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IX.—*On the Organization of the Infusoria, especially the* Vorticellæ. By Dr. C. F. J. Lachmann*.

[With a Plate.]

In the summer of 1852, when I had the pleasure of working in the laboratory of Professor J. Müller, he called my attention and that of another of his pupils, M. A. Schneider, to Stein's memoirs upon the Infusoria†.

These memoirs, in conjunction with the older and contemporaneous ones of Focke‡ and Cohn §, appeared to commence a new æra in the theory of the Infusoria; by their means we first obtained information regarding their propagation, of which, up to that time, we knew nothing, except fissation and gemmation. Important and interesting as were the facts discovered by the three observers above mentioned, they still only formed the imperfect commencement of a history of the development of the Infusoria, to the further advancement of which many must contribute. Stein's observations appeared to be far from sufficient to show his supposition of the connexion between the *Vorticellæ* and *Acinetæ* as anything more than a rather vague hypothesis. For this reason we endeavoured to test their correctness by our own observations, and if possible either to fill up the deficiencies in Stein's series of observations, or to prove his supposition to be false.

* Translated from Müller's Archiv, 1856, p. 340, by W. S. Dallas, F.L.S.

† Untersuchungen über die Entwickelung der Infusorien; Wiegmann's Archiv, 1840, p. 91. Neue Beiträge zur Kenntniss der Entwickelungsgeschichte und des feineren Baues der Infusorien; Siebold und Kölliker's Zeitschrift, iii. p. 475. (Translated, Annals, new series, vol. ix. p. 471.)

‡ Amtlicher Bericht der Naturforscherversammlung zu Bremen, 1844, p. 110.

§ Siebold und Kölliker's Zeitschrift, iii. p. 277.

We soon succeeded in getting Stein's *Acineta* of the Duck-weed*, which he regards as the resting-form of *Vorticella nebulifera*. A. Schneider first found a specimen with an embryo already rotating, the escape of which we then expected with impatience; but this, like all the other specimens whose birth we observed during the summer, escaped from our sight before becoming attached and converted into an *Acineta* or a *Vorticella*.

Once, however, Professor Müller, whilst searching for an *Acineta*-bud which had escaped from him, found an animal which was exactly like it, swam very slowly, and at last, becoming perfectly stationary, gave forth rays and grew into an *Acineta*.

This observation of course increased our doubts as to the correctness of Stein's view. It is true we were not certain whether the animal which became an *Acineta* was truly an *Acineta*-bud, which, according to Stein's representations, ought to have become a *Vorticella*, or whether it was not perhaps a *Vorticella* already metamorphosed, which had then become converted into an *Acineta*, certainly in a very different manner from that supposed by Stein. In any case, this fact could not but urge us to trace the subject further.

In the course of that summer no decisive observation was made. But when I afterwards continued these observations in Brunswick, Würzburg, Göttingen, and Berlin, and paid a close attention to the organization of the families of Infusoria in question, and also to that of other families, I arrived at the conviction that Stein's view of the conversion of the *Vorticellæ* into *Acinetæ* was erroneous: that his description of the *Vorticellæ*, although far better than that of his predecessors, was still very defective: and that all Infusoria are neither polygastric, as Ehrenberg states, nor composed of formless substance, as asserted by Dujardin; but that, as already stated by Meyen†, they are animals with a large digestive cavity,—which, however, must not be regarded, as he thought, as the interior of a cell, but the part which Meyen and most of the recent authors regard as the cell-membrane must be looked upon as the parenchyma of the body,—which does not represent the membrane of a cell any more than that of the Polypes,—a view which has been taught for years by Professor J. Müller in his Lectures on Comparative Anatomy. In the hope that perhaps they may possess some interest, I venture to communicate the principal results of my investigations of the Infusoria. I may therefore be permitted to describe the digestive apparatus of the *Vorticellæ* somewhat in detail, and to compare it with that of the other

* Die Infusionsthierchen auf ihre Entwickelungsgeschichte untersucht, 1854, p. 59.

† Müller's Archiv, 1839, p. 74.

Infusoria, so as by this means, as also by reference to the other systems of organs to be observed in the Infusoria, to support my opinion previously expressed regarding the structure of these animals; and in the exposition of the portions of the developmental history of the Infusoria at present known, to refute the above-mentioned opinion of Stein.

Although the *Vorticellæ* were amongst the first Infusoria discovered by Leeuwenhoek in 1675*, and from their attachment by means of a stem, appear to be for the most part more accessible to observation than many of the other free-swimming Infusoria, yet their external coarser structure remained very imperfectly known up to the time of Ehrenberg, as is proved at once by the great changes of place (*Irrfahrten*) in the systems of zoologists which had to be made, especially by certain developmental forms of them, which are so admirably brought together by Ehrenberg in his great work on the Infusoria†.

