The description follows the appearances, as seen in passing the eye over a thin section from the circumference to the centre.

PHENOMENA of INTERNAL MOVEMENTS in DIATOMACEÆ of the NORTH SEA, belonging to the GENERA *COSCINODISCUS*, *DENTICELLA*, and *RHIZOSOLENIA*. With a Plate. By PROFESSOR MAX SCHULTZE.

THE sea around Heligoland is rich in large Diatoms, which are frequently brought up in considerable numbers by the fine net. Several of the species very abundant there have been found by Ehrenberg at Cuxhaven, as *Coscinodiscus*, *Zygoceros*, *Eucampia*, *Triceratium* ('Abhandl. d. Akad. d. Wiss. z. Berlin,' 1839). Others are still not known out of that region, as *Chatoceros* (Brightwell, 'Quart. Journ. of Micr. Science,' 1856, p. 105, tab. vii), *Denticella*, *Rhizosolenia*.

By far the most numerous forms of the genus last named occurred towards the end of the autumn. The *Rhizosolenia* are readily to be distinguished with the naked eye, and were wanting on no day in the excursions undertaken in company with my father and the Messrs. G. Wagener, Lieberkühn, and Kupfer. In a glass containing them one perceives, by transmitted sunlight, a glittering, proceeding from small rods of a hair-like fineness, which refract and bend the light, like crystals of Cholesterine, but more strongly, so that they shine in all the colours of the rainbow. The rods not unfrequently attain the length of 2 to 3 lines.

Perfect examples of the genus *Rhizosolenia* Ehrbg., so far as I am aware, have only been found by Brightwell up to the present, and were first mentioned in No. XX of the 'Quart. Journ. of Micr. Science,' 1857, p. 191, and were afterwards figured in the later numbers of the same Journal. These being all procured from the stomachs of Ascidians and Salpæ, as also from *Noctiluca*, were seen filled in part with organic, but not living, contents. Still, Brightwell, in the last-mentioned place, states, from his own observation, that *Rhizosolenia setigera* shows a movement like other Diatoms, in which the tubes push themselves slowly backwards and forwards. Here also it is mentioned that *Rhizosoleniæ* occur freely, swimming in the seas of warmer latitudes.

Herr G. Wagener first drew my attention to the peculiar currents of granules occurring in the *Rhizosoleniæ*, which

induced me then to make further researches among other Diatoms, where they had been observed by G. Wagener, also in *Coscinodiscus*, and finally I saw them in a large *Denticella*. Great transparency of the siliceous coats is necessary for a clear observation of the streams of granules. Those forms of *Coscinodiscus* the sculpture of whose shells is very delicate, as *C. centralis*, Ehrbg. ('Micro-geologie,' tab. xxii, fig. 1), with which a form common at Heligoland agrees, are consequently more fitted than others, such as *C. radiatus* and *C. patina*, Ehrbg., which are finely marked, and possess an opaque, sharply sculptured shell. For the same reason *Triceratium*, of which many species occur at Heligoland, is not adapted for observation. In several Diatoms placed together, whilst living, in a fluid adapted for the preservation of Medusæ,* could be observed, in addition, a radiate, threaded arrangement of the organized contents, corresponding with that in which the granular streams would have been observed in life, as, for instance, in the large transparent *Navicula angulata*.

The whole movements I have seen neither in *Rhizosolenia*, nor in *Coscinodiscus* and *Denticella*. The internal movements are of the following kind :

Coscinodiscus and *Denticella* (figs. 11—13) show, in the living state, a nucleus placed almost in the centre, but still drawing near to one of the side walls ; it is a round, colourless vesicle, of the size of a human blood-corpuscle, with a large, strongly refracting nucleolus—it might be taken for a cell with a nucleus, but which last would then want the nucleolus. Around this body is found an accumulation of a finely granular colourless mass, from which radiate a multitude of finer and coarser cords, passing through the internal space of the Diatoms, which is of a water-like clearness, in all directions. They all come to an end at one of the surfaces of the siliceous covering, lying closely round an exceedingly

