RECENT PROGRESS IN OUR KNOWLEDGE OF THE CILIATE INFUSORIA *

II.

THE reproductive process was lately followed by myself through some of its stages in a very beautiful Vorticellidan obtained abundantly from a pond in Brittany.† The zooids which form the colonies in this Infusorium are grouped in spherical clusters on the extremities of the branches. They present near the oral end a large and very obvious contractile vesicle, and have a long cylindrical nucleus curved in the form of a horseshoe.

In the internal protoplasm are also imbedded scattered green chlorophylloid granules. No trace of the so-called nucleolus was present in any of the specimens examined.

Among the ordinary zooids there were usually some which had become encysted in a very remarkable way, and without any previous conjugation having been noticed. These encysted forms were much larger than the others and had assumed a nearly spherical shape; the peristome and cilia-disc had become entirely withdrawn, the contractile vesicle was still obvious, but had ceased to manifest contractions; brownish spherical corpuscles with granular contents, probably the more or less altered chlorophylloid granules of the unencysted zooid, were scattered through the parenchyma, and the nucleus was not only distinct, but had increased considerably in length. Round the whole a clear gelatinous envelope had become excreted.

In a later stage there was formed between the gelatinous envelope and the cortical layer of the body a strong, dark-brown, apparently chitinous case, the surface of which in stages still further advanced had become ornamented by very regular hexagonal spaces with slightly elevated edges. In this state the chitinous envelope was so opaque that no view could be obtained through it of the included structures, and in order to arrive at any knowledge of these it was necessary to rupture it. The nucleus thus liberated was found to have still further increased in length, and to have become wound into a convoluted and complicated knot. Along with the nucleus were expelled multitudes of very minute corpuscles with active Brownian movements.

In a still further stage the nucleus had become irregularly branched, and at the same time somewhat thicker and of a softer consistence; and finally, it had become broken up into spherical fragments, each with an included corpuscle resembling a true cell nucleus in which the place of a nucleolus was taken by a cluster of minute granules.

In this case the original nucleus of the Vorticellidan had thus become broken up into bodies identical with the so-called eggs of Balbiani, but this was unaccompanied by any conjugation or by the formation of anything which could be compared to spermatozoal filaments.

What I believe we may regard as now established in the phenomena of reproduction in the Infusoria is, that besides the ordinary reproduction by spontaneous fission of the entire body, the nucleus at certain periods, and after more or less change of form has occurred in the Infusorium body, becomes broken up into fragments, each including a corpuscle resembling a true cell nucleus; and that this takes place without necessarily requiring the influence of conjugation or the action of spermatozoa; that these fragments after their liberation from the body of the Infusorum become developed—still without the necessity of spermatic influence—directly or indirectly into the adult form.

Whether proper sexual elements ever take part in the life history of the Infusoria remains an open question.

Everts ‡ has given an account of observations which, with the view of testing the statements of Greeff, he made on *Vorticella nebulifera*. Greeff, as we have seen, followed Claparede and Lachmann in attributing to the Vorticellæ a true cœlenterate structure; and Everts, by his own investigations, has convinced himself of the untenableness of this view, and has been led to regard the Vorticellæ as strictly unicellular.

He recognises the distinction between the cortical layer (which forms not only the periphery of the body but the whole of the stalk on which this is supported), and the central mass in which the nutriment is deposited, collected into pellets and digested; but instead of regarding this central mass as chyme, he looks upon it as an integral constituent of the entire body, like the central portion of an Amœba. The nucleus is imbedded in the inner side of the cortical layer, which is itself differentiated into certain secondary layers. He describes the deeper part of the cortical layer as exhibiting a rotation of its granules independent of the rotation which occurs in the central parenchyma, and moving in a direction opposite to that of the latter. Everts's account of the structure of Vorticella is thus in accordance with the conception of it as a cell with a parietal nucleus; a cell, however, in which differentiation is carried very far without the essential character of a simple cell being thereby lost.

