

## XIX.—On the Organization of the Infusoria, especially the Vorticellæ. By Dr. C. F. J. LACHMANN.

[Concluded from page 128.]

IN the Infusoria we have found the alimentary apparatus to be a large nutritive or stomachal cavity filled with chyme, and furnished with a mouth and anus. In the *Vorticellinæ* we have seen an œsophagus, ciliated internally, depending from the mouth, and widening below into the pharynx. The internally ciliated œsophagus occurs also in many other Infusoria, but its dilatation into a pharynx is to be detected in no other family.

The œsophagus (*Schlund*), beset internally with fine cilia, and terminating below by an oblique truncation without dilating into a pharynx, is most distinctly seen in the *Paramecia* and the allied genera. In these animals, which are furnished with uniform fine cilia, sometimes all over and sometimes only upon a considerable portion of the body, and in which there is no row of stronger cilia leading to the mouth, after a morsel has been passed from the œsophagus into the alimentary cavity, we see the latter distinctly with a somewhat oblique termination; a little drop of water is then soon whirled through its lower extremity, against the tenacious fluid chyme-mass by which it is limited; the drop gradually becomes larger, and is completely surrounded by the chyme, the lower extremity of the œsophagus being applied to it only on one side. When the morsel thus formed has attained a certain size, which is not always the same, it is passed into the chyme-mass, where it then behaves in the same way as the fusiform masses of the *Vorticellinæ*, and also soon participates in the rotation of the chyme. In these animals also, as in the *Vorticellinæ* and all Infusoria furnished with a ciliated œsophagus, the water and food, instead of being united into drops or morsels, may be mixed at once with the chyme, evidently from an altered condition of the latter. In these Infusoria (Ehrenberg's *Colpodea*, with the exception of the species of *Amphileptus* and *Uroleptus*\*, the *Cyclidina* of Ehrenberg and

\* With Focke I refer *Loxodes Bursaria*, Ehrbg., to *Paramecium*, as the situation of the anus at the hinder extremity of the body does not appear to me sufficient for a generic separation of this animal from the closely allied *Paramecia*, the anus in *Paramecium Colpoda* being placed very near the hinder extremity, which is still more strikingly the case in a new colourless *Paramecium* very nearly related to the colourless *P. Bursaria*. I do not, however, with Perty, think it necessary to revive O. F. Müller's name of *Paramecium versutum*, as there is scarcely ever any certainty in the synonymy previous to Ehrenberg; and I think therefore that we should never again introduce an older specific name for an Infusorium, if it has a name given to it by Ehrenberg, even when it is not improbable

*Glaucoma*) the anus is situated on the ventral surface near the posterior extremity, or at the posterior extremity itself. Many of these Infusoria possess in front of the mouth a peculiar apparatus, consisting of bristles or a folded membrane; which of these is the case, it is difficult to decide (*Paramecium Chrysalis*, Ehrbg. = *Pleuronema*, Duj., *Cyclidium*, Ehrbg., *Alyscum*, Duj., Perty's *Aphthoniæ*); in some the margins of the buccal orifice appear to be produced into two valves, which are in constant motion (*Glaucoma*, *Cyclidium margaritaceum*, Ehrbg. = *Cinetochilum margaritaceum*, Perty, the family of the *Cinetochilinæ* of Perty).

The alimentary apparatus in many other Infusoria is just the same as in these (*Colpodea*, &c.), except that a particular series of cilia, distinguished from those covering the rest of the body by their greater strength and length, leads to the mouth (as in the *Bursariæ*, *Spirostomum*, and the *Stentorinæ*). These cilia then form a curved line, usually open towards the right, or, as in *Spirostomum* and the *Stentorinæ*, a prolongation of a line of this kind, namely a spiral turning towards the left (Pl. IX. figs. 6-8 *b, f*). In the *Bursariæ* and *Spirostomum* the anus is placed at the posterior extremity of the body; in the *Stentorinæ* (figs. 6-8 *e*), on the back, close beneath the series of cilia\*.

that he may have overlooked an older name. This maxim appears to me to be equally justifiable with that of preferring the specific names of Linnæus to older ones in other departments of the animal and vegetable kingdoms, as otherwise we must get into an inextricable confusion of names, different authors frequently referring the older specific names to very different species.

\* I have already characterized the new genus *Chatospira* belonging to the *Stentorinæ*. I am at present acquainted with two species of this genus from the fresh waters near Berlin. One of these, *C. Mülleri*, Lachm. (figs. 6 & 7), is slender; the first cilia (*b*) of the series of cilia are somewhat, but not remarkably, longer and stronger than the rest: when rolled up, the process bearing the series of cilia forms more than one turn of the spiral. The animal inhabits flask-shaped horny sheaths, which I have hitherto found only in the open cells of torn leaves of *Lemna trisulca*. The second species, *C. mucicola*, Lachm., inhabits mucous tubes; it is shorter and more compressed; the rolled-up process does not form a complete turn of the spiral; the first cilia are considerably longer than the rest, the first one especially being nearly twice as long as most of the others. Like all the *Stentorinæ*, both species are beset all over with fine cilia; but I cannot yet state with certainty whether *C. Mülleri*, like *C. mucicola* and *Stentor polymorphus*, possesses longer hairs between the cilia. It is possible that the free-swimming *Stichotricha secunda* of Perty, which he arranges with the *Oxytrichinæ*, is allied to my *Chatospiræ*; his figure, however, is very inexact, and might perhaps represent a *Loxodes* or *Amphileptus fasciola*; and as he does not describe the position of the anus, which he never figures, any more than the contractile vesicle and the nucleus, I do not venture to place his *Stichotricha* with the *Stentorinæ*. If it should turn out that it belongs to that family, it must be placed beside the analogous sheath-inhabiting *Chatospira*, as a genus not inhabiting a sheath.

In Ehrenberg's families of the *Oxytrichinæ*, *Euploteæ*, and *Aspidiscinæ*, as in the preceding, we also meet with an internally ciliated œsophagus (fig. 10 *h*), and a curved line open towards the right, composed of strong cilia (fig. 10 *b*, *f*) leading to the mouth (fig. 10 *f*). But besides the cilia of the surface of the body, or still more frequently without these, we find peculiar and more powerful organs of motion, the number and arrangement of which may serve for the distinction of the species and genera. These consist partly of very thick cilia placed in rows, which might be called ciliary bristles (*Oxytrichinæ*), partly of peculiarly grouped powerful processes, very thick at the base, and serving as feet, which were denominated *uncini* by Ehrenberg\* (in all three families); and besides these, the thin setiform processes, distinctly articulated at the base, and called *styli* by Ehrenberg, occur at the posterior extremity of some *Oxytrichinæ* and *Euploteæ*†. The anus in these animals is situated in the posterior part of the ventral surface (fig. 10 *e*). The internally ciliated œsophagus, which in the preceding always formed an open tube, is often collapsed in these at its inner extremity, and thus forms a transition to the œsophagus of the following groups.

Many Infusoria have a completely collapsed œsophagus—which, as forming a tube distinct from the parenchyma of the body, and hanging freely in the alimentary cavity, is perhaps entirely wanting in some species; at least I have hitherto been unable to detect it in *Amphileptus*, most species of *Trachelius*, *Enchelys*, *Coleps* and *Trachelocerca*, in which it only appeared to be a canal through the parenchyma of the body,—and these are generally incapable of forming roundish morsels like the species hitherto under consideration; but they usually swallow larger particles, which then pass separately into the cavity of the body, often even without being accompanied by water. It is very difficult to determine whether the œsophagus of these animals is furnished internally with cilia. In some, such as *Coleps*, this almost appears to be the case; these swim to any slimy mass, such as a deliquescent Infusorium, press the anterior extremity of the body against it, and open the mouth and œsophagus, which are usually closed, so as to form a wide canal; the mass lying before the *Coleps* then passes through

\* Of these, the anterior serve for the actual creeping or climbing; the posterior ones might be suitably denominated *trailing feet*, as they are generally trailed along behind the animal, and only employed occasionally in giving a subsequent push: these are cleft at the end in some species, as, for example, in *Euplotes patella*.

