Further observations on the movements of diatoms / by Jabez Hogg.

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Jabez HOGG, L. L. D., F. R. M. S., M. R. C. S.,
Hon. Fellow of the Belgium Microscopical Society, etc.

(Mémoire présenté à la Société belge de Microscopie, à la séance du 30 décembre 1882).

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Some few years before Schultze published his observations on the movements of Diatoms I had devoted attention to the subject. In 1855 I contributed a brief resumé of my investigations to the Quarterly Journal of Microscopical Science (London) *.

The late Professor Smith stated that Diatoms were endowed with motive power of some kind. He refers to the subject in his *Synopsis*, Vol. I, page XXIII, in the following terms : « Although motion may be detected in the frustules of attached species, as those of *Gomphonema*, when forcibly separated from their stipes, and in which there is an ardent tendency to change their position, ... I am constrained to believe that the

* See : Quarterly Journal of Microscopical Science, p. 235. 1855. Also, my work on the Microscope, 3d Edition, p. 307, 1856.

movements of others of the Diatomaceæ are owing to the forces operating within the frustule, and are probably connected with the endosmotic and exosmotic action of the cells. The fluids which are concerned in those actions must enter and be emitted through the minute foramina at the extremities of the siliceous valves. »

Other references are made to the subject, but from the conclusions drawn it is evident that Professor Smith had not bestowed sufficient time and attention upon the movements of Diatoms, otherwise he could not have failed to perceive that the elastic power possessed by the external tubular sheath of either *Gomphonema*, or *Schizonema*, in no way explains the movements exhibited by the frustule as it leaves the tube. When a separated frustule is ejected through the ruptured opening, from the open extremity of the tube, it does not, as Professor Smith supposed, leave the tubular sheath by any motive power acquired from the elastic nature of the walls of the tube; but, having acquired some other and independent impetus, for as it approaches the open extremity it sharply jerks itself out and swims off with increased speed, quite prepared for a more active stage of existence. It is perfectly certain also, that the stipulate processes in one genus, and presumably in all, are emanations from the frustules, and not the frustules from the stipes. In the sheath of *Cocconema* I observed a young brood of frustules, very minute in size, closely aggregated in a transparent subglobose plasma; not far removed, were a number of larger, probably older frustules, many of which had delicate stipes attached, and these, although free, exhibit no sign of motion of any kind. It is probable, therefore, that the formation of the

stipes is concurrent with that of the silex, or siliceous skeleton of the Diatom. Be this as it may, it is an undoubted offset of the frustule, and from which the frustule can detach itself at any moment after it has fulfilled its purpose in the process of development.

In the genus *Cocconema*, the stipes are of a comparatively large size; notwithstanding this, from their great transparency there is much difficulty in demonstrating their presence; and the attenuated contractile filament of even larger frustules can in no way be seen. When high powers are employed, it is manifest to the practiced eye, that the rapid movements performed by the free valves of Diatomaceæ are not to be explained upon any endosmotic and exosmotic theory. If taken at a period of the year favourable to the conditions of Diatom life, they will be seen to move about with considerable rapidity over the field of the microscope often moving against the current of the water in which they exist. They will avoid organisms, or impediments lying in their way and separate themselves from a mass of mineral or vegetable matter. Motivity of this nature is certainly deserving of a better description than that given to it by some authors: « a languid roll »; and which only occurs when the frustule is either dying, or in a state of exhaustion from want of oxygen.

Before I proceed further, it will be as well to notice, *en passant*, other theories of the movements of Diatoms. First, that of an undulating protoplasmic membrane; second, that of cilia arranged in numerical order throughout the sutural line of the frustule; third, cilia projecting from the openings, « *foramina* », at the extremities of the frustule. Nägeli's modified endosmose and exos-

mose movement, scarcely merits separate mention. It is of too ambiguous a nature to furnish data for the motile agency observed in Diatoms.

The movements of the endochrome referred to by Nägeli, are necessarily confined to the interior of the valve, and although globules are occasionally seen to move languidly along the marginal portions, in some species, they are never seen to pass to the extremity, nor make a complete circuit of the frustule. Nothing approaching to cyclosis, as seen in Desmids, takes place at the extremities of Diatoms. Siebold's theory is equally unsatisfactory.

By attentively following a Diatom, under high power magnification and careful illumination, its movements are seen to be under its own control. It will attack a body relatively larger than itself; it will force the sharp or taper end of its frustule into a mass of matter, and receed from it, with a jerky motion. This action it will repeat many times over or until it has opened a way for itself. Such movements will be explained by the alternate extension and retraction of a delicately constructed prehensile organ, or organs, contractile prehensile filaments, protruding through an opening or operating on the external surface of the siliceous frustule. It is but necessary to have prehensile filaments capable of extension, in the transverse direction of each half of the frustule, to which they may be attached, to further comprehend the forward and backward movements performed by the Diatom. For a nearly parallel example I may refer to the pediculate Rotifer : the pedicle of which consists of a highly contractile spiral style. This the Rotifer alternately expands and contracts at will; and

performs as is well known many very active movements. Take another example from amongst the simpler forms of life, — cryptogamic plants, whose spores, possessing contractile filaments, have considerable powers of extension and contraction, and are otherwise employed as motile agents. We may then without further argument assume, that Diatoms are furnished with a somewhat similar agency, whereby their movements are effected. We have diversity of form, structure and means employed to ensure the same end, but it has been observed, that there is nevertheless a « reign of law » throughout all Nature 's operations and works.