Before the time of Ehrenberg, authors regarded the *Vorticellæ* as animals of somewhat the form of a hollow hemisphere or bell fastened by its convex part to a stalk. In front of the supposed opening of the hollow bell (Ehrenberg first showed that this was closed, and that there was only a small opening on the side of the surface closing the orifice of the bell (*Stirn*) leading into its interior), a vortex was seen to be produced, which drew all small particles suspended in the water to the bell; but nevertheless none of the authors could persuade themselves into the belief that in this case small particles were actually taken up or eaten, even O. F. Müller asserting‡, "In omnibus meis observationibus ne minimum animalculum vel moleculam unquam devorari—vidi. Pelliculas vegetabiles tangere et quasi rodere amant (*Vorticellæ*); aquam vero nutritione eorum sufficere facile persuadeor." With regard to the mode in which this vortex was produced, of course the opinions were for a long time by no means satisfactory. In many, the cilia producing this movement were not yet found, so that Wrisberg§, and even Agardh‖ and Wiegmann¶, explained the attraction of the smaller Infusoria towards the bell of the *Vorticella* by a power of fascination like the celebrated one of the Rattlesnake; and Bory de Saint Vincent constituted a peculiar genus (*Convallarina*) for theseaciliated *Vorticellæ***. In others, some, but not all, of the cilia surrounding the anterior opening were detected;

* Philosophical Transactions, 1676.
† Die Infusionsthierchen, pp. 275 and 286.
‡ Animalcula Infusoria, p. xii. § Observat. Infus. p. 63.
‖ Verhandlungen der K. Leop. Akad. ii. 1. p. 135.
¶ *Ibid.* iii. 2. p. 557.
** Dictionnaire Classique, iv. p. 412.

but as the magnifying powers employed were not sufficiently strong and defined to show the individual cilia, one or two small constantly moving horns (*Hörnchen*, Leeuwenhoek) or whip-lashes (*Vipperspitzen*, Rösel*) only were discovered on each side of the orifice of the bell seen in profile, where several moving cilia came behind each other, and thus caused a strong shadow. In some the number of cilia seen increased, so that at last, in many, an entire circlet of cilia surrounding the margin of the bell was discovered.

Besides these parts belonging to the nutritive apparatus, two other organs were seen in some *Vorticellæ* (by Rösel† in *Epistylis flavicans*, Ehrbg.),—the band-like body indicated by Ehrenberg as the testicle, and by Von Siebold‡ as the "nucleus," and the contractile space characterized as a seminal vesicle by Ehrenberg; the latter, however, was observed only as a clear round spot, without any perception of its periodical disappearance. The globular masses of swallowed and aggregated particles in the interior of the body were regarded as swallowed monads or "vesiculæ interaneæ," or as ova. Gleichen§ was not even led to the right conclusion by his feeding the animals with colour, but preferred regarding the red masses of excrement coloured by the administration of carmine, not as what they were, but as eggs, to which he then attributed a particular attraction for carmine‖. [He gave the Infusoria carmine as food, with the view of perhaps seeing the internal parts coloured thereby, as the bones of Pigeons fed with madder become red, but not to ascertain the form of the digestive apparatus by the deposition of a readily recognizable substance, such as the coloured particles, in its interior. Ehrenberg was the first to employ feeding with colour for the latter purpose.]

In the stem, even of the species in which this is contractile, no differentiation of parts was yet known. Gleichen¶ probably only saw the inner (muscular) filament, and regarded the particular parts of it, which he detected during contraction, as eggs, which were laid through the ovipositor (the stem).

For the *Vorticellæ*, as for most Infusoria, Ehrenberg** gave the clue to the recognition of their organization by his discovery of

* Insektenbelustigungen, iii. p. 602. † *Ibid.* iii. p. 614. tab. C.

‡ Vergleichende Anatomie.

§ Abhandlung über die Samen- und Infusionsthierchen, p. 140.

‖ A similar explanation is given by Laurent, whose fancy, working in a particular direction, easily overcame his slight power of observation. See his Etudes physiologiques sur les Animaux des Infusions végétaux, comparés aux Organes élémentaires des Végétaux; Nancy, 1854,—a book filled with the most astonishing errors.

¶ *Loc. cit.* p. 153.

** Abhandl. der Berl. Akad. 1830–31, and Die Infusionsthierchen, 1838.

the true commencement and termination of their digestive apparatus. [With regard to his opinion of its intermediate portions we shall have to speak further hereafter.] In showing that the supposed open mouth of the bell-shaped body of *Vorticella* is closed by a disk (*Stirn*) set with a circlet of cilia, at the edge of which there is a pit containing the mouth and anus, he only overlooked the projecting seam, which is often even turned backwards, which surrounds the disk (*Stirn*) outside the cilia and the pit, and is indicated even by Rösel and O. F. Müller. To this seam Stein* now again calls attention†; he calls it the "peristome‡," and shows that it is separated by a furrow from the disk bearing the cilia, so that this only forms the upper surface of a "bonnet-shaped" process projecting within the peristome, which he calls the "rotatory organ" (*Wirbelorgan*); on this he distinguishes the upper surface bordered by the circlet of cilia as the "disk" (*Scheibe*), and the lateral walls as the "stem" (*Stiel*) of the rotatory organ. The *Vorticellæ* can retract the rotatory organ deeply into the body, and then form a cap-like cover over it by the sphincter-like contraction of the peristome.

