suddenly, as if by mutation, their walls became silicified. Hence all of their earlier history is lost, and at their first appearance in geological time they had reached their present form.

Forms like *Lysigonium* (*Meloseira*) seem closely related to the unsilicified filamentous algae and are probably derived from them. And the round diatoms in which the cells are separate may be considered as the cells of a filament which have become separated.

In the filamentous diatoms that form ribbon-like bands, instead of cylindrical filaments we have the same structure except that the filaments have become flattened. And the single-celled long (flat) diatoms may be considered as the cells of such a filament broken apart.

Whatever views various botanists have as to the relationships of diatoms, they are nearly all agreed that diatoms and desmids are

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closely related. By their mode of forming zygospores, desmids are closely related to the filamentous *Conjugatae, e.g., Spirogyra.* And some diatoms in their formation of auxospores have a form of conjugation very similar to that of desmids. For this reason it seems best to place both diatoms and desmids with the filamentous *Conjugatae* under the phylum *Zygophyceae,* making of the unsilicified groups a separate class and of the siliceous ones a class of equal rank, the *Bacillarioideae.*

THE USE OF THE TERM VARIETY

Diatoms vary so greatly in size and form between one auxospore stage and the next that the early collectors who based their species on size and form alone described as species many conditions that are mere stages in the life history of a single species. The size necessarily decreases with each cell division until an auxospore is formed, except in those genera whose valves do not overlap, because each new valve is formed inside of an old one. If one part of the girdle is thicker than the rest, the new valve formed inside this valve will be slightly constricted at this point; and this constricting process will continue, making the constriction deeper and deeper with each division until the next auxospore stage is reached. If the thickening is at the ends, the valves will grow proportionally shorter with each division. So some species occur in many conditions that have been described as distinct species. The earlier works recognized few varieties, making a separate species for each condition in which a species was found. Later writers have brought together many of these so-called species and called them varieties, or in some cases, forms. But the term variety can scarcely be applied to diatoms. The species of diatoms present the same varieties now that they did in Tertiary times; so if these varieties are thus fixed, they are not varieties, but species. And those that merely represent conditions between two auxospore stages are not entitled to a separate name any more than an oak tree two feet high deserves a name separate from the name given to an older tree of the same species.

It is only by a most thorough and careful study of any species that all of the forms in which it may appear can be determined.

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This work has been done for very few species. Hence the assigning of any form to a place as a species or that of a mere form has been and still is a matter mainly of individual judgment, in very few cases supported by sufficient data.

For these reasons the term variety has been discarded in the present work except as it has been necessary to use it in referring to other descriptions. It is probable that future work will greatly reduce the number of species of diatoms.

DESCRIPTIONS AND DRAWINGS

Many of the descriptions have been adapted from other works, but in all cases so modified as to include any peculiarities found in our local forms. The drawings are all original except that of *Chaetoceros elmorei,* this one being taken from the drawing accompanying the original description by Professor C. S. Boyer. The drawings are of actual specimens and in no case has an attempt been made to represent generalized or typical forms. In diatoms the same species occurs in many forms, hence the large number of figures given for some species.

All of the localities where each species has been found are given. This forms a fair measure of the frequency of occurrence of any species.

The writer wishes to express his indebtedness to the late Professor C. E. Bessey and Professor E. H. Barbour, of the University of Nebraska, for advice and assistance in the work throughout; also to Professor C. S. Boyer, of Philadelphia, for the identification of several species as well as for many valuable suggestions. The work of Mrs. Eleanor Barbour Cook on a particularly rich deposit of diatomite at Agate, Nebraska, has been incorporated into this work, all of the species reported from Agate being from this collection and from one sent by Mr. Harold J. Cook.

The fossil material from Greeley County was collected in 1887 by Mr. Russell and given to Professor Bessey, who furnished it to the writer. That from other localities was furnished by Professor Barbour, some of it having been collected by Mr. A. C. Whitford, that from Thedford by Mr. J. N. Neely and Mr. J. M.

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McMillan, and that from Merriman by Mr. L. E. Fagan. The collection from Loup City was furnished by Mr. Clarence O. Peterson, and that from Hay Springs by Prof. R. W. Ellis.

