A

MANUAL OF THE INFUSORIA.

VOLUME I.

"Our little systems have their day,
They have their day and cease to be ;
They are but broken lights of Thee,
And Thou, O Lord, art more than they."

TENNYSON, *In Memoriam.*

A

MANUAL OF THE INFUSORIA:

INCLUDING A DESCRIPTION OF ALL KNOWN

FLAGELLATE, CILIATE, AND TENTACULIFEROUS PROTOZOA,

BRITISH AND FOREIGN,

AND AN ACCOUNT OF THE

ORGANIZATION AND AFFINITIES OF THE SPONGES.

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VOLUME I.

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TO

THOMAS HENRY HUXLEY, LL.D., F.R.S.,

TO WHOM THE AUTHOR IS INDEBTED FOR MANY MARKS OF PERSONAL KINDNESS

AND WORDS OF ENCOURAGEMENT

DURING THE PREPARATION OF THIS TREATISE;

AND TO WHOSE TEACHING IN THE LECTURE-ROOM AND LABORATORY HE IS CHIEFLY

BEHOLDEN FOR HIS QUALIFICATION

TO ENTER AS A HUMBLE LABOURER UPON THE ARENA OF SCIENTIFIC INVESTIGATION,

THIS 'MANUAL OF THE INFUSORIA' IS GRATEFULLY

Dedicated.

PREFACE.

It is now some ten years since the author, then but a recruit in the ranks of practical microscopists, elected to concentrate his attention upon the group of organisms that form the subject of this treatise. At a very early period of his investigations, formidable obstructions to substantial progress in the course mapped out, presented themselves in connection not only with the very backward condition of the literature of this country relating to this topic, but by reason also of the exceedingly wide and scattered area of Continental bibliography that had to be explored and sifted before it was possible to arrive at any adequate idea of the state of contemporary knowledge concerning almost any given type that might be the subject of examination. It was the recognition of, and continual contact with these difficulties that suggested to the author the advantages that would accrue both to himself and all English-speaking microscopists, from the compilation of a treatise, brought up to date, that should contain a concise description of the innumerable species known to science whose descriptions were distributed throughout many scattered sources, and that led to the efforts, now carried into execution, to supply this desideratum.

It was in the first instance suggested that this Manual should be based upon the same lines as the, at the time, only other English treatise devoted to the subject, 'A History of the Infusoria,' by Andrew Pritchard, the fourth and last edition of which was published so long since as the year 1861; that it should include in a similar manner an account of the several distinct groups of microscopical organisms known as the Rotifera, Desmidiaceæ, Diatomaceæ, and other Protophytes which form, as being a reproduction of Ehrenberg's 'Infusionsthiere,' so conspicuous a feature of Mr. Pritchard's book. It soon became apparent, however, that to compass so comprehensive a task with any degree of efficiency would extend the size of this treatise far beyond convenient limits, and that indeed more than sufficient material for a work on the same scale as the one above-named had accumulated in connection with the Infusoria in the most limited and restricted sense as represented by the Flagellate, Ciliate, and Tentaculiferous Protozoa.

Those readers and subscribers, therefore, who at first sight may experience some disappointment at the relatively narrow scope of this work, will, the author trusts, find on a closer acquaintance with it, sufficient compensation in the vastly extended assemblage of forms here included within the ranks of the true Infusoria as compared with that dealt with in any pre-existing treatise. The most notable accessions in this connection are undoubtedly associated with the class Flagellata, hitherto occupying in our text-books a very uncertain status upon the border-land of the animal and vegetable kingdoms, but which is now shown to include an infinitely varied series of unquestionable animal forms. All these Flagellata, to which the author has devoted special attention, are of exceedingly minute size, requiring the highest magnifying powers of modern construction for their correct interpretation. The majority of the Flagellate types figured and described in this treatise, indeed, not only represent the outcome of the most recent research, but may be regarded also as a first instalment of the almost inexhaustible harvest that awaits the garnering of the industrious investigator. It is hoped that this work may in this manner constitute a fresh basis of departure, and supply an incentive towards the acquisition of a yet truer and more comprehensive knowledge of the diversified and exquisitely beautiful representatives of this, excepting to the initiated, practically invisible world.

For the general Biologist, to whom for the most part the Infusorial series represents but a single scarcely noteworthy link in the grand scheme of organic nature, it has been the endeavour of the author to demonstrate that there yet remain in connection with this group certain side issues of the highest interest and importance. Should he combine with his general knowledge of the morphology and embryology of the more highly organized Metazoic animals, a practical acquaintance with that remarkable order here figured and described at length under the title of the Choano-Flagellata, he will scarcely fail to recognize the close bond of affinity that subsists between these Infusoria and the Sponges, however much the last named organisms may be apparently modified in the direction of a Metazoic formula. In connection, again, with the innumerable varieties of ciliated embryos of the Annelida, Echinodermata, Mollusca, and other Invertebrate series, there is, as indicated in the opening pages of Vol. II., ample scope for speculation with respect to the by no means improbable derivation of these higher organisms from Infusoria Ciliata, of which, in their embryonic condition, they are indeed, in so many cases, the most remarkable possible homotypes.

Some apology is perhaps due from the author on account of the very considerable interval that has elapsed since the first announcement of this work and its ultimate publication, as also for the delay that has intervened between the issue of the first part in October 1880, and the concluding number in June 1882. With respect to that first named, it may be stated that the publication, dated November 1878,* of Stein's 'Infusionsthiere' Abth. III. Heft 1, devoted to the Flagellata, occasioned an almost complete recasting of the manuscript referring to this group, then ready for the press, the work involved being greatly increased through the fact that the diagnoses and descriptions of the species figured being reserved by Stein for an as yet unpublished volume, the onus of forming diagnoses from these figures for the many new forms illustrated, devolved upon the author. Since, again, the publication of Part I. of this Manual in October 1880, the energy of Continental investigators in this department of Biology has been so marked that it became requisite, at the risk of some slight delay, to make suitable provision both in the text and plates of the later numbers of the treatise for the record of their discoveries. No more substantial illustration of this circumstance could perhaps be afforded than by a reference to Part VI., devoted chiefly to the class Tentaculifera, in which it will be found that no small space is occupied by the description and illustration of many new and interesting species described by Maupas so recently as November 1881, the same number including the results of the author's yet later personal investigation of the remarkable type *Dendrosoma radians.* Such inconvenience therefore as subscribers may have sustained in consequence of its tardier issue, they will, the author hopes, consider to some extent counterbalanced by the considerable augmentation and continuation literally up to date of the subject-matter of this treatise.

Having during the progress of this work received from numerous English and American sources an intimation that a few suggestions respecting the apparatus and means employed by the author for the effectual investigation of the more minute Flagellate Infusoria would be greatly appreciated, he has much pleasure in submitting, in connection with Pl. LI., an illustration, with accompanying explanation, of a simple method whereby, with the least expenditure of manipulative energy, the best results may be readily obtained. For his first acquaintance with this method, as also for the kind permission to make the present use of the same, the author's thanks are due to Mr. E. M. Nelson, F.R.M.S., one of our leading and most experienced experts in the use of the higher powers of the compound microscope.

The pleasing task yet devolves upon the author of tendering his grateful acknowledgments to the officers of the libraries of the various scientific societies, including more especially those of the Royal, Linnean, and Zoological Societies, as also of the Royal College of Surgeons, for their

* Not received in England till January 1879.

ready and valuable assistance in working out the voluminous and, in many cases, exceedingly intricate bibliography of the present subject. He has also to record his high appreciation of the accurate and highly artistic manner in which Mr. W. Rhein has reproduced on stone the drawings for the plates committed to his care.

For an abundant supply of living material for investigation, much of which has been utilized in the record of new data, and for the illustration of this Manual, the best thanks are due from the author to Mr. Thomas Bolton of Birmingham, and to Mr. John Hood of Dundee.

Lastly, but not leastly, the author has to acknowledge his great indebtedness to the Council of the Royal Society, through whose recommendation a grant from the Government Fund for the Promotion of Scientific Research has been on several occasions allotted him, thus assisting him with the means of obtaining the necessary costly microscopical apparatus, and of devoting that time to original research, without which the prolonged investigations recorded in this treatise, more especially in connection with the Flagelliferous Infusoria, could scarcely have been accomplished.

LONDON, *May* 1882.

making a free adaptation of the admirable thesis propounded by the illustrious Oken, we find in their primeval shape the very bricks and mortar out of which the entire superstructure of the organic world has been erected. So early as the year 1805, long before the conception of the unicellular nature of the Infusoria by Theodor von Siebold, this astute philosopher, the co-originator with Goethe of the vertebrate theory of the skull, had enunciated the opinion that the infusorial animalcules consisted of simple cells or vesicles, and formed the protoplasmic basis from whence all higher organisms were fashioned or evolved, and into which condition of simple cells or vesicles these same higher organisms were again resolved by the process of dissolution. The divine fiat, "Dust thou art, and unto dust thou shalt return," thus received unconsciously at the hands of Oken a practical and truly remarkable illustration. Finally, among the world of Infusoria we arrive at that dim boundary line, too subtle and obscure for arbitrary definition, that separates, or more correctly blends into one harmonious whole, the two departments of the animal and vegetable worlds; and here, moreover, with all reverence be it said, we approach, if anywhere, the confines of the organic and inorganic, and are brought face to face with that already half-lifted veil behind which lies, waiting to reward our patient search, the very clue to the deep mystery of Life itself.

Postponing to a succeeding chapter a detailed account of the structural, developmental, and other vital phenomena pertaining to the Infusoria, as made manifest by the light of modern investigation, it has been decided that some space in the first instance might be advantageously devoted to a brief epitomization of the more important epochs in the history of these minute organisms, as accumulated step by step from the time of their earliest discovery. As a matter of necessity, man's acquaintanceship with the puny members of this organic group has been comparatively short, and is co-extensive only with the invention and practical application of the microscope. None of the myriad forms—though in some few instances conspicuous in their concrete state or discernible individually by the unassisted vision, as mere moving points—yield up the secret of their separate organization and life-history without the aid of that most invaluable and indispensable auxiliary to biological discovery. In like manner, our present advanced, though still far from perfect knowledge, of the Infusoria has been acquired by slow degrees, and contemporaneously with the improvements made upon that instrument, each successive stage of progress achieved in this direction representing, indeed, but a reflex of the higher perfection of the appliances placed from time to time at the disposal of the histologist through the augmented skill of the optician. It is much to be regretted that authentic evidence is wanting that can identify with absolute certainty the first inventor of the microscope, or rather of those simple spheres of glass or doubly convex lenses, mostly home made, employed over two centuries ago, with which in the hands of the earliest investigators, as presently related, such truly astonishing results were obtained, and out of which the highly perfected optical instruments of the present day have, by slow and tedious steps, been finally elaborated. Fontana, of Naples, Cornelius Drebell, the Dutchman, and Zacharius Jansen and son, fellow-countrymen of Drebell, have thus alike been respectively credited by different authorities with this distinction. However this may be, it is at all events generally conceded that the microscope, in its simplest form, was first brought into public notice in or about the year 1619. Regarded at this early date in the mere light of an ingenious and interesting toy, little or no promise was then given of the important rôle in the onward march of science it was afterwards destined to fulfil. Nearly half a century, indeed, elapsed before its aid was invoked for the systematic exploration of the hidden mysteries of nature. With the exception, perhaps, of the Italian philosopher Petrus Borellus, our own countryman Dr. Robert Hooke, author in the year 1665 of the famous 'Micrographia Illustrata,' claims the first place in the ranks of scientific microscopic investigators. The discovery of the minute organic beings that form the special subject of this treatise, fell, however, a few years later to the lot of the illustrious Dutchman Antony van Leeuwenhoek. The accounts of the animalcules first observed, as given by Leeuwenhoek and a few other investigators who, animated by his example, towards the close of the seventeenth century devoted their attention to the further exploration of this fascinating and then newly opened field for discovery, possess intrinsically such high classic interest, and display, notwithstanding the simple and imperfect character of the optical appliances employed, so keen an insight into, and appreciation of, the structural features and phenomena of the various forms encountered, that quotations from the same, with a faithful reproduction of their original quaint style of diction, are herewith appended *in extenso.* Leeuwenhoek's earliest contribution to the literature of this subject necessarily takes the first place upon the list, and is found embodied in the 'Philosophical Transactions,' vol. xii. No. 133, for the year 1677. The title of his first record and associated account of the various species therein described runs as follows:—

"Observations communicated to the Publisher by Mr. Antony van Leeuwenhoek, in a Dutch letter of the 9th of October, 1676, here Englished, concerning little animals observed in Rain, Well, Sea, and Snow Water, as also in Water wherein Pepper had lain infused."

OBSERVATION I.

"In the year 1675 I discovered living creatures in rain-water which had stood but four days in a new earthen pot, glased blew within. This invited me to view this water with great attention, especially those little animals appearing to me ten thousand times less than those represented by Mons. Swammerdam, and by him called water-fleas or water-lice, which may be perceived in the water with the naked eye. The first sort by me discovered in the said water, I divers times observed to consist of 5, 6, 7, or 8 clear globules, without being able to discover any film that held them together, or contained them. When these *animalcula* or living atoms did move, they put forth two little horns, continually moving themselves; the place between these two horns was flat, though the rest of the body was roundish, sharpening a little towards the end, where they had a tayle, near four times the length of the whole body, of the thickness (by my microscope) of a spider's web; at the end of which appear'd a globul, of the bigness of one of those which made up the body; which tayl I could not perceive, even in very clear water, to be mov'd by them. These little creatures, if they chanced to light upon the least filament or string, or other such particle, of which there are many in the water, especially after it hath stood some days, they stook entangled therein, extending their body in a long round, and striving to dis-entangle their tayle; whereby it came to pass, that their whole body lept back towards the globul of the tayle, which then rolled together serpent-like, and after the manner of copper or iron-wire that having been wound about a stick, and unwound again, retains those windings and turnings. This motion of extension and contraction continued a while; and I have seen several hundreds of these poor little creatures, within the space of a grain of gross sand, lie cluster'd together in a few filaments.