* This fluid, consisting of common salt ʒiv, alum ʒij, sublimate gr. iv, dissolved in two quarts of distilled water, is well adapted for the preservation of small organisms, procured by fishing with the fine net in the sea. One rinses out the corner of the net in a glass filled with this solution instead of sea-water. In this manner, after several repetitions, one obtains a sediment which may serve as a mine for the whole year. Noctiluca, Echinoderm, and Annelid larvæ, Entomostraca, Diatoms, Polythalamie, and Polycystinæ are admirably preserved, both in their soft parts as well as their hard structures. To make them transparent, glycerine should be afterwards added. In the circumnavigation of the world, glasses containing this fluid, each filled at different places and noted, would furnish richer and better material for the study of geographical distribution and variety of forms than searching the stomachs of animals or the filtering of several bottles brought back filled with sea-water.

delicate layer of the same finely granular matter. In the latter, as in the fine granular substance enveloping the nucleus, and frequently in an incompletely fixed state of the wall, entirely concealing it, are imbedded vesicles of a coloured material. These are ochre-yellow, and round or somewhat pointed; they are of the latter form in *Denticella*. They lie close to the siliceous covering, either presenting an entirely uniform distribution at equal distances from one another (as in the examples delineated), or are arranged in reticulated cords, uniting among each other, as has been more than once seen in *Coscinodiscus*. In the threads and in the finely granular external layer are found appearances of currents. Specimens brought freshly from the sea, or kept at most some hours in a glass, are alone fitted for the observation of these. From the finely granular mass surrounding the nucleus the stream goes in, and to the, as it appears, more homogeneous, if not structureless, mass, consisting of threads at the periphery; and in the same threads, or others, different granules return back to the centre. The threads are thickest near the nucleus, and attenuate themselves on their way by division, anastomosing reticulately with one another, till, in their finer distribution, they represent a delicate web lying close to the siliceous coat, in which, or in a more homogeneous layer, immediately on its exterior, the coloured vesicles are imbedded. The nucleus does not always lie close to the siliceous covering; it may also approach the middle of the internal space. *Coscinodiscus* possesses a form like a shallow round box, whose bottom and top is arched like a watch-glass. If one views such a body from the side, and the nucleus with the granular mass enveloping it is situated in the middle, between both side walls, there goes more frequently a stronger cord of granular matter from it to the centre of the latter. In this way the middle appears possessed of a darker axial cord. In such a middle situation, the nucleus seems to increase before the commencing propagation by division. After the appearance of two new watch-glass-shaped walls, with their convex surfaces turned to one another, that sprout of division possesses a nucleus closely adhering to the newly formed wall. So also in *Denticella* (as fig. 12 shows), where certainly the situation of the nucleus is disclosed only by the accumulation of the darker granular mass, as the centre of the radiating threads. The coloured vesicles are omitted in this figure; they presented the same uniform distribution as in fig. 11, so that a complete removal of the same seems not to interfere with the appearance of the division.

Somewhat differently does the granular stream flow on in *Rhizosolenia*. The long, completely transparent, very delicate siliceous tubes possess yellow contents, as Brightwell indeed saw; and certainly this yellow colour is dependent on coloured vesicles of a long oval, nearly rod-shaped figure, almost equaling in their long diameter those of *Coscinodiscus* and *Denticella*. They lie imbedded in a colourless substance, containing fine granules, which is again the seat of the appearances of currents, in which here, however, departing from the Diatoms first described, the coloured vesicles take a lively part. A denser opaque accumulation of the granular matter and coloured frustules, situated sometimes in the middle, at others nearer one end of the tube, in which a nucleus, as in *Coscinodiscus* and *Denticella*, could not be seen, presents itself as the centre of the currents. These do not radiate in all directions through the middle of the tube, but confine themselves closely from the beginning to the surface of the siliceous coat, and run off usually as fine, stretched, parallel threads, until, in the pointed end of the tube, they unite themselves again to a generally small expanding opaque mass. I once counted in the circumference of the tube sixteen such granular threads, flowing parallel and beside each other. The current is in each of the threads double. Small granules, flowing in a more homogeneous substance, sometimes more quickly, at others more slowly, collect themselves together here into a little mass; they are there seen only singly, projecting out on the margin beyond the surface of the thread, or apparently entirely imbedded in it. Frequently one or many of the coloured frustules are laid hold of by the current and carried far away to a distance; others lie quietly between the streams in a perfectly undisturbed layer. Bridge-like joinings, meltings away, and divisions also occurred. So much I remember. Alas! more accurate notes I did not make. It may be that the phenomenon, for that reason, will commend itself to others for further research.