† That one of these styles, in *Euplotes patella*, bears setiform branches, has been already observed.



this canal into the interior of its body, apparently without any swallowing movements on its part, so that it can hardly be driven in, except by ciliary action. In others, on the contrary, the cilia of the œsophagus appear to be wanting, as in *Amphileptus*, *Enchelys*, *Trachelius*; these perform regular movements of deglutition, in order to overcome their prey, which usually consists of Infusoria of tolerable size; they push themselves, as it were, with swallowing motions, like the Snakes, over their prey, so that they can very rarely be fed with colour, and this never forms stomach-like morsels, except when it is contained in this form in the Infusoria devoured. The mouth in these animals is sometimes placed at the anterior extremity (*Coleps*, *Enchelys*), sometimes not (*Trachelius*, *Amphileptus*); the anus is sometimes situated posteriorly, and sometimes not.

This group of Infusoria is approached by those with peculiar bacillar thickenings, or eel-pot-like teeth (Ehrenberg) in the œsophagus, which is also collapsed. In these the œsophagus usually extends in the form of a collapsed tube far beyond this bacillar apparatus; in *Chilodon cucullulus*, for example, nearly to the posterior extremity of the animal. The mouth, which is not unfrequently protrusible, is situated sometimes at the anterior extremity of the animal (*Prorodon*), sometimes not (*Chilodon*, *Nassula*, *Liosiphon*, *Trachelius Ovum*\*). The anus is generally placed at the posterior extremity of the animal, but in some cases on the ventral surface near the hinder end (*Chilodon cucullulus*, in which it is nearly on the right margin of the body).

In the greater part of the Infusoria furnished with flagella, the reception of food appears to take place in the same way as in the last-mentioned groups of ciliated Infusoria. Although Ehrenberg states that he saw the reception of food by *Monadina* and *Cryptomonadinæ*, and figures coloured particles in animals belonging to these families, this was denied by many, who either thought that they were to be transferred to the vegetable kingdom as unicellular plants, or regarded them as astomatous animals. Cohn† was the first to re-establish the eating of these animals, and I have also succeeded in seeing it in many of them; I have not only seen coloured particles in the interior of the body, of which, from the minuteness of the object, one might always have remained in doubt as to whether they were really contained in its interior, but I have also twice observed *Monadina* which contained a small *Bacillaria*, the excretion of which in the vicinity of the posterior extremity taking place soon

\* For the knowledge of the bacillar apparatus in the latter, I am indebted to Dr. Lieberkühn.

† *Entwicklungsgeschichte der mikroskopischen Algen und Pilze*, p. 62 (Nova Acta Acad. C. L. vol. xxiv. pt. i. p. 162).



afterwards, also made me consider the existence of an anus probable. Last summer, Professor J. Müller, in company with M. E. Claparède and myself, observed great numbers of an animalcule, which was probably *Bodo grandis*, Ehrbg., but might also have been an *Astasia*, and which devoured *Vibriones* of two to four times its own length: in this way the animalcules acquired the most extraordinary forms, and the mouth was close to the insertion of the flagellum. With some attention, one or more contractile vesicles may be detected in all transparent animals of this family; of the more opaque species I was also able to observe this and its contractions in the anterior part of the body in *Chilomonas Paramecium* and *Cryptomonas ovata*.

The *Volvocinae*, *Astasiae* and *Dinobryinae* must apparently be arranged close to these animals, or at least those which possess a contractile space, although they have not yet been observed feeding. That they really receive no nourishment into an alimentary cavity, is certainly not proved. In certain cases Perty states that he has found very fine vegetable filaments in *Euglenæ*; but even if we do not regard this statement as sufficient for the observation of the eating, yet we have very recently ascertained modes of taking nourishment by Infusoria which might possibly occur also in the *Volvocinae*, &c., when it would certainly not appear by any means wonderful that they should only be discovered at so late a period. Has not Claparède\* only just made us exactly acquainted with the process of feeding in *Actinophrys*? If a similar mode of feeding, by the reception of the food in a process suddenly thrown out, also takes place in the above-mentioned creatures, it would be rarely observable in them, and it would only be by a happy chance that we should perceive the short moment of feeding; and then, if the nourishment consisted of small monads which are easily liquefied, we should not recognize them as such in the body of the animal. The observation would be equally rare and difficult if these animals, like the *Acinetæ* (*vide infra*), extracted the fluids of other animals by means of retractile suckers; and this is the less improbable, as Dr. Wagener has communicated to the Society of Naturalists of Berlin † an observation of Dr. Lieberkühn, who saw a flagellated Infusorium swim up to another, attach itself to this by a process projecting from one end, and thus suck out its contents. But even though the feeding of these creatures has not yet been seen ‡, I think we must, from analogy, refer them to the animal kingdom.

\* Ueber *Actinophrys Eichhornii*, Müller's Archiv, 1854, p. 54; translated in the Annals, vol. xv. 1855, pp. 211 & 285.

† In the July Meeting, 1855.

‡ It is probable that a mouth will be discovered in all aquatic Infusoria,

A contractile space, such as I have now certainly seen in a great number of the above-mentioned forms\*, has not yet been observed in any vegetable cell, or in the spore of an undoubted plant: endeavours specially directed to this object have hitherto been always futile. For this reason I believe, with A. Schneider †, that we must associate these creatures which are furnished with a contractile space with those which present the greatest external resemblances to them, and also possess a contractile space, namely the *Monadinae*, and therefore with the animal Infusoria, as long as no contractile space is found in indubitable vegetable cells.

In the *Peridinia*, which are furnished with flagella and cilia, no contractile space has hitherto been found; but, on the other hand, in company with E. Claparède, I made some observations on the Norwegian coast upon *Peridinium tripus* ‡, *furca*, and *fusus*, which promise, if pursued further, to make us acquainted with the mode of reception of food. From the point of insertion of the flagellum, on one side of the large notch, in the upper part of the row of cilia, a clear canal passes into the body of the animal, and dilates at the extremity to form a cavity of variable diameter. The flagellum is often seen to contract rapidly into a spiral form, and apparently disappear; and not unfrequently we may then succeed in perceiving that it is jerked back into the above-mentioned cavity, from which it soon returns into its previous position. Now it certainly appears worth while to see whether small particles of food are not carried into the cavity by this jerking-in of the flagellum.

The dispute as to the position of the *Bacillariae* and *Closterinae*,

and that only a number of the Entozootic species (the *Opalinae*) will prove to be truly astomatous. *Bursaria cordiformis*, Ehrbg., and *B. intestinalis*, Ehrbg., however, are erroneously referred to the *Opalinae*, as they possess a mouth.

\* Cohn does not consider his observation of the contractile space in *Chlamydomonas* and *Gonium* as sufficient to justify our regarding these creatures as animals. Besides these, E. Claparède and I observed the contractile space also in *Syncrypta Volvox*, and then in *Volvox*, in which its position is quite correctly described by Busk (Quart. Journ. of Micr. Science, i. 1853). I can completely confirm Focke's observation of the contractile space in *Dinobryon Sertularia*, and also found one in *Euglena viridis*. Claparède saw it in *Euglena Pleuronectes* and *E. Acus*. The detection of the contractile spaces in the *Euglenae* is rendered particularly difficult, not only by the mobility of the animal, but also by the circumstance that it lies directly over or close to the clear spot, indicated by Ehrenberg as a ganglion.

† Muller's Archiv, 1854, p. 203.