Whilst Ehrenberg, in accordance with the idea which he had of the structure of his *Polygastrica*, supposed he saw an intestinal canal proceeding from the mouth, to the sides of which vesicular stomachs were attached, and which, being bent into a loop, led back again to the lateral pit on the margin of the bell; the alimentary tube, according to Stein, is only an inversion of the external membrane, which hangs down into the soft parenchyma of the body in the form of a short tube, truncated below. The balls of food formed at the end of the œsophagus penetrate through the parenchyma of the body in curves, sometimes describing more than one circuit, and are again thrown out backwards through the œsophagus: in *Opercularia berberina*, Stein§ (*Epistylis berberiformis*, Ehrbg.) alone, he saw the balls of excrement pass through the lower wall of the throat (*Rachen*), as he calls the commencement of the œsophagus in the *Opercularieæ*, in which it is wider than in most other *Vorticellinæ*, and not through the œsophagus, and then thrown out.

* *Loc. cit. supra*, especially in Die Infusionsthierchen auf ihre Entwickelungsgeschichte untersucht, 1854, p. 8.

† The descriptions and figures of the *Vorticellæ* by Dujardin and Perty are very inexact; but yet Dujardin's figures indicate the relations of the parts correctly, although, like all his figures of Infusoria, they are very indistinctly and carelessly executed.

‡ In the figures it is indicated by *a a*.

§ Die Infusionsthierchen auf ihre Entwickelungsgeschichte untersucht, 1854, p. 101. Of Stein's works I shall only quote this book, which is so rich in interesting observations.

If we consider a little more closely the nature of the circlet of cilia which bears their food to the *Vorticellæ*, we find* that it does not form a complete circle, but a spiral line†. This begins in the vicinity of the orifice called the mouth by Stein (Pl. IX. figs. 1–3 *c, d*) a little to the right of it upon the ciliary disk (fig. 1–5 *b*), runs above this orifice towards the left and round the margin of the ciliary disk; but before it again reaches its starting-point, it descends upon the stem of the rotatory organ into the commencement of the digestive apparatus.

This commencement of the digestive apparatus (fig. 1 *c, d, e*; fig. 2 *c, e*; fig. 3 *c, d, e, f*, and fig. 4 *c, e, f*) cannot yet be regarded as the throat, or as a part of the œsophagus (as Stein has done), for the anus opens into it (at *e*); we will therefore, by the recommendation of Professor J. Müller, distinguish it by the name of *vestibulum* from the other parts of the alimentary apparatus. Ehrenberg figures this part too shallow, as a lateral pit in which the mouth and anus are placed; whilst Stein only distinguishes it from the true œsophagus in the *Opercularicæ*, in which it is rendered remarkable by its width, but in most of the *Vorticellinæ* regards it as the commencement of the œsophagus.

The vestibulum continues the spiral line formed by the row of cilia, constituting a bent tube, which contains a portion of this spire of cilia. In accordance with the direction of this spiral, the concavity of the tube is turned towards the right and its convexity towards the left: on the convex side the lumen of the tube is still more enlarged, especially in the parts placed furthest inwards where the anus opens (at *e*). Between the anus and the mouth which leads further inwards into the œsophagus (figs. 3 & 4 *e, f*) springs a bent bristle (figs. 1–5 *e, g*), which is generally long enough to project outwards beyond the peristome. This bristle is stiff, and is only displaced a little to one side occasionally, when balls of excrement which are too thick to pass between it and the wall of the vestibulum are thrown out from the anus, but it immediately returns again to its old position.

From the mouth a short tube, the *œsophagus* (figs. 3 & 4 *e, f, h*; fig. 5 *h*), with a far smaller lumen than the vestibulum, leads to a rather wider fusiform portion (figs. 4 & 5 *h, i*), which we will call the *pharynx*. In most *Vorticellinæ* (those with a con-

* To facilitate the subsequent description, we must distinguish a dorsal and ventral surface and an anterior and posterior part in the bodies of the *Vorticellæ*: we follow in this the mode of indication of Ehrenberg, denominating the attached part of the body the posterior, and the disk or rotatory apparatus the anterior, and characterizing that side of the bell which is nearest to the mouth as the ventral side.

† Ehrenberg represents this line as a spiral in some *Vorticellæ*, but generally reversed, whilst Stein describes it as a circle.

tractile stem, and the species of *Epistylis* and *Trichodina**) the longitudinal axis of the vestibulum and œsophagus runs tolerably parallel to the plane of the ciliary disk, whilst that of the pharynx has rather the direction of the axis of the body. In these, therefore, the axis of the ciliary spiral, which is continued as far as the pharynx, changes its direction at the commencement of the vestibulum: whilst it coincided with the axis of the body outside the vestibulum, it stands almost perpendicular to it within the vestibulum and in the œsophagus. In the very elongated forms of the *Ophrydinæ*, Ehrbg., which inhabit sheaths (*Ophrydium, Vaginicola, Cothurnia*†), the longitudinal axis of the vestibulum and œsophagus coincides more with that of the body, as also in the genus *Opercularia* (as circumscribed by Stein) and *Lagenophrys*, Stein; in the two latter the vestibulum is very wide, whilst in the elongated species it is narrow, but generally possesses a deep excavation for the anus.