The granular currents described, namely, those in the interior of *Coscinodiscus* and *Denticella*, entirely resemble those known to exist in *Noctiluca*. In it they proceed from a dark mass, which eccentrically took the place on which the spherical body possesses a heart-shaped recess, and radiate in all directions in the interior of the hollow space of the body, which is filled with a clear fluid, passing away into an exceedingly fine network of streams immediately under and surrounding the skin, and ultimately melting away with skin itself, which (if we would transfer an idea from the

plant-cell to the *Noctiluca*, only represents the most external layer of the proto-plasm) is of the nature of clear albumen; this also appears not to be wanting in *Coscinodiscus*, though in it covered by the siliceous coat, as it is in most plant-cells by one of cellulose. The currents of granules are also perfectly similar to those found in the extended threads of Gromiæ, Polythalamia, and Polycystinæ. Unger has briefly ('Anatomie und Physiologie der Pflanzen,' 1855, p. 282)—a view previously more specially propounded by Cohn ('Nachträge zur Naturgeschichte des *Protococcus pluvialis*,' Aus d. Leopoldinischen Akademie-Schriften)—classed together the currents in the fluid contents of plant-cells (2 B), the hairs on the filaments of *Tradescantia*, with the phenomena presented by the threads of *Amæba porrista*, or the Polythalamia, as I describe them, and the movements of the protoplasm he declares are exactly similar to those of the so-called sarcode of the Rhizopoda. I have compared the frequently described phenomena in the hairs on the filaments of *Tradescantia* with the currents in the Diatoms, as well as in the threads of the Rhizopoda, and must acknowledge their great similarity. I chose for the observation *Tradescantia procumbens*, the hairs of whose filaments present very transparent cell-walls and entirely colourless contents; the latter, in *Tr. zebrina*, for instance, being more or less real, detracts somewhat from the distinctness of the movement phenomena. In the former, also, the granules are larger, and the material of the threads apparently more homogeneous. From the layer of protoplasm enveloping the nucleus proceed several thicker or thinner threads, traversing the cell in all directions, more frequently, however, lying close to the cell-wall (as in *Rhizosolenia*). They consist clearly of a basic material, with strongly refracting granules imbedded in it. The latter flow in the interior, or, as it were, on the surface of the threads, either in one direction only, or in opposite directions at the same time in one and the same thread, as may not unfrequently be observed. In the broadest threads this double direction of the current is nearly universal, but it occurs also in the finest, which are almost imperceptible. The granules generally pass by each other undisturbed, or it may happen that one is taken back by the others—a proof that the double direction of the stream is not due to two separate threads. Individuals flowing quickly overtake others going more slowly in the same thread, and may then, as I once saw, suddenly turn back and proceed in company. The threads divide themselves frequently in a forked manner, and a granule reaching the point of division stops before committing itself