‡ Numerous observations and measurements of transition forms made by ourselves, as well as a number of drawings most kindly communicated to us by Professor Boek of Christiania, seem to prove that *P. tripus* and *P. megaceros* are not specifically distinct.

or the *Desmidiaceæ* and *Diatomeæ*, cannot certainly yet be regarded as decided. It is well known that a contractile vesicle has not as yet been discovered in them; their power of motion, their fissiparity, and the discovery by Focke of cilia in the interior of the *Closteria*\*, cannot settle the dispute. The retractile pseudopodia described by Ehrenberg have not been detected by other observers: the presence of colour in creatures of this group, proved by Ehrenberg, has been supposed capable of explanation otherwise than by the eating of coloured particles, as unfortunately the act of feeding was not observed, and the accumulation of colour in particular places, which are then regarded as the nuclei of these unicellular plants, appears to find an analogue in the discovery of Hartig†, that the cell-nuclei of all plants acquire colour more strongly than their other parts.

A peculiar mode of feeding, which has hitherto always been misunderstood, still remains to be mentioned. It has long been known (since the time of O. F. Müller) that other Infusoria often remain adhering to the tentaculiform rays of the *Acinetæ*, which are usually thickened at the extremity; and that, when they do not soon succeed in freeing themselves, they die. Even O. F. Müller supposed in consequence that the *Acinetæ* sucked out the contents of these animals, but he says nothing of the mode in which this is effected, and indeed could not observe it with his imperfect instruments. Ehrenberg believed that the captured animals were brought close to a mouth situated between the tufts of rays, and sucked out by this. Stein and Perty denied the existence of a mouth in these animals, and grouped them with the *Actinophrydes*; the former, again, distinguished the eating *Actinophrydes* (the true species of the genus *Actinophrys*, *A. Eichhornii* and *Sol*, with *difformis*, Ehrbg. and *oculata*, Stein) and those which did not eat (non-pedunculated individuals of *Podophrya fixa*, and therefore true *Acinetinæ*‡). The Infusoria which come in contact with the rays of the latter are said to die upon them, and then to become dissolved, when the fluid thus produced is taken up by the rays by endosmose. According to Perty, the death of the Infusoria is caused by an impalement on the extremely fine filaments of the *Acinetæ* and *Actinophrys*. Both these ideas were equally paradoxical and incorrect: the true mode of feeding, as may be seen without much difficulty

\* Physiologische Studien, Heft 1.

† Communicated to the Naturforscherversammlung in Göttingen, 1854.

‡ To these, and indeed to the same genus as *Podophrya fixa*, belongs the *Actinophrys ovata* of Weisse, which I have had the opportunity of observing in the neighbourhood of Berlin.



in the larger species, especially the *Acineta ferrum-equinum*, Ehrbg.\*, is as follows:—

When an Infusorium touches the button-like or plate-like dilated apex of the ray of an *Acineta*, it usually remains adhering to it; the apex of the ray becomes still more extended in the form of a plate, so as to constitute a sucking disk, and the ray becomes thicker and shorter; at the same time other rays make grasping movements, and endeavour to attach their extremities, which are becoming dilated into sucking-disks, to the captured prey. If the latter does not soon succeed in making its escape by great exertions, by which the rays of the *Acineta* are often greatly disarranged and injured, the *Acineta* begins to suck out its contents. Each ray is a sucking proboscis, and we soon see that a current of chyme-particles runs from the alimentary cavity of the captured Infusorium into the body of the *Acineta*, through the axis of the rays which, after seizing the prey, have become shortened and thickened. In the body of the *Acineta* the chyme-particles still run at first in a slender row, but afterwards they collect in a drop (fig. 14), which, although drops are also formed in the chyme of the *Acineta* by other suckers, soon becomes amalgamated with these. When a considerable quantity of the chyme of the captured animal has passed over into the body of the *Acineta*, a remarkable change gradually takes place in its appearance: if it was previously pale, nearly transparent, and only very finely granulated (fig. 14), larger, dark globules, resembling fat-drops, now make their appearance here and there; and these soon increase, so that the body, which at the same time of course increases in thickness, acquires a coarsely granular aspect, and becomes opaque (fig. 15). The globules or drops which make their appearance can only be formed in the body of the *Acineta*, as they are far larger than the chyme-particles which are seen flowing through the sucker†. The animal whose contents are thus sucked out, gradually collapses and dies; many become liquefied when only a little of the chyme is extracted from them, others still live for a long time; in large animals, such as *Stylonychia Mytilus*, *Paramecium Aurelia*, &c., the sucking often continues for several hours. Whether the *Acinetina* possess an anus, or in what way they again throw off effete matters, has not yet been ascertained.

With regard to the structure, and especially the nutritive apparatus of the Rhizopoda (including besides the Foraminifera

\* This has subsequently been described by Weisse as *Acineta cothurnata*, and by Stein as the diadem-like *Acineta*.

† These alterations in the appearance of the body occur also in other Infusoria when they have devoured animals (Infusoria).

of D'Orbigny, or the Polythalamia, the *Amœbeæ*, the *Arcellinæ*, and the *Actinophrydes*\*), I can add nothing fresh to the statements of the most recent authors (especially those of Max Schultze upon the Polythalamia and of Claparède upon *Actinophrys*†). I have seen the flowing of the granules in the processes of the Polythalamia and in *Actinophrys*, their transfer from one process into another which was amalgamated with it in the Polythalamia, and the eating and conjugation of *Actinophrys*, as described by the above-mentioned authors. As we know scarcely anything of their reproduction, I shall not refer to it in what follows.

Besides the skin and the alimentary apparatus, two other organs remain to be mentioned, as being common to all Infusoria, both of which Ehrenberg believed were to be reckoned parts of the male sexual apparatus. To regard the globules considered by Ehrenberg as ova (Perty's "Blastien") as being really such, in the present state of our knowledge of the Infusoria, is unnecessary, as the exclusion of brood from them has never been observed, and the theoretical necessity which induced that naturalist to give them this interpretation is fulfilled by the discovery of very small embryos formed in a different manner. (To these we shall refer hereafter.) The globules regarded as ova and as "Blastien," are partly the roundish corpuscles, sometimes coloured, sometimes colourless (already mentioned), which occur in the parenchyma of some Infusoria; partly chyme-particles, and lastly, in part the oil-drop-like globules which are seen to make their appearance in the Infusoria after the reception of animal food‡.

That the interpretation proposed by Ehrenberg for the two organs still to be taken into consideration, namely the contractile space and the glanduliform body, is destitute of any certain foundation, and exceedingly improbable, has already been sufficiently demonstrated by others; but yet no unity of opinion has been arrived at with regard to their true signification.

The contractile space (seminal vesicle, according to Ehrenberg) is regarded by most of the recent authors, except O. Schmidt and E. Claparède, in accordance with Dujardin's example, as a

\* Which the *Acanthometræ*, and probably also other creatures possessing a siliceous skeleton, and the position of which is doubtful (the *Polycystinæ* of Ehrenberg, and perhaps the Sponges and *Thalassicollæ*), appear to approach in their structure, according to the most recent observations of Claparède (Monatsbericht der Akad. der Wiss. zu Berlin, 1855, p. 674), which I was so fortunate as to be enabled to repeat and confirm immediately after they were made.

† Translated in the Annals, vol. xv.

‡ Even the yellow ova of *Bursaria flava*, Ehrbg., appear to be coloured oil-drops.

cavity destitute of proper walls (vacuole), which is sometimes supposed to form the analogue of a heart\*, and sometimes that of an excretory† or respiratory‡ water-vascular system. In order to be able to judge of these views, we must first of all examine rather closely into the behaviour of the contractile space, and for this purpose those Infusoria in which processes or branches of the vesicle can be detected, appear to be particularly important.

Radiating branches of the contractile spaces were first discovered by Ehrenberg in *Paramecium Aurelia* and some other Infusoria. When the contractile space is full and wide open, the rays can only be observed as fine lines, or, when the light is not good, are entirely imperceptible; by the sudden contraction of the space, however, they instantly swell into a pyriform commencement close to the position of the contractile vesicle which has disappeared. With favourable illumination, when the animals possess the proper degree of transparency, the rays may be traced in *Paramecium Aurelia* across the half of the animal, and we may sometimes perceive a bifurcation of one or other of them. During the slow re-appearance of the contractile space, the rays gradually decrease, and they have almost entirely disappeared, or become reduced to fine lines, when the vesicle has attained its full extension. These rays, as well as the contractile spaces, lie, as in all Infusoria, close under the skin ("cuticula" of Cohn), in the parenchyma of the body ("cortical layer" or "cell-membrane" of Cohn).