The portion of the ciliary spiral which is situated outside the vestibulum is not of equal length in all *Vorticellinæ*: in many (*Vorticella, Carchesium, Zoothamnium, Scyphidia, Trichodina*‡,

* *Trichodina pediculus*, Ehrbg. and *T. mitra*, Siebold. The other species of Ehrenberg's genus—*Trichodina grandinella* (*Halteria grandinella*, Duj.), *tentaculata* and *vorax*,—are not *Vorticellinæ*, and this is also the case with *Urocentrum*. On the other hand, Dujardin's genus *Scyphidia* approaches this group of the *Vorticellinæ*; it was founded by him for the sessile, stemless forms, without a carapace. It is true that all the species described by him and Perty as belonging to this genus are to be removed from it, as they have a short stem, and only appear to be particular states of pedunculate *Vorticellinæ*, in which the stem has not attained its usual length; but on the other hand two other species must be included in it, both of which attach themselves to the naked parts of small freshwater Mollusca, and never form a stem, but which were often observed by me in process of division, and are easily distinguished from other forms, which are also attached at first, by their posteriorly-truncated form and a projecting pad at the margin of the hinder end. The *Sc. limacina* (*Vorticella limacina*, O. F. Müller) lives on small species of *Planorbis*. The body is nearly cylindrical, tapering a little at each end, and annulated; the peristome is narrow and not turned backwards; the ciliary disk is narrow and furnished with a projecting umbilicus in the middle, and the posterior truncated surface is provided with a thick pad-like margin. Length of the animal $\frac{1}{20}$–$\frac{1}{30}$‴. The second species, *Sc. physarum*, Lachmann, lives on the naked parts of species of *Physa*. It is longer and more uniformly cylindrical than the preceding; the peristome is longer and often turned backwards, and the hinder margin is thinner and shorter.

† The genus *Tintinnus*, of which, in company with M. E. Claparède, I observed many species on the Norwegian coast, is ciliated all round, and differs so greatly in the alimentary apparatus from the *Vorticellinæ*, that it is impossible for it to remain in the same family. A species inhabiting a gelatinous sheath occurs also in the freshwater in the Thiergarten at Berlin.

‡ The most recent describer of *Tr. pediculus* mentions the existence of a ciliary spiral leading to the mouth: Stein regarded this as a circle.—Müller's Archiv, 1855, p. 357.

some species of *Epistylis,* &c.) it scarcely describes more than one circuit round the disk, whilst in *Opercularia articulata* and *Epistylis flavicans* it runs round the disk three times*, and in others the length lies between these two extremes. This portion consists of a double row of cilia; those of the outer row are usually somewhat shorter than those of the inner, and inserted upon the ciliary disk nearly in the same line, but at a different angle, as they appear to be far more strongly bent outwards†: in the vestibulum and œsophagus the cilia appear to stand in a single row. The peristome bears no cilia: those represented upon it by Stein belong to the outer series of cilia of the disk, or to that portion of the spiral which descends on the stem of the rotatory organ into the vestibulum. The latter also, perhaps in conjunction with the bristle above mentioned, appear to have been what induced Ehrenberg to suppose the existence of a frilled lower lip in *Epistylis nutans,* and Stein in all the *Opercularieæ.*

To see the particulars above described, it is peculiarly advantageous to observe animals which have died during expansion; the outline of one of these is shown in Pl. IX. fig. 2.

By the vortex produced in the water by the cilia of the spiral, the small particles swimming in the vicinity are attracted and at last reach the vestibulum; a portion of them is constantly thrown out again, and another portion is whirled down into the pharynx through the œsophagus. Besides the cilia of the spiral, some stronger cilia (*e* and *f*) also stand in the vestibulum in front of the mouth; these do not take part in the regular activity of the others, but only strike forcibly sometimes, apparently to remove from the vestibulum coarse substances which may have got into it, and also the masses of excrement. [These are also figured by Stein in all *Vorticellinæ.*] In the fusiform pharynx (*h*, *i*) the nutritive matters are aggregated into one morsel, which, when it has attained a certain size, is passed into the interior of the body‡. Meyen§ calls this fusiform part a stomach, in which I cannot agree with him, as it evidently serves only for the aggregation of the food into morsels, and the digestion only takes place further in the interior of the body; I have therefore preferred for it the

* For this reason Stein describes three circles of cilia on the disk of the former.

† In the Plate the cilia of the outer series are only indicated at the margin of the figures, but omitted in the remainder of the ciliary spiral in order to prevent the figures from appearing too complicated.