Much of the recent material has been collected by friends of the writer, among whom are: Prof. W. E. Allen, Fresno and Stockton, Calif.; Rev. J. M. Bates, Atkinson, Ewing, Long Pine, and Red Cloud; Prof. A. T. Bell, Crete; Prof. C. E. Bessey, Ashland; Miss Grace Bradburn (Mrs. Chas. Frisch), Broken Bow; Miss Pearl Chase, Ainsworth; Prof. F. E. Clements, Holt County; Miss Alba Cosner, New Helena; Miss Harriet Ege, Rosebud, S. Dak.; Miss Cora Elmore (Mrs. C. H. Bancroft), Talmage; Mr. Wm. Fleming, Cheyenne, Wyo.; Prof. J. H. Flodman, Wahoo; Miss Ethel Hansen, Grand Island; Mr. W. J. Hesser, Plattsmouth; Miss Isabel Johnston, Lodi; Mr. Ray Kellenbarger, Anselmo; Mr. E. F. Lange, Fairbury; Mr. Ray McCann, Estes Park, Colorado; Mr. Theodore Moline, Polk; Prof. A. K. Peiterson, Weeping Water; Prof. N. F. Petersen, many places in eastern Nebraska; Prof. Roscoe Pound, Sheridan County, Cherry County; Prof. J. H. Powers, Colorado; Prof. A. A. Reed, Crete; Mr. J. A. Reed, Blue Springs; Mrs. Perry Robbins, New Helena; Mr. Windom Rosene, Stromsburg; Prof. DeAlton Saunders, Bellevue; Miss Laura Sutherland, Chippewa Falls, Wis.; Miss Lil'an Sutherland, Pawnee City; Miss Fae Troyer (Mrs. Wm. Fleming), Turtle River and Dallas, S. Dak.; Prof. J. E. Weaver, Crete; A. C. Whitford, Dismal River and many other places in the Sand Hills; Prof. Elda R. Walker, lakes in Sand Hills; Prof. R. T. Young, Devils Lake, N. Dak. Besides these much material from the vicinity of Grand Island has been furnished by members of the writer's own family.

Artificial Key to the Genera

A. Valves round.
- *b.* Cells without horns (Fam. *Coscinodiscaceae*).
  - *c.* Cells united in filaments. 1. *Lysigonium*, page 36.
  - *cc.* Cells single.
    - *d.* With distinct central and marginal portions. 2. *Cyclotella*, page 39.
    - *dd.* Central and marginal portions grading into one another.
      - *e.* With marginal spines. 3. *Stephanodiscus*, page 40.

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ee. Without marginal spines.
4. *Coscinodiscus*, page 41.

bb. Cells with horns (Fam. *Chaetoceratacae*).
5. *Chaetoceros*, page 42.

bbb. Cells with short processes. 6. *Biddulphia*, page 43.

AA. Valves linear, elliptical, oval, or sometimes irregular.

b. Valves with a pseudoraphe, *i.e.*, a clear longitudinal strip.

c. Cells in girdle view rectangular, nearly as broad as long (Fam. *Tabellariaceae*).

d. Transverse ribs of the valves when present not extending into the cell cavity.

e. Valves with a few heavy ribs.
7. *Tetracyclus*, page 44.

ee. Valves with striations, no ribs.
8. *Striatella*, page 45.

dd. Ribs seen in girdle view to extend deeply into the cell.
9. *Denticula*, page 46.

cc. Cells elongated in both valve and girdle view.

d. Cells wedge-shaped in girdle view (Fam. *Meridionaceae*).

e. Without transverse ribs.
10. *Sceptroneis*, page 47.

ee. With transverse ribs.
11. *Meridion*, page 48.

dd. Cells rectangular in girdle view, or if of other form, the rachis not median (Fam. *Fragilariaceae*).

e. Rachis median.

f. Valves with heavy ribs.
12. *Odontidium*, page 49.

ff. Valves with striations, no ribs.

g. Cells short; in filaments.
13. *Fragilaria*, page 51.

gg. Cells longer, forming fan-like stalked clusters.
14. *Synedra*, page 53.

ggg. Cells symmetrical, in radiating clusters.
15. *Asterionella*, page 57.

ee. Rachis near one margin.

f. Rachis nearly on ventral margin, not interrupting the striations. 16. *Eunotia*, page 57.

ff. Rachis somewhat removed from the ventral margin, interrupting the striations.
17. *Ceratoneis*, page 60.

bb. One or both valves with a raphe; cells usually elongated.

c. Rachis median or nearly so; valves not keeled (Fam. *Naviculaceae*).

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d. Cells rectangular in girdle view.

e. Cells with striations and a row of transverse septa around the margins.