"I also discovered a *second* sort, the figure of which was oval, and I imagine their head to stand on the sharp end, these were a little bigger than the former. The inferior part of their body is flat, furnished with divers incredibly thin feet, which moved very nimbly and which I was not able to discern till after several Observations. The upper part of the body was round, and had within 8, 10, or 12 globuls, where they were very clear. These little animals did sometimes change their figure into a perfect round, especially when they came to lie on any dry place. Their body was also very flexible; for as soon as they hit against any the smallest fibre or string, their body was bent in, which bending presently also jerked out again. When I put any of them in a dry place, I observ'd, that changing themselves into a round, their body was raised pyramidal-wise with an extant point in the middle, and having lain thus a little while with a motion of their feet, they burst asunder, and globuls were presently diffus'd and dissipated, so that I could not discern the least thing of any film, in which the globuls had doubtless been inclosed: And at this time of their bursting asunder I was able to discover more globuls than when they were alive.

"But then I observ'd a *third* sort of little animals, that were twice as long as broad, and to my eye yet eight times smaller than the first. Yet for all this, I thought I discerned little feet, whereby they moved very briskly, both in a round and streight line.

"There was further a *fourth* sort, which were so small that I was not able to give them any figure at all. These were a thousand times smaller than the eye of a big louse; For I judge, the axis of the eye of such a louse to be more than ten times as long as the axis of any of the said little creatures. These exceeded all the former in celerity. I have often observ'd them to stand still as 'twere upon a point, and then turn themselves about with that swiftness, as we see a top turn round, the circumference they made being no bigger than that of a small grain of sand, and then extending themselves streight forward, and by and by lying in a bending posture.

OBSERV. II.

"The 26. May it rained hard; the rain growing less I caused some of the rain-water, running down from the house top, to be gathered in a clean glass, after it had been washed two or three times with the water. And in this I observed some few very little living creatures, and seeing them, I thought they might have been produced in the leaden gutters in some water that had there remained before.

OBSERV. III.

"On the same day, the rain continuing, I took a great porcelain-dish, and exposed it to the free air upon a wooden vessel, about a foot and a half high, that so no earthy parts, from the falling of the rain-water upon that place, might be spattered or dashed into the said dish. With the first water that fell into the dish, I washed it very clean, and then flung the water away, and receiv'd fresh into it, but could discern no living creatures therein; only I saw many irregular terrestrial parts in the same. The 30th of May, after I had, ever since the 26th, observ'd every day twice or thrice the same rain-water, I now discovered some but very few, exceeding little animals, which were very clear. The 31st of May, I perceived in the same water more of those animals, as also some that were somewhat bigger. And, I imagine, that many thousands of these little creatures do not equal an ordinary grain of sand in bigness: And comparing them with a cheese-mite, to be like that of a bee to a horse: For, the circumference of one of these little animals in water, is not so big as the thickness of a hair in a cheese-mite.

Observ. IV.

"June 9th, having received, early in the morning, some rain-water in a dish, as before, and poured it into a very clean wine-glass, and exposed it about 8 of the clock in the morning to the air, about the height of the third story of my house, to find, whether the little animals would appear the sooner in the water, thus standing in the air: Observing the same accordingly the 10th of June, I imagin'd I saw some living creatures therein; but because they seem'd to be but very few in number, nor were plainly discernible, I had no mind to trust to this observation. The 11th of the same month, seeing this water move in the glass from a stiff gale of wind (which had blown for thirty-six hours without intermission, accompanied with a cold, that I could very well endure my winter-cloaths,) I did not think I should then perceive any living creatures therein; yet viewing it attentively, I did, with admiration, observe a thousand of them in one drop of water, which were of the smallest sort, that I had seen hitherto.

Observ. V.

"The 9th of June I put of the same rain-water in a very clean wine-glass on my counter of study, and viewing the same, I perceived no living creatures in it.

"The 10th of June, observing the mentioned rain-water, which now had stood twenty-four hours in my study, I noted some few very small living creatures in which by reason of their extreme minuteness I could see no figure, and among the rest I discovered one that was somewhat greater, of an oval figure. *Note*, that when I say I have viewed the water, I mean, that I have viewed only three, four, or five drops of the water, which I also flung away.

"The 11th of June, looking upon the water afresh, I saw the said little creatures again, but there were then but very few of them.

"The 12th, I saw them as the day before; besides I took notice of one figured like a mussel-shell, with its hollow side downwards, and it was of a length equal to the eye of a louse.

Observ. VI.

"The 17th of this month of June it rained very hard; and I catched some of that rain-water in a new porcelain-dish, which had never been used before, but found no living creatures at all in it, but many terrestrial particles, and, among others, such as I thought came from the smoak of smith's-coals and some thin thrids, ten times thinner than the thrid of a silk-worm, which seemed to be made up of globuls; and where they lay thick upon one another, they had a green colour. The 26th, having been eight days out of town, and kept my study shut up close, when I was come home and did view the said water, I perceived several *animalcula*, that were very small, and herewith I desisted from making at this time any further observations of rain-water.

"Mean time, this town of Delft being very rich in water and we receiving from the river Maase fresh water, which maketh our water very good; I viewed this water divers times, and saw extream small creatures in it, of different kinds and colours; and even so small, that I could very hardly discern their figures: But some were much bigger, the describing of whose motion and shape would be too tedious: this only I must mention here, that the number of them in this water was far less than that of those found in rain-water; for I saw a matter of twenty-five of them in one drop of this town-water, that was much. In the open court of my house I have a well which is about 15 foot deep, before one comes to the water. It is encompassed with high walls, so that the sun, though in *Cancer*, yet can hardly shine much upon it. This water comes out of the ground, which is sandy, with such a power, that when I have laboured to empty this well, I could not so do it but there remained ever a foot's depth of water in it. This water is in summer time so cold, that you cannot possibly endure your hand in it for any reasonable time. Not thinking at all to meet with any living creatures in it (it being of a good taste and clear), looking upon it in September of the last year, I discovered in it a great number of living animals, very small, that were exceeding clear, and a little bigger than the smallest of all that I ever saw; and I think, that in a grain weight of this water there were above 500 of these creatures, which were very quiet and without motion. In the winter I perceived none of these little animals, nor have I seen any of them this year before the month of July, and then they appeared not very numerous, but in the month of August I saw them in great plenty.

"July 27, 1676, I went to the sea-side at Schevelingen, the wind coming from the sea with a very warm sun-shine; and viewing some of the water very attentively, I discovered divers living animals therein. I gave to a man, that went into the sea to wash himself, a new glass bottle, bought on purpose for that end, intreating him, that being on the sea, he would first wash it well twice or thrice, and then fill it full of the sea water; which desire of mine having been complied with, I tyed the bottle close with a clean bladder, and coming home and viewing it, I saw in it a little animal that was blackish, looking as if it had been made up of two globuls. This creature had a peculiar motion, after the manner as when we see a very little flea leaping upon a white paper; so that it might very well be called a water-flea; but it was by far not so great as the eye of that little animal which Dr. Swammerdam calls the water-flea. I also discovered little creatures therein, that were clear, of the same size with the former animal which I first observed in this water, but of an oval figure, whose motion was serpent-like. I took notice of a third sort, which were very slow in their motion: Their body was of a mouse-colour, clear towards the oval point; and before the head, and behind the body there stood out a sharp little point angle-wise. This sort was a little bigger. But there was yet a fourth sort somewhat longer than oval. Yet of all these sorts there were but a few of each, so that in a drop of water I could see sometimes but three or four, sometimes but one.

"*Observations of water, wherein whole Pepper had layn infused several dayes.*

"1. I having several times endeavoured to discover the cause of the pungency of pepper upon our tongue, and that the rather because it hath been found, that though pepper had layn a whole year in vinegar, yet it retained its full pungency; I did put about $\frac{1}{3}$ of an ounce of whole pepper in water, placing it in my study, with this design, that the pepper being thereby rendered soft, I might be enabled the better to observe what I proposed to myself. The pepper having layn about 3 weeks in the water, to which I had twice added some snow-water, the other water being in great part exhaled; I looked upon it the 24. of April 1676, and discovered in it, to my great wonder, an incredible number of little animals of divers kinds; and among the rest some that were 3 or 4 times as long as broad; but their whole thickness did, in my estimation, not much exceed that of the hair of a louse. They had a very pretty motion, often tumbling about and sideways; and when I let the water run off from them, they turned as round as a top, and at first their body changed into an oval, and afterwards, when the circular motion ceased, they returned to their former length.

"The 26th of April I took $2\frac{1}{2}$ ounces of snow-water, which was almost three years old, and which had stood either in my cellar or study in a glass bottle well stopped. In it I could discover no living creatures: And having poured some of it into a porcelain thea-cup, I put therein half an ounce of whole pepper, and so I placed it in my study. Observing it daily until the 3rd of May, I could never discover any living thing in it; and by this time the water was so far evaporated, and imbibed by the pepper, that some of the pepper-corns began to lye dry. This water was now very thick of odd particles; and then I poured more snow-water to the pepper, until the pepper-corns were cover'd with water half an inch high. Whereupon viewing it again the 4th and 5th of May, I found no living creatures in it; but the 6th I did very many, and these exceeding small ones, whose body seemed to me twice as long as broad; but they moved very slowly and often roundways.

"The 7th I saw them yet in far greater numbers.

"The 10th I put more snow-water to the pepper, because the former was again so exhaled, that the pepper-corns began to dry again.

"The 13th and 14th I saw the little creatures as before; but the 18th the water was again so dryed away, that it made me pour in more of it. And the 23rd I discovered, besides the aforesaid little animals, another sort, that were perfectly oval, and in figure like cuckow-eggs. Me thought the head of them stood on the sharp end: their body did consist, within, of 10, 12 or 14 globuls, which lay separate from one another. When I put these *animalcula* in a dry place, they then changed their body into a perfect round and often burst asunder, and the globuls, together with some aqueous particles, spread themselves everywhere about, without my being able to discern any other remains. These globuls, which in the bursting of these creatures did flow asunder here and there, were about the bigness of the first very small creatures. And though as yet I could not discern any feet in them, yet me thought, they must needs be furnished with very many, seeing that the smallest creatures, which I said before to be very plentiful in the water, and lay sometimes more than 100 of them on one of the oval creatures, were by the motion made in the water by the great ones (though to my eye they seem'd to lye still) driven away by them as we blow a feather from our mouth. Of the same oval creatures I never could discover any very little ones, how attentive soever I was to observe them.

"The 24th of May observing this water again, I found in it the oval little animals in a much greater abundance. And in the evening of the same day, I perceived so great a plenty of the same oval ones, that 'tis not one only thousand which I saw in one drop; and of the very small ones, several thousands in one drop.*

"The 25th I saw yet more oval creatures: and the 26th I found so vast a plenty of these oval creatures, that I believe there were more than 6 or 8000 in one drop, besides the abundance of those very little animals whose number was yet far greater. This water I took from the very surface; but when I took up any from beneath, I found that not so full of them by far. Observing that these creatures did augment into vast numbers, but not being able to observe them increase in bigness, I began to think whether they might not in a moment, as 'twere, be composed or put together: But this speculation I leave to others. The 26th of May at night, I discovered almost none of the little creatures, but saw some with tayls, of which I have spoken heretofore, to have seen them in rain-water: But there drove in the water throughout an infinity of little particles, like very thin hairs, only with this difference, that some of them were bent.

"May the 26th, I took about $\frac{1}{3}$ of an ounce of whole pepper, and having pounded it small, I put it into a thea-cup with $2\frac{1}{2}$ ounces of rain-water upon it, stirring it about, the better to mingle the pepper with it, and then suffering the pepper to fall to the bottom. After it had so stood an hour or two, I took some of the water, before spoken of, wherein the whole pepper lay, and wherein were so many several sorts of little animals; and mingled it with this water, wherein the pounded pepper had lain an hour or two, and observed that when there was much of the water of the pounded pepper, with that other, the said animals soon died, but when little they remained alive."

* "This phænomenon and some of the following ones seeming to be very extraordinary, the author hath been desired to acquaint us with his method of observing, that others may confirm such observations as these."

