doubled, and the already large exportation to the Dominion of Canada increased nearly 100 per cent. The total exports of salt during the fiscal year ending June 30, 1904, were 25,508,577 pounds, valued at \$99,066, whereas in the year ending June 30, 1903, 16,446,380 pounds were exported at a valuation of \$70,296, an increase for 1904 of 55.1 per cent in quantity, but of only 40.9 per cent in value.

FIG. 1.

FIG. 2.

These facts relating to the production of salt in 1904 have been collected for the United States Geological Survey by Dr. Edmund Otis Hovey. They are published for gratuitous distribution, as an extract from the Survey's forthcoming volume "Mineral Resources of the United States, 1904."

DIATOMS, THE JEWELS OF THE PLANT WORLD.*

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 org-

FIG. 3.

FIG. 4.

anisms, 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,

kontæ, 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 fre-

FIG. 6.

FIG. 7.

FIG. 8.

quently 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 the most amazing numbers of individuals are found in the arctic

other like the lid and bottom of an ordinary pasteboard box, Figs. 1 and 2, 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 watch-case milling, hexagonal network, the interspaces of which are often

FIG. 5.

FIG. 9.

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

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 struc-

FIG. 10.—*Coscinodiscus asteromphalus*, E., $\times 185$. Sendai, Japan. Photograph by A. A. Adee.

FIG. 11.—*Lepidodiscus elegans*, Witt., $\times 620$. Simbirsk, Russia. Photograph by A. A. Adee.

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) Hetero-

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

tures 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

* Delivered at the U. S. National Museum, Washington, D. C., under the auspices of the Washington Biological Society, and published in the Smithsonian Miscellaneous Collections.

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 larger vacuoles filled with cell-sap, and two or

Fig. 12.—*Biddulphia Roperiana*, Grev., variety *mollis*, Mann, $\times 400$. Pacific Ocean, S. S. "Albatross," station 3608.

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 chlorophyll 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 diatom instantly disappears and the plants are seen to be

Fig. 13.—*Plagiogramma sceptrum*, Mann, $\times 375$. Galapagos Islands.

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 chlorophyll-bearing plants, by the assimilation of inorganic substances in solution in the water about them through the agency of sun-

Fig. 14.—*Stephanopyxis ferox*, Grev., $\times 400$. California guano. From Moebius's Plates of Diatoms.

light in conjunction with the chlorophyll 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

Fig. 15.—*Triceratium* sp.? $\times 660$. Bering Sea.

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 chlorophyll 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 incased in an inflexible 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

Fig. 16.—*Entogonia Davyana*, Grev., $\times 300$ (= *Heibergia Barbadosis*) Barbados. From Moebius's Plates of Diatoms.

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.

Fig. 17.—Secondary markings within the hexagonal network of *Triceratium favus*, Bright, $\times 1060$. Oamaru, N. Z. Photograph by A. A. Adee.

This peculiarity is the origin of the name "diatom," from *δια τομῶν*, to cut through. An examination of Figs. 3 and 4 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

stored. 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 "auxospore" is formed, and within this a single large diatom is built, like the parent frustule, but approximately double the size. See Figs. 5 and 6.

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 pro-

Fig. 18.—*Amphora*, n. s., $\times 565$. Pacific Ocean.

duce a single auxospore, within which a single diatom, double the former size, is again formed. See Fig. 7.

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. 8.

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 conjugation yearly to balance the reduction. Frequently conjugation does take place only once in a

Fig. 20.—*Cestodiscus ovalis*, Grev., $\times 335$. Moron, Spain. From Moebius's Plates of Diatoms.

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

Fig. 19.—*Triceratium Campechianum* Cl., $\times 720$. Florida. Photograph by A. A. Adee.

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

Fig. 21.—*Actinopterychus Wittianus* O. Jan., $\times 200$. Hayti. From *Diatomaceen*, Jeremie in Hayti.

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 (Naegeli 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 of the frustules; for the plant will often stand upon end

Fig. 22.—*Brunia japonica*, Temp., $\times 100$. Japan.

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 accordion-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. 9, 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.

Fig. 23.—*Aulacodiscus* n. s., $\times 1000$. Pacific Ocean, S. S. "Albatross," Station 4029 H.

One widely-known brand of tooth-powder is composed entirely of diatom shells. As an absorbent of nitroglycerine they have been extensively used in the man-

* Since writing the above, Prof. T. O. Palmer has kindly directed my attention to his article in *Proc. Acad. Nat. Sci., Phila.*, 1898, in which he claims to have stained *E. notia* so as to indicate fine protrusions from the frustules. I have not as yet been able to verify these processes and can only express the hope they may prove to be of more value in shedding light on this mystery than similar claims of protrusions revealed by staining that have been made by earlier writers.

ufacture 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 the 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

Fig. 24.—*Navicula invenusta*, Mann, $\times 375$. Galapagos Islands.

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

Fig. 25.—*Navicula bullata*, Norm., $\times 350$. Western Australia. From Moebius's *Plates of Diatoms*.

