DIATOMS, THE JEWELS OF THE PLANT-WORLD[1]

By ALBERT MANN

To anyone familiar with the beautiful plants which form the subject of this lecture it seems strange that so few people know of their existence, for they are abundant everywhere. The evident explanation of this, however, is the extreme minuteness of these organisms, most of which are wholly invisible to the naked eye. Among the 4,000 or more species there is one, *Coscinodiscus rex,* a perfect Goliath among his brethren, which is nearly as big as the head of an ordinary pin; but with this exception, the larger forms can better be compared to the point of the pin, while many are so extremely small that the highest powers of the microscope are needed to display their form and the carvings with which they are ornamented.

The diatoms belong to the group of flowerless, aquatic plants known as the Algæ. Where these are divided into six groups the Diatoms constitute one of the six; thus (1) Rhodophyceæ, the red algæ; (2) Phæophyceæ, the brown algæ; (3) Chlorophyceæ, the green algæ; (4) Bacillariæ, the diatoms; (5) Heterokontæ, the yellow-green algæ; (6) Cyanophyceæ (Myxophyceæ), the blue-green algæ. I am disposed, however, to classify them as a sub-order in the Order *Conjugatæ* belonging to the green algæ, or Chlorophyceæ; and for the following reasons—(1) they have a unicellular thallus, (2) they have large, elaborate and symmetrically arranged chloroplasts, (3) they frequently produce resting-cells with thick walls, (4) they secrete gelatinous masses in which the individuals are embedded, (5) they display a double mode of multiplication, namely, that by fission, or division of one cell into two, and that by sexual reproduction by means of non-motile isogametes. The attempt to classify them with the brown algæ is absurd.

The distribution of the diatoms is practically universal. They occupy all waters, torrid, temperate, and arctic; fresh, salt, and brackish; still and running. There is hardly a brook, pond, puddle, lake, river, or sea on earth that is destitute of these plants, unless the water be so contaminated with poisonous matter as to inhibit all life. The largest and most elegant forms belong to the tropics, but

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the most amazing numbers of individuals are found in the arctic regions. Dr. Nansen found them in undiminished abundance at the northern limits of his polar journey.

Geologically the diatoms seem to have first appeared in the closing measures of the Middle Cretaceous; in other words, they are, though low in organic complexity, comparatively recent in the scale of successive life-forms. The statement of Castracane, that they have been found in the Carboniferous Era, and the still more amazing claims that have been made of finding them in Devonian and even Silurian deposits are generally discredited. It should be remarked here that the precise period of entrance of these organisms should be quite clear, because of the prolific multiplication of individuals characteristic of these forms on the one hand and of the indestructible nature of their remains on the other.

Diatom structure can be best understood by looking first at the external skeleton or casing, and then at the living substance within it. Each plant, a unicellular individual, secretes for itself an external case or box of clear and very dense silica, consisting of two valves, an upper and a lower, the one slipping over the other like the lid and bottom of an ordinary pasteboard box, Figs. 8 and 9, *A, B*. This case is not of uniform shape; but among the 4,000 or more species there can be found almost every conceivable form, so long as the form displays symmetry on one or both of its axes. Thus there are round, square, triangular, stellate, oval, ovoid, crescent, sigmoid, cuneate, bacillar, etc., forms. It is evident that this great variety in the symmetrical contour of these structures adds considerably to their beauty and attractiveness. The variety is further enhanced by numerous outgrowths in the form of spines, horns or domes, so arranged as to preserve the symmetry of the valves from which they spring. The two valves themselves, which are with few exceptions identical in shape and markings, are carved and ornamented with an elegance and variety that is well-nigh inconceivable. Indeed it may safely be stated that there is hardly a kind of surface ornamentation known that has not been utilized in beautifying these structures. Polished beads of varying size arranged in radiating or concentric rows, shining bars, wavy ridges, delicate

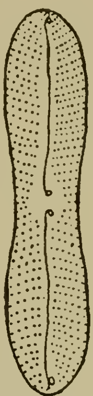


FIG. 8.