‡ Pouchet (Comptes Rendus, Jan. 15, 1849) speaks of a respiratory organ in the *Vorticellæ,* which, from his description, can only be the pharynx. The value of his statements regarding the polygastric structure of the Infusoria is sufficiently clear from this, as he considers the commencement of the digestive apparatus as not belonging thereto.

§ Müller's Archiv, 1839, p. 75.

name of pharynx, which is open to but little objection. This pharynx is not merely a vacuity in the surrounding gelatinous substance, only produced by the water whirled into it, but it has proper walls which preserve its fusiform shape, even when no food is contained in it.

The morsel passed from the pharynx into the interior of the body runs nearly to the posterior extremity of the *Vorticella*, and then turning upwards (fig. 4 *l*) rises on the side of the body opposite to the pharynx. During this portion of its course, it usually still retains the spindle-shape communicated to it by the pharynx, and only here changes to the globular form, often rather suddenly: this induced me at first to think that the morsel was still enclosed in a tube during this part of its course, and this opinion seemed to be supported by the circumstance that before and behind the morsel, two lines are not unfrequently seen (fig. 4 *l*), which unite at a short distance from it, like the outlines of a tube which it has dilated. Subsequent observations, however, have again shown me that this opinion is an improbable one, for the circumstances described must also occur, when a fusiform morsel is passed with some force and rapidity through a quiescent or slow-moving tenacious fluid mass: the above-mentioned lines, before and behind the morsel, must be produced by the separation and reunion of the gelatinous mass, even if the morsel is not surrounded by a tube. But the existence of a tube depending from the pharynx appears also to be directly contradicted by the fact, that on the one hand the curves described by the morsel are sometimes larger and sometimes smaller, and on the other that the morsel acquires the globular form sometimes sooner and sometimes later, according as it is pushed out of the pharynx with greater or less force and rapidity. The masses whirled into the pharynx are not always aggregated into a morsel, but sometimes, under conditions which have not yet been satisfactorily ascertained, all the masses which reach the pharynx are seen to pass quickly through it without staying in it; they then stream through the mass surrounding them in a clear streak, which, like the morsels, describes a curve at the bottom of the bell, and only mix with the mass when their rapidity of motion has diminished*. We might easily be inclined to regard the clear, bent streak with the particles flowing in it, as an intestine; and this has probably been done by Ehrenberg, who states that he distinctly saw the bent intestine in some *Vorticellinæ*, especially in *Epistylis plicatilis*, in which I have also been able to study the phænomenon very closely. But in this case,

* A roundish morsel, which might be regarded as a full stomach, is then never formed.

also, there are the same reasons against the supposition of an intestinal tube, as in that of the lines appearing before and behind a fusiform mass: here likewise, not only the form, but also the length of the curve varies: whilst at one time it is but short, and soon terminates by the intermixture of the particles contained in it with the surrounding mass, it may immediately afterwards be twice as long or longer*, a variation which appears only to depend upon the force with which the cilia of the rotatory organ act; so that we cannot explain the whole phænomenon otherwise than that the water with the particles contained in it streaming with some rapidity into the mass with which the body is filled, cannot mix with the latter immediately, but only when its rapidity of motion is diminished by friction; just as we see a rapid stream which falls into a sluggish or stagnant pool, or into the sea, still retaining its independence for a certain space, so that if it differs in its colour or turbidity from the water of the sea or pool, we may distinguish it from the latter, with which it does not mix for a long time, in the form of a streak, which is often of great length.

When the nutritive particles in the body of the *Vorticellæ* have attained the end of the clear streak under a constant diminution of their rapidity, and in the other case, when the morsel has lost its spindle-shape and become globular, they have no longer any separate movement, but now only take part in a circulatory motion, in which all the parts in the interior of the body, with the exception of the band-like organ (testicle, according to Ehrenberg; nucleus of Von Siebold and most recent authors†), are engaged. This circulation is usually slow (slower than in the green *Paramecium Bursaria*, Focke), and therefore generally overlooked; it rarely ceases for a time entirely. The morsel of food performs sometimes more, sometimes fewer circuits with the rotating mass, until at last it arrives in the vicinity of the anus (*e*), when its circulation ceases, and the anus opens and allows the mass to escape into the vestibulum (fig. 3 *e*).

From this description of the processes of nutrition in the *Vorticellinæ*, it may be seen at once that it is impossible to attribute to them an intestine with many adherent vesicular stomachs, as Ehrenberg supposes. The existence of the circulation of the entire contents of the body contradicts this supposition. Ehrenberg himself soon saw the insufficiency of the first explanation

* It may even make a complete circuit and return nearly to its point of commencement beneath the pharynx.