In many *Vorticellæ* we also find processes going off from the contractile vesicle (Ehrenberg even states that he has frequently seen the contractile vesicle of *Carchesium polypinum* lobate or almost radiate); of these I have been able to trace one particularly, in *V. nebulifera*, *campanula* and *Carchesium polypinum*, up to close beneath the skin of the ciliary disk; this, when seen from above, exhibited a longish section (fig. 3 *k*). From this a fine branch appears to run, on the upper wall of the vestibulum, transversely across this to the other side; at least I have seen a thin process hanging down like a short curtain into the vestibulum from the side turned towards the ciliary disk (in fig. 3 it is represented by the broad dotted line which runs transversely across the vestibulum from *k*), which swelled up when the above-mentioned process became enlarged in consequence of the contraction of the vesicle.

In *Dendrosoma radians*, Ehrbg., a fine vessel runs through

\* Wiegmann, Archiv, 1835, i. p. 12; Von Siebold, Vergl. Anat.

† Bergmann and Leuckart, Vergl. Anat. pp. 184 and 214.

‡ O. Schmidt, who, however, admits the existence of walls to the vesicle. Frierp's Notizen, 1849, p. 5; Vergl. Anat. p. 220.



the whole length of the body, and sends branches into its ramifications: it is furnished with a number of contractile spaces, partly in the stem and partly in the branches.

The processes of the contractile space are seen with remarkable distinctness in the large *Stentor polymorphus* (including *S. Roeselii* and *Mülleri*), in which a very considerable portion of a vascular system may be recognized. The large contractile space lies a little to the left of the œsophagus, near the plane of the ciliary disk (fig. 8 k). From it a longitudinal vessel runs to the posterior extremity of the animal, and an annular vessel round the ciliary disk (*Stirn*) close under its series of cilia. Both these are visible even during the expansion of the contractile vesicle, but swell up suddenly like the vessels of the above-mentioned Infusoria during its contraction: at this time the longitudinal vessel usually exhibits considerable dilatations, which, when superficially examined, may easily be taken for independent, disunited cavities (vacuoles). (See figs. 8 and 9; the latter figure shows a diagrammatic section of a part of the posterior extremity of *Stentor*, in the parenchyma of which the dilatations of the longitudinal vessel are seen on the left side.) The annular vessel exhibits a more uniform lumen; only two roundish dilatations make their appearance in it, one close to the anus on the dorsal side of the animal, and the other close to the œsophagus on the ventral surface (fig. 8 o o). Both vessels gradually decrease during the reappearance of the contractile vesicle, apparently without any contraction of their own, in the same way as the vessels of the *Paramecia*. The longitudinal vessel of the *Stentors* and a similar one in *Spirostomum ambiguum* were first described by Von Siebold\*, whilst their existence has been erroneously denied by Eckhardt†.

As we thus find a vascular system in the *Stentors*‡, and in other Infusoria recognize the parts lying nearest to the centre (the contractile space), sometimes easily and sometimes with difficulty, we may certainly conclude that such a system exists in all Infusoria which possess a contractile space, even when no branches have been detected running out from this. That this system does not merely consist of accidental chasms in the parenchyma of the body (vacuoles of Dujardin), is apparent from its regularity. When it is asserted, in proof of the inconstancy of these vacuoles, that exactly similar ones frequently make their appearance in other parts of the body, this appears to me

\* Vergleichende Anatomie, p. 21.

† Wiegmann's Archiv, 1846, p. 237.

‡ In opposition to the opinion that this is a system of seminal canals, the existence of the annular vessel in *Stentor* may also be taken, in addition to the reasons brought forward by other authors.

to arise from very different things being confounded together. The swelling dilatations of existing vessels are certainly often regarded as such vacuoles, without its being remembered that these dilatations always gradually decrease again, whilst the true vascular centres, the contractile spaces, always diminish suddenly in healthy animals. Moreover, in diseased Infusoria, an exudation of a fluid, with which the parenchyma is normally imbued, appears to take place from it even into the cavity of the body, and perhaps into chasms of the parenchyma, as we often see it take place in Infusoria, and many other low Invertebrate animals, on the surface of the body. These sarcode-drops appear to be incapable of ever being again absorbed, but their formation always appears to lead, although slowly, to the death of the animal.

Although we may now assert positively that the contractile space is the centre of a vascular system, which does not consist of chasms formed in the parenchyma by its accidental separation, another and more difficult question concerning its nature remains to be cleared up, namely, whether the vessels and the contractile space possess proper walls, or whether they are only regular and constant chasms in the parenchyma, and whether the contractile space is or is not a vesicle. The mode of contraction, which differs from the other contractile phenomena of the parenchyma of the body, appears to speak decidedly in favour of the vesicular nature of the contractile space. The circumstance that, before its complete expansion, it frequently appears to be divided into two or three, is not opposed to this, as a vesicle may very well be constricted into two or more parts by the partial contraction of annular portions, or by strictures. Some other facts appear to be in favour of the vesicular nature of the contractile space, such as the phenomenon presented by *Spirostomum ambiguum*, already referred to, in which balls of excrement pass to the anus between the contractile space and the outer skin of the animal, and, although often arching the wall of the contractile space into a semiglobular form, yet never break through into it. In *Actinophrys*, the supposition that there is a membranous boundary at least on the outside of the contractile vesicle, can hardly be rejected, as its wall, which is situated on the outermost surface of the body, must burst at the moment of greatest expansion, if it were only composed of the gelatinous parenchyma of the body\*.

The behaviour of the contractile vesicle in *Actinophrys*, also, hardly allows us to suppose that it has an opening outwardly ;

\* See Frey, Hautbedeckungen der wirbellosen Thiere; Von Siebold, Vergl. Anat.; and especially Claparède, Müller's Archiv, 1854, p. 417, translated in the Annals, *loc. cit.*

nor have I ever been able, in other Infusoria, to confirm O. Schmidt's assertion\* that the contractile vesicle opens externally. In many Infusoria we see one or more pale spots upon the contractile vesicle, which may easily be taken for orifices, but, on closer examination, prove to be only thin spots in the parenchyma of the body and the skin, by which the action of the external water upon the contents of the vascular system is certainly facilitated, so that they probably serve for respiratory purposes. These round clear spots are particularly numerous upon the contractile space of *Spirostomum ambiguum*. As, therefore, we do not possess the certain proof of one of the most essential requirements of a water-vascular system, the existence of an external orifice, and some things even appear to be directly opposed to it, we can only, like Wiegmann†, Von Siebold, and others, regard it as a blood-vascular system.

Before passing to the consideration of the nucleus, we will refer to some other conditions of structure, although these have only been detected in particular Infusoria, as the consideration of the nucleus cannot be separated from that of the reproduction, which then still remains to be examined.

Of other systems of organs, besides the nutritive and circulatory apparatus already referred to, we have comparatively little to say, and that mostly of a negative nature. If the clear spots already mentioned on the contractile vesicle are not to be regarded as the indications of a respiratory system, nothing is known of such a system, as Pouchet's supposed respiratory apparatus of the *Vorticellæ* is only their pharynx. The above-mentioned thinner spots in the skin may facilitate respiration, which probably otherwise takes place by the whole skin.

Nothing is known of organs of secretion, although Ehrenberg describes such organs in *Nassula elegans*, *Chilodon ornatus*, and other species, as the sources of a coloured gastric juice; but the coloured spots which they are said to form are regarded by others (Von Siebold) only as pigment-spots. In most, if not all Infusoria the whole surface of the body is capable of exuding a gelatinous matter. Some do this regularly, and the gelatinous matter exuded either retains its gelatinous consistence (*Stentor*, *Chatospira mucicola*, and others), or, hardening into a horny matter (*Arcellinæ*, *Ophrydinæ*, *Tintinnus*, *Chatospira Mülleri*, &c.), forms a sheath (*urceolus*) into which the animal can retract itself more or less completely. In some species of the genus *Diffugia* grains of sand are stuck into this hardening sheath; in the *Polythalamia* it becomes calcified. Besides this exudation of

\* Froriep's Notizen, 1849, p. 6, and Vergl. Anat. p. 220.