to the one or the other way. The shape and direction of the thread are subject to continual change. The forked division, for instance, proceeds from the base of the threads at the cell-nucleus to the other ends, which meet together on the internal surface of the cell-wall. Or it forms out of the forked division a bridge to a thread lying close beside it, while the branch part melts away with this. The bridge then runs upwards or downwards between both threads; it shortens itself, while the latter draw near one another; finally they melt away completely with each other into one, so that now a broader stream flows where there were formerly individual fine threads. On the internal surface of the cell-wall is found a thin, coherent, protoplasmic layer. So it appears after the application of reagents, which cause it (the primordial utricle) to become shrivelled. By means of syrup I could bring out here what A. Braun arrived at in the Characeæ ('Monatsberichte der Berliner Akademie d. Wiss.,' 1852, p. 225). The cell-contents, sharply circumscribed, drew themselves back from the membrane of the cell; besides, the appearance of currents in the interior still continued for a long time. In this way one can convince himself that the granular currents and fluctuations (for such are here frequently alone present in places), occurring in the mid-layer of the protoplasm, are not related to the last layer (Hautschicht, Pringsheim) but only to the inner stratum of the parietal layer (granular layer). In this way those in *Noctiluca* are comparable with the above. In distilled water I have seen the appearance of a stream maintain itself in individual cells for twelve hours, and in thin syrup for twenty-four. It would be well worth the trouble to try the influence of a series of solutions on the movements described, perhaps like those made by Kölliker with the spermatozoa. In this way interesting disclosures might be expected.

The movements remarked in the protoplasm of plant-cells ought not, in my opinion, to remain neglected, as they may act as an explanation of the mysterious appearances of life in the sarcodæ threads of the Rhizopoda, and I recommend the comparative study of the former to those who consider the threads in Polythalamia as possibly or probably a compound of small cells. In *Tradescantia* the same phenomena occur in undoubted cell-contents, which must, therefore, be related to animal life.

Of Rhizosoleniæ I have observed two different species. The largest, and by far the most abundant, is undoubtedly identical with Brightwell's *R. styliiformis*, described in the 'Quarterly Journal of Microscopical Science,' Jan., 1858,

xxii, p. 94, and delineated in Plate V, fig. 5. The tubes are cylindrical, pretty abruptly pointed at both ends, and furnished at the extremity with a small siliceous point, apparently solid, or at least with very thick walls, sharply marked off from the cavity of the cylinder. The pointing of the species, according to various positions of the tube obtained by rolling it round, originates nearly like a cut-out quill-pen. The length and thickness of the tubes vary much. I have seen them from 0.4 to 0.7" Par. in length, and 0.025 to 0.04" in thickness. The most examples are found in the act of division, which is in an oblique direction, while others consist of from three to six individuals cohering together. Of such I have measured several. A. Four coherent individuals, 0.68", 0.42", 0.4", 0.46" in length. B. Three ditto, 0.7", 0.76", 0.68" in length. C. Three ditto, 0.72", 0.54", 0.52" in length. D. Six individuals attached to each other, 0.52", 0.74", 0.5", 0.52", 0.5" in length; the last was broken off; the entire length of the tube was 3". Characteristic of *R. styliiformis* are the ringed markings which the shell possesses. These appear not remarkable in water, but come out very sharply after subjection to a red heat, or desiccation after previous treatment by acids. I have taken pains in fig. 4 to give a most correct drawing of the same, as they appear in that position of the *Rhizosolenia* which resembles a cut quill-pen, with the cut surface turned towards the observer. The upper part of the two individuals shown in fig. 3, still hanging together after the division, turned round in its long axis towards the left about 90°, would then present the same view as fig. 4. The oblique falling-off side of the young ends is presented to the beholder. On it, in the middle, is found a design like the tip of a lance. It is, to look at, in a manner like an impression of the once closely applied end of another individual. Here a confinement of the shell to the very last may take place during the division, perhaps even an aperture in the siliceous coat remains in the dark lines, *a, a*, which I could sometimes nowhere discover. The ringed markings of the shell are made by linear incisions, therefore the shell most commonly breaks in the rings. A wider and finer marking of the siliceous coat could not be discovered, either in the red-hot condition or by the use of oblique light.