† As we shall hereafter see that the signification of this organ cannot yet be established with certainty, we shall provisionally retain the name of nucleus, but without wishing to attach thereto the idea of a cell-nucleus.

which he attempted of the movement of the internal parts of the body*, which had then been seen only in a few species of Infusoria by Focke†, namely, referring them to a displacement of the parenchyma of the body, and perceived that the actual circulations compel the admission of a large cavity, in which the circulating masses are contained. Ehrenberg, however, supposed‡ that this condition of the animals was not to be considered as the normal one, as Meyen had done§, and regarded it only as a transitory pathological state produced by the enlargement of one stomach at the expense of the others. In this case, therefore, the contents of all the previous stomachs would be poured into one; every portion previously contained in a stomach might consequently have retained the globular form, which it had acquired in consequence of the shape of the stomach. This supposition appeared to explain the phænomena so long as the rotation could be considered only as a transitory state occurring in particular species‖; but if it were correct, the new masses taken in during the rotation could no longer assume the globular form, but must simply mix with the contents of the large stomach. But we see that the formation of the globular morsels takes place even when the rotation of the masses contained in the large cavity of the body is very lively, and we also find that in most Infusoria¶ the state of rotation is the ordinary one, and that the quiescent state of the internal masses is only transitory, so that we are compelled to regard the state in which the body includes a large digestive cavity, as the normal condition.

In opposition to Ehrenberg's views, Dujardin, as is well known, developed his theory of sarcode and vacuoles**, according to which the whole body of the Infusoria only consists of formless, moveable animal substance, into which the food is pressed or whirled by cilia, and in which cavities (*vacuoles*) may be formed in any place, filled with a transparent fluid, which, like the entire mass of which the animal is composed, is denominated *sarcode* by Dujardin. This opinion now finds but little accept-

* Die Infusionsthierchen, p. 262.
† Isis, 1836, p. 786.
‡ Müller's Archiv, 1839, p. 81.
§ *Ibid.* p. 74.

‖ Ehrenberg was the more fixed in this conviction, as he really believed he had directly seen the branched intestine which he ascribed to all his Enterodelous Polygastrica in *Trachelius Ovum*; we shall have occasion to speak of it further on.

¶ In all which possess an open ciliated œsophagus. (See further on.)

** Histoire naturelle des Infusoires. This theory may be regarded as a carrying out of the idea which found the greatest number of adherents in the preceding and the commencement of the present century up to the time of Ehrenberg: according to this, the Infusoria were only vivified mucus.

ance* in its original meaning, and we may refer to it in common with the modification which it has undergone in Germany, as in both we have to combat the opinion that the mass rotating in the interior of the body of the Infusoria is to be regarded as a part of the parenchyma of the body, whilst we may rather consider it, with Ehrenberg, as chyme, or the contents of a digestive cavity.

The principal modification which was effected in Dujardin's opinion, in Germany, is, as is well known, the further development of the analogy of an Infusorium with an animal or vegetable cell pointed out by Meyen in 1839, and which has been especially adopted by Von Siebold† and Kölliker‡. According to them, the whole body of an Infusorium consists of a cell-membrane and its tenacious fluid contents, both of which are contractile (the contractile space, or the "seminal vesicle" of Ehrenberg, was then only a contractile part of the cell-contents): the cell-nucleus was seen in the body regarded by Ehrenberg as the testicle, and the nucleolus of the cell was found in a corpuscle not unfrequently placed in the nucleus, but in many cases (curiously enough for the cell-theory) lying close to it. No hesitation was caused by the fact that the cell had an orifice, the mouth, from which a tube hung down as an œsophagus into its interior. The existence of an anal opening was generally denied, and it was supposed that the unserviceable matters were pushed out through any part of the cell-wall; at the utmost it was admitted that a particular portion of the cell-wall was to be regarded as the anal region, which was peculiarly adapted for this purpose.

If we may, *à priori*, regard the existence of unicellular animals

* Perty supports it in his book 'Zur Kenntniss kleinster Lebensformen' by the most superficial and inexact figures. During the past year Perty has published a letter, in which he attacks Ehrenberg in the most savage—one may even say unjustifiable manner, and entirely forgets the great services done by this naturalist to our knowledge of the Infusoria. Without noticing whether and how far his reproaches are just, the spirit in which they are made is certainly not to be tolerated, and Perty, of all men, has the least cause for making such statements, as by the slight alteration of a few names, a great part of his charges might be turned against himself with equal, if not greater propriety. I shall be excused if, as a proof of this, I here reprint one of Perty's strongest expressions with such alterations; the variations from Perty's original are shown by the insertion of his expressions in parentheses:—"Establishment of that ridiculous monster: Phytozoidia (Polygastrica), in which the most incompatible things: Infusoria of a truly animal nature, creatures of doubtful position, and decided plants of various groups (Rhizopoda, Infusoria, Phytozoidia, decided plants of various groups) are thrown together into a monstrous whole."

† Zeitschrift für wiss. Zoologie, i. p. 270.