Everts regards the external wall as corresponding with the ectoderm, and the internal softer body-substance with the endoderm of higher animals. If by this the author meant to indicate a homological identity between the structures thus compared, it is plain that he would have taken an entirely mistaken view based on a misconception of the essential nature of an ectoderm and endoderm. These membranes are essentially multicellular, and are always results of the segmentation of the vitellus in a true ovum. They can therefore never be attributed to a unicellular animal, in which no true segmentation process ever takes place. In his rejoinder, however, to an elaborate criticism of his memoir by Greeff, he explains that he intended to compare the two layers of the Infusorium body analogically, not morphologically, with an ectoderm and endoderm.

The same author has further made some interesting observations on the development of Vorticella. He has noticed that reproduction is here ushered in by a longitudinal cleavage, in which after division of the nucleus the body of the Vorticella becomes cleft into two halves, still seated on the common stalk. Each of these develops near its posterior end a wreath of vibratile cilia, while the peristome and the cilia-disc over the mouth are entirely withdrawn, and then breaks loose from its stem and swims freely away. These free-swimming Vorticellæ now encyst themselves, the cilia disappear, and the contents of the encysted animal acquire a uniform clearness with the exception of the nucleus, which persists unchanged. In the next place the nucleus breaks up into eight or nine pieces, and then the wall of the cyst becomes ruptured and gives exit to these fragments, which now appear as spontaneously moving spherules. These increase in size, develop on one end a cilia wreath, within which a mouth makes its appearance, and the free-swimming nucleus-fragment becomes gradually changed into a form which entirely agrees with the *Trichodina grandinella* of Ehrenberg.

These Trichodinæ now multiply by fission, first developing a posterior wreath of cilia, and then dividing transversely between the anterior and posterior wreaths. After this each fixes itself by the end on which the mouth is situated; a short stem becomes here developed, and the cilia wreath gradually disappears. Then upon the free end the peristome and cilia disc make their appearance, and the growth of the stem completes the development.

Everts remarks that in this process we have an example of alternation of generations. There is one point, however, in which he has overlooked its essential difference from a true alternation of generations, namely, the absence of any intercalation of a proper sexual reproduction.

Ray Lankester * has subjected to spectrum analysis the blue colouring matter of *Stentor cæruleus*. This occurs in the form of minute granules in the cortical layer of the animal, and Lankester finds that it gives two strong absorption bands of remarkable intensity, considering the small quantity of the matter which can be submitted to examination. He cannot identify these bands with those of any other organic colouring matter, and to the peculiar pigment in which he finds them he gives the name of *stentorin*.

He has also examined the bright green colouring matter of *Stentor Mülleri*, and finds that instead of giving the stentorin absorption bands, it gives a single band like that of the chlorophylloid matter of *Hydra viridis* and of Spongilla.

Ray Lankester † has also described, under the name of *Torquatella typica*, a remarkable marine Infusorium, which, though quite destitute of true cilia, can scarcely be separated from the proper Ciliata. With the general structure of the ciliate Infusoria, the place of a peristomal cilia wreath is taken by a singular plicated membrane, which forms a wide, frill-like, very mobile appendage, surrounding the oral end of the animal, and projecting to a considerable distance beyond it. The author regards *Torquatella typica* as the type of a distinct section of the Ciliata to which he gives the name of *Calycata*.

Of all the authors who since Von Siebold have applied themselves

* Anniversary Address to the Linnean Society, by the President, Dr. G. J. Allman, F.R.S., May 24. Continued from p. 137.

† British Association Reports, 1873.

‡ Everts, Untersuchungen an *Vorticella nebulifera*. Sitzungsberichte der Physikalisch-Medicinischen Societat zu Erlangen. 1873.