† Archiv, 1835, i. p. 12.



gelatinous matter for the purpose of forming sheaths, another gelatinous exudation also occurs in a great many Infusoria, which leads to the formation of a completely closed and generally round case enclosing the animal which secretes it: this is the cyst-formation, first described by Guanzati, and so often observed of late, the object of which appears to be the protection of the encysted animal from unfavourable circumstances in the water inhabited by it, and from death by desiccation. How far encystation is connected with reproduction, we shall see hereafter. The cysts are not always smooth; thus Cienkowsky\* saw *Podophrya fixa* form transversely annulated cysts† and also describes other cysts with a stellate surface (*Stylonychia pustulata*‡); Stein observed longitudinally-ribbed cysts in *Epistylis branchiophila*; and I have seen finely-shagreened ones in a small undescribed species of *Epistylis*.

A nervous system has not yet been detected. Whether the pigment-spots regarded by Ehrenberg in some Infusoria as eyespots, are really so, is uncertain; a peculiar refractive body has not yet been detected in them, whilst one occurs in the form of a concavo-convex lens without a pigment-spot, close to the mouth, in *Bursaria flava*, Ehrbg. Whether the clear bodies which Ehrenberg supposed were to be regarded as ganglia in some flagellated Infusoria, and the reniform bodies discovered by Stein in the peristome of *Opercularia articulata*§ belong to a nervous system, is still very problematical.

With the exception of the cilia and other external appendages of the body already mentioned, special organs of motion have hardly yet been detected. Ehrenberg's account of muscular striæ giving origin to the series of cilia in many Infusoria is not satisfactorily confirmed, and is regarded by most authors as founded upon an illusion. The parenchyma of the body (not the skin) of most Infusoria is contractile, although no one has yet succeeded in distinguishing special muscles or muscular layers. I have also been unsuccessful in my search for them; but, on the other hand, I was so fortunate, in common with my friend, E. Claparède, as to observe an indubitable separate contractile layer, in which longitudinal striæ were generally to be

\* Siebold and Kölliker's Zeitschr. vi. p. 302, and Bull. de l'Acad. Impériale de St. Pétersb. 1855, p. 297.

† Stein regarded these cysts as transition steps between *Vorticella microstoma* and *Podophrya fixa*, and thought that they were produced by the encystation of the former, and not of the latter. Weisse described them (Bull. Acad. St. Pétersb.) as independent Infusoria, under the name of *Orcula trochus*.

‡ I have also seen these cysts, and think that they are what Weisse has described (Bulletin, &c.) under the name of *Discodella multipes*.

§ *Loc. cit.* p. 117.

detected, in various *Vorticellinæ*, in which Ehrenberg states that he saw muscular striæ at the posterior extremity. It forms a hollow cone, the apex of which is situated in the hinder extremity of the animal, and, in the contractile-stemmed species, is produced into the muscle of the stem; in its apparent section it of course appears like two small fibres separating from each other like a fork, as which, indeed, it has hitherto been always regarded, except by Ehrenberg\*. This layer is very beautifully seen in *Epistylis plicatilis*, in which we may most completely convince ourselves that it is a special stratum, which possesses contractility. In *Epistylis plicatilis*, namely, during the contraction of this stratum, the non-contractile part of the parenchyma which surrounds it, with the skin covering it, separates from the contractile layer, and forms the well-known folds, whilst the contractile or muscular layer becomes shortened and thickened without folding. The structure of the contractile stem is carefully treated of by Stein† and especially by Czermak‡, to whose statements I may refer. As the sole function of the innermost part of this stem appears to be contraction, and it is not perfectly structureless, I think we need not hesitate in calling it a stem-muscle; and I cannot allow any value to Stein's objection, namely, that it still contracts even when the stem is not attached to another object, for the muscle does not thus lose its insertion, as it is attached to the sheath of the stem itself by its hinder extremity, and not to the foreign object. Perhaps the transverse annulations which are exhibited by the bodies of some *Vorticellinæ*, are to be attributed to muscular fibres; at all events, they do not belong to the skin, but to the parenchyma of the body.

After we have thus mentioned what has been ascertained up to this time with regard to organs unconnected with reproduction in the Infusoria, nothing remains to be considered except the mode of propagation.

Without entering into a controversy upon the *generatio æquivoca*, which now, fortunately for science, is almost solely defended by men§ whose observations are so superficial, that no criticism of them is necessary, we may pass at once to the true

\* Stein asserts that this does not occur in all contractile-stemmed *Vorticellinæ*; I have always succeeded in seeing it, even in the *Vorticella microstoma* and *Zoothamnium affine*, St., which Stein represents without it.

† *Loc. cit.* p. 78.

‡ Siebold and Kölliker's *Zeitschr.* iv. p. 438. I cannot confirm Czermak's statement, that the stem of the *Vorticellinæ* is sometimes twisted to the right and sometimes to the left, as I have always found it twisted in the same direction as the spiral of cilia, in a great number of cases in which I examined it carefully with this view.

§ Pineau, Dr. Gros, &c.

modes of reproduction of the Infusoria. In them we meet with an undoubtedly asexual reproduction, and also with a mode of propagation which it is probable will hereafter be proved to be of a sexual nature, or which must be regarded as the analogue of the sexual reproduction of the higher animals,—namely, a propagation by embryos. The purely vegetative mode of propagation consists in fission and gemmation.

Fission, as is well known, is the most widely-diffused mode of propagation of the Infusoria, and the one with which we have been longest acquainted. Nevertheless, it has not been so closely studied as, perhaps, it deserved; for our knowledge of it has made but little progress since Trembley's beautiful description of the fission of the Stentors. By the generalization of a few observations, principally with reference to the cell-theory, we have come very recently to believe that the nucleus always induces the fission by its becoming divided, or at least constricted. This view, however, is not correct. There are certainly cases in which the nucleus first of all divides, but in other cases its division only takes place when the rest of the body is already far advanced in division; and in others again the actual fission of the nucleus does not lead to that of the body, but embryos are developed in it, as we shall soon show. The fission is generally commenced rather by a new formation of contractile vesicles\*, from dilatations of the existing vessels, as appears from Stein's observations on *Stentor*. In those Infusoria in which a peculiar series of stronger cilia leads to the mouth (such as *Oxytrichina* and *Euplotea*), the furrow in which this series of cilia is situated, is seen subsequently [to,] or simultaneously [with the division of the contractile vesicle] to become produced backwards over the mouth; in this prolongation cilia are produced, and its posterior extremity becomes deepened into a mouth and œsophagus, which then opens towards the alimentary cavity of the animal; then, simultaneously with the external constriction of the body, the new furrow is separated from the old one. (In *Stentor* the new frontal series of cilia first makes its appearance on the old animal as a lateral, straight series,—the *crista lateralis* of Ehrenberg.) In animals which also possess peculiar processes of the body as organs of motion (hooks, styles, &c.), the fission usually takes place in such a manner, that each of the newly-formed animals acquires a portion of these from the old animal, whilst the other part is of new form-

\* Even Ehrenberg refers to this in some cases. Wiegmann adduces it in support of his opinion that the contractile vesicle is to be regarded as the heart. The greater part of the following observations on the development of the Infusoria were made by me in conjunction with my friend, E. Claparède.



ation. Stein gives an incorrect representation of the fission of the *Vorticellinæ*, as he supposes that before this takes place the ciliary disk, œsophagus, &c. of the old animal are absorbed, and when the fission has advanced further, two new ciliary disks are formed. This, however, is not the case: by careful observation the movement of the cilia is seen, during the whole process of fission, upon the ciliary apparatus, and in the vestibulum and œsophagus of the animal which is closed up by the peristome.