Although it is scarcely possible to fix with certainty the specific identity of the numerous animalcules enumerated by Leeuwenhoek in the foregoing "Observations" in various instances, the characters recorded are so well defined as to clearly indicate the generic group to which the organism described should be relegated. Taking, for example, the first form encountered by him in rain-water, having a globular body with two little anterior horns and a long thread-like tail, which under certain conditions contracted into a spiral form, there can be no question that this type represents some species of *Vorticella*, or bell-animalcule, and is apparently identical with the form now known by the distinctive title of *Vorticella microstomum*. While the recorded presence of the two anterior "horn-like processes" appears at first sight to represent a somewhat anomalous structural characteristic, this seeming incongruity vanishes on applying to it the standard of a slightly later acquired knowledge of the members of this infusorial group, and through which medium it is at once made evident that the appendages above referred to as seen by Leeuwenhoek represented merely the imperfectly defined optical aspect of the lateral edges of the characteristic peristomal fringe of cilia. As a remarkable illustration of the manner in which "history repeats itself" even in the annals of scientific discovery, it may be here noted that a precisely similar error of interpretation is associated by Mr. H. J. Carter, close upon two centuries later, in his figure and description of the flagellate organism described in this volume under the name of *Salpingœca Carteri* (see Pl. VI. Fig. 39). The characteristic membranous collar distinctive of this type and its allies, which occupies a position corresponding with that of the ciliary wreath of a *Vorticella*, is so exceedingly transparent as to be distinctly visible only with the aid of the highest magnifying powers of the modern compound microscope. The structure as observed by Mr. Carter with inadequate magnification, displayed simply its two lateral peripheries, assuming under such conditions the aspect of two projecting ear-like processes, and under which latter designation they are chronicled in the description quoted. The second oval form described by Leeuwenhoek as furnished on the under side with divers incredibly thin feet, and having a soft flexible body capable of assuming a variety of figures, would appear to be a species of *Oxytricha*, while in the little animal like a mussel-shell, having also on its under side little feet, recorded in the course of his fifth Observation, is at once recognized a form closely allied to, if not specifically identical with the cosmopolitan type *Stylonychia mytilus*. It is well worthy of note, that while Leeuwenhoek in this first recorded account of the members of the infusorial world more usually associates with them the vague terms of little animals or creatures, he employs for them at the commencement of his discourse that of "animalcula," or, in English, animalcules, generally adopted in conjunction with that of the Infusoria by the majority of later writers. In his observations of various species discovered by him in an infusion of pepper we finally find the origin of the burning question of the possible "spontaneous generation" of these minute beings, and which, while not entirely accepted by Leeuwenhoek, is conceived and tossed by him as a very apple of discord to posterity.*

The period intervening between this first discovery of the Infusoria by Leeuwenhoek, and his further contribution to the literature of the same subject in the year 1703, is signalized by the corroboration of that authority's observations, and an extension of our knowledge of the group, at the hands of several of our own countrymen, among whom have to be more especially mentioned the names of Sir E. King, John Harris, and Stephen Gray. In each case the results obtained by these early investigators are recorded in the pages of the 'Philosophical Transactions,' and in connection with one contribution, that of Sir E. King, is to be found the first published illustration of infusorial life. The form thus represented was obtained in an infusion of pepper, and appears to be identical with the *Enchelys arcuata* of Ehrenberg. This authority also places on record the results of the experimental application of certain chemical and other substances to living animalcules, a subject which will be found referred to at greater length in the section devoted to this special topic. The account of John Harris's investigations contained in the 'Philosophical Transactions' for the year 1696, embodies the earliest description given of *Euglena viridis*, and some remarkably shrewd and philosophic speculations as to the manner in which Infusoria were so rapidly and unaccountably developed. These latter were altogether opposed to the then newly-conceived theory of spontaneous generation, and, as hereafter shown, add their weight to the evidence which has been since adduced in a similar direction. Mr. Harris's description of *Euglena* and certain other associated forms, that first mentioned being evidently a species of *Anguillula*, and the second a Rotifer, probably *R. vulgaris*, is as follows:—

"On July 7th, 1694, I examined a small drop of rain-water that had stood in a gally-pot in my window for about two months. In the thick part of the drop—for the water from whence I took it had contracted a thickish skum—I found two sorts of animals as a kind of eels like those in vinegar. I saw here also an animal like a large maggot, which would contract itself up into a spherical figure, and then stretch itself out again; the end of the last appeared with a forceps like that of an earwig; and I could plainly see it open and shut its mouth, from whence air-bubbles would frequently be discharged. Of these I could number about four or five, and they seemed to be busie with their mouths as if in feeding. April 27th, 1696. With a much better microscope I examined some rain-water that had stood uncovered a pretty while, but had not contracted any such thick and discoloured a skum as that before mentioned had. A little thin white skum, that like grease began to appear on

* In association with the discoveries of Leeuwenhoek here recorded, it is worthy of remark that a cabinet of the microscopes, to the number of twenty-six, as self-constructed and employed by that investigator, and consisting of simple doubly convex lenses, were originally presented by him to the Royal Society of England, but have long since been lost sight of. The latest tidings of them would appear to be furnished by Mr. Henry Baker, who in his work, 'The Microscope Made Easy,' published in the year 1785, attests to having had these glasses under examination away from the Society's premises and at his own private residence. The recovery of such precious heirlooms, and the reconsignment of the same to their former custody, or among the series of optical instruments belonging to the Royal Microscopical Society, where perhaps they would be even more highly prized, is a consummation most devoutly to be wished, and may possibly be helped forward by this notice.

the surface, I found to be a congeres of exceeding small animalcula of different shapes and sizes. At the same time I look't on a small drop of the green surface of some puddle-water, which stood in my yard; this I found to be altogether composed of animals of several shapes and magnitudes. But the most remarkable were those which I found gave the water that green colour, and were oval creatures, whose middle was of a grass green, but each end clear and transparent. They would contract and dilate themselves, tumble over and over many times together, and then shoot away like fishes. Their head was at the broadest end, for they still moved that way. They were very numerous, but yet so large, that I could distinguish them very plainly, with a glass that did not magnify very much.

"April 29th, 1696. I found another sort of creatures in the water (some of which I had kept in a window, in an open glass). They were as large as three of the other, with the green border about their middles, but these were perfectly clear and colourless. Then also examining more accurately the belts or girdles of green that were about the animals, mentioned above, I found them to be composed of globules, so like the rowes or spawn of fishes, that I could not but fancy that they served for the same use in the little creatures: For I found now since April 27. many of them without anything at all of that green belt or girdle; others with it very much and that unequally diminished, and the water filled with a vast number of small animals, which before I saw not there, and which I now looked on as the young animated frye, which the old ones had shed. I continued looking on them at times for two days, during which time the old ones with the green girdles decreased more and more; and at last I could not see one of them so encompassed, but they were all clear and colourless from end to end.

"May 18th, 1696. I look't in some of the surface of puddle-water which was blewish, or rather of a changeable colour, between blew and red. In a large quantity of it I found a prodigious number of animals, and of such various bignesses, that I could not but admire their great number and variety; but among these were none with those girdles before-mentioned, either of green, or any other colour. I then also examined the surface of some other puddle-water, that look't a little greenish; and this I found stockt with such an infinite number of animals, that I yet never saw the like anywhere but in the *Genitura masculina* of some creatures. Among these there were many of a greenish colour; but they all moved about so strangely swift, and were so near to each other, that tho' I tried my eyes, I could not distinguish whether the green colour were all over their bodies, or whether it were only round their middle in girdles, as before, but from the roundness of their figure and their smallness, I judge that they chiefly consisted of the young animated spawn of the kind of animals mentioned already. I found that the point of a pin dipt in spittle would presently kill them all; as I suppose it will other animalcula of this kind."

The interest attached to the writings upon this same subject of Stephen Gray, published also in the same volume of the 'Philosophical Transactions' for the year 1696, is connected most prominently with the discovery made by this early investigator, that particles contained within a simple sphere of glass, or animalcules contained in a corresponding globule of water, become when viewed under favourable conditions more powerfully magnified than with the assistance of any ordinary bi-convex lens. Several varieties of animalcules were described by Stephen Gray, as examined by him with this most simple optical apparatus, among them being a form, apparently the *Halteria grandinella* of Dujardin, in association with which he places on record the earliest account of what, while interpreted by him as a possible act of generation, was more probably an instance of the more ordinary phenomenon of transverse fission. A brief abstract, in his own words, of Stephen Gray's account of his discoveries in these several directions is herewith subjoined:—

"I know not well how at this time to account for this strange phenomenon, that an object should be placed so far within the focus of a spherule, as to be within the glass, and yet seen distinctly to the eye so near it; but since by matter of fact, I found it was so, I made this inference, and concluded, that if I conveyed a small globule of water to my eye, and that there were any opacous or less transparent particles than the water therein, I might see them distinctly.

"Exp. 4. Having by me a small bottle of water, which I knew to have in it some of those minute insects, which the deservedly famous observator Mr. Leeuwenhoek discovered, by the help of excellent microscopes. Having seen them with the common glass microscopes, and with the first aqueous, as above mentioned, I poured a few drops of this water on the table, and taking a small portion thereof on a pin, I laid it on the end of a small piece of brass wire, of about one-tenth of an inch diameter. I continued to lay on two or three portions of water, till there was formed somewhat more than an hemispherule of water; then keeping the wire erect, I applied it to my eye, and standing at a proper distance from the light, I saw them and some other irregular particles, as I had predicted, but most enormously magnified; for whereas they are scarce discernible by the glass microscopes, or the first aqueous one, within the globule, they appeared not much different both in their form, nor less in magnitude than ordinary peas. They cannot well be seen by daylight except the room be darkened, after the manner of the famous dioptrical experiment, but most distinctly by candle-light; they may be very well seen by the full moon light, and the pin sometimes takes up the water round enough to shew its objects distinct.

"The insects I have yet this way observed, are of two sorts, globular and elliptical: I shall first describe the former. They are of a globular form, they are but a little less transparent than the water they swim in; they have sometimes two dark spots diametrically opposite, but these are rarely seen; there are sometimes two of these globular insects sticking together; where they are joined 'tis opacous, possibly they may be in the act of generation; they have a twofold motion, a swift progressive irregular one, and at the same time a rotation on their axes at right angles to the diameter that has the dark spots, but this is seen only when they move slowly. They are almost of an incredible minuteness. Mr. Leeuwenhoek is moderate enough in his computation, when he tells us * he saw insects in water, so small, that 30,000 could not more than equal a coarse sand; but I believe it will seem a paradox to him, when one that tells him so shall at the same time say, that he can see them by only applying the bare eye, to a portion of water wherein they are contained."

In the year 1703 Leeuwenhoek contributed to the 'Philosophical Transactions' an account of several species of animalcules observed by him on the roots of duckweed obtained from the River Maes at Delf-haven in Holland, which was accompanied by woodcut illustrations of the various forms encountered. Among them are especially conspicuous a species of *Vorticella*, apparently *V. nebulifera*, and a tube-dwelling variety allied to, if not identical with *Vaginicola crystallina*. In addition to the true Infusoria above named, Leeuwenhoek figured and described for the first time the Freshwater Polyp (*Hydra*) and a large sedentary Rotifer most nearly resembling *Limnias ceratophylli*. The majority of these types are represented as adherent to a single rootlet of duckweed, having interspersed among them several acicular diatoms (*Fragillaria*), and a few other exceedingly minute stalked particles referred to by him as "little flower-like figures," and which

* 'Phil. Trans.,' No. 213, p. 198.

are undoubtedly minute sedentary Flagellata, such as *Spumella* or *Oikomonas.*

The issue of the 'Philosophical Transactions' following upon the one containing the foregoing figures and descriptions, is conspicuous for the insertion, at the hands of an anonymous writer, of an account of a considerable number of infusorial forms obtained from an infusion of pepper. The type first described by Leeuwenhoek, *Vorticella microstomum* or *putrinum*, is here figured for the first time, as also *Paramecium aurelia* showing its characteristic ciliation, a species of *Euplotes*, *Enchelys*, *Oxytricha*, and a variety of other animalcules whose identity cannot so easily be determined. Among the delineations given of the *Euplotes*, one example represents an animalcule dividing by transverse fission, and is referred to in the accompanying text as a probable example of copulation. The highest interest attached to this early contribution to microscopic literature is, however, associated with the fact that it embodies a remarkably clear and graphic account of several species of the exceedingly minute and low-organized Phytozoa, *Vibrio* and *Spirillum*—briefly referred to by Leeuwenhoek in the preceding quotations as "an infinity of little particles like very thin hairs which drove through the water"—which is accompanied by illustrations of the types observed, equal both in execution and the scale of magnification employed to those produced by workers in this same field of research for more than a century later. The apparatus, nevertheless, at the disposal of this early investigator was the single-lensed instrument only manufactured by Mr. Wilson, but out of which he testifies to having succeeded in obtaining a magnification of no less than 640 diameters. In recognition of their attenuate serpentine form and movements, this discoverer proposed to confer upon the hair-like bodies just referred to the distinctive title of "Capillary Eels." A brief abstract of this anonymous author's original and earliest recognizable description of these exceptionally minute and highly interesting organisms is here appended. After submitting an account of the instrument employed and various forms observed by him in his infusion of pepper, he continues :—

"One sort I never discovered till but three or four days ago. These are very long slender worms, of which my pepper-water is prodigiously full. They are all of the same thickness, but their lengths are very different, some twice and some thrice as long as others, and at a medium I judge the proportions of their length to their breadth at least as 50 to 1. To the largest magnifiers they look like threads of horse-hair, (to a naked eye), from a quarter to three-quarters of an inch long, and their motion is equable and slow and generally they wave their bodies but little in their progression, though sometimes they make greater undulations. But what is more remarkable, they swim with the same facility both backward and forward, so that I cannot distinguish at which end the head is, and I have seen the same worm go forward with one end, and back again with the other end foremost about twenty times together. And sometimes they will (like leeches) fix one end on the glass plate (on which I lay the water), and move the loose part of their body round about very oddly. These I take leave to call Capillary Eels, and I have given you as well as I could a representation of their appearance to a great magnifier, in the several postures I have seen them swim.

"Oct. 6th, 1702. I thought those which I called capillary eels had been peculiar to pepper-water, but have since observed the same (tho' but few) in some standing water which drained from an horse dunghill. Among these the prettiest object was a great number of a kind of eels which appear most distinctly when the water is almost dry, which make brisk shoots, and have a pretty wriggling motion; they are of different lengths, and are about the thickness of what I call capillary eels."

Among the contributors to our knowledge of infusorial life during the earlier half of the eighteenth century the names of Louis Joblot, Henry Baker, and Abraham Trembley hold a prominent position. Joblot, author in the year 1718 of a large treatise upon microscopes and the forms of microscopic animals to be found in various artificial infusions, was unfortunately led, through his possession of a more than ordinarily romantic imagination, to embellish very considerably his descriptions and drawings of the various types observed, these latter being in many instances moulded by his facile pen into the similitude of satyrs' heads, and other monstrosities having no existence in the plain and solid ground of fact. Henry Baker's work, 'The Microscope Made Easy,' published in the year 1742, while embracing a general account of all the various forms of microscopes in use up to that date, and of subjects suitable for examination with the aid of that instrument, includes in addition, a description with figures of many forms of animalcules discovered by himself in organic infusions. This special subject is, however, treated still more extensively in his subsequent volume, 'Employment for the Microscope,' published in the year 1753. In this last-named treatise is to be found the first printed account, accompanied by an easily recognizable figure, of the species now well known by the title of the Swan Animalcule, *Lacrymaria olor*, and upon which Mr. Baker conferred the name of the "Proteus." Of this he writes :—

"Having one evening been examining of the slime-like matter taken from the side of a glass jar, in which small fishes, water-snails, and other creatures had been kept alive two or three months, by giving them fresh water frequently, I was diverted with the sudden appearance of a little creature whose figure was entirely new to me, moving about with great agility, and having so much seeming intention in all its motions, that my eyes were immediately fixed upon it with admiration. Its body in substance and colour resembled a snail's; the shape thereof was somewhat elliptical, but pointed at one end, whilst from the other a long, slender and finely proportioned neck stretched itself out, and was terminated with what I judged to be an head, of a size perfectly suitable to the other parts of the animal. In short, without the least fancy, which is ever carefully to be guarded against in the use of the microscope, the head and neck, and indeed the whole appearance of the animal, had no little resemblance to that of a swan: With this difference, however, that its neck was never raised above the water, as the neck of a swan is, but extended forwards, or moved from side to side, either upon the surface of the water, or in a plane nearly parallel to the surface thereof. It swam to and fro with great vivacity, but stopped now and then for a minute or two, during which time its long neck was usually employed, as far as it could reach, forwards, and on every side, with a somewhat slow but equable motion, like that of a snake, frequently extending thrice the length of its body, and seemingly in search of food. I could discern no eyes, nor any opening like a mouth in what appears to be the head; but its actions plainly prove it an animal that can see; for notwithstanding multitudes of different animalcules were swimming about in the same water, and its own progressive motion was very swift, it never struck against any of them, but directed its course between them, with a dexterity wholly unaccountable, should we suppose it destitute of sight."