18. *Mastigloia*, page 61.

ee. Cells with striations but no septa.

f. Valves not keeled.

g. Raphe straight or nearly so.

h. No heavy lines bordering the raphe.

i. Cells straight in girdle view.

j. Central nodule round.

k. Face of valves flat; raphe straight.

19. *Navicula*, page 62.

kk. Face of valves convex; raphe slightly sigmoid.

20. *Scoliopleura*, page 94.

jj. Central nodule elongated transversely forming a stauros.

21. *Stauroneis*, page 95.

jjj. Central nodule elongated longitudinally into 4 horns.

22. *Diploneis*, page 97.

ii. Cells curved in girdle view; only one valve with a raphe.

j. Cells elongated.

23. *Achnanthes*, page 98.

jj. Cells nearly circular.

24. *Cocconeis*, page 100.

hh. Raphe bordered by two heavy lines giving the appearance of a double raphe.

25. *Brebissonia*, page 103.

gg. Raphe sigmoid.

26. *Gyrosigma*, page 104.

ff. Valves keeled. 27. *Amphiprora*, page 107.

dd. Cells wedge-shaped both in girdle and valve view.

e. Cells straight in girdle view.

28. *Gomphonema*, page 107.

ee. Cells curved in girdle view.

29. *Rhoicosphenia*, page 114.

ddd. Raphe arcuate; cells more or less moon-shaped.

e. Valves without transverse ribs.

f. Raphe and central nodules not close to the margins of the valves.

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g. Terminal nodules near the ends, raphe more or less curved.

30. *Cymbella,* page 115.

gg. Terminal nodules usually distant from the ends, raphe straight.

31. *Encyonema,* page 122.

ff. Raphe and central nodule close to the ventral margin.

32. *Amphora,* page 124.

ee. Valves with transverse ribs; raphe not evident.

33. *Cystopleura,* page 125.

cc. Cells usually elongated; rachis usually on the margin of the valve, so that striations are not interrupted by it; valves with a dotted keel (Fam. *Bacillariaceae*).

34. *Homoeocladia,* page 130.

ccc. Cells usually oval or elliptical, seldom elongated; with two wings (Fam. *Surirellaceae*).

d. Valve surface undulate. 35. *Sphinctocystis,* page 145.

dd. Valve surface not undulate.

e. Valves cuneate, reniform, elliptical, or linear.

36. *Surirella,* page 147.

ee. Valves nearly circular, bent into saddle shape.

37. *Campylodiscus,* page 150.

Class Bacillarioideae

One-celled aquatic plants living in filaments, or more commonly broken into single cells; free, attached to the substratum, epiphytic on other plants, or enclosed in gelatinous tubes; cell wall of cellulose infiltrated with silica; the wall of each cell (frustule) consisting of two plates (valves) which form the ends of the cell and are connected by two or more girdles, the one fitting outside the other like the cover of a box. Protoplasm parietal and forming a large mass in the center of the cell in which the nucleus is located and which separates the central vacuole into two parts. Chromatophores plate-like or granular; chlorophyll obscured by a brownish coloring matter, phycoxanthin. In the elongated, free-swimming families, *Naviculaceae, Bacillariaceae,* and *Surirellaceae,* there is a longitudinal slit (raphe) which in *Naviculaceae* is median, or nearly so, and in the other families is lateral. Propagation by cell division in which each daughter cell retains one of the valves of the mother cell. Reproduction by the sexual or asexual formation of auxospores.

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Systematic Key to the Families and Genera

A. Order *Eupodiscales*. Round Diatoms. Cells in cross section usually circular, less commonly polygonal, elliptical, and rarely irregular; valves marked concentrically or radially by dots, areolations, lines, or ribs; cells often with spines, processes, or horns.

b. Cells without horns. Family 1. *Coscinodiscaceae*, page 36.

bb. Cells with long horns or bristles.
Family 2. *Chaetocerotaceae*, page 42.

bbb. Cells with shorter spines or processes.
Family 3. *Biddulphiaceae*, page 43.