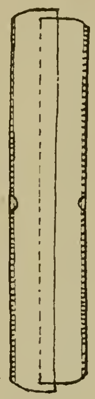
A.  B

FIG. 9.

watch-case milling, hexagonal network, the interspaces of which are often further ornamented with secondary sculpture, intricate arabesque designs, in short a diversity and delicacy of embellishment that makes these plants the most ornate of all living objects. The highest efficiency of the microscope is often taxed in revealing some of the minuter markings; and valves that were formerly thought to be quite smooth, and which, therefore, bear the inappropriate name, "hyaline" or "pellucida," are now under better objectives found to be intricately carved with intersecting lines. It should be here stated that the few illustrations accompanying this description convey no adequate idea of the objects they represent; for in black and white it is quite impossible to reproduce the appearance of these structures of shining silica, often further beautified by prismatic colors refracted from their various surfaces.

Outside of this silica casing there is a very thin and perfectly transparent organic pellicle, in vital connection with the living substance within, erroneously called a gelatinous sheath. It is this internal living substance which determines the position of the organism as a plant, and which presents some of the most interesting problems connected with its life-history. It is made up of normal plant protoplasm (cytoplasm) with a single large centrally placed nucleus. Rarely there are two nuclei, found only in two or three species, where they are said to be constant. Generally there are two large vacuoles filled with cell-sap, and two or more chloroplasts. These latter are usually symmetrically arranged, in the elongated diatoms on either side of the median line and in the circular forms in evenly distributed granules or larger masses radially disposed. The green chlorophyl composing these bodies is disguised by an overlying brown or buff pigment called diatomin, which is so readily soluble in alcohol that when living diatoms are treated with that liquid the diatomin instantly disappears and the plants are seen to be bright green. The reserve food material stored up by the diatoms is not in the form of starch grains, but of globules of deep yellow, dense and highly refractive oil, either floating in the sap of the vacuoles or embedded in the cytoplasm.

Turning now to the physiology of the diatoms the question of their nourishment may be considered. This takes place as in other chlorophyl-bearing plants, by the assimilation of inorganic substances in solution in the water about them through the agency of sunlight in conjunction with the chlorophyl masses; and in consequence of this fact it is plain that they are precluded from such waters as are not sufficiently lighted; as, for example, subterranean streams and the deeper parts of the sea. No actual test has been made of the ocean depth at which diatoms can flourish, but the limit is probably something below 100 fathoms. Specimens of diatoms are, it is true, obtained from all depths, even from the abysses of 6,000 fathoms or more; but in such cases they are invariably the dead and empty frustules of plants that have been transported there by surface currents. There are a few diatoms partly or wholly destitute of chlorophyl and which therefore live a saprophytic life. Such is *Nitzschia putrida*, a colorless form, and *Bacillaria paradoxa* another *Nitzschia*, which is only partly saprophytic and therefore not wholly colorless.

The food-product of assimilation can never be utilized by the individual plant to any great extent; for being encased in an in-

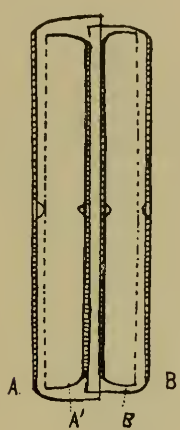


FIG. 10.

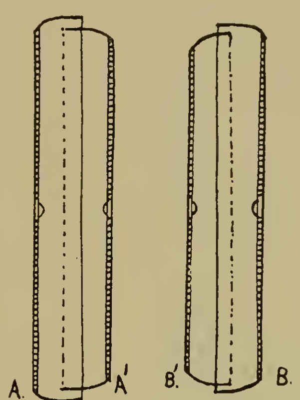


FIG. 11.