Somewhat conclusive evidence of the prehensile contractile filamentous theory, is, I believed, furnished by the addition of a minute quantity of colouring matter to the contents of the cell, in which the Diatoms are confined. When a particle or two of colouring matter comes within reach of a filament, it is seized upon, and follows the subsequent movements of the Diatom.

Occasionally a coloured particle will be seen to be affected in the following manner. At a point equal to the length of the frustule, it is grasped *en passant*; or it may be seized at some intermediary distance of the extreme limit of the prehensile filament, when it is instantly drawn towards the frustule with a jerky motion, and secured. On more than one occasion, a cell of *Palmoglœa* was seized in the way described, and seen to travel along the longitudinal sutural aspect of the valve, and in a contrary direction to that of progression, the progress of the frustule being at the moment perceptibly slower and somewhat more jerky. When not so engaged it appeared to be occupied in securing *points*

d'appui on the slide and coverglass. Any and every movement however, must be performed at some disadvantage in so confined a space as that afforded by a very shallow cell : a succession of normal movements is scarcely possible under the circumstances.

Another disturbing element of even more importance comes into play during the microscopical investigation of minute organisms. The siliceous skeleton of Diatoms belonging to the filamentous order, although enveloped in a nearly structureless protoplasm, is found to greatly interfere with the interpretation of structure, while it increases the difficulty of arriving at the precise nature and distribution of organs of prehension and progression. Diffraction phenomena, it should be remembered, are not confined to lined objects, nor to opaque, semi-opaque or transparent elements; in short they are universal whenever the strictly uniform propagation of luminous waves is disturbed by the interposition of any element of unequal refraction. Diffraction phenomena have always been a great stumbling block in the way of the interpretation of structure of every kind, especially of the siliceous valves of Diatoms. In the present case, however, it appears to me to be simply necessary to limit the action of the prehensile filaments to the boundary of the plastic envelope, or a very little beyond it, and the difficulty in the way of comprehending the movements of the Diatomaceæ disappears, although they cannot always be satisfactorily demonstrated.

It has been contended that the movements of Diatoms are either produced by cilia numerically arranged throughout the ventral longitudinal line of the valve or projecting from the « foramina » at the extremity. For some

time I shared in this view but further observations have changed my opinion. The very general distribution of cilia and flagella among the lower as well as higher organisms, is liable to affect one's judgement; that exquisite example amongst unicellular plants, the *Volvox globator*, the enveloping membrane of which is perforated in every direction by an endless number of cilia, being a noteworthy example.

In once again entering upon the investigations of the movements of Diatoms, I have been anxious to divest myself of all preconceived opinions, of either cilia or other organs, and having obtained during the past summer a bountiful supply of lively specimens, I at once made them the subject of careful and prolonged study. Portions taken from the bulk, together with cells of *Palmoglœa*, were transferred to a growing slide, the last named being arranged in groups of from two to a dozen or more primary cells. By expansion of the transparent outer membrane these cells soon displayed the phenomenon of self-division; but neither in the compound state, nor as single cells did any of them exhibit any other kind of motivity. The Diatoms on the contrary were incessantly on the move, passing to and fro, over the field of the microscope. Now and again they would seize upon a *Palmoglœa* and carry it off. Any retraction of the contractile filament of the Diatom produced a sudden jerky movement of the cell; but as soon as it relinquished its hold it returned to a state of perfect rest. Occasionally a fresh attack was made and the cell was seen to follow in the track of the Diatom. The movements were so remarkable, that no one observing them, could, I venture to think, refer them to

other motile organs than that of prehensile filaments or other voluntary contractile bodies under the perfect control of the frustule.

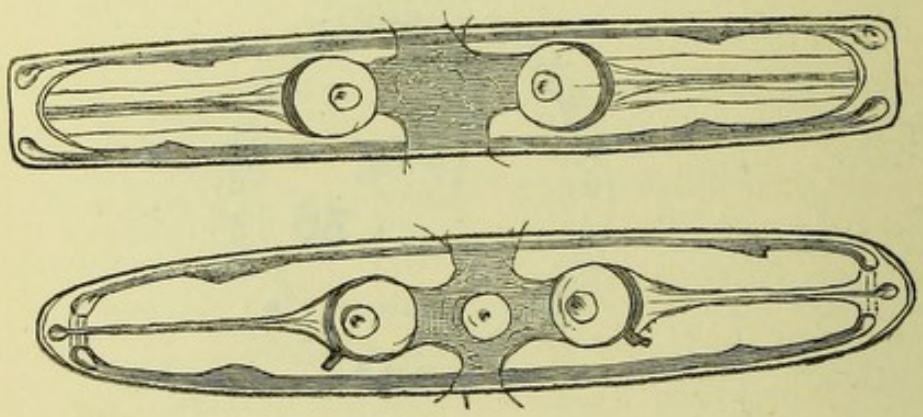
At another time a minute organism belonging to a different genus would dart across the path of a Diatom or come into contact with it, when it was at once seized and for a moment arrested. Two *Navicula* would cross each other, and the resultant action would be of an intermediary or restraining character, and on suddenly relinquishing their hold of each other they would separate with a bound. At another time the motive action of a Diatom was seen to be of a halting nature, as if waiting to gather up its contractile organs before attempting any advance.