Henry Baker's speculations concerning the probable origin of animalcules in hay and other infusions will be referred to in a future chapter.

Abraham Trembley's name, while most famous in association with his remarkable discoveries concerning the extraordinary recuperative properties after mutilation possessed by the fresh-water polypes, *Hydra vulgaris* and *viridis*, has also to be included in the list of contributors to our early knowledge of the Infusoria. In the course of his investigations and experiments upon the more highly organized forms just mentioned, he was the first to encounter many of the larger Stentors or trumpet-animalcules, and regarding them as structurally allied to the latter, described them in the 'Philosophical Transactions' for 1744 under the respective titles of the white, blue, and green funnel- or tunnel-like polypes. Through a prolonged study of these forms Trembley made himself familiar with, and recounted at length, the peculiar oblique manner in which they subdivide, the mode in which the new head and oral aperture is formed upon the posterior segment, and a new caudal prolongation upon the anterior one, being related with such true and exhaustive detail as to leave but little to be added in this connection by later investigators. Under the title of "Clustering Polypes" this authority also figured and described several varieties of *Epistylis*, notably *E. flavicans*, relating precisely the manner in which by constant and even longitudinal subdivision and prolongation of the supporting pedicle the branched compound colony is built up. This premised affinity of the trumpet-animalcules with the polypes suggested by Trembley received the full approbation of the father of systematic natural history, the immortal and illustrious Linnæus, by whom they were included in the tenth edition of his famous 'Systema Naturæ,' published in the year 1758, under the title of *Hydra stentorea*.

Five years later, 1763, we find for the first time the term "Infusoria" introduced for the distinction of the minute beings that form the subject of this treatise. M. F. Ledermuller, of Nuremberg, to whom must be awarded the credit of creating this highly suggestive title, which has since been almost universally adopted, employed it in the first instance for the distinction of all those microscopically minute animals discovered by himself and earlier investigators in water in which hay had been for some few days previously steeped. This new title he further proposed to extend to all the microscopical forms of animal life inhabiting infusions and putrid liquids, including also those discovered in stagnant rain-water nearly a century previously by Leeuwenhoek; the Stentors were, nevertheless, left by him in the position among the polypes assigned to them by Linnæus and Trembley. The names of Rösel, 1755, Wrisberg, 1765, and Pallas, 1766, may be mentioned among the more prominent contributors to our earliest knowledge of the larger forms of animalcules, chiefly Vorticellidæ and Stentoridæ, preceding the appearance of what to the present day holds rank as the earliest standard work that embodies a complete and systematic account of the members of the infusorial world. Reference is here made to the 'Animalcula Infusoria' of Otho Friedrich Müller, a posthumous quarto volume published in the year 1786, containing no less than fifty plates and 367 pages of letterpress devoted to the description and illustration of close upon three hundred species, fluviatile and marine, investigated and drawn from the life by this indefatigable worker during a period extending over no less than twenty years.

This early pioneer in the then *terra incognita* of the Protozoic sub-kingdom had already in his 'Vermium terrestrium et fluviatilium succincta Historia,' 'Zoologica Danicæ Prodromus,' and 'Zool. Dan. Icones,' published respectively in the years 1773, 1776, and 1779, given descriptions and illustrations of a large number of these numerous types, to all of which he attached distinctive generic and specific titles in conformity with Linnæus' then newly-introduced binomial system of nomenclature; each of these compilations, however, possess but minor value compared with the work first quoted. To this latter, one is justified, indeed, in conceding as important a status, as compared with all preceding literature upon the subject, as is subsequently commanded by C. G. Ehrenberg's classic volume, 'Die Infusionsthierchen,' published a little over half a century later. As might be anticipated, O. F. Müller embraces in his 'Animalcula Infusoria' numerous minute organisms that find no place in the infusorial group as at present constituted, although in this respect he trespasses but slightly from the path subsequently pursued by Ehrenberg. In all, Müller institutes seventeen generic denominations, the whole of which are still in use, and only one, his genus *Cercaria*, being founded upon forms not admitted into Ehrenberg's system of classification, while another, his genus *Vibrio*, embraces in addition to many common forms of *Bacteria*, *Vibrio*, and *Spirillum*, as now recognized, various examples of the microscopic hair-worms or *Anguillulæ*. The several species of *Stentor* were now recognized as members of the same infusorial series, and transferred to his somewhat comprehensive genus, *Vorticella*. As a necessary consequence of the very imperfect instruments available for investigation at this early date, little more than a rough general outline of the species examined, and no details of their internal organization, are usually recorded, while in many of the types figured the cilia are but represented in part, or even altogether omitted. A reproduction of O. F. Müller's generic subdivisions and earliest proposed scheme of classification of the Infusoria will be found in the chapter hereafter devoted to this special subject.

In the long interval intervening between the publication of Müller's 'Animalcula Infusoria' and the appearance of Ehrenberg's world-famed treatise, a considerable number of investigators occupied themselves in the study of these minute organisms, but without achieving any very notable results.

Bonnet, Goeze, Gleichen, Eichorn, Spallanzani, and Schranck, towards the termination of the eighteenth, and Treviranus, Oken, Dutrochet, Nitzsch, and Bory de St. Vincent, during the commencement of the present century, are among the more conspicuous of these. Gleichen's name, perhaps, deserves special notice, he being the first to demonstrate, through the admixture of finely comminuted carmine with the water, the capacity of Infusoria to appropriate this and other solid substances as food. Spallanzani detected within the body-plasma of various species the bubble-like pulsating space or spaces afterwards denominated contractile vesicles, while the presence of an internal, more solid, gland-like structure, the nucleus or endoplast, and the capacity of many to increase by longitudinal or transverse subdivision were familiar to the majority of these observers. Examples of these last-named phenomena were, indeed, figured and described by Müller, and had, as already intimated, been observed long previously by Trembley in association with the Stentors or trumpet-animalcules. Dutrochet, in the year 1812, achieved a progressive step by the recognition of the essential distinction of all the species referred by O. F. Müller to the genus *Brachionus;* these were shown to exhibit a much higher organization than the ordinary Infusoria, possessing well-developed internal organs, and a much more complex type of external contour, and were now distinguished for the first time by the title of Rotiferæ or wheel-animalcules. This distinction, pointed out by Dutrochet, was recognized by Lamarck and Cuvier in their respective classifications of the animal kingdom, the Infusoria as embodied in Cuvier's scheme including all of Müller's types, subdivided into two leading orders, the one including the more complex Rotiferæ, and the other the apparently structureless and homogeneous animalcules. These latter were, indeed, accepted by Cuvier and all leading authorities up to the year 1830 as the simplest forms of animal life, exhibiting a degree of organization most appropriately compared with mere specks of animate jelly variously modified in external shape.

With the last-named date commenced an entirely new era in the history of the Infusoria. For fourteen years previously Christian Gottfried Ehrenberg had been devoting studious attention to the investigation of the lowest grades of vegetable and animal life, the matured fruits of which now took the scientific world completely by surprise. He at this time commenced the publication of his various essays, seeking to demonstrate that the Infusoria, notwithstanding their minute size, possessed a degree of organization as perfect and complex as that of the higher animals, which culminated in the year 1838 in the production of his world-famed history of the Infusoria, 'Die Infusionsthierchen als Volkommene Organismen.' This magnificent folio treatise, embodying no less than 532 pages of letterpress and an accompanying atlas of 64 coloured plates, including several hundred specific forms delineated for the most part with a life-like exactitude, will ever remain a lasting memorial of the unflagging industry and talent of this most indefatigable investigator.

Notwithstanding the comparative imperfection of the optical appliances at his disposal, it may indeed with justice be said that Ehrenberg's figures, so far as they relate to contour and broad superficial details of structure, are scarcely to be improved upon, and considerably excel, in execution, the delineation of the same forms included in many more modern treatises. Ehrenberg, like Müller, associated together under the collective title of the Infusoria a vast assemblage of minute animal and vegetable organisms, a small section only of which finds its equivalent under the same classificatory term in its more modern and restricted sense. In addition to the true Infusoria he still retained the Rotifera, or wheel-animalcules, the descriptions and illustrations of these monopolizing over one-third of the text and plates of his entire volume, while a very considerable portion of the remainder is occupied with the description and delineation of the essentially vegetable Desmidiaceæ and Diatomaceæ, to which are also added many forms of Rhizopoda and unicellular plants other than the Bacillaria.

It was to the residual portion, that alone coincides with the tribe Infusoria as at present recognized, that Ehrenberg attributed the possession of a highly complex internal structure, whose chief feature was further described as consisting of a large number of pedunculate bubble-like stomach-cavities associated with one another in a clustered form. The most weighty testimony relied on by Ehrenberg in support of this theory was derived from his repetition and extension of the experiments of Gleichen, by whom it was demonstrated that carmine, indigo, or other pigmentary matter suspended in the water was freely devoured. After passing through the oral aperture this coloured matter was found to become collected in small spherical bubble-like masses, variously distributed throughout the body-substance or parenchyma, and without apparently taking the pains to assure himself that these vacuoles occupied a permanently fixed position, Ehrenberg assumed that such was the case, and assigned to each vacuole the significance of a distinct food-receptacle or stomach; it was with special reference to these supposed numerous stomach-cavities that the title of the Polygastrica was adopted by him for the distinction of this particular group. Ehrenberg's conception of the high and complex organization of his so-called Polygastrica, however, by no means ended here. The transparent vacuole possessing the property of contracting rhythmically, first observed by Spallanzani, conjointly with the still more universally recognized gland-like nucleus or endoplast, were pronounced to be integral parts of the male generative organs, the former representing a seminal vesicle, and the latter a seminal gland or testis. The minute granular corpuscles distributed more or less abundantly throughout the substance of the body were declared to be eggs, which after fecundation from the seminal vesicle were discharged through the anal aperture or vent. The possession by these Polygastrica of a complex muscular, nervous, and blood-circulating system was likewise insisted on, though no proof in these latter instances was brought forward; the coloured eye-like pigment specks conspicuous in *Euglena*, *Ophryoglena*, and various other types, were finally regarded by him as highly differentiated visual organs.

Ehrenberg's evidence in support of his many-stomached or polygastric theory was built on too insecure a foundation to stand the test of contemporary investigation, and before which, indeed, the entire superstructure of his most ingeniously conceived digestive, neural, hæmal, and reproductive systems was speedily demolished.

The first and most prominent authority to call in question the accuracy of Ehrenberg's interpretations was M. Felix Dujardin, who, firstly in various contributions to the 'Annales des Sciences Naturelles,' extending through the years 1835–38, and later in a special treatise devoted to this subject, 'Histoire Naturelle des Infusoires,' 1841, brought forward evidence that threw an entirely new light on the organization of the members of this group. Through an investigation, in their living state, of various representatives of the minute marine shell-forming organisms upon which D'Orbigny, in the year 1826, conferred the distinctive title of Foraminifera, Dujardin discovered that their internal structure was far more simple than had been previously conjectured. Guided only by an acquaintance with the empty shells or tests of these minute beings, and taking into account their predominating nautiloid form and chambered character, D'Orbigny and his contemporaries concluded that their fabricators exhibited a correspondingly high degree of organization, and described them as diminutive representatives of the Cephalopodous order of the Mollusca. Dujardin, examining various Mediterranean forms belonging chiefly to the genera *Cristellaria*, *Miliola*, and *Vorticialis*, speedily determined that their living occupants could lay claim to no such exalted position, being found by him to possess no distinct organs or differentiated tissues, but in their place a simple transparent gelatinous body, capable of extending fine thread-like prolongations of its substance in every direction, by means of which they adhered to and crept over submerged objects. Dujardin likewise discovered in both salt and fresh water minute organisms possessing similarly extensile gelatinous bodies and still more simple, unchambered, and mostly corneous tests, upon which he conferred the generic names of *Gromia* and *Euglyphia*. Between these several types and Ehrenberg's test-inhabiting polygastric genera *Arcella* and *Difflugia*, and the still more simple shell-less *Amœbæ*, Dujardin soon recognized that there subsisted the closest affinity, and separating them from all other forms, instituted for their reception, in reference to their peculiar mode of locomotion by root-like extensions of their body-substance, the class title of the Rhizopoda. Dujardin further conferred upon the plastic, gelatinous, and apparently homogeneous body-substance of these Rhizopoda the distinctive name of "sarcode," and finally sought to demonstrate that in all those infusorial forms described by Ehrenberg as exhibiting a polygastric type of structure, their body-substance possessed a similar simple gelatinous or sarcode consistence, although, through the superaddition of a denser external membrane, they were incapable of emitting thread- or root-like pseudopodic processes. No trace of a muscular or nervous system could be detected by this authority, while the non-existence of the complex digestive apparatus described by Ehrenberg was effectually demonstrated. On feeding Vorticellæ and other animalcules with carmine, in accordance with the plan adopted by Gleichen and Ehrenberg, Dujardin found that the food-particles, after their reception at the oral aperture, were not retained in definite and permanently fixed stomach-sacculi, but after aggregation into small spheroidal masses were passed backwards into the body-sarcode or parenchyma, and there freely circulated until digestion or rejection at the anal aperture. The somewhat similar and characteristic independent circulation of the inner sarcode or parenchyma of *Paramecium bursaria* and *Vaginicola crystallina* was also recorded for the first time by Dujardin. The contractile organ, first discovered by Spallanzani, and interpreted by Ehrenberg as belonging to the reproductive system, was pronounced by this investigator to be a mere vacuolar space situated close to the surface, apparently fulfilling a respiratory function by the continual absorption and expulsion of water.