flexible silica box its chance of growth is restricted to a very slight increase in breadth by the slipping apart of the upper and lower valves or lids: in other words, each diatom is formed at its own maximum length. Most of the reserve food is therefore utilized in the multiplication of individuals. This takes place in two curious ways. The first and common method is the asexual one of fission, or the separation of a single plant into two along a median dividing line. Although this is the usual method of multiplication in unicellular plants as well as in single cells of multicellular plants, the process in the diatoms is peculiar in taking place, not transversely, that is along the short axis, as is done in the bacteria, the other algæ, etc., but longitudinally from end to end. This peculiarity is the origin of the name "diatom," from δία τομέω, to cut through. An examination of Figs. 10 and 11 will make this process clear. It is easy to see that smaller individuals must be formed at each repetition of this process, as the two new valves are always formed within the old ones. The diatom loses approximately one-sixtieth of its length by this method; and if it were continued indefinitely the forms would necessarily dwindle to the vanishing point! This however is corrected by means of the second or sexual method of reproduction, a process that brings about two important results; the diatom's vitality is rejuvenated and its ancestral size is restored. This process, called conjugation, may take place in any one of three ways; —

1. The nucleus of a single diatom divides karyokinetically; the cell contents swell, bursting apart the valves; the mass passes out into the water, becomes spherical, secretes a large quantity of jelly-like substance; the two daughter nuclei reunite; a large "auxo-

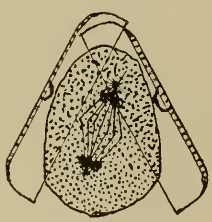


FIG. 12.

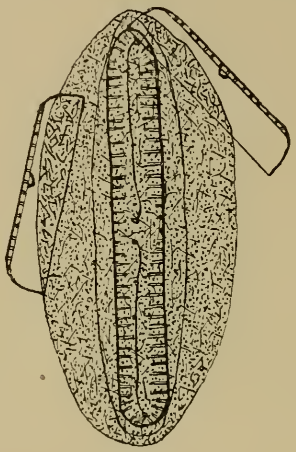


FIG. 13.

spore" is formed, and within this a single large diatom is built, like the parent frustule, but approximately double the size. See Figs. 12 and 13.

2. The second method is where two diatoms come into contact; the contents swell, as before; the two nuclei remain undivided, but fuse together and produce a single auxospore, within which a single diatom, double the former size, is again formed. See Fig. 14.

3. In the third method two parent diatoms join; the nucleus of each divides karyokinetically; the four daughter nuclei unite, the two from one plant with the two from the other, producing two auxospores and giving rise to two large frustules. See Fig. 15.

The first method is common among diatoms that are fixed, and especially those which grow in long filaments. The second is rather uncommon, being confined to a few species. The third is perhaps the most frequent of all and is especially characteristic of the moving diatoms.

Conjugation takes from eight to twenty days for its completion; and as the diatoms lose by each act of fission about one-sixtieth in length, and as they divide every five or six days under normal conditions of nourishment, it would require not more than one act of con-

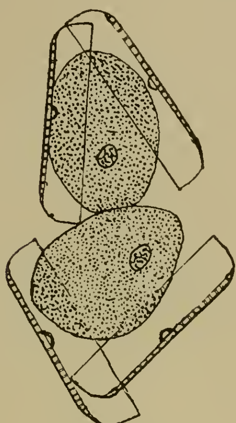


Fig. 14.

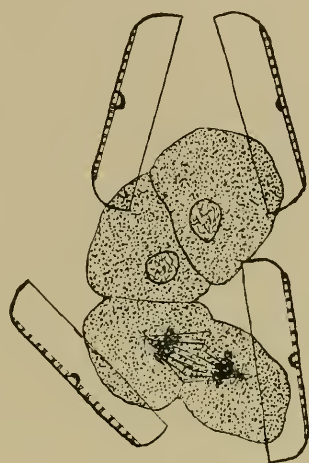


Fig. 15.

jugation yearly to balance the reduction. Frequently conjugation does take place only once in a year; and then it is, at least in our latitude, quite uniformly early in spring, often before the ice has entirely disappeared from the streams.