* Quart. Journ. Mic. Sci., 1873. † Ibid. 1874.

to the investigation of the Infusoria, Haeckel must be mentioned as the one who has brought the greatest amount of evidence to bear on the question of their unicellularity. In a very elaborate paper which has quite recently appeared,* and which is remarkable for the clearness and logical acuteness with which the whole subject is treated, Prof. Haeckel, resting mainly on the observations of others, and partly also on his own, argues in favour of the unicellularity of the Infusoria from the evidence afforded both by the phenomena of their development and by the structure of the mature organism. He confines himself chiefly to the Ciliata—which, indeed, he regards as the only true Infusoria—while he considers the unicellularity of the Flagellata as too obvious to require an elaborate defence. The value of this paper will be obvious from the analysis of it which I now propose to give.

In stating the argument derived from development, Haeckel does not accept as established the alleged sexual reproduction of the Infusoria, and he believes it safest to regard as non-sexual "spores" the bodies (*Keimkugeln*) which result from the breaking up of the nucleus, and which Balbiani regarded as eggs.

These bodies consist of a little mass of protoplasm usually destitute of membrane, and including a nucleus within which one or more refringent granules admitting of comparison with a true nucleolus may sometimes be witnessed—characters which are all those of a simple genuine cell. From this spore the embryo is developed by direct growth and differentiation of parts; but however great may be the differentiation, there is never anything like the formation of a tissue.

The development of the Infusoria is thus entirely in favour of the unicellular theory. This theory, however, is just as strongly supported by the study of their mature condition; and here Haeckel gives an admirable exposition of the structure of the true or Ciliate Infusoria.

The parts which are common to all Ciliata and which first differentiate themselves in the ontogenesis or development of the spore, are the cortical layer, the medullary parenchyma, and the nucleus, which is situated on the boundary between the two. The differentiation of the protoplasm of the naked spore into a clearer and firmer cortical substance, and a more turbid, granular, and softer medullary substance, corresponds entirely with what we see in the parenchyma cells of higher animals. These two products of differentiation are designated by Haeckel "exoplasm" and "endoplasm."

The exoplasm is originally a perfectly homogeneous and structureless, colourless hyaline layer distinguishable from the turbid granular soft protoplasm of the internal body mass, by containing in its composition less water, by absence of included granules, and by its high independent contractility. All the mobile appendages of the body, the cilia, bristles, spines, hairs, hooks, &c., are nothing but structureless extensions of this exoplasm and participate in its contractility. In this respect they entirely correspond to the cilia and flagellæ of the cells which form the ciliated epithelium of multicellular animals.

In many Ciliata we find this cortical layer or exoplasm itself subsequently differentiated into distinct strata. In the most highly differentiated Ciliata four layers may be distinguished as the result of this secondary differentiation of the exoplasm. These are: (1) the cuticle layer, (2) the cilia layer, (3) the myophan layer, (4) the trichocyst layer.

The *cuticle* is nothing but a lifeless exudation from the surface. In the majority of Ciliata there is no true cuticle, and in those which possess it, it presents itself under various forms, as seen in the thin, chitine-like, hyaline homogeneous pellicle of Paramæcum and Trichodina, the outer elastic layer of the stem of the Vorticellinæ, the protective sheath of Vaginicola, the chitin-like cases of the Tintinnodeæ and Codonellidæ, the beautiful lattice-like siliceous shells of the Dictyocystidæ, and many other shells, cases, and shield-like protections.†

The *cilia layer* occurs in all Ciliata; it lies immediately beneath the cuticle where this is present, and the whole of the cilia and other mobile appendages are its immediate extensions. These must therefore perforate the cuticle or its modifications when such protective coverings exist.

The *myophan layer* is identical with that which most authors describe as a true muscular layer. It has been demonstrated in most of the Ciliata. It appears as a system of regular parallel fine striæ in the walls of the body, and in the Vorticellidæ occupies also the axis of the stem, where it forms the characteristic "stem-muscle" of these animals. There can be no doubt that these striæ represent contractile fibrils, which, by their contraction, effect the various form changes of the animal. They are thus *physiologically* analogous to muscles. From a *morphological* point of view, however, we must regard them as only differentiated protoplasm filaments. In the morphological conception of true muscle, its cell nature is absolutely indispensable. The so-called muscle-fibrils of the Infusoria never show a trace of nucleus. They can be viewed only as *parts* of a cell due to the differentiation of the sarcode molecules of its protoplasm; and as they are thus only sarcode filaments, Haeckel designates them by the term "myophan," as indicating a distinction from proper muscle.