This simple interpretation of the organization of the Infusoria arrived at by Dujardin, in opposition to that of Ehrenberg, soon gained powerful adherents. Among the more noteworthy authorities who also by their independent and almost contemporaneous researches, arrived at conclusions coinciding with those of Dujardin and antagonistic to the polygastric theory, may be mentioned the names of Meyen and Focke. Thuret and Unger, again, from a botanical point of view, indicated the close correspondence of the zoospores of *Chara*, *Vaucheria*, and various confervoid algæ with the monadiform animalcules referred by Ehrenberg to the genera *Chlamydomonas*, *Phacelomonas*, and *Microglena*. The most decisive advance made towards the elucidation of the true structure and affinities of the Infusoria, following upon Dujardin's investigations, was, however, accomplished by Carl Theodor von Siebold. It was this biologist who, in his 'Text-book of Comparative Anatomy,' published in the year 1845, first enunciated the theory, anticipated to some extent by Oken, Schleiden and Schwann, that the representatives of the Infusoria were unicellular organisms. Each separate animalcule possessed, in his opinion, the value only of a simple cell, of which the central gland-like organ observed by so many previous authorities, was now for the first time declared to be homologous with an ordinary cell-nucleus, and described under a like distinctive title. The contractile spaces or vesicles were further interpreted by Siebold as possessing a circulatory or cardiac function. The simple sarcodic nature of the body-substance of the Infusoria, first pointed out by Dujardin, was fully recognized by this authority, and all the organisms possessing such a simple unicellular structure were assembled together as the representatives of an independent sub-kingdom of the Invertebrata, upon which he conferred

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the suggestive title of the Protozoa. These Protozoa Siebold further divided into the two subordinate classes of the Rhizopoda and Infusoria, the former corresponding with the same section as similarly named by Dujardin, and including all those forms whose locomotion was accomplished by the extension of lobate or filiform processes or pseudopodia, while the latter embraced those in which cilia or flagelliform appendages fulfilled a similar function. The distinction between the Ciliate and Flagellate sections of the Infusoria was also fully recognized by this investigator, who, however, conferred upon them titles differing from those now recognized. The Ciliata only being regarded by him as possessing a distinct oral aperture, were denominated the "Stomatoda," and the supposed entirely mouthless flagellate animalcules, the "Astomata." Siebold, by his creation of the sub-kingdom Protozoa, acceptation of the Infusoria as simple sarcode organisms possessing individually the morphological value of a simple cell, and restriction of the Infusoria to the Ciliate and Flagellate members of the Protozoa, practically initiated that definition of the boundaries and organization of the class that receives the most powerful support at the present day, and is closely adhered to by the present author.

As might be anticipated, a universal concession to Siebold's unicellular interpretation of infusorial organization was by no means granted at the period of its announcement to the scientific world. Although the polygastric hypothesis, in the sense rendered by Ehrenberg, was speedily rejected, there have not been wanting those who from that earlier date up to the present time have sought to associate with these microscopic beings a complex type of structure, and to demonstrate their affinities with many of the more highly organized invertebrate sub-kingdoms. Among the first opponents of Siebold in this direction the names of Eckard and Oscar Schmidt are the most prominent. Both founded their arguments against the unicellular theory partly from their independent observation of the development of embryos from within the interior of the body-substance of *Stentor cæruleus* and *polymorphus*, while the latter more especially sought to demonstrate the close affinity of the higher ciliate animalcules with the Turbellarian group of the sub-kingdom Annuloida. O. Schmidt's indication of this supposed affinity was brought about by his discovery in *Paramecium aurelia* and *Bursaria* (*Panophrys*) *flavicans* of a subcuticular layer of minute rod-like bodies—now familiarly known (as trichocysts) to be developed in many infusorial forms—similar to those met with in various Turbellaria and lower Annelides. He further discovered that the contractile vesicle in various animalcules communicated with the outer water, a fact which at once suggested to his mind the probable correspondence of this structure with the water-vascular system of the last-named higher zoological groups.

These results of O. Schmidt's researches bring us to the year 1849, a date memorable for the appearance on the field of that accomplished investigator to whom we are most indebted for our present knowledge of the morphology and development of the infusorial animalcules, and from whom also we have received that scheme of classification of the Ciliate section of the class that obtains the widest recognition at the present day, and is mainly adopted in this volume. It is almost superfluous to add that the authority here referred to is none other than Friedrich Ritter von Stein, who, after his first contribution to the literature of this subject in the year first named, may be said thenceforward, and up to the present day, to have made a life-study of the history, habits, and organization of the representatives of this highly interesting group. The earliest published results of this eminent observer are specially remarkable for their association with a theory relating to the development of the Vorticellidæ, which commanded at the time almost as large a share of attention and adverse criticism as followed upon Ehrenberg's polygastric interpretations. Instead of accepting *Acineta* and its numerous allies, collected together in this treatise under the title of the Tentaculifera, as animalcules possessing an independent history and organization, Stein was led, through their frequent occurrence in company with certain species of Vorticellidæ, and by his observation of the production by some *Acinetæ* of Vorticella-like ciliated embryos, to regard these organisms as developmental conditions only of the latter. In accordance with this interpretation, the *Podophrya fixa* of Ehrenberg was pronounced by Stein * to be a transitional or acinete phase of *Vorticella microstoma; Acineta mystacina*, that of *Vaginicola crystallina;* and the form here included under the name of *Podophrya lemnarum* as a similar condition of *Opercularia nutans*. Additional instances in support of this Acineta theory were brought forward by Stein in the 'Zeitschrift für Wissenschaftliche Zoologie' for February 1852, its most extensive application and amplification being, however, embodied in his separate treatise 'Die Infusionsthiere auf ihre Entwickelunggeschichte,' published at Leipzig in the year 1854. This volume, notwithstanding the fact that its associated Acineta theory was shortly after disputed, and ultimately abandoned by Stein himself, still constitutes what may be almost regarded as a monograph of the Vorticellidæ and Tentaculiferous section of the Infusoria. In addition to embodying the most accurate account and delineations of the form, structure, and developmental phenomena of numerous representatives of these groups that had yet appeared, similar details concerning various Holotrichous types were likewise included; the multiplication of *Colpoda cucullulus*, through encystment and the subdivision of its substance into two, four, or eight spore-like bodies, as amply described later on, being among the most important of these supplementary data thus recorded. The supposed relationship of the twelve or more acinete types described by Stein to an equivalent number of Peritricha, including representatives of the genera *Vorticella*, *Epistylis*, *Opercularia*, *Zoothamnium*, *Cothurnia*, *Vaginicola*, *Spirochona*, and *Ophrydium*, is referred to at length in the descriptions hereafter given of the Acinetæ as independent organisms.

* Wiegmann's 'Archiv für Naturgeschichte,' 1849.

Contemporaneously with the earlier publications of Stein as above recorded, mention must be made of the work of Maximilian Perty, 'Zur Kentniss kleinster Lebensformen,' published at Bern in the year 1852. This treatise, like the earlier ones of Müller and Ehrenberg, embraces an account, with illustrations, of a heterogeneous assemblage of microscopic aquatic beings, including Rotifera, Rhizopods, and Bacillaria in addition to the ordinary Infusoria. These latter are, however, together with the Rhizopoda, separated by Perty from the associated animal and vegetable organisms, and collated together as distinct classes of a subkingdom, essentially identical with the Protozoa of Von Siebold, but upon which he conferred the new title of the Archezoa. The class of the Infusoria is further divided by Perty into the two orders of the Ciliata and Phytozoida, the former comprising all the ordinary ciliate animalcules, and the latter flagellate organisms generally, whether of an animal or vegetable nature. The innumerable infusorial forms figured and described by Perty were collected by himself entirely in the vicinity of the Bernese Alps, and embrace many new species, some of which have not been since met with, while a few, such as his *Eutreptia viridis* and *Mallomonas Plosslii,* are delineated in this present volume after examination, for the first time, with the higher magnifying powers of the compound microscope in its present comparatively perfected state. Taken as a whole, Perty's illustrations of the Infusoria, and of his Ciliata in particular, are exceedingly rough and unsatisfactory, being inferior in many respects to those previously given by Ehrenberg, and not to be compared with the contemporaneous ones of Stein. The view taken by this author with reference to the organization and internal structure of the Infusoria, is distinguished by its opposition to both the unicellular one of Siebold and the polygastric one of Ehrenberg. In place of these, Perty substituted the interpretation that these microscopic beings are composed of an aggregation of separate cells, none of which have attained their complete development, but remain indistinguishably united with each other. He thus, as presently related, anticipated to some extent the views adopted by Max Schultze in the same direction. The presence of any nervous, muscular, or other complex organization he entirely denied, as also that of a distinct internal parenchyma, the body being described by him as composed wholly of simple contractile substance. The thickly ciliated cuticular surface of *Stentor* and other forms he nevertheless compared to the ciliated epithelium of more highly differentiated organic types.

The first onslaught upon the Acineta theory enunciated about this date by Stein, was delivered by Johannes Lachmann, who, in Müller's 'Archives' for the year 1856, adduced testimony strongly in favour of the independent organization of *Acineta* and its allies, showing the characteristic manner in which they preyed upon other Infusoria, and their mode of reproduction through the separating of a portion of the central nucleus or endoplast. Corroborative evidence of a still more conclusive character, and which indeed finally established the claim of these remarkable animalcules to hold rank as the members of a distinct order of the Infusoria, was brought forward by the last-named investigator in conjunction with Edouard Claparède, in three extensive essays, published in volumes v. to vii. of the 'Mémoires de l'Institut Genevois,' extending over the years 1858 to 1860. These three memoirs, derived from the joint work of the above authorities, both co-workers in the laboratories, and disciples of the eminent Johannes Müller, form, as issued more recently in a single volume, the well-known 'Études sur les Infusoires et les Rhizopodes,' containing collectively over seven hundred pages of text, and thirty-seven quarto plates, constantly referred to in these pages, and which holds rank as one of the most complete and important contributions to the literature of the present subject as yet extant. That portion of the volume above quoted which relates more especially to the organization of the Acinetæ, proving the same to be entirely independent of the Vorticellidæ, and thus reversing the verdict of Stein, is embodied chiefly in the so-called third part of the 'Études.' Actually, however, this section of the work was published the first of all, its substance being included in the conjoint prize essay communicated to the Paris Academy of Sciences in February of the year 1855. The scheme of classification adopted by Claparède and Lachmann is submitted in its fully extended state later on, but may be briefly referred to here as comprising the ordinary infusorial orders of the Ciliata and Flagellata, two smaller groups of similar value being, however, instituted, the one entitled the Suctoria for the reception of *Acineta*, *Podophrya*, and all corresponding forms in which prey was seized and incepted through the medium of tubular and suctorial tentacle-like appendages, while that of the Cilio-flagellata was proposed by the same authorities for the distinction of *Peridinium* and various associated types which have as locomotive organs a girdle or other supplementary series of fine vibratile cilia, in addition to one or more flagellate appendages.

Claparède and Lachmann's interpretation of the organization and affinities of the Infusoria, for which, however, the first-named writer would appear to be chiefly responsible, is altogether opposed to the unicellular one of Von Siebold. While conceding to these organisms a separate and even the lowest position in the animal scale, they proposed to regard them as approximated most nearly, on the one hand, to the Cœlenterata, and on the other, more remotely, to the lower Annelids. In accordance with the views of these Geneva anatomists, the Infusoria were, in short, represented as possessing a well-defined body-wall, the softer internal area enclosed and bounded by which constituted an equally distinct chyme-filled somatic or gastric cavity. A very considerable accession to the number of known forms of animalcules, and more especially as relates to the previously little studied marine types, e. g. genera *Freia* (*Follicularia*), *Tintinnus*, and *Peridinium*, was effected through the indefatigable labours of Claparède and Lachmann, while the evidence accumulated by them respecting the developmental phenomena of the class in general is of the utmost value.

The same decade, conspicuous for the substantial progress effected towards a more accurate and extensive knowledge of the Infusoria at the hands of Stein, Claparède, and Lachmann, includes divers other names which, although not similarly associated with the authorship of separate treatises, hold a deservedly high place in the annals of infusorial literature. That of Balbiani is especially noteworthy in this direction, he having been the first, in the year 1858, to announce that the hitherto supposed longitudinal fission of *Paramecium aurelia* and various other animalcules, was not an act of division at all, but one of genetic or sexual union, attended with complex internal changes, as detailed at length in the chapter devoted to an account of the reproductive phenomena of this class.

Max Schultze's name, though more intimately connected with the history of the Rhizopodous section of the Protozoa, demands notice here, he having in the years 1860 and 1861 developed and modified to a marked extent the unicellular theory of the Infusoria first originated by Von Siebold. By this author the frequent absence from, and non-essentiality of, a bounding membrane or distinct cell-wall to many lower unicellular protozoic structures, was especially insisted on, the probability also being suggested that many, such as *Actinosphærium Eichornii*, and others possessing a multiplicity of nucleus-like structures, were composed of a greater or less number of wall-less cells indistinguishably amalgamated with each other. Further, Max Schultze in his demonstration that the soft plastic contents only, independently of an outer bounding wall, constitute the very essence or essential factor of cell organization, proposed to distinguish this soft and contractile substance by the characteristic title of "protoplasm" in contradistinction to that of "sarcode," introduced in a somewhat similar but narrower sense some years previously by Dujardin. With this author there also originated the brilliant and fortunate conception that the cell-contents of all animal and vegetable organisms were composed of a similar simple protoplasmic basis, such forms again, in their simplest expression, as in an *Amœba*, consisting of a mere animated speck or lump of undifferentiated protoplasm. Max Schultze's interpretation concerning the probable composite structure of certain Rhizopoda and Radiolaria received substantial confirmation at the hands of Ernst Haeckel, in his magnificent monograph of the Radiolaria, published in the year 1862.