Two other methods of reproduction are claimed as taking place among the diatoms; namely, by means of exceedingly minute spores; and by means of daughter plants, two to sixteen in number, formed within the body of the parent plant. But as the former is wholly unsubstantiated, and the latter, described by G. Murray (in *Proc. Roy. Soc. Edin.*, vol. 21) is, to say the least, most anomalous, no attempt will be here made to describe them.

There is one other physiological process of the diatoms which has up to the present time puzzled all its investigators, their motion. Many of the diatoms grow attached to some support, some of the round and oval forms lying flat on the fronds of other algæ, while others are fixed at the ends of gelatinous stalks, singly or in clusters, or grow as zigzag chains or in rows like beads or in flat bands as long filaments. But large numbers are free; and these, especially

Nitzschia and *Navicula,* display a liveliness of motion that is easy to watch but hard to understand. The majority of these forms are boat-shape, and their motion has a stately character quite different from the erratic movements of the lower animal organisms. But these tiny crafts move without oar or sail, paddle-wheel or propeller. They apparently present the anomaly of moving without any organ of locomotion! Many theories have been invented to explain this mystery; as fine protruded pseudopodia (Ehrenberg), osmotic currents of water (Naegli and H. L. Smith), rows of cilia (J. D. Cox), a stream of protoplasm moving along the "raphe" a line on each valve, generally in the middle that is thought to be a narrow cleft (Muller). But none of these fit the case. No method of staining known has been able to show any protrusions. Whatever be the final explanation, it must explain not swimming but creeping; for these organisms are perfectly inert and helpless unless in contact with some fixed surface. This alone disposes of all theories requiring cilia, flagellæ, osmotic currents, etc. The power, too, must be considerable; for diatoms will push aside in their course inert matter many times their bulk. The theory must also apply to the *ends*

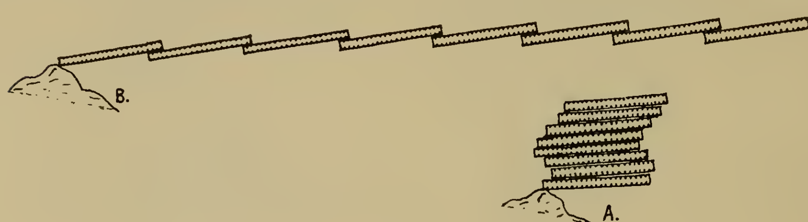


FIG. 16.

of the frustules; for the plant will often stand upon end and swing about most vigorously. It is not at all improbable that the so-called "gelatinous sheath," which overlies uniformly the entire external surface and is connected with the living cell contents through numerous minute pores, is the seat of this motion, and by undulatory movements over its surface produces the phenomenon that is so evident and so puzzling. Any one who will watch the strange accordeon-like extending and retracting movements of those well-named diatoms, *Bacillaria paradoxa,* especially when, fully extended, they touch each other only at the tips and yet form a series as rigid as a rod, will see that some explanation based on the external membrane fits the case better than any other. See Fig. 16, *A* and *B*.