The *trichocyst layer* occurs also in many Infusoria, but not in all. It is a thin stratum of the exoplasm lying immediately on the endoplasm, and including in certain species the trichocysts. The presence of these bodies, which possess a striking resemblance to the thread-cells of the Cœlenterata, has, as we have already seen, been urged as an argument in favour of the multicellularity of the Infusoria. But, as Haeckel argues, no evidence of multicellularity can be derived from this fact. The thread-cells of the Cœlenterata are themselves the products of a cell, and we often find many of them originating in a single formative cell quite independently of the nucleus; the formative cell may in this respect be compared with the entire body of the Infusorium.

It is the endoplasm, or internal parenchyma of the Infusoria that has given rise to the most important differences of opinion, and in his account of this part of the Infusorium-organism Haeckel chiefly directs his criticism against the views advocated by Claparede and Lachmann, and by Greeff.

These authors, as we have already seen, compare the Infusoria with the Cœlenterata, and regard the endoplasm not as a real part of the body, but merely as the contents of the alimentary canal—as a sort of food mash or chyme contained in a spacious digestive cavity whose walls are at the same time stomach wall and body wall, and into which the mouth leads by a short gullet. As Haeckel urges, however, it needs only a correct conception of the intestinal cavity throughout the animal kingdom and of its distinction from the body cavity, in order to show the untenableness of this position. The main point of such a conception lies in the fact that the intestinal cavity and all extensions of it (gastro-vascular canals, &c.) are always originally clothed by the endoderm or inner leaflet of the blastoderm, while the body cavity is always formed on the external side of the endoderm, and between this and the ectoderm or outer leaflet of the blastoderm. The body cavity and intestinal cavity of animals are thus essentially different; they never communicate with one another, and always arise in quite different ways.

Again, the contents of a true intestinal cavity consist only of nutritious matter and water, in other words, of chyme; while the fluid which fills the body cavity is never chyme, but is always a liquid which has transuded through the intestinal wall, and which may be called chyle, or blood in the wider sense of the word.

Haeckel has thus taken, I believe, the true view of the intestinal and body cavities of animals. He had already advocated it in his work on the Calcareous Sponges. It necessarily in-

* Haeckel, "Zur Morphologie der Infusorien." Jenaische Zeitschr., Band vii. heft 4, 1873.

† In the same number of the *Zeitschrift*, Haeckel ("Ueber einige neue pelagische Infusorien") describes some highly interesting Infusoria which spend their lives in the open sea and are distinguished by the possession of variously formed shells. His attention was first directed to them by finding their elegant empty shells in the extra-capsular sarcode of Radiolariæ. These pelagic Infusoria appear to belong to two different groups, which stand nearest to the Tintinnodeæ of Claparede and Lachmann. He designates them as *Dictyocystidæ* and *Codonellidæ*.

The family of the Dictyocystidæ is based on Ehrenberg's *Dictyocysta*, and is characterised by the possession of a siliceous perforated lattice-like shell so closely resembling that of many Radiolariæ, that Haeckel at first mistook it for the shell of one of these. The shell is in all the species bell-shaped or helmet-shaped, and the body of the animal, which is fixed to the fundus of the bell, and can be projected far beyond its margin, has a wide funnel-shaped peristome on whose edge are two concentric wreaths of strong cilia. He describes four species, distinguishing them by characters derived from their siliceous latticed shell.