Stein, already mentioned as having in the year 1854 published an important work devoted more especially to the organization of the Vorticellidæ and their supposed associated *Acinetæ*, gave abundant evidence of continued activity in the same field by the production, in the year 1859, of the first volume of the folio series still in course of progress, having as its aim the description and illustration of all known infusorial forms. In this volume Stein carried into practical application the new system of classification of the higher or Ciliate section of the Infusoria first introduced by him a few years previously,* and which has since been generally adopted as the most natural and convenient scheme yet proposed. In accordance with this, the ciliate animalcules were divided, with reference to the character and distribution of their cilia, into the four subordinate orders of the Holotricha, Heterotricha, Hypotricha, and Peritricha ; this special volume, in addition to including a complete summary of the biography and organization of the Infusoria as known up to that date, constituting an exhaustive account or monograph of the Hypotrichous section. The position conceded to the Infusoria by Stein in this treatise is that of the highest group of the Protozoa, though, taken individually, a more complex type of organization is assigned to them than is involved with the unicellular interpretation of Von Siebold. The characteristic contractile vesicle, with its frequently associated radiating canals, more particularly, is here accepted as formerly by O. Schmidt and Claparède and Lachmann as indicative of a more or less remote relationship with the Turbellaria and lower Annelids.

The interval intervening before the issue, in the year 1867, of Stein's second volume of his 'General History of the Infusoria,' bore substantial fruit through the researches of Balbiani and T. W. Engelmann in the direction of that more extended knowledge of the developmental phenomena of the class referred to at length in a succeeding chapter. The number of known infusorial forms was also considerably enriched, and their structure accurately described and delineated by the authority last quoted and many other able investigators, among whom the names of A. Quennerstedt, H. J. Carter, Frederick Cohn, J. D'Udekem, and A. Wrzesniowski, are especially conspicuous.

In association with the period now under consideration the novel interpretation of the affinities of the Infusoria and proposed subdivision of the group introduced by R. M. Diesing, may be suitably referred to. In accordance with the views of this author, the sub-kingdom of the Protozoa, as instituted by Von Siebold, possessed no real existence, the entire assemblage of forms included in it representing simply lower or imperfectly developed conditions of various more highly organized animal groups. The Rhizopoda and Foraminifera were thus held by Diesing, following the views of D'Orbigny, to be degraded headless Mollusca, the majority of the Ciliata and mouth-bearing Flagellata to be lower worms, while the Vorticellidæ and Stentors, with reference to the closely approximated location of their oral and anal apertures, were referred to the Polyzoa, and collected into a group upon which he conferred the title of the Bryozoa Anopisthia. This breaking up of the class of the Infusoria and distribution of its members among various other Invertebrate sub-kingdoms, while first proposed by Diesing in the year 1848, received its full development in his 'Systema Helminthum, Order Prothelmintha,' and 'Revision der

* 'Sitzung. der königl. Böhmischen Gesellschaft der Wissenschaften,' Oct. 1857.

Prothelminthen,' published respectively in the years 1850, 1865, and 1866. These last-named contributions constitute practically a synopsis, with accompanying diagnoses, of all the infusorial forms then known, exclusive of the Vorticellidæ and Stentoridæ, the chief value of which undoubtedly depends upon their very complete bibliographic references. In no case does Diesing appear to have personally acquainted himself with even a single example of the numerous types epitomized, his diagnoses being framed entirely upon the descriptions given by their original discoverers, and whose errata are also necessarily reproduced. Thus, accepting the dictum of Ehrenberg, all the Flagellata are erroneously represented as possessing a distinct oral aperture, *Volvox*, *Pandorina*, and other undoubted mouthless Phytozoa even being included in the category. Viewed as a whole, Diesing divides his so-called order of the Prothelmintha into the two sub-orders of the Mastigophora and Amastiga, the same corresponding respectively, exclusive of exceptions above named, with the Flagellate and Ciliate divisions of the Infusoria first instituted by Von Siebold. The Flagellata, or Mastigophora, are further separated by him into the two sections of the Atrichosomata and Trichosomata, the latter group including only the Peridinidæ and other allied forms possessing cilia in addition to the characteristic flagella, and therefore corresponding with the order of the Cilio-Flagellata as comprehended in this volume. The two sectional titles of the Holotricha and Hypotricha introduced by Stein are made by this author to include all his recognized representatives of the Amastiga or Ciliata. A considerable number of new generic names, established some with, and some without, substantial grounds, were, as hereafter frequently attested to, founded by Diesing on various of the older specific forms.

Here mention may be most appropriately made of the one complete book devoted to the organization of the Infusoria that had so far, or has since up to the publication of this present volume, issued from the British press. This work, 'A History of the Infusoria,' by Andrew Pritchard, which in the year 1861 arrived at its fourth enlarged and revised edition, the first appearing in the year 1834, can, however, in no way be cited as an independent treatise, it constituting merely an excellent and abbreviated transcript of the technical descriptions of all so-called infusorial forms published up to the year 1858, and included chiefly in the works of Ehrenberg, Perty, and Dujardin. The views of these and other contemporaneous authorities are fully enunciated, and the whole series of forms described made to amalgamate with the system of classification adopted by Ehrenberg in his 'Die Infusionsthierchen.' No original views, no trace of original research, nor any record of newly discovered species, are contained in this volume, which must therefore be considered rather as a compilation than as an independent work. As such, and in connection with the state of our knowledge at that time, its utility was unquestionable, and more especially to the general working microscopist, since its scope, corresponding with that of Ehrenberg's *opus magnum*, includes not only the Infusoria proper, but also the several entirely unrelated groups of the Diatomaceæ, Desmidiaceæ, Confervaceæ, and many Rhizopods, Radiolaria, and even Acari. It is scarcely to be wondered at that, placed in front of so vast and heterogeneous an assemblage of organic forms, the author should have called in extraneous assistance, and hence it is we find the names of J. T. Arlidge, W. Archer, J. Ralfs, and W. E. Williamson—all high authorities on one or other of the several groups separate from the true Infusoria—associated as coadjutors in the fourth edition of Mr. Pritchard's work.

Stein's second volume, issued, as already mentioned, in the year 1867, constitutes a monograph of the Heterotrichous order of the Ciliata, and forms a worthy companion to the one previously published, the series of types included in this section being delineated and described with an accuracy and exhaustiveness of detail hitherto unapproached. This monograph embodies, in addition to the above-mentioned more special subject-matter, data of the highest importance concerning the general organization and reproductive phenomena of the Infusoria, and is also notable for containing a formal abandonment, with some slight reservation, of his original theory associated with the *Acinetæ*, and acknowledgment of the claim of these animalcules to the independent position assigned to them by Claparède and Lachmann. This reservation, as above intimated, was manifested by Stein's continued adhesion to the opinion that certain infusorial types, e.g. *Stentor*, *Stylonychia*, and *Urostyla*, commenced their existence within the parent body as minute ovate or subspheroidal embryos, with or without cilia, and possessing in addition a greater or less number of retractile tentaculiform appendages corresponding with those of the ordinary Acinetæ. These supposed embryos of the associated Ciliata are, however, now shown to be minute parasites, referable chiefly to Claparède and Lachmann's genus *Sphærophrya*.

The following year (1868) commands a conspicuous position in the bibliography of the present subject, through its association with the discovery by Professor H. James-Clark, of the Agricultural College of Pennsylvania, U.S.A., of certain Flagellate Infusoria exhibiting an entirely new type of structure, accompanied by his simultaneous announcement that all sponges consist essentially of colonial aggregations of similar Flagellate animalcules. Three years later, 1871, the present author had the good fortune to encounter the greater portion of H. James-Clark's types, and several new but closely allied forms, upon this side of the Atlantic, and having since selected this group as the subject of special attention, has so augmented its original numbers and demonstrated their distinctive features as compared with the more ordinary Flagellata, as to have felt justified in establishing for them a new order, upon which it is here proposed to bestow the title of the Choano-Flagellata. Pursuing the path indicated by Professor Clark with reference to the structure and zoological position of the sponges, the result of the author's investigations has, as recorded in the chapter hereafter devoted to this special subject, been the accumulation of additional data of the most substantial character in support of the previously suggested affinities.

Among the numerous contributors towards a more extended knowledge of the Infusoria as yet unreferred to, may be mentioned, more especially in association with the Ciliata, the names of Wrzesniowski, Richard Greeff, and Edouard Everts, and with the Flagellata, that of L. Cienkowski. Among the former Greeff is exceptionally prominent, he being led, through his discovery in the Vorticellidæ of a more complex pharyngeal apparatus and muscular system—hereafter described—than had hitherto been attributed to them, to adopt a Cœlenterate interpretation of infusorial structure closely identical with that first enunciated by Claparède and Lachmann. Cienkowski's investigations are especially interesting, as being productive of a masterly account of the structure and developmental history of *Noctiluca*, which is definitely shown by him to be intimately related to the more ordinary Flagellata.

Associated with those that take a prominent position within the present decade as expositors of the structure and affinities of the Infusoria, Professor Ernst Haeckel's name is eminently noteworthy. In his admirable essay, "Zur Morphologie der Infusorien," published in the 'Jenaische Zeitschrift,' Bd. vii. Heft 4, for the year 1873, this gifted biologist brings forward, beyond question, the most powerful evidence in support of the unicellular composition of these protozoic organisms adduced since the first conception of the theory by Carl von Siebold, in the year 1845. The lucid exposition given by him of the general morphology, reproduction, and developmental aspects of the higher Infusoria, may be further said to constitute one of the most complete accounts of this interesting group yet produced. It must be noted here, however, that Professor Haeckel in his essay admits to the rank of true Infusoria those representatives of the class only that are here collated under the title of the Ciliata, the equally or even more abundant and important class of the Flagellata being dismissed as containing an association of doubtful forms, chiefly referable to the vegetable kingdom. The great progress that has been made since the date of this essay in our knowledge of the last-named group will no doubt, however, exert its influence, and reconcile Professor Haeckel to its occupation of a position in the animal scale contiguous to that conceded in his earlier classificatory systems to the Ciliata.

Comparatively insignificant as has hitherto been the sum of contributions to our knowledge of infusorial life and structure by English investigators, and as is conspicuously evidenced on reference to the Bibliographical list appended to this volume, a brilliant exception is furnished in connection with the names of Messrs. W. H. Dallinger and J. Drysdale, whose joint investigations are recorded in various numbers of the 'Microscopical Journal' extending through the years 1873 to 1875. The chief interest and value attached to the results achieved by these joint workers is accomplished through their having struck upon and most successfully followed up an entirely new channel of discovery. Employing the highest and most perfectly constructed modern powers of the compound microscope, and concentrating upon their task an amount of energy and patience scarcely before equalled, Messrs. Dallinger and Drysdale directed their attention to unravelling the mystery so long associated with the inconceivably rapid production of low flagellate organisms or monads in organic infusions, and more especially such as are so abundantly produced in fish macerations. Taking turn by turn at the microscope, and patiently watching the same forms from hour to hour and day to day, the entire life-history of numerous species of these most minute organisms was now revealed for the first time. Not only was it found that these animalcules increased to an indefinite extent by the familiar phenomena of longitudinal and transverse fission, but also that under certain conditions two or even more individuals of the same species would become intimately united, the result of this fusion or coalescence being the formation of encystments, whose contents broke up into a greater or less number of spore-like bodies, which speedily developed into the parent type. In some cases these reproductive spores were so excessively minute as to defy individual detection under a magnifying power of no less than 15,000 linear, their presence being indicated only by their presenting as they escaped *en masse* from the investing envelope the aspect of a fluid possessing a slightly higher refractive index than the surrounding water. The power to withstand great vicissitudes of temperature—in some cases even up to and beyond boiling point, and *pari passu* the practical indestructibility of these monad spores—was also proved by these investigators; the facts elicited as a whole, affording some of the most important evidence yet educed towards the solution of the much-vexed question of spontaneous generation, and in demonstration of the dominance of the inexorable law of "like begetting like" among even these most minute and humble members of the organic world. The special bearing of Messrs. Dallinger and Drysdale's evidence upon these highly interesting points receives extensive notice in a future chapter.

Among the more recent literary productions bearing upon the subject of the Infusoria, brief allusion must be here made to the 'Études sur les Microzoaires ou Infusoires proprement dits,' published by E. de Fromentel in the year 1876. The expectations raised by a first glance at this portly volume and its thirty quarto plates receive a somewhat severe shock on proceeding to a more intimate acquaintance. This writer is apparently entirely ignorant of the work achieved in the same field by Stein, Engelmann, and other modern German investigators, their names not being so much as mentioned throughout the whole course of his treatise. With scarcely an exception, his entire series of diagnoses of the innumerable forms, new and old, are so vague and indefinite as to be scarcely in advance of the necessarily incomplete ones given last century by O. F. Müller, while the numerous figures accompanying these descriptions will in most instances scarcely compare favourably with those handed down to us by Perty and Dujardin. Taken as a whole, it is but too evident that De Fromentel's volume is published prematurely, the author possessing but the most superficial acquaintance with his subject. As a consequence, and notwithstanding the fact that many new forms of high interest are embodied in his volume, the reader closes De Fromentel's book regretting the fine opportunity lost and that so much valuable space and expenditure of time should have been bestowed upon a work so inadequately representing our present comparatively advanced knowledge of infusorial morphology.