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 Simbirk, Russia; Alicata, 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.

SPECIFIC INDUCTIVE CAPACITIES OF METALS.—Theory and fact are at variance in the calculation of the resistance of wires for direct and for alternating currents of high frequency. A. Broca shows that the discrepancy can be removed by taking into account the specific inductive capacity of the metal. On doing this he obtains an approximate value for the specific inductive capacity by a new method. Putting it as proportional

to the square of the refractive index, he shows that for frequencies between 500,000 and 1,200,000 per second the specific inductive capacity is of the order of 10^4 . Beyond a frequency of 3,000,000 the specific inductive capacity increases nearly in proportion to the period. Nothing can as yet be said concerning lower frequencies, as no data are available.—A. Broca, *Comptes Rendus*, June 26, 1905.

DISCOVERIES AT EPHEBUS.

It was announced in the London Times rather less than a year ago that the trustees of the British Museum had obtained a *firman* for the resumption of excavations in the great Temple of Artemis at Ephesus, and had intrusted the direction of the work to Mr. D. G. Hogarth. The site had not been touched since 1874, when the exploration conducted by the original discoverer, the late Mr. J. T. Wood, was brought to an end, and his great pit, coextensive with the platform of the temple, had become an overgrown morass. It has always been felt that his five seasons' work did not lead to final results. In his publication he treated at length of the Hellenistic "Wonder of the World," and he sent to England some magnificent remains of it in the shape of architectural sculpture; but he hardly dealt at all with the earlier temple which he discovered at a lower level, and identified with that to which King Croesus contributed. The late Dr. A. S. Murray, Mr. Ferguson, and others endeavored to supply the omission by study of the various fragments of architecture and sculpture found by Wood; and quite recently the architect of the Austrian Ephesian expedition, Dr. Wilberg, made a small scale plan and notes of the parts of the early temple surviving *in situ*, so far as they could be discerned amid the dense overgrowth. But more information was obviously required, and to obtain this there must be a fresh clearance. It was suspected, moreover, that Wood's lowest stratum of ruins was not the earliest existent on the site; and it was hoped that not only would architectural remains be found below, but that various small objects might be recovered belonging to all the successive temples, which would supplement the exceedingly meager haul made by Wood, and throw further light on the most important local cult of the great Asian goddess.

The suspicion has been amply justified. There are the remains of two more temples below Wood's lowest, the earliest resting on the virgin sand of the original marsh. The date of its foundation, judged by the numerous offerings dedicated in it and now brought to light, is about the year 700 B. C. The hope that small cult-offerings would be found has also been realized in a very remarkable and unlooked-for way. While the scanty remains of the Hellenistic temple, which served as a quarry for centuries, were found to have been pretty thoroughly explored by Wood, and those of the "Croesus Temple," which he exposed, yielded little beyond new architectural evidence and architectural sculpture, the strata below proved extraordinarily rich in fine products of archaic Ionian art, inspired in many cases by Egyptian models, but thoroughly Greek in character and workmanship. The earliest antiquities found on the site are essentially Hellenic. If, as has often been believed, there was a pre-Greek, perhaps Lydian or "Hittite," cult of the Great Goddess at Ephesus, her primitive shrine must be looked for elsewhere, probably among the hills south of the plain, where lay the ancient holy place, Ortygia.

The new excavation was begun in the first week of last October, and, with an interruption of three months from December to March, during which some twenty inches of rain flooded the site, was continued into the present summer and brought to a conclusion in the third week of June. After the tangled jungle and the heaps of stones, with which Wood had left the pit encumbered, had been cleared away in the early autumn, little difficulty was experienced in exposing the platform of the great sixth century temple, and making a detailed plan of all that survives of it. But, in clearing out the rectangular structure which stands exactly in the center, and was probably the base of the holy image, Mr. Hogarth perceived that there was at least one temple below, and that the lower stratum would prove even better worth investigation. There was just time before the heaviest rains to search a small part of the central area, and extract a quantity of objects of unique character and value; but the exploration of the rest of the stratum had to be postponed. On resuming, the diggers found themselves flooded out. The whole temple area was a vast pond from which only the highest stones of the Hellenistic stratum emerged. No natural outfall could be made as the pit is far below the general level of the neighborhood, and the only recourse was to pump. A powerful engine was hired from the shops of the Aidin Railway, together with a twelve-inch pump, and this was installed in April, and kept at work till the end of the campaign. While the deep central area with its numerous springs was fenced in and kept more or less dry with smaller pumps and hand labor, the engine lifted the mass of the water and sent it down a channel into the Cayster marsh, and thus with infinite difficulty and under very unhealthy conditions the objective of the exploration was completely attained.

Briefly, the outcome is this. Of the uppermost or Hellenistic temple, that built after the famous arson of Herostratus, hardly any new knowledge has been gained. Its component parts have almost wholly disappeared into the walls of medieval Ayasuluk and into the limekilns, a row of which stood on the north of the pit as grim witnesses to the fate of the world's wonder. Parts of two heads and some minor frag-