Light did not appear to exert any appreciable influence on the movements of the frustules; in fact it appeared to me that they rather avoided the sunlight thrown upon them. The application of heat, raising the temperature of the slide some eight or ten degrees F., seemed to arrest their movements, which gradually became slower and ultimately ceased altogether. Their movements were indeed, entirely stopped, for on transferring the contents of the slide to a watch-glass and adding a drop or two of fresh water to it, then standing it aside for twenty-four hours, the frustules on further examination were found perfectly motionless and their endochrome shrunken and disorganised. This was possibly caused by coagulation of either the internal albuminoïd matter, or the external protoplasmic envelope. The *Palmoglœa* on the contrary were even more lively, and actively engaged in the process of cell-division.

Among the contents of one cell were some fine

illumination, and a staining fluid to differentiate this. In some of the larger frustules I have observed a slight protrusion and retraction of an irregularly shaped mass moving in a limited space about the central nodule, also a swarming or rolling motion among the albuminoïd or

* Drawings of these frustules were submitted to the *Société belge de Microscopie*.



OUTLINE OF PINNULARIÆ, SHOWING VESICLES.

specimens of *Pinnularia* which presented an unusual appearance. Each frustule had two large colourless contractile vesicles on either side of the median nodule, and a central nucleus in each. The outermost, peripheral portion, of the vesicles was reflexed, turned inwards upon itself; the intermediary space between the two being occupied by a fine granular mass. The other portion of the frustule was packed closely with a rich brownish-yellow coloured endochrome, interspersed amongst which about the median line were a few oil globules *. The phenomenon of cyclosis, as I have before said, was not seen to take place in any of the many specimens of Diatoms examined.

Ehrenberg, with objectives inferior to those of the present day, satisfied himself that the movements of Diatoms were due to a twofold action : that of a retractile foot, and of retractile ciliary processes. I have not been able to confirm his conclusions. I have occasionally seen bodies closely resembling cilia, sometimes many such protruding from certain portions of the frustules, but I do not believe them to be associated with ~~any~~ the external movements of the diatoms. « A retractile foot », or rather an extension of protoplasm beyond the margin of the frustule, as in that of certain Rhizopods, is demonstrable, but it requires considerable magnification, well managed illumination, and a staining fluid to differentiate this. In some of the larger frustules I have observed a slight protrusion and retraction of an irregularly shaped mass moving in a limited space about the central nodule, also a swarming or rolling motion among the albuminoïd or

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oily particles which fill-up the central space, while the endochrome remains in a perfectly fixed position, throughout the length of the frustules and beneath the plasmic mass. I have partially succeeded in demonstrating the presence of a protoplasmic envelope by using various magenta stains ; but I have not obtained constant results. On adding a drop of magenta stain to the specimen under the microscope, a delicate rose-pink colour is quickly communicated to the marginal portions of the frustules, but neither the endochrome nor albuminoïd globules are at all affected by the stain during the life of the Diatom.

A number of brackish water Diatomaceæ, *Pleurosigma balticum, angulatum* and *quadratum, Surirella splendida, Nitzschia,* etc., readily took a simple stain of the kind mentioned, and were thus rendered more attractive objects. The elongated wand-like bodies, which serve to distinguish *Bacillaria* from most other genera, take the stain, and the plasmic band which unites its frustules together into a compact family is made more evident. This genus exhibits a special modification of another kind. The contractile connecting filament is seen spread out into a broad band, which completely encloses the aggregate linear series and at the same time becomes an intermediary layer of contractile tissue between each pair of frustules : at once an example of cause and effect, being the chief agent of progression and also of that remarkable sliding to and fro motion, the counter part of the gliding movement performed by *Amœba*.

The greater buoyancy of some Diatoms, is possibly owing to the larger quantity of oil globules contained in

their cells. In *Surirella splendida,* they are very numerous, and the smaller globules exhibit an active rotatory motion throughout the central portion of the valve.

To these fragmentary observations, I have only to add that they were conducted under a magnification of from one to two thousand diameters. The objectives employed were respectively, n° 8 Hartnack, $^1/_{10}{}^{th}$ Ross, $^1/_{16}{}^{th}$ Gundlach, water immersions. A $^1/_{10}{}^{th}$ homogenous immersion lens was also used, but in no way did it materially assist my observations. The illumination was lamp-light and a Ross achromatic-condenser; day-light, sun-light, when it could be got, modified and toned down by interposing coloured glass and monochromatic fluids.