The family of the Codonellidæ, based on the genus *Codonella*, Haeckel, is also provided with a bell-shaped case, but this, instead of being formed of a siliceous lattice work, consists of a chitine-like organic membrane, through which siliceous particles are scattered. The family is, however, chiefly characterised by the peculiar form of its peristome. This is funnel-shaped and provided on its margin with a thin collar-like expansion. The free edge of this collar is serrated, and each tooth carries a stalked lobe of a piriform shape, regarded by Haeckel as probably an organ of touch. At some distance behind the circle of piriform lobes is situated a ring of long, strong, whip-like cilia, which form powerful swimming organs. The three species described are distinguished by the form of their chitinous cases.

volves a belief in the homological identity of organisation between very distant groups of the animal kingdom, a belief which all recent embryological research has only tended to confirm.

(*To be continued.*)

SCIENTIFIC SERIALS

American Journal of Science and Arts, June.—The original articles in this number are :—Results of dredging expeditions of the New England Coast in 1874, by A. E. Verrill. More than 100 species new to the fauna of southern New England were secured. Most of these are northern species, but many are undescribed. A table giving nature of bottom and temperature at the surface and bottom of the sea is given.—Mr. Fontaine's paper on the Primordial Strata of Virginia is continued and concluded. At the end is given a comparison with the metamorphic crystalline rocks of the Blue Ridge.—On the occurrence of the Brown Hematite deposits of the Great Valley, by Frederick Prime, jun.—Note on some new points in the elementary stratification of the Primordial and Canadian rock of south central Wisconsin, by Roland Irving. The order for the Lower Silurian strata of Wisconsin has been generally accepted as (beginning from below) 1. Potsdam sandstone ; 2. Lower magnesian limestone ; 3. The St. Peter's sandstone ; 4. The blue and buff limestones ; 5. The Galena limestone ; 6. The Cincinnati group. The succession as now made out is (beginning from below) 1. The Lower or Potsdam sandstone ; 2. The Mendota limestone ; 3. The Madison sandstone ; 4. The main body of limestone ; 5. The St. Peter's sandstone. A table of correlation is given with the Mississippi Bluffs and the Minnesota River.—On the application of the horizontal pendulum to the measurement of minute changes in the dimensions of solid bodies, by Prof. O. N. Rood.—On diabantite (a chlorite), by G. W. Hawes.—Re-discovery of double star H.I. 41, by S. W. Burnham. It is about 46′ north of the well-known double star ψ' Draconis, and is easily found without an equatorial mounting.—On the distribution of electrical discharges from circular discs, by C. J. Bell.—Examination of gases from the meteorite of Feb. 12, 1875, by A. W. Wright.—On limonite with the colour and transparency of göthite, by Prof. Mallet.—Under the head "Scientific Intelligence," the original notes are :—On the surface geology of Ohio ; On the Prototaxites of Dawson ; On the Crustaceans of the caves of Kentucky and Indiana, together with several reviews.

Fourth and Fifth Annual Reports of the Wellington College Natural History Society, Dec. 1872 to Dec. 1874.—We are gratified to see that this Society is in a much more hopeful condition than it was when we noticed its last Report, the tone of which was almost despairing. The attendance has been very much better, and the interest taken in the Society by the boys is evidently increasing. Judging from the lists a fair amount of field-work in natural history has been done, and the Society is gradually forming good collections. But, as the preface to one of the Reports hints, there is still much room for improvement in the subjects and character of the papers read at the meetings. Except in the case of lectures by outsiders, the majority of the papers are the result of reading and not of observation or experiment, and not many of them can strictly be called scientific. Now, however useful such exercises as these may be to the boys, this is scarcely the sort of work one looks for from members of a Natural History Society. We think this Society might well take a leaf out of the Rugby Society's Report, and go in much more extensively for organised field-work, encouraging the boys to use their eyes and their hands on nature as well as on books, and to bring forward papers embodying the results of their observations, papers of a character similar to the interesting one of the president, the Rev. C. W. Penny, on "Natural History in the Christmas Holidays." Not only would the members thus reap much benefit, both in the way of discipline and instruction, but we are sure a greater interest in the Society would be created in the School. The Society has evidently got a good second start, and we trust that the next Report will show as great an advance on the two under notice as these do on the previous one.