‡ *Ibid.* i. p. 200. The theory of the animal cell in Schleiden and Nägeli's Zeitschrift für wissenschaftliche Botanik, 1845, &c.

as possible, we can certainly not consider the Infusoria as such, at least not those which are most accessible to observation, namely, the larger forms, especially Ehrenberg's Enterodela; the smaller species, which are more difficult to observe, must then be judged by analogy, until we understand better how to observe them. Even if we do not hesitate on account of the remarkable position of the nucleolus outside the nucleus in many Infusoria, the presence of an oral aperture, or, as we shall hereafter show to be the case in the *Acinetinæ*, of many mouths, of an œsophagus, and of a second orifice, the anus* (the existence of which we shall prove), there is still a great deal that can be urged against the cell-theory, for which we are particularly indebted to Cohn's observations.

Cohn showed† that in the Ciliata, besides the thin skin of the body which bears the cilia, or the cell-membrane according to previous views, two other strata are distinguishable in the body, —the inner rotating layer, and a quiescent "cortical layer‡," often of considerable thickness, surrounding this; he considers this cortical layer as the cell-membrane, which is enveloped externally by a ciliated cuticula, and only regards the internal, frequently rotating layer as the cell-contents.

The cuticle, which in plants is generally regarded as a hardened cell-secretion, is then said, in those Infusoria which are ciliated all round, to bear small, four-sided prisms, at the apex of each of which there is a cilium; these are generally arranged in spiral series, crossing each other§. The supposed cell-membrane or cortical layer encloses the contractile vesicle and a system of vessels proceeding from this (see further on); it also frequently contains chlorophyll-globules, or colourless globules of the same form, which were regarded as eggs by Ehrenberg, but as to the signification of which we have as yet no observations. In many Infusoria, especially the *Ophryoglenæ* (in which it lasts long after the decomposition of the animal) and (less persistent) in many species of *Paramecium* (*P. Bursaria*,

* The idea of the cell would certainly by this means be remarkably modified, and by its too great extension would lose all signification.

† Siebold und Kölliker's Zeitschrift, iii. p. 257, v. p. 420.

‡ These are very well seen in Infusoria treated with chromic acid.

§ In *Stentor polymorphus* (to which *S. Müller*i and *Roeselii* are also to be referred) single long hairs stand between these, similar to the hairs of many Turbellaria (fig. 9); this is also the case in a species of Infusorium allied to the *Stentors*, which will be hereafter described. The foot-like hooks (*uncini*) and styles (*styli*) articulated to the body, occurring in the *Oxytrichinæ* and *Euplotes* (and the *Aspidiscinæ* of Ehrenberg) are well known: a portion of the former, those which are trailed along, are split up at the apex into as many as eight parts in various *Euplotes* (for instance, *E. patella*); one of the styles in *E. patella* bears a number of small lateral branches.

Focke, *P. Aurelia*, *P. caudatum*, and *Bursaria leucas**), there are fusiform rods in the cortical layer, from which Allman states he has seen urticating filaments projected†. In the *Vorticellæ* we shall hereafter have to describe in the cortical layer a contractile layer as the continuation of the muscle of the stem. We cannot certainly regard a part so complicated as the membrane of a cell; I believe that this "cortical layer" (of Cohn) is rather to be considered as the parenchyma of the body of the Infusoria, whilst the rotating mass only constitutes the contents of a large digestive cavity or stomach, and therefore must be regarded as chyme, and that Cohn's "cuticula" forms the true skin of the Infusoria.

The "cortical layer" alone is contractile: in torn Infusoria fragments of it not unfrequently contract, whilst the internal mass, the chyme, which flows out, never does this. When an Infusorium is sucked out by an *Acineta*, the cortical layer or parenchyma of the body may often contract for a long time, and the contractile vesicle placed in it may also continue its contractions for hours; nay, I have observed a *Stylonychia*, which, although a considerable part of its chyme had been sucked out of it by an *Acineta*, still underwent division, so that one of the gemmules of division swam away from it briskly, and only the other half of the old animal was destroyed. This appears also to a certain extent to prove that the mass sucked out does not represent the true parenchyma of the body, and as it only fills the large cavity of the body in the form of a tenacious fluid mass, and becomes mixed with the nutritive matters, especially when no small masses are formed, it is certainly the most natural course to regard it as chyme. It cannot be urged against this view, that in those Infusoria which contain chlorophyll-corpuscles in the substance of their bodies, we sometimes meet with single corpuscles in the rotating mass, as they may certainly be easily loosened from the parenchyma, and thus get into the chyme-mass. The nucleus, indeed, projects into the chyme-mass; but as a general rule, it appears to be affixed to the parenchyma of the body, as we do not see it rotate with the chyme-mass‡: in *Opercularia berberina*, Stein sometimes saw

* See O. Schmidt, 1849, p. 5.

† Similar, but much thicker corpuscles, which presented a deceptive resemblance to the urticating organs of the *Campanulariæ*, were found by me and my friend, E. Claparède, in an animal living as a parasite upon *Campanulariæ*, which is probably to be referred to the *Acinetinæ*, and which we shall take another opportunity of describing. In the oval embryos, ciliated on one side, which were squeezed out of the body of the mother, we were enabled to convince ourselves that these corpuscles were enclosed from two to nine together in a roundish proper vesicle (cell?).