The second species, which is rarer in Heligoland, I have named *R. calcaravis* (figs. 5—8). It is smaller than the first, and occurs in solitary, not in numerous, individuals adhering together. Length 0.20"—0.25"; thickness, 0.025. Specimens of 0.25" already showed the oblique division in

the middle. Once only I saw three individuals hanging together, and of these one was caught again in the act of dividing. Their lengths were 0.15, 0.15, and 0.225." On the siliceous coat I could not perceive a ringed marking. The pointing at the ends is waved, and the extreme point, sharply marked off, as in *R. styliformis*, is bent like a bird's claw. The level of the curves of these points in the two ends of one individual are not parallel, but cut themselves at a sharp angle. The two specimens delineated at fig. 8 present a provisional, not clearly explicable peculiarity. They were found without organized contents. They adhered firmly to one another, as they are figured, being only slightly changed that the cause of their cohesion may be shown. The length of the specimen on the left was 0.2", that on the right 0.25". In both the upper point was broken off nearly at the middle; but a kind of termination was again effected by a very delicate membrane. Both contained in the interior, moderately near one end, two spikes of new individuals made fast to each other in an inverted direction. I suppose these examples were caught in the act of dividing, for which purpose they had developed the new spikes in the middle. They may be released later from their original situation by the death and subsequent maceration of the contents. Lastly, the young points differed from one another. As is evident in figs. 9 and 10 (magnified 330 diam.) the point of the former has a double, strongly refracting contour, while that of the latter is paler and more delicate. Fig. 9 lay in the specimen figured on the right above, and in that on the left below, *a, a*. Fig. 10 was the reverse, *b, b*. After the division in the *Rhizosoleniæ*, as also in *Coscinodiscus* and *Denticella*, the siliceous covering of the parent individual still remains for a long time uninjured over the divided place (compare figs. 6 and 12). After this is cast off, the offspring of the division always adhere for some time to one another. So likewise in *Rhizosolenia styliformis*, as in fig. 2, where the dotted lines indicate the original union by the siliceous covering which is here at present wanting. Specimens are frequently seen to whose free ends still adhere portions of the already cast-off siliceous covering of the parent. *Rhizosoleniæ* broken off, close the opening with a siliceous plate arched like a watch-glass. Still they appear, in addition, immediately after the closure to develop a new and regular terminal process. I have seen specimens of the species, at least, which certainly show, if it may be so somewhat artificially explained, that the broken-off point, getting placed inside the tube, may become incarcerated by the ensuing closure.

The Diatoms shown in figs. 11 and 12 must be referred to the genus *Denticella*, if we consider Ehrenberg's *D. amita* ('Microgeologie,' tab. xxx, A, figs. 2, 3, 7) as the typical form. They agree very closely with the form named by Bailey *Zygoceros* (*Denticella*?) *mobiliensis* ("Microsc. Observ. made in South Carolina, Georgia, and Florida," 'Smithson Contrib.,' vol. ii, p. 40 of the separate copies, tab. ii, figs. 34 and 35), which cannot be, however, a *Zygoceros*, but is a true *Denticella*, as Herr J. Müller informed me in reply to an inquiry respecting his opinion. One might impute the difference from our species to the inaccuracy of Bailey's somewhat rough drawing. The size Bailey does not mention. The specimen given in fig. 11 measured 0.11" in length (without the prickles), and 0.065" in breadth. That in fig. 12 was 0.125" in length, and 0.098" in breadth. The lengths of the individual sprouts of division were 0.055 and 0.065"; it was thus much less than their breadth, which, in connexion with the other measurements already given, presents a great variety in form. Young specimens, at first released by the division, sometimes appear broader than they are long, at others longer than they are broad. Besides, there occurred at Heligoland much smaller *Denticellæ*, which (either the young of our species or of a new one) appeared to have originated in a different manner than by division. The cross-cutting of our *Denticella* is barley-corn shaped, and ends naturally above and below in two external projections. The spines are placed internal to the projections, not in the two lines uniting the projections to one another, but the one to the right and the other to the left of them. Hence the uneven appearance the one has compared with the other in the two individuals caught in the act of dividing (fig. 12).

In water the siliceous coat appeared destitute of all finer structure. With great pains two cross lines can be perceived, running parallel to each other, which are shown in our drawings. These are always at the same distance from the upper and under ends, and approach more closely to one another the shorter the individual. After the application of a red heat, and by the use of oblique light, there is brought into view a fine hair-like marking of the surface, as seen in *Navicula angulata*. Such a fine clothing *D. mobiliensis* of Bailey, from the coast of Florida, shows. After all the information given, our *Denticella* will be easy again to recognise. I have named it *Denticella regia*.