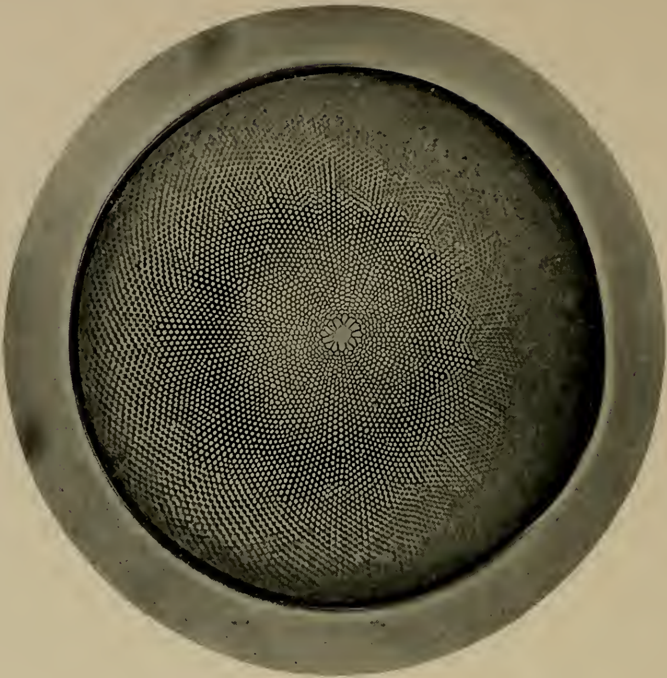
A few words should be said upon the practical uses of the diatoms. The first of these is as polishing powders. Under the name of " tripoli" they have been long in use to give brilliancy to metallic and other surfaces; while, either mixed with soap or put up dry, they are sold under fancy names for the same purpose. One widely known brand of tooth-powder is composed entirely of diatom shells. As an absorbent of nitro-glycerine they have been extensively used in the manufacture of various dynamite compounds. They are also employed as a substitute for asbestos in the composition of jackets for steam-pipes, as packing in refrigerators, etc. They have at least a semi-practical use in refuting the utilitarian theory of the origin of species; their rigidly exact yet infinitely diversified carving and ornamentation refusing absolutely to fit into such a conception. Diatoms have a most curious use among the more abject inhabitants of Lapland and Bohemia as a substitute for or an adulterant of food. Under the name of "berg mehl" diatomaceous earth is mixed with flour, fat, etc., and eaten. It is hardly supposable that this fossil earth contains any appreciable amount of nourishment. The philosophy of the practice is probably the fact that where a hungry man has a stomach capacity of two quarts and a food supply of only a pint, he can cajole himself and gain a sense of plethoric bounty by adding three pints of inert matter to his supply,—a sort of "square meal," it is true, but a very hollow one! The diatoms do, however, form a considerable part of the world's food supply, at least in an indirect way; for they are one of the principal sources of nourishment for mollusks, the clams, oysters, etc., whose stomachs always contain large quantities of these plants; as well as constituting a good part of the food of small fishes and of the animal organisms on which larger fish feed. Thus they are a sort of primary source of organic food, on the abundance of which many of our most valued food products depend.

It is well to mention here that the diatoms give promise of great practical value in determining the origin of sea-bottoms and the direction and extent of the sea-currents by which they are transported. Their use to applied science in this respect is now being investigated.

There will be no difficulty for anyone interested in the examination of these plants in finding them, either as living or fossil forms. Wherever there is a brown coloration of the surface of the mud, submerged stones or twigs, not a red-yellow, which is due to iron, but a brown-yellow to almost black, there are diatoms in abundance. It is their characteristic color, when found in masses; and a little of the material placed under the microscope will reveal thousands of them. Or if fossil material is needed, diatomaceous earth can be found in almost every State in the Union and almost every land on earth. Immense beds exist, for example, at Nottingham, Md.; Richmond, Va.; Keene, N. H.; Monterey, Santa Monica, Rodondo Beach, Cal.; near Spokane, Wash.; etc.; while smaller deposits are frequent in many other localities. In foreign lands there are large deposits at Sendai, Japan; Ananino and Simbirsk, Russia; Alicate, Sicily; Bilin, Bohemia; Luneberg, Germany; Mors, Jutland; Oamaru, New Zealand; Springfield, Barbados; etc.

The cleaning of diatoms of organic matter and the preparation of these and fossil forms as permanent microscopic mounts cannot be entered into here. The processes are easily learned from any good work on the microscope.

SMITHSONIAN INSTITUTION,
WASHINGTON, D. C., March, 1905.