Fission had not been previously observed in the family of the *Acinetinæ*, and it has only been very recently described by Cienkowsky\* in *Podophrya fixa*; one of the two buds of fission acquires cilia all over it, retracts its suckers, and swims away, becoming again converted into a *Podophrya* by the loss of its cilia; the same thing takes place in *Acineta mystacina*, and here also one of the buds of fission is ciliated all over.

Far less general than fission is the process of gemmation, which is only known as yet in *Vorticellinæ*, *Acinetinæ* (here only in *Dendrosoma radians*, Ehrbg.), and in *Spirochona gemmipara*, Stein, the position of which still appears doubtful to me†. In the *Vorticellinæ* the bud is formed as a swelling of the parenchyma on some part of the body, into which a diverticulum of the digestive cavity of the parent animal extends. The alimentary cavity of the bud thus formed is subsequently divided from that of the mother, and finally the entire bud separates, with development of a posterior circlet of cilia. In *Dendrosoma radians*, Ehrbg., a branch of the nucleus grows into the bud whilst it still remains united to the parent animal. Fission and gemmation pass into each other almost imperceptibly, as the buds of gemmation are not always much smaller than their parent; if it be desired to draw a sharp line of demarcation between them, we may say that in fission each of the new-formed animals acquires a pre-existing part of the nucleus of the old animal; whilst in gemmation, one part, the bud, only acquires a newly-formed part of the old nucleus, or none at all; (in the latter case, of course, a nucleus must be developed independently in the bud).

The true generation has only been known at a very recent period. The first observation upon this subject, which, however,

\* Bull. Acad. de St. Pétersb., 1855, p. 297.

† In Müller's Archiv for 1854, p. 205, A. Schneider describes a mode of propagation in *Diffugia Enchelys* as sprouting or gemmation, which, nevertheless, is perhaps more properly to be regarded as fission. Stein also describes (p. 191) a propagation by formation of buds in *Uvella bodo*, Ehrbg. = *Phacelomonas bodo*, Stein.

has been completely disregarded, was made by Von Siebold\*, upon an Infusorium (*Bursaria* or *Opalina*) living as a parasite in the intestine of the Frog: in this he found a number of small embryos in a cavity at the posterior extremity of the body. Embryos were subsequently rediscovered, first by Focke† (whose observations were confirmed and enlarged by Cohn‡ and Stein§) in *Paramecium Bursaria*, Focke = *Loxodes Bursaria*, Ehrbg., then by Eckhardt|| in *Stentor polymorphus* and *cæruleus* (confirmed by O. Schmidt¶), by Stein\*\* in many *Acinetæ* and in *Chilodon*, and, although less exactly, by Cohn†† in *Urostyla grandis*. From the observations of Focke and Stein, a division of the nucleus appeared to take place in the formation of embryos; whilst Eckhardt does not refer to this, and Cohn regards its division as improbable. I have been so fortunate as to observe the formation of embryos, not only in many *Acinetinae*, but also in numerous other Infusoria. As the description of these observations, which were for the most part made in conjunction with E. Claparède, would lead us too far, we shall furnish this in a separate memoir; and I only give here the scheme of development, such as we have observed it more or less completely in different cases.

The development of the embryos takes place in the nucleus, or in a part of it. The nucleus is usually seen first of all to divide into two or more parts, when the same processes take place in one or several of these parts, which in other cases occur in the undivided nucleus. The nucleus is usually roundish or longish, or even (as in many *Vorticellinae* and *Stentor*) much elongated and band-like: it is enveloped in a peculiar membrane, as Stein has proved, and generally presents a homogeneous or finely granular appearance; it appears constantly to enclose a cavity surrounded by thick walls (the substance of the nucleus), sometimes (*Chilodon*) containing a smaller body, the nucleolus, which in other species is situated close to the nucleus. Upon or in the wall of the nucleus or one of its products of division, we now sometimes perceive small round globules, which increase in size, finally acquire a contractile vesicle, and become converted into embryos; these at last become furnished with cilia, escape out of the parent animal, and swim about

\* In his Memoir upon the development of *Monostomum mutabile*, in Wiegmann's Archiv, 1835.

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

‡ Siebold and Kölliker's Zeitschr. iii. p. 277.

§ *Op. cit. supra.*

|| Wiegmann's Archiv, 1846.

¶ Frierip's Notizen, 1849, p. 7.

\*\* *L. c. supra.*

†† *L. c. supra.*

freely, generally in a form more or less differing from that of the mother. Very different numbers of embryos may be formed in one section of the nucleus; in the same species we sometimes find many and sometimes only one embryo formed in it; and an embryo which has been developed alone in a fragment of the nucleus is usually as large as all the embryos formed in a similar fragment which has developed many of them, taken together.

The true import of the nucleus of course is not decided by this statement; [we cannot say] whether it is to be regarded as a germ-stock, in which germs are formed asexually; as an ovary, in which the ova are developed at the same time; or, in accordance with Focke's views, as a uterus, in which the ova or germs, formed in another place (perhaps in the nucleolus?), are further developed.

The fate of the embryos which are unlike their parents, after their birth, is still unknown in most cases. For the *Acinetæ*, Stein, as is well known, has set up a peculiar theory, which he has endeavoured to support by many examples; according to this, the *Acinetæ* are metamorphosed *Vorticellæ*, which, in this altered form, assist in propagation by the production of embryos; the embryos, as Stein supposed, again became *Vorticellæ*: unfortunately he never observed this directly, but always lost sight of the embryos before their fate was decided. In support of the transformation of the *Vorticellæ* into *Acinetæ*, he brought forward some supposed transitions, the series of which, however, still presented considerable gaps. Many of these intermediate forms, which are always encysted states, have so far distinct characters, that they might also be referred as encysted states to a great many other Infusoria, so that they can only furnish a proof of the asserted transition, when we are certain that, in a series of observations upon the transformation of one species, we have always to do with the same individual, so as to exclude the possibility of confounding individuals of other species therewith. For, the reason, and almost the only one, that Stein can adduce in favour of his opinion, in most of the *Acinetæ*, except the analogy with the other *Acinetæ*, which led him to think their relationship to the *Vorticellæ* probable,—namely, the frequent occurrence of certain *Acinetæ* and *Vorticellæ* in each other's company,—is evidently no more a proof of relationship in this than in other cases. The frequent parasitism of certain *Acinetæ* upon certain *Vorticellinæ* furnishes no better proof; we often find other Infusorial parasites upon the same *Vorticellinæ*, so that we have our choice as to which we will regard as related to the host.

In favour of the relationship between some *Acinetinæ* and *Vorticellinæ*, Stein adduces an alternation in their occurrence; so



that in a vessel which at first contained a great number of *Vorticella microstoma*, these in course of time gradually diminished, whilst individuals of a particular species of *Acineta*, in this case *Podophrya fixa*, made their appearance in constantly increasing numbers. In this case changes may very probably have taken place in the conditions of the surrounding medium, which were unfavourable to the former species, and compelled them to become encysted, whilst they probably only furnished the other species with the favourable conditions for their existence and propagation. A similar alternation in the occurrence of species is observed in many species\*, so that the admission of their relationship would compel us, with Pineau †, Dr. G. Gros ‡, and Laurent §, to regard the greater part of the Infusoria as stages in the development of the same species, nay, even to place them in relationship to the Rotifera, Worms, and Crustacea. In the alleged relation between *Vorticella microstoma* and an *Acineta*, we also find a very natural reason for the simultaneous increase of the *Acineta* and diminution of the *Vorticellæ*, in the fact that the latter are very often sucked out by the former, frequently three to four *Vorticellæ* at once by a single *Acineta*. The supposed intermediate steps between the two forms of Infusoria are, as Cienkowsky || has proved by direct observation, in part erroneously explained. Stein's transversely costate cyst (tab. 4. fig. 30 ¶), which he supposes to have been produced from a *Vorticella*-cyst, and to pass into a *Podophrya*, through the state represented in fig. 31, according to Cienkowsky was rather produced through the intermediate step, fig. 31, from a *Podophrya*, but without becoming converted into a *Vorticella*-cyst.