A few names only are now wanting to conclude this list. With the exception of Stein's most recently issued volume, 'Der Organismus der Infusionsthiere,' Abth. iii. Heft 1, 1878, containing a general account of the Flagellata, with twenty-four magnificently executed plates—referred to at length in the introductory portion of Chapter VII., no works of primary importance remain to be enumerated. At the same time various authorities, through the exhaustive investigation of special representatives of the infusorial world, have considerably extended our knowledge and appreciation of the structure and affinities of the group as a whole, contributing largely towards the establishment of that solid basis of practical evidence from whence future exploration must depart. Hertwig, Bütschli, Sterki, Ernst Zeller, Wrzesniowski, Mereschkowsky, and C. Robin are more especially deserving of mention in this last-named category, their respective publications receiving due notice in both the subsequent Bibliographic list and in association with the systematic descriptions of those specific types that formed the more immediate subject of their investigation.

This chapter may be concluded with the citation of one other prominent and most worthy name. John Tyndall, the talented physicist and contributor to the 'Philosophical Transactions' for the years 1876 and 1877 of two most important papers treating upon the optical deportment of the atmosphere in relation to the phenomena of putrefaction, and upon the vital persistence of putrefactive and infective organisms, has beyond question, through his most carefully conducted experiments and philosophic deductions, as hereafter reported *in extenso*, furnished some of the most crucial evidence yet adduced towards the subversion of the now well-nigh abandoned doctrine of Heterogeny, or, in other words, the production of Infusoria and other lowly organized animal and vegetable types out of inorganic elements.

CHAPTER II.

THE SUB-KINGDOM PROTOZOA.

THE contents of the preceding chapter constitute a brief chronological summary of the more important advances gained in our knowledge of the Infusoria from the date of their first discovery by Leeuwenhoek up to the present time. A comprehensive survey of the organization and affinities of the members of this zoological group, as illumined by the light of recent research, has now to be proceeded with.

As an *initial step* in this direction, a short space must, however, be first devoted to a consideration of that larger subdivision of the animal kingdom, of which as a whole the Infusoria are most generally and here definitively accepted as a constituent group or groups. This subdivision, the Protozoa of Von Siebold, or Archezoa of Max Perty, has undergone much modification at the hands of biologists since its first institution in the year 1845. Great diversity of opinion exists, even at the present day, with respect to the delimitations both of its own borders and those of the minor sections and orders into which it may be most conveniently and naturally subdivided. As here accepted, the sub-kingdom Protozoa may be defined as embracing all those forms of life referable to the lowest grade of the animal kingdom, whose members are for the most part represented by organisms possessing the histologic value only of a single cell, or of a congeries or colonial aggregation of similar independent unicellular beings. In such cases as *Opalina* and other multinucleate forms, in which from the compound character of the nuclear or endoplastic element the organism would appear to be composed of several cells, these cells are indistinguishably fused with each other, and have not allocated to them separate functions or properties as in all more highly organized multicellular animals or Metazoa.

The essential body-substance of all Protozoa consists of apparently homogeneous, or more or less conspicuously granular, slime-like sarcode or protoplasm, all organs of locomotion or prehension consisting of simple or variously modified prolongations of this element. The food-substances ingested by the Protozoa may be incepted by a single well-defined oral orifice or cytostome, or there may be a plurality of such apertures. Among the Rhizopoda and many Flagellata, on the other hand, such material may be indefinitely received at any point of the periphery, while in yet a fourth series, chiefly endoparasitic—such as the Opalinidæ—there is no oral aperture, definite or distributed, the zooid absorbing through the surface of its integument the nutritious liquid pabulum in which it is constantly immersed. In their development the Protozoa exhibit a tendency to increase chiefly by the process of binary subdivision or gemmation, or through the breaking up of the entire body into a number of sporular elements, which may or may not be preceded by the conjugation or zygosis of two or more individual zooids or units. No sexual elements developed separately, and corresponding with the ova or spermatozoa of higher animals, occur among the Protozoa, and in no case is there associated with the developmental phenomena of this sub-kingdom the formation of a multicellular germinal layer or blastoderm, the fundamental origin and groundwork of all tissue structures in the more highly organized animal groups or Metazoa.

The earliest subdivision of the Protozoa into secondary sections or orders as initiated by Von Siebold partook, as related in the preceding chapter, of the simplest possible character. All the types then known were separated by this author into the two subordinate groups of the Rhizopoda and Infusoria, the former characterized by the pseudopodous, and the latter by the ciliate or flagelliform character of the locomotive appendages. Correlated with the systems of the present day, this proposed primary subdivision of the Protozoa still finds many advocates, an identical plan, though in different wording, being indeed adopted by Professor Huxley in his 'Anatomy of Invertebrated Animals,' 1878, p. 76, and in which it is suggested that all Protozoa may be conveniently distinguished as Myxopods and Mastigopods. These two correspond so precisely and respectively, with reference to their locomotive appendages, with the Rhizopoda and Infusoria as instituted by Von Siebold, that but little advantage is to be gained apparently by the proposed exchange. With reference to the latter of these two terms, it is further worthy of remark that it coincides to a considerable extent, in both sound and the sense implied, with the Mastigophora of R. M. Diesing.

Following out the further subdivision of the two foregoing primary sections of the Protozoa into secondary groups or orders which has up to the present time found most extensive support, the first—that of the Rhizopoda, or Myxopoda—is found to include the Amœbina, Foraminifera, and Radiolaria, while the second—that of the Infusoria, or Mastigopoda—embraces in a similar manner, and in accordance more especially with the classification-scheme introduced byMessrs. Claparède and Lachmann, the four orders of the Ciliata, Cilio-Flagellata, Flagellata, and Suctoria. For this last group—that of the Suctoria—Professor Huxley has proposed to substitute the very appropriate title of the Tentaculifera, recent investigation having shown that the more customary suctorial organs may be replaced by simply prehensile and non-suctorial tentacles. By some, the small endoparasitic group of the Gregarinidæ is reckoned to constitute a third and distinct class of the Protozoa, but it is evident that we have here a degraded group of the ordinary Rhizopoda most nearly allied to the Amœbina, which exhibit a like modification of structure with relation to the latter as is presented by the Opalinidæ with respect to the ordinary Ciliata. The much-vexed question of the zoological position and affinities of the Spongida or Porifera has necessarily to be considered in association with the delimitation of the sub-kingdom Protozoa. Formerly the members of this important section were regarded mostly as forming either a subordinate group of the Rhizopoda, or an independent class of the Protozoa. More recently, however, there has been a tendency to exclude the sponges entirely from the Protozoic sub-kingdom, and to assign to them a position more nearly approximating that of the Cœlenterata, or zoophytes and corals, among the more highly organized tissue-constructed animals or Metazoa. Professor Ernst Haeckel, the most powerful supporter and also the originator of this proposed innovation, has based his arguments in favour of such transfer chiefly upon his own peculiar interpretation of the structure and developmental phenomena of those bodies, the swarm-gemmules or so-called ciliated larvæ, hereafter described, by which the local distribution of special sponge species is periodically effected. Taking on trust this developmental interpretation of Ernst Haeckel, many leading biologists have committed themselves to a similar exclusion of the Spongida from the Protozoa, and it is thus that in Professor Huxley's recently quoted work—which must be accepted as the latest and most important exposition of Invertebrate anatomy in this country—a like allocation of this much-debated group to the Metazoic section of the animal kingdom is upheld. Postponing for a future chapter a complete summary of the grounds upon which an interpretation entirely opposed to that advocated by Professor Haeckel is adopted in this volume, it will suffice for present purposes to state that a considerable interval devoted to a careful investigation of the structural and developmental phenomena of the sponges and Protozoa generally has resulted in the arrival by the present author at the opinion that—(1) these phenomena accord essentially and entirely with those presented by the typical Protozoa ; (2) that there is no formation of a germinal layer or true tissue structure in any period of their development ; and (3) that the position of the Spongida among the Protozoa is most nearly allied to that Infusorial group here distinguished by the title of the Choano-Flagellata, and out of which, by the process of evolution, there is substantial reason to presume they were primarily derived.

Proceeding with the consideration of the subdivision of the Protozoa into subordinate classes and orders, it has been further found, in association with the investigations above referred to, that the older and primary groups of the Rhizopoda and Infusoria, or of the Myxopoda and Mastigopoda, as more recently proposed, by no means allow of as clear and natural a grouping of their various orders as it is possible to submit, while it is still less efficacious for the indication of the many complex affinities that undoubtedly subsist between one and another, or, as it is often found, between one and many of these orders. The inadequacy of the several systems hitherto proposed for the fulfilment of these last-named requirements, as also an outline of one closely corresponding with that here introduced, were respectively recognized and provided for by the author in association with the paper entitled 'A Monograph of the Gymnozoidal Discostomatous Flagellata, with a Proposed New Scheme of Classification of the Protozoa,' communicated to the Linnæan Society on the 21st of June, 1877, and referred to at some length in the 'Annals and Magazine of Natural History' for January 1878.* In accordance with the scheme then proposed, and as now submitted in its more extended form with certain amendments, the fundamental basis upon which the subdivision of the Protozoa into primary groups or sections is founded, bears relation not so much to the varied character of the locomotive or prehensile appendages possessed by the representatives of this sub-kingdom as to the nature of the oral apparatus or systems subordinated to the function of food-ingestion. Comparing small things with great, this morphological element yields indeed as convenient and sound a basis for taxinomical diagnosis as is afforded by the oral systems of the higher Invertebrata or the dental formulæ of the mammalian class.

Following out this newly proposed plan of subdivision, it will be found that the entire series of the sub-kingdom Protozoa range themselves into four natural and readily distinguished groups or sections. In the first, most lowly organized, and with reference to its subordinate subdivisions or orders most numerically abundant of these several groups, an oral orifice in the literal sense of the term has no existence, food being incepted indifferently at any point of the periphery or general surface of the body. This most simple or elementary type of structure of the Protozoa is best illustrated by such familiar examples as *Amœba* and *Actinophrys*, the various representatives of the Foraminifera, and certain Flagellata such as *Spumella* and *Anthophysa*. For the distinction of these most simply organized forms, characterized by the indefinite or generally diffused character of their oral or introceptive area, the divisional title of the PANTOSTOMATA is here adopted in place of that of the Holostomata originally proposed in the earlier communications by the present author as above mentioned. This latter term, while scarcely conveying the sense intended, possesses the disadvantage of having been previously employed for the distinction of a group of the Mollusca. Next in the ascending scale a group of the Protozoa is met with, in which though differentiation has not proceeded so far as to arrive at the constitution of a distinct oral aperture, the inception of food-substances is limited to a discoidal area occupying the anterior extremity of the body, and is associated with the special food-arresting apparatus described in detail later on. To this section of the Protozoa are naturally relegated all the minute collar-bearing flagellate animalcules first discovered by Professor H. James-Clark, of which so

* Mr. Saville Kent, "Observations upon Professor Ernst Haeckel's Group of the Physemaria and on the Affinities of the Sponges."

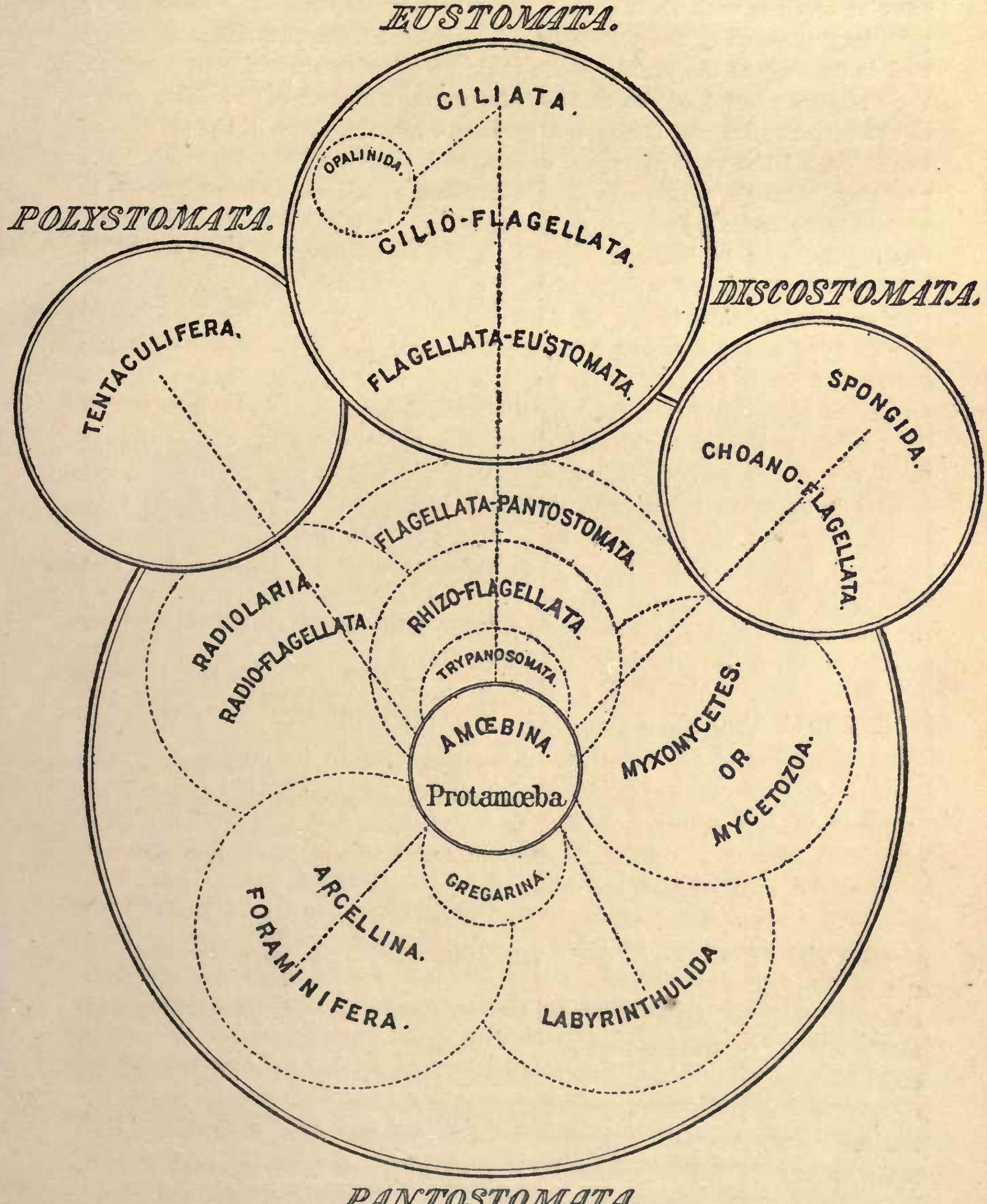
many new species are figured and described in this volume, and also the entire assemblage of the sponges or Porifera. For this group, and with reference to the characteristic discoidal configuration of the introceptive area, the title of the DISCOSTOMATA, as previously proposed, is still retained. In the third section of the Protozoa, as here defined, the highest degree of organization is arrived at. Here alone, and for the first time, a single simple or often highly differentiated oral aperture or *true mouth* is met with, for which reason the group appropriately commands the title of the EUSTOMATA. Associated with this section are found the majority of those organisms that collectively constitute the class Infusoria in the more modern acceptation of the term, it embracing the majority of the Ciliata, the Cilio-Flagellata, and such Flagellata as *Euglena* and *Chilomonas*, in which the presence of a distinct and circumscribed oral aperture has been clearly demonstrated. With the fourth and remaining natural Protozoic section, the oral or inceptive apparatus exhibits a remarkable and highly characteristic structural modification. This is not, as in the preceding groups, restricted to a definite area, nor is it associated indefinitely with the entire general surface of the creature's body. In place of this, a variable and usually considerable number of flexible retractile tentacle-like organs radiate from diverse irregularly disposed or definite regions of the periphery, each of which subserves as a tubular sucking-mouth, or for the purposes of grasping food. The representatives of this section, including the so-called suctorial animalcules of Claparède and Lachmann, or Tentaculifera of Professor Huxley, may be literally described as many-mouthed, and appropriately designated the POLYSTOMATA.