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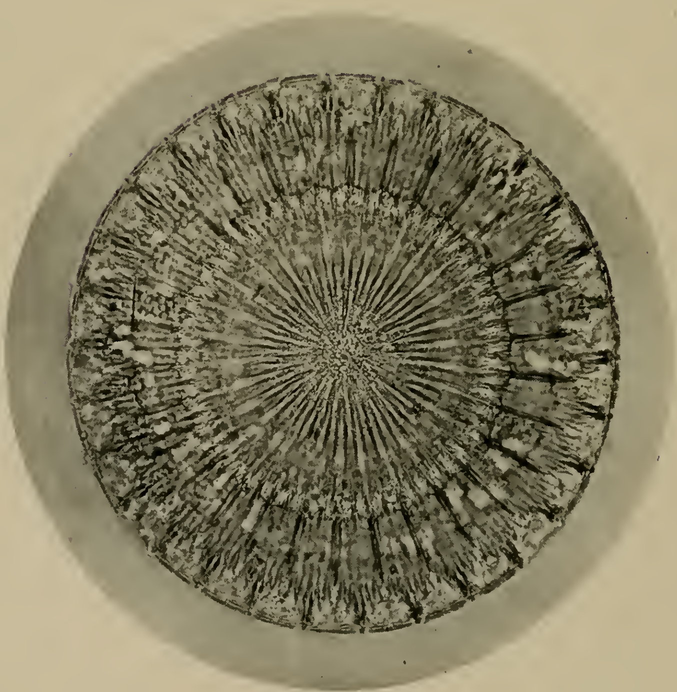

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Plate XXII

Figure 1. *Coscinodiscus asteromphalus,* E., × 185. Sendai, Japan. Photograph by A. A. Adee.

2. *Lepidodiscus elegans,* Witt., × 620. Simbirsk, Russia. Photograph by A. A. Adee.

PLATE XXIII

FIGURE 1. *Biddulphia Roperiana,* Grev., variety *mollis,* Mann, × 400. Pacific Ocean, S. S. "Albatross," station 3608.

2. *Plagiogramma sceptrum,* Mann, × 375. Galapagos Islands.

3. *Stephanopyxis ferox,* Grev., × 400. California guano. From Moebius' Plates of Diatoms.

4. *Triceratium* sp.? × 660. Bering Sea.

5. *Entogonia Davyana,* Grev., × 300 (= *Heibergia Barbadensis*) Barbados. From Moebius' Plates of Diatoms.

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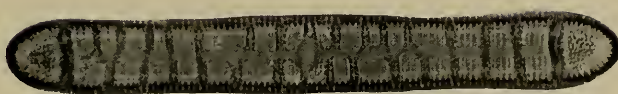

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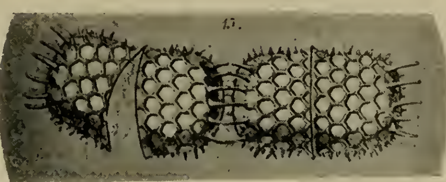

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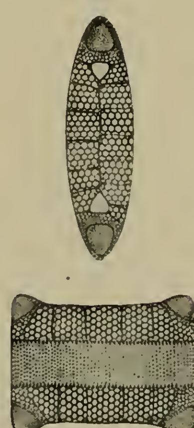

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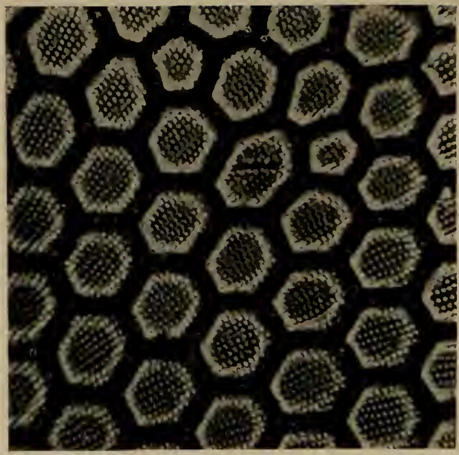