An alternation of this kind in the appearance of particular Infusoria, can only allow us to conclude that they are related, when we have convinced ourselves by strict isolation that there are only individuals of the one species and none of the other in a particular small space, when we take care that none of these can have access from without, and enable ourselves to watch the individuals. This has always been neglected by Stein; only one of his observations\*\* appears nearly to fulfil this requirement, so

\* See Schrank, Fauna Boica, iii. 2. p. 19; Cohn, in Siebold and Kölliker's Zeitschr. iii. p. 258, &c.

† Ann. des Sci. Nat. 3 série, iii. p. 182, iv. p. 103, and ix. p. 100.

‡ Ann. des Sci. Nat. 3 série, xvii. p. 193, and various papers in the Bull. de la Soc. Imp. de Naturalistes de Moscou.

§ Various memoirs in the Mémoires de la Soc. des Sciences, &c. de Nancy, and Etudes Physiol. sur les Animalcules des Infusions Végétales, 1854.

|| Bull. de l'Acad. de St. Pétersb. 1855, p. 297.

¶ *Orcula Trochus* of Weisse.

\*\* *L. c. supra*, p. 39.

that it seems to have led him to the incorrect assertion\*, that he had "by direct observation" seen *Vaginicola crystallina* become converted into *Acineta mystacina*. But even this observation was not exact. On a number of filaments of Confervæ which he had thrown into a glass filled with clear spring-water, because they were particularly rich in *Vaginicolæ*, Stein found, after the lapse of several days, "instead of the *Vaginicolæ* scarcely anything but *Acinetæ*." Stein does not say that he convinced himself that at the commencement there were no *Acinetæ* at all adhering to the Confervæ, or that he obtained any certainty as to the identity of the individuals by the identity of the spot on which an *Acineta* sat with that to which a *Vaginicola* was previously attached,—two things which certainly ought to have been done in order to prove a direct observation of the transition of one form into the other; and yet, as he could not find the sheaths of the *Vaginicolæ*, which had probably fallen down, he allows himself to be led away into a bold hypothesis, which is to solve the difficult problem of the conversion of the hard sheath of the *Vaginicolæ*, which is widest at the bottom, into an *Acineta*-sheath, which is narrow at the base.

I now endeavoured to settle the existing doubts by strict isolation. For three years I have effected this, at different times, with different *Vorticellinæ*, namely with *Vorticella microstoma*, *campanula*, and *nebulifera*; *Carchesium polypinum*; *Epistylis plicatilis*, and *Opercularia nutans*: on each occasion I preserved about twenty or thirty individuals of one of the above-mentioned species, sometimes in a small glass tube, sometimes on an object-glass, keeping them moist, and preventing desiccation by the occasional addition of distilled water. In this way I obtained cysts of *Vorticella microstoma* often enough, but no *Acinetinæ* were ever developed either from this or from the other *Vorticellinæ*. From the cysts of *Vorticella microstoma* unaltered *Vorticellæ* escaped, sometimes at the end of three or even four weeks.

After I had convinced myself that the conversion of *Vorticella* into *Acinetæ* was not to be proved in this way, but was rather rendered more improbable by the experiments instituted, I attempted to test the other part of Stein's hypothesis,—to ascertain the fate of the embryo of *Acineta*. An observation of Professor J. Müller, which renders probable the conversion of such young animals into an *Acineta* resembling the parent, has already been adduced. Subsequently I succeeded several times in obtaining a certain result. In order to facilitate observation and avoid confounding the roving embryos with similar animals, I generally isolated each *Acineta*, containing one or two em-

\* *L. c. supra*, p. 36.

bryos, in a drop of water upon an object-glass, and then observed the escape, the roving, and lastly the quiescence of the bud. Thus I could even quit the microscope for some time, and yet be sure of again finding the same individual, and not confounding it with others; in some cases I remained the whole time at the microscope. I first succeeded in the summer of 1853, when in Würzburg, in tracing the fate of some buds of *Acinetæ*, which I at first regarded as Stein's *Acineta* of the Duckweed, but which I do not now consider to be distinct from Stein's *Acineta* of the *Cyclops*, although it attached itself to the Duckweed or swam about freely in the water\*. Cienkowsky† also has recently followed the destiny of the embryo of an *Acineta*, which appears probably to be identical with that above mentioned, for, that Cienkowsky (as well as Stein for his *Acineta* of the *Cyclops*) figures the embryo much smaller than I have ever seen it, can certainly not constitute a specific distinction, as in other Infusoria also, the buds of one species, nay even of one individual, may be of very different size. Cienkowsky arrived at the same result as myself: after roving about very rapidly for a time, the bud became quiescent, lost its cilia, and developed the radiate suckers which characterized it as an *Acineta*. The period of the rapid swarming of the embryos of *Acinetæ* is very variable: I have observed some which attached themselves to become converted into *Acinetæ* within half an hour, whilst in other cases I had to wait for several hours. Cienkowsky states that he has followed the embryo for more than five hours before it became quiescent. Embryos of the *Acineta ferrum-equinum*, Ehrbg., I certainly did not follow during the whole period of their swarming under the microscope; but, by careful isolation, I had ensured the identity of the individual without uninterrupted observation. I then always found, after the lapse of several hours, besides the old *Acineta*, a young one of the size of the gemmule. I once followed one of these, until, after some hours of roving, it reposed upon a fragment of *Lemna*; a few hours afterwards I found in the same spot a young *Acineta* of exactly the size of the bud. Similar observations were afterwards made by E. Claparède and myself upon some other *Acinetæ*, and always with the same result, although sometimes the bud died before becoming converted into an *Acineta*.

If proof was thus furnished that the embryos of *Acinetæ* were again converted into *Acinetæ*, the objection might still be raised that this was perhaps to be laid to the unfavourable circumstances to which the animals were exposed in the little drop of water under the microscope, and that, under more favourable

\* Stein's *Acineta* of the Duckweed may probably be a peculiar species.

† Bull. de l'Acad. de St. Pétersb. 1855, p. 297.



conditions, the embryos were probably converted into *Vorticellæ*. I therefore endeavoured to ascertain this also, and for this purpose isolated at different times a number of individuals of the large *Acineta ferrum-equinum*, Ehrbg., which were perceptible even with the lens, in a small glass tube, as I had isolated *Vorticellæ* in other cases. In order that they should not be in want of nourishment, I put a number of individuals of *Paramecium Aurelia* and *P. Bursaria* with them in the tube, and to preserve the water in a good state, also placed in it a *Lemna minor*. These experiments required the greatest care, and their difficulty is a sufficient explanation of my not having obtained clear results in all cases. Thus in one case I found two specimens of *Vorticella campanula* in one of my glasses, when I came to look at it again in eight days; in another I found several of the *Vorticella nebulifera* without a single *V. campanula*. This difference of the *Vorticellæ* discovered must show at once that they had only got in by accident, and had not been developed from the embryos of the *Acineta*. How difficult it is to avoid such an accident, was proved to me by a case in which I had placed some *Acineta* in a glass tube, and thought that I had convinced myself of the absence of any *Vorticellinæ*; and yet, on again examining it with the lens, I discovered, under the leaf of *Lemna* which had been put in, a large *Vorticella campanula*, which I of course took care to remove immediately. Two experiments, however, gave me a perfectly clear result. One of these was given up at the end of a week, but the other was continued for seven weeks, during which the contents of the glass tube were frequently examined, partly with the lens and partly with the microscope; but in both I never obtained a single *Vorticella*, but only a considerably increased number of *Acineta*. The number of the latter was also augmented in the other experiments, which did not give a pure result.