AA. Order *Naviculales*. Flat Diatoms. Filaments flattened, usually fragmented into single cells; cells narrowly elliptical to linear, less commonly broadly elliptical, lunate, cuneate, or irregular; valves marked pinnately or transversely by dots, areolations, lines, or ribs; cells (in our species) without spines, processes, or horns.

b. Rachis of the valves (*i.e.*, the line between the divergent pinnate markings) evident as a narrow, unmarked strip (pseudoraphe) rarely wanting; valve without a slit (raphe).

c. Cells usually little shorter than broad, or longer, with numerous interzones, mostly united in filaments.
Family 4. *Tabellariaceae*, page 44.

cc. Cells usually much shorter than broad (rod-shaped of older authors, the longer axis of the rod representing one of the transverse axes of the cell), often united in filaments.

d. Cells cuneate in girdle view (*i.e.*, valves not parallel), rachis median, interzones present.
Family 5. *Meridionaceae*, page 47.

dd. Cells rectangular in girdle view, or if cuneate, the rachis not median; interzones present or absent.
Family 6. *Fragilariaceae*, page 49.

bb. Rachis containing an elongated slit (raphe) through the cell wall.

c. Rachis commonly median, often more or less lateral, not keeled, or when keeled not punctate; interzones present or absent.
Family 7. *Naviculaceae*, page 60.

cc. Rachis lateral, less often median, punctate-keeled, raphe not plainly visible.
Family 8. *Bacillariaceae*, page 130.

bbb. Rachis evident as a narrow, unmarked strip, or keeled, valve with two lateral wing keels, each enclosing a raphe.
Family 9. *Surirellaceae*, page 145.

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Key to the Genera

Order *EUPODISCALES*

Family 1. COSCINODISCACEAE

A. Cells forming filaments; girdle side marked.
1. *Lysigonium* (*Meloseira*), page 36.

AA. Cells single; girdle side not marked.
- *b.* Valve with distinct central and marginal portions.
  2. *Cyclotella,* page 39.
- *bb.* Central and marginal portions of the valve grading into one another.
  - *c.* With marginal spines.
    3. *Stephanodiscus,* page 40.
  - *cc.* Without marginal spines.
    4. *Coscinodiscus,* page 41.

Family 2. CHAETOCEROTACEAE

5. *Chaetoceros,* page 42.

Family 3. BIDDULPHIACEAE

6. *Biddulphia,* page 43.

Order *NAVICULALES*

Family 4. TABELLARIACEAE

A. Transverse ribs of the valves, when present, not extending into the cell cavity.
- *b.* Valves with a few prominent transverse ribs.
  7. *Tetracyclus,* page 44.
- *bb.* Valves tranversely striate.
  8. *Striatella* (*Tabellaria*), page 45.

AA. Transverse ribs of the valves extending deeply into the cell cavity.
9. *Denticula,* page 46.

Family 5. MERIDIONACEAE

A. Valves punctate or variously punctate-striate, without transverse ribs.
10. *Sceptroncis* (*Opephora, Peronia*), page 47.

AA. Valves finely striate and with transverse ribs.
11. *Meridion,* page 48.

Family 6. FRAGILARIACEAE

A. Rachis median.
- *b.* Valves with transverse ribs, or if not ribbed, with a central clear space (pseudoocellus).
  12. *Odontidium* (including *Diatoma*), page 49.

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bb. Valves without transverse ribs and without central clear space.
c. Cells in filaments.
13. *Fragilaria,* page 51.
cc. Cells single or forming fan-like, stalked clusters.
14. *Synedra,* page 53.
ccc. Cells in radiating clusters.
15. *Asterionella,* page 57.
AA. Rachis near one margin.
b. Rachis nearly on ventral margin, not interrupting the striations.
16. *Eunotia,* page 57.
bb. Rachis somewhat removed from ventral margin, interrupting the striations.
17. *Ceratoneis,* page 60.

Family 7. NAVICULACEAE

A. Valves parallel.
b. Frustules with marginal septa.
18. *Mastigloia,* page 61.
bb. Frustules without marginal septa.
c. Rachis of valves not keeled.
d. Raphe straight or nearly so.
e. Raphe with a simple border.
f. Septa of interzones when present not fenestrated.
g. Cells straight in girdle view.
h. Central nodule round.
i. Valves flat, raphe straight.
19. *Navicula,* page 62.
ii. Valves convex; raphe slightly sigmoid.
20. *Scoliopleura,* page 94.
hh. Central nodule elongated transversely, forming a stauros.
21. *Stauroneis,* page 95.
hhh. Central nodule elongated longitudinally into four horns.
22. *Diploneis,* page 97.
gg. Cells curved in girdle view.
23. *Achnanthes,* page 98.
ff. Septa of interzones fenestrated; only one valve with a raphe.
24. *Cocconeis,* page 100.
ee. Raphe bordered by two ridges.
25. *Brebissonia,* page 103.
dd. Raphe strongly sigmoid or arcuate.
26. *Gyrosigma* (*Pleurosigma*), page 104.

PREVIEW

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