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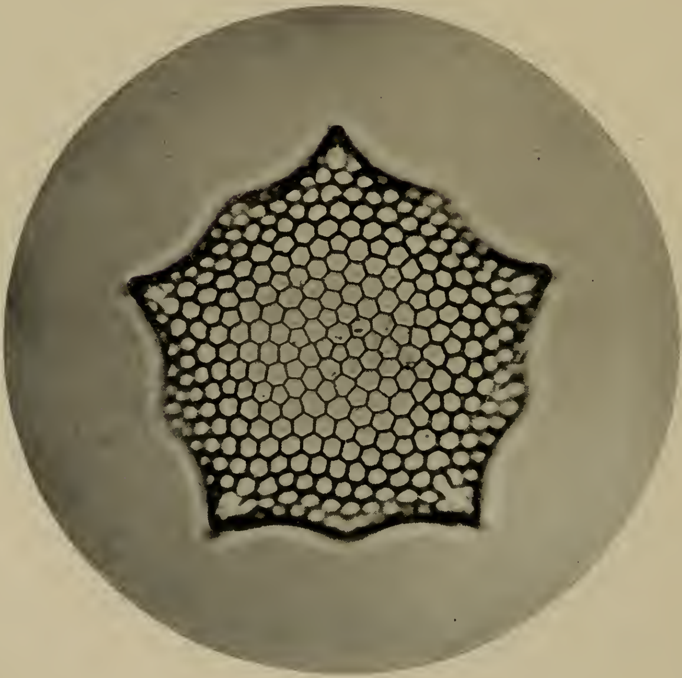

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Plate XXIV

Figure 1. Secondary markings within the hexagonal network of *Triceratium favus*, Bright, × 1060. Oamaru, N. Z. Photograph by A. A. Adee.

2. Amphora, n. s., × 565. Pacific Ocean.

3. *Triceratium Campechianum* Cl., × 720. Florida. Photograph by A. A. Adee.

Plate XXV

Figure 1. *Cestodiscus ovalis,* Grev., × 335. Moron, Spain. From Moebius' Plates of Diatoms.

2. *Actinoptychus Wittianus* O. Jan., × 200. Hayti. From Diatomaceen, Jeremie in Hayti.

3. *Brunia japonica,* Temp., × 100. Japan.

4. *Aulacodiscus* n. s., × 1000. Pacific Ocean, S. S. "Albatross," Station 4029 H.

5. *Navicula invenusta,* Mann, × 375. Galapagos Islands.

6. *Navicula bullata,* Norm., × 350. Western Australia. From Moebius' Plates of Diatoms.

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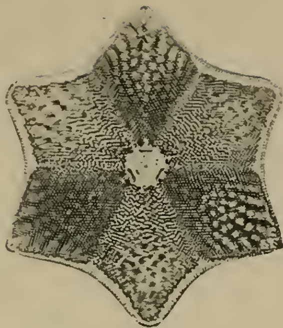

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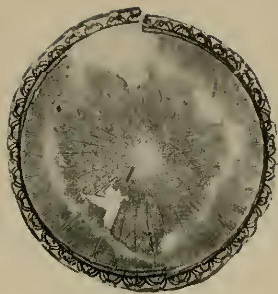

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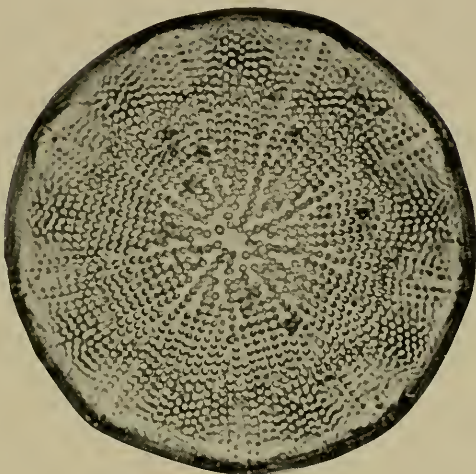

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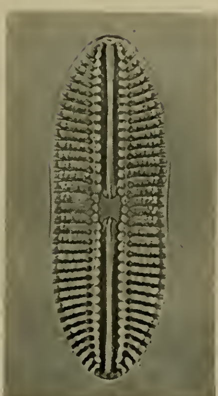

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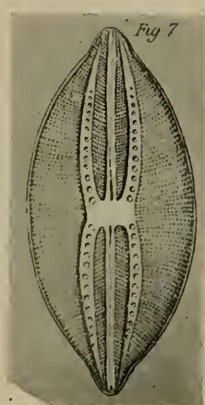

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