‡ When it divides, as is usually the case in the development of embryos

the nucleus moved a little out of its previous position by a mass of food striking against it; but as it soon returned again to its position, this rather speaks for than against its attachment. In different individuals of the same species, the nucleus does not always occupy the same situation,—a circumstance which may probably be explained by fissation, as in the transverse division of an Infusorium, in which the simultaneously divided nucleus lies about in the middle, one portion of the nucleus will be situated in the posterior part of the anterior bud, whilst the other part will occupy the anterior part of the posterior one.

In many respects the parenchyma of the body of Infusoria resembles that of the Turbellaria, in others that of the Polypes; they also approach the latter especially by the possession of a large digestive cavity, in which, as in the *Actiniæ*, a tube (œsophagus), open at the bottom, generally hangs down. Whether the wall of this digestive cavity or stomach be one and the same with the parenchyma of the body, or separate from this, cannot at present be decided in most cases, although the former appears to be the case: in *Trachelius Ovum* alone we see a proper stomach-wall separated from the rest of the parenchyma by spaces filled with fluid, and thus form an arborescent ramified canal, which however must not be confounded with the nucleus*.

The digestive cavity of the Infusoria (certainly at least that of the cilated and some of the flagellated forms) possesses, besides the mouth, a second orifice, the anus. This is certainly denied by most of Ehrenberg's opponents, but a long and careful observation of an individual will always show that the fæces are invariably thrown out at the same part of the body, and in many Infusoria we may frequently recognise the anus in the form of a small pit, on the surface of the animal, even for a considerable time before and after an excretion; (this is often the case in *Paramecium Aurelia*, *P. Bursaria*, Focke, and *Stentor*). That the fæces are not forced through the parenchyma at any point on the surface of the body, is proved especially by the careful observation of

(see below), individual fragments of fissation usually separate and rotate with the chyme. When Siebold says (in his Comparative Anatomy, p. 24) that he has often seen an Infusorium rotate round its nucleus, it is not improbable that he has taken a rotating embryo (which, indeed, was not known at that time) for the nucleus.

* That this structure, described by Ehrenberg and disputed by others, really exists, was affirmed to me by Dr. Lieberkühn before I had the opportunity of investigating it closely myself; when I subsequently obtained this abundantly, I was enabled to convince myself of the correctness of the statement. The animals devoured (*Trachelius Ovum* is one of the most voracious robbers) are always seen lying in the ramifications of the stomach, in the clear spaces between them, except in crushed animals. The clear round spaces in the parenchyma of the body are certainly no stomachs, but contractile spaces.

Spirostomum ambiguum, and some new animals which are to be united with the *Stentors* in one family. In the former, the anus is situated at the hinder end of the animal, and close in front of it is the very large contractile vesicle; when fully expanded this vesicle appears to be surrounded only by a thin membrane, but nevertheless we see balls of excrement, often several at the same time, on different sides of the vesicle, separating the laminæ of its apparently simple covering, and forming projections which are often nearly hemispherical both towards the vesicle and the outer surface of the body. If masses of excrement do usually penetrate through the parenchyma of the body, we should expect it to be the case here when the tension of this is so great; we should also expect to see the masses of excrement pass into the contractile space if it were not a vesicle, but only a space in the parenchyma without proper walls. Neither of these things occurs, however; the fæcal masses are not deposited from the body until they have reached the anus at the hinder extremity of the body. A similar strong expansion of a thin part of the body by fæcal masses, without any rupture, is seen, as already mentioned, in some new *Stentorinæ*, which are distinguished from the genus *Stentor* by their having that part of the parenchyma of the body which bears the ciliary spiral and the anus (which in all the *Stentorinæ* lies on the dorsal surface of the body close under the ciliary spiral (figs. 6, 7 & 8 *e*) and not in a common pit with the mouth) drawn out into a thin process. In one genus, of which I observed two species (one is the *Vorticella ampulla* of O. F. Müller) in company with E. Claparède on the Norwegian coast, and which I will describe elsewhere, this process is broad and foliaceous, and bears the rows of cilia on the margin, whilst the anus is placed far up on the dorsal surface of a thin plate. In the other genus, *Chætospira*, Lachmann (figs. 6 & 7), observed by me in fresh water near Berlin, the process is narrow and bacillar; the series of cilia commences at its free extremity, and only forms a spiral when in action by the rolling-up of the lamina; in this genus also the process bears the anus. In both, fæcal masses (as at *m* in fig. 6) which are thicker than the process in its extension, pass through it to the anus (*e*), without breaking through it, notwithstanding the great expansion of its walls.

Not unfrequently, several balls of excrement unite into a large mass before the anus, in order to be passed out together. When an excretion takes place, the anus is seen to open (but often closes once more and opens again before the expulsion of the masses is effected), and then the fæcal masses are often expelled slowly.

[To be continued.]