The preceding statements appear to me to furnish sufficient proof that Stein's opinion of the relationship of the *Vorticellinæ* and *Acineta* is not only completely destitute of any real foundation, but even, as an hypothesis, extremely improbable. I must be excused if I have dwelt too long upon this theory; but it appeared to be well worth a thorough examination, as it introduced into science a perfectly new mode of propagation, which could not be referred to any of the known modes of reproduction, not even to the alternation of generations; and it was certainly high time to apply the standard of a fundamental criticism to it, as it has unfortunately been already regarded by many as a fact ascertained with certainty. An alternation of generations of the kind hitherto known in other animals cannot be recognized in the alternation of the modes of reproduction of the Infusoria,

the increase by fission or gemmation, and that by embryos\* ; for the same animal which has propagated vegetatively for a time by fission and bud-formation, and consequently performed the functions of a nurse, may be seen subsequently playing the part of a mother by the production of embryos ; nay, one animal may at the same time increase by the vegetative process of fission and propagate by the development of embryos, as is proved to me by observations on Stentors. If an alternation of generations in the received sense should occur amongst the Infusoria, it could only be in this way, that the very small embryos produced in the nucleus, or those to be mentioned immediately, might be produced asexually, and even when sexually mature might not increase vegetatively, but by sexual reproduction ; but this supposition is totally unsupported, and even contradicted by the observations on the *Acinetæ*.

I may now be permitted to mention a mode of reproduction which has hitherto been observed in but few cases, and even in these not sufficiently to enable us to decide whether it is to be regarded as a modification of the above-mentioned production of embryos in the nucleus, or as an independent kind of propagation. It has as yet been described only by Stein† in *Vorticella microstoma* and *nebulifera*, and by Cienkowsky‡ in *Nassula viridis*§.

In these cases the reproduction was commenced by encystation, and then several large circumscribed bodies, probably enlarged parts of the nucleus, made their appearance in the body, which gradually became converted into a simple vesicle without recognizable organs (the mother-vesicle, *Mutterblase* of Stein) : these afterwards became elongated into processes, which broke through the cyst, and bursting at the apex, allowed a great number of small, Monad-like creatures to escape, which soon dispersed themselves in the water. It was only in his most recent observations on *Vorticella microstoma*, that Stein saw the production of larger globules, "daughter-vesicles" (*Tochterblasen*), in the interior of the mother-vesicle ; but previously he had seen nothing of the kind : it must remain uncertain whether

\* Even if this were proved to be sexual reproduction.

† *L. c. supra*.

‡ Siebold and Kölliker's Zeitschr. vi. p. 301. In a note (4) on p. 301 of the Bulletin de l'Acad. de St. Pétersb., Cienkowsky mentions the same circumstance with regard to *Nassula ambigua*, Stein. I do not know whether by this he refers to the same observations with regard to *Nassula viridis*, alluded to above.

§ Perhaps the reproduction of *Chlorogonium euchlorum*, described by Weisse and Stein, also belongs here (unless it be a division into numerous segments after a change of skin), and possibly the state of *Acineta mystacina* represented by Stein on tab. 1. fig. 20 of his work.

he had overlooked them; whether, instead of several globules, only one very large one, entirely filling the mother-vesicle, had been produced; or whether two different modes of development actually occur in this case. This is the only mode of reproduction of the Infusoria which has hitherto been observed in encysted animals alone; but some observations made by E. Claparède and myself upon an undescribed vaginicolous Infusorium, indicate that encystation is not a necessary condition even for this mode of propagation. The internal formation of embryos in *Chilodon* has been observed by Stein, especially in encysted animals, but nevertheless, according to him, it also occurs in free animals. Fission is very frequent in the interior of cysts; many Infusoria appear to undergo fission more frequently in cysts than when swimming freely; so that it may appear probable that the cyst serves as a protection for the animal when dividing, but it is certainly not necessary, as we are acquainted with no example of an Infusorium which always encysts itself for the purpose of fission. Thus the principal, if not the only object of encystation appears to be protection against unfavourable external circumstances.

With regard to the peculiar process of copulation or zygosis of the Infusoria, as its object is still entirely unknown, I shall only state, that, except in the Diatomaceæ and Desmidiaceæ, the position of which is still doubtful, it has hitherto been observed particularly in *Actinophrys* and *Acinetinæ*\*. According to an oral statement, E. Claparède has also seen *Vorticellinæ* (especially *V. microstoma*) in zygosis; and I have twice met with double animals of *Carchesium*, still sitting upon a double stalk and constantly becoming more amalgamated, so that the cavities of both the fused animals communicated, and the morsel which was passed from the pharynx of one animal usually ascended in the cavity of the other up to the lower surface of its ciliary disk. The rotatory organs remained separate, and after the lapse of some time, the double animal cast itself loose from the stems, and swam about for more than twenty-four hours by means of a circlet of cilia, which was produced around the rounded hinder extremity formed by the coalescence of the two posterior extremities of the individual animals.

If we now once more sum up the results of the preceding statements, we find,—that the Infusoria cannot be regarded as unicellular animals, although they have not a polygastric digestive apparatus, but possess a large alimentary cavity furnished with an anus, and into which an œsophagus usually hangs down from the mouth; that a vascular system, of which the central

\* I have seen several in conjugation; amongst others, even the *Acineta mystacina*.



point is formed by the contractile vesicle, is contained in the parenchyma of the body of all; that, besides fission and gemmation, they possess another mode of reproduction, in which small embryos are formed in the nucleus, but that an alternation of generations has never been detected in the Infusoria; and, lastly, that Stein's view of the connexion of the *Vorticella* and *Acinetæ* is an unfounded and improbable hypothesis.

## EXPLANATION OF PLATE IX.

All the figures, with the exception of fig. 8, are magnified about 300 diameters. The lettering of the separate parts is, as far as possible, the same in all the figures; so that *a, a* indicates the peristome; *b*, the commencement of the series of cilia leading to the mouth; *c, d*, in the *Vorticellæ*, the entrance into the vestibulum, which lies between *c, d* and *e, f*; *e*, the anus; *f*, the mouth; *g*, the outer extremity of the bristle situated in the vestibulum; *h*, or *f, h*, the œsophagus; *k, i*, the pharynx; and *k*, the contractile vesicle.

*Figs. 1-5. Vorticellinæ.* Of the cilia of the outer series, only those which are visible at the margin of the figure are indicated.

*Fig. 1. Vorticella campanula*, seen from the ventral side. At *e* we see through the mouth into the lumen of the œsophagus; the pharynx is not visible in this position; of the stronger cilia situated in front of the mouth, only one is represented. The pale curved body represents the nucleus.

*Fig. 2. Vorticella nebulifera*, inflated and dying, so that the peristome is obliterated. The portion of the ciliary spiral which is situated on the back of the animal is only indicated by a dotted line.

*Fig. 3. Carchesium polypinum*, seen from the front directly upon the ciliary disk; the ciliary spiral is only indicated by a dotted line. The pharynx is only seen in section: *k* represents the section of the process running from the contractile vesicle towards the ciliary disk.

*Fig. 4. Opercularia berberina*, Stein, seen from the back. The portion of the ciliary spiral situated in the vestibulum is only indicated by a line. At *l*, in this and the following figure, a still fusiform morsel is represented. The pale body to the left above *h* represents a section of the nucleus.

*Fig. 5. Scyphidia limacina*, Lachm. By mistake, the cilia are not represented on the extreme margin of the ciliary disk, as they should be.

*Figs. 6, 7. Chaetospira Mülleri*, Lachm., sitting in its sheath, *n*. Of the fine cilia covering the whole body, a few are represented only in fig. 6.

*Fig. 6.* A rotating animal. At *m* is a ball of excrement on its way to the anus.

*Fig. 7.* An animal only just extended, and not rotating.

*Fig. 8. Stentor polymorphus*, not much magnified. On the right side the contractile vesicle, *k*, is seen, with the lateral vessel, exhibiting various inflations, running backward; *o, o* are the two dilatations of the annular vessel. The anus, *e*, lies on the dorsal surface, which is turned from the observer.

*Fig. 9* shows a section through the posterior extremity of a *Stentor*. The thin, pale, outermost portion represents the skin bearing the cilia and hairs; and the darker portion, situated more internally, the