Riga Society of Naturalists.—Nos. 8 and 9 of this Society's publications contain three papers of importance, besides meteorological reports and notes of smaller interest. The more important papers are : On some theories of earthquakes, by Prof. Schweder.—On the changes in the Düna estuary, by M. Gottfried.—On the fauna of Spitzbergen, by Prof. Nordenskjöld, showing that this fauna consists of 15 species of quadrupeds, 23 of birds, 23 of fishes, 64 of insects, 100 of Crustaceæ, and 130 of sea molluscs.—There is also an obituary notice of the late Dr. Ernst Nauck, who died at Riga on Jan. 26 last.

SOCIETIES AND ACADEMIES

London

Royal Society, June 10.—"Experiments on Stratification in Electrical Discharges through Rarefied Gases," by William Spottiswoode, M.A., Treas. R.S.

In the stratified discharges through rarefied gases produced by an induction-coil working with an ordinary contact-breaker, the striæ are often unsteady in position, and apparently irregular in their distribution. Observations made with a revolving mirror, which the author hopes to describe on another occasion, have led him to conclude that an irregular distribution of striæ does not properly appertain to stratification, but that its appearance is due to certain peculiarities in the current, largely dependent upon instrumental causes.

The beautiful and steady effects obtained by Mr. Gassiot with his Leclanché battery, and also more recently by Mr. De la Rue with his chloride-of-silver battery, have abundantly shown the possibility of stratification free from the defects above mentioned ; but it must be admitted that the means employed by those gentlemen are almost gigantic. The present experiments were undertaken by the author with the view of ascertaining, first, how far it was possible to approach towards similar results with instruments already at his command ; and secondly, whether these would afford other modes of attack, beside the battery, on the great problem of stratified discharges.

The induction-coil used was an "18-inch" by Apps, worked occasionally by six large chloride-of-silver cells, kindly lent the the author by Mr. De la Rue, but more usually by ten or by twenty Leclanché cells of the smallest size ordinarily made by the Silvertown Company. He has also, in connection with the same coil, 120 of the latter cells, connected in twenties for quantity, and forming six cells of twenty times the surface of the former. These work the coil with the ordinary contact-breaker very well, giving 11-inch sparks whenever required. A "switch" affords the means of throwing any of the three batteries in circuit at pleasure.

Having reason to think that the defects in question were mainly due to irregularity in the ordinary contact-breaker, he constructed one with a steel rod as vibrator, having a small independent electromagnet for maintaining its action. The details of construction of this contact-breaker are described.

With a contact-breaker of this kind in good action, several phenomena were noticeable ; but first and foremost was the fact that in a large number of tubes (especially hydrocarbons), the striæ, instead of being sharp and flaky in form, irregular in distribution and fluttering position, were soft and rounded in outline, equidistant in their intervals, steady in proportion to the regularity of the contact-breaker. These results are, the author thinks, attributable more to the regularity than to the rapidity of the vibrations. And this view is supported by the fact that, although the contact-breaker may change its note (as occasionally happens), and in so doing may cause a temporary disturbance in the stratification, yet the new note may produce as steady a set of striæ as the first. And not only so, but frequently there is heard, simultaneously with a pure note from the vibrator, a strident sound, indicating that contacts of two separate periods are being made, and yet, when the strident sound is regular, the striæ are steady. On the other hand, to any sudden alteration in the action of the break (generally implied by an alteration in the sound) there always corresponds an alteration in the striæ.

The author then attempts to show the extreme delicacy in action of this kind of contact-breaker, or "high break," as it may be called.

The discharges described above are usually (although not always) those produced by breaking contact ; but it often happens, and that most frequently when the strident noise is heard, that the current produced by making contact is strong enough to cause a visible discharge. This happens with the ordinary as with the high break ; but in the latter case the double current presents the very remarkable peculiarity, that the striæ of one current are so arranged as to fit exactly into the intervals of