A tabular view of these four sections of the Protozoa as above defined, with their included classes, orders, and characteristic genera, is herewith annexed. Upon examining this table it will be apparent that the *secondary* subdivisions or classes of the Protozoa, as therein defined, by no means coincide precisely with those more comprehensive and fundamental sections or groups into which the sub-kingdom may, as just proposed, be *primarily* divided. Thus, within the section of the Pantostomata are found comprised the whole of the class Rhizopoda, and a portion only of the Flagellata. The remainder of this last-named class falls partly within the section of the Discostomata, which so far as known includes Flagelliferous Protozoa only, and partly within the more highly differentiated group of the Eustomata; while within the boundaries of the latter section are included, in addition to the Stomatode Flagellata, the entire class of the Ciliata. It is in point of fact altogether impossible in any such arbitrary and necessarily artificial, lineally arranged table to adequately and intelligibly illustrate the innumerable cross-relationships or lines of evolution that undoubtedly connect these various orders and classes with one another. The special diagrammatic scheme given on the page succeeding that of the tabular view, has therefore been constructed by the writer with the purpose of as far as possible indicating, with the following explanation, the more obvious of these affinities :—

Tabular View of the Sections, Classes, Orders, and Typical Genera of the Sub-Kingdom PROTOZOA.

Sections.	Classes.	Orders.	Genera.
A. PANTOSTOMATA. Ingestive area diffuse.	I. Rhizopoda. Appendages pseudopodic, lobate or radiate.	1. Amœbina	*Amœba.*
		2. Gregarinida	*Gregarina.*
		3. Arcellinida	*Gromia, Arcella.*
		4. Foraminifera	*Rotalia, Nummulina.*
		5. Labyrinthulida	*Labyrinthula.*
		6. Radiolaria	*Actinophrys, Collosphæra.*
	II. Flagellata. Appendages flagelliform.	7. Mycetozoa	*Æthalium, Didymium.*
		8. Trypanosomata	*Trypanosoma.*
		9. Rhizo-Flagellata	*Mastigamœba, Podostoma.*
		10. Radio-Flagellata	*Actinomonas, Euchitonia.*
		11. Flagellata-Pantostomata	*Spumella, Anthophysa.*
B. DISCOSTOMATA. Ingestive area discoidal, not constituting a distinct mouth.		12. Choano-Flagellata (vel Discostomata-Gymnozoida)	*Codosiga, Salpingœca, Protospongia.*
		13. Spongida (vel Discostomata-Cryptozoida)	*Halisarca, Grantia, Spongilla.*
C. EUSTOMATA. Ingestive area taking the form of a single distinct mouth.		14. Flagellata-Eustomata	*Euglena, Noctiluca.*
		15. Cilio-Flagellata	*Peridinium, Heteromastix.*
	III. Ciliata. Appendages ciliate.	16. Holotricha	*Paramecium.*
		17. Heterotricha	*Stentor, Spirostomum.*
		18. Hypotricha	*Euplotes, Oxytricha.*
		19. Peritricha	*Vorticella, Ophrydium.*
D. POLYSTOMATA. Ingestive areas distinct and multiple.	IV. Tentaculifera. Appendages tentaculate.	20. Actinaria	*Ephelota.*
		21. Suctoria	*Acineta, Dendrosoma.*

DIAGRAMMATIC SCHEME :—SHOWING RELATIONSHIPS, AND PRESUMED PHYLOGENY, OR LINES OF EVOLUTION, OF SECTIONS, CLASSES, AND ORDERS OF THE SUB-KINGDOM PROTOZOA.



Referring to the foregoing diagrammatic scheme, it will be observed that the four primary sections of the PANTOSTOMATA, DISCOSTOMATA, POLYSTOMATA, and EUSTOMATA, including their more important classes and orders as embodied in the preceding table, are circumscribed by a broader and double circular line. Making use of a convenient metaphor, these circular sections with their varied contents may be compared to so many planetary systems or constellations, all derivable from one common centre and indicating at the points where their peripheries are made to intersect, their mutual relationship to, and interdependence on each other. The centre of the entire series and common source from whence, through the process of evolution, all the various types, orders, and classes of the Protozoa have probably through a more or less extensive epoch of time developed, is undoubtedly to be found among the most simply organized Pantostomata, finding there its typical embodiment in the amœban order, the hypothetic primeval ancestor of which may, for convenience' sake, appropriately receive the generic name of *Protamœba*. Accepting this last-named generic type as the common basis for departure, the dotted lines radiating outwards from it exhibit, so far as it is possible to predicate, the various directions apparently traversed by the several phylogenetic lines or tracks of evolution before their arrival at the more complex and outlying members of the series. Selecting that phylogenetic line connecting the central or amœban group with the most highly differentiated Eustomata typified by the class Ciliata, as a first example in illustration of this proposed scheme, the following explanation may be submitted. The first cycle of development in this direction, exhibiting a transition from the Rhizopodal or Myxopodous towards the Flagelliform or Mastigopodous structural type, is evidently embodied in the group or order of the Trypanosomata. An *Amœba* flapping through the water, or other inhabited fluid, through the medium of a flattened, crest-like and undulating extension of its lateral margin, constitutes to all intents and purposes a representative *Trypanosoma*. Although among the few known members of this series a flagellate appendage is not as yet perfectly developed, such organ may be said to exist in its most pristine and rudimentary condition in the tag-like prolongation of one extremity of the body that constitutes so important a characteristic of the species *Trypanosoma sanguinis*, as more recently figured by Professor E. Ray Lankester, and reproduced in Pl. I. Figs. 1 and 2 of this volume. The lateral crest-like extension which represents the most prominent characteristic of this order, carries with it an equally, if not still more important significance. A similar structure associated with the title of an undulating crest or membrane, is constantly recurring among the more highly organized groups of both the Flagellate and Ciliate Protozoa, and undoubtedly takes its origin from this source. As illustrations in this direction, reference may be made to the supplementary undulating membranes that form a permanent characteristic of certain species of the genera *Trichomonas*, *Hexamita*, and *Conchonema*, among the Flagellata; and of

Lembus, Condylostoma, and *Spirochona*, among the Ciliate class of the Protozoa. Furthermore, as recorded by the author in the systematic portion of this treatise, the characteristic adoral fringe of certain higher Ciliata, such as *Stentor* and *Euplotes*, is developed through the splitting up of a similar primary undulating membrane.

In the next cycle of advance, as exemplified in the order of the Rhizo-Flagellata, the several genera, *Mastigamœba, Rhizomonas*, and *Podostoma*, while retaining the general characteristics of repent or floating *Amœbæ*, have superadded a distinct flagellum, and undoubtedly constitute the root-forms of several leading sections of the Protozoa hereafter referred to. The retraction of the pseudopodic processes of the Rhizo-Flagellata, with the retention of the flagellum and capacity to incept food at any point of the periphery, is alone required to perfect the passage to the next succeeding order, that of Flagellata-Pantostomata. In this group we find a considerable diversity in the number and character of the flagellate appendages, this organ being single in such simple types as *Monas* and *Bodo*, double in *Spumella* and *Anthophysa*, while in others such as *Tetramitus, Hexamita*, and *Lophomonas*, the number is very considerably increased. It is among the Polymastigous section of this order, somewhere near *Lophomonas*, that the remarkable compound marine type *Magosphæra planula*, Pl. I. Figs. 12–17, upon which Professor Haeckel has proposed to found a new class group entitled the Catallacta, should apparently be placed. A special feature of *Magosphæra*, as described by Haeckel, is exhibited by its tendency to revert to a repent amœboid phase pending the process of encystment and reproduction. A similar disposition is, however, as hereafter shown, shared by the majority of the Pantostomata.

In proceeding to the next group or order in the direct line of evolution, the boundary line that circumscribes the class of the Pantostomata is necessarily traversed, and the associated forms, while still characterized by the possession of one or more flagellate appendages, exhibit their higher grade of organization through the development of a well-defined oral aperture. This order, upon which is here conferred the title of the Flagellata-Eustomata, embraces among its more familiar genera the types *Euglena, Astasia, Noctiluca*, and *Anisonema*. The interesting order of the Cilio-Flagellata, including chiefly the Peridiniidæ and a few aberrant forms such as *Heteromastix* and *Mallomonas*, are alone wanting to make the phylogenetic line from Amœba to the most highly specialized class of the Protozoa, that of the typical Ciliata, entirely complete. Arriving at the termination of this evolutionary line or phylum, it is requisite to make a passing reference only to the group of the Opalinidæ, which, although possessing no oral aperture, are plainly retrograde forms of Holotrichous Ciliata, exhibiting, by reason of their endoparasitic habits, a similar loss of this otherwise essential organ of nutrition as obtains in the corresponding parasitic Cestoidea among the Annelidous, or the Rhizocephala among the Crustaceous sections of the Invertebrata.

Returning once more to the Amœbina, and following out the line that terminates in the Tentaculifera, the first important divergence from the preceding track is encountered on arriving at the newly instituted order of the Radio-Flagellata. This small group, to which at present are referred the four genera, *Actinomonas*, *Spongocyclia*, *Spongasteriscus*, and *Euchitonia*, may be said to retain the same relationship with respect to the ordinary Radiolaria as subsists between the Rhizo-Flagellata and various other orders of the Pantostomata. In the form *Actinomonas*, figured and described for the first time in this volume, Pl. I. Figs. 7, 8, and 18, the permanent possession of a terminal vibratile flagellum alone distinguishes it from a stalked Heliozoidal Radiolarian such as *Actinolophus* in its naked phase, and with which type it was presumed at first sight to be identical. Inversely, it needs only the withdrawal of the radiating pseudopodia, with the retention of the flagellum, to produce the Pantostomatous Flagellate genus *Oikomonas*. The primary derivation of the entire Radiolarian order from the Flagelliferous section of the Pantostomata is clearly indicated in association with the embryonic conditions of its representatives, and all of which, so far as at present known, exhibit a Pantostomatous Flagellate structure. The direct metamorphosis of such a simple flagellate zooid into the Radiolarian type *Actinophrys*, as recently observed by the author, will be found recorded in the systematic description of the Radio-Flagellata, and is illustrated at Pl. I. Figs. 9–11.

The passage from the extensive group of the Radiolaria with its subsections of the Heliozoa, Monocyttaria, and Polycyttaria, onward to the Tentaculifera, appears at first sight to be somewhat obscure. As shown, however, in the chapter devoted specially to their description, the Tentaculifera, as now known, form among themselves two natural subordinate groups or orders: the one, that of the Suctoria, being distinguished by the sucker-like form and function of the radiating tentacles; while in the other, that of the Actinaria, these appendages closely resemble ordinary pseudopodia, being simply adhesive, and in some instances, e. g. *Ephelota*, invertile. The transition from the Radiolaria to the Tentaculifera is apparently accomplished through this last-named group, such types as *Zooteira* and *Actinolophus* on the one hand, and *Ephelota* and *Actinocyathus* on the other, representing the most conspicuous connecting forms. The Tentaculifera, in their highest phase of development, exhibit several noteworthy peculiarities. The embryos do not, as with most Radiolaria, take a flagelliferous or monadiform contour, but are, while mouthless, more or less thickly ciliate. The ciliation in the different genera and species, moreover, varies considerably, the several more important deviations in this respect exhibiting a remarkable conformity with the three types of ciliation that characterize the three leading orders of the ordinary Ciliata, as distinguished by the respective titles of the Holotricha, Hypotricha, and Peritricha. On account of this last-named circumstance, it may be reasonably inferred that some genetic relationship subsists between the two sections of the Polystomata and Eustomata, this probable affinity being indicated in the accompanying diagrammatic plan by the intersection of the circles enclosing the respective groups. A speculation as to the possible affinities of the Tentaculifera in a totally independent direction is recorded in the chapter devoted more especially to the general organization of the Infusoria.

The line of evolution or phylogeny from the Amœbina to the Discostomatous class of the Protozoa, remains to be traced. The direct relationship of the highest and most complex factor in this section, that of the Spongida, to the more simple Choano-Flagellata, as illustrated by the genera *Codosiga*, *Salpingœca*, and other recently discovered types, is, as explained in Chapter V., devoted to the organization of the sponges, too obvious to need extensive comment here. As there demonstrated, the representatives of this last-named organic group can be regarded only as specialized, colonial stocks of similar collar-bearing Flagellata living immersed within a channelled and collectively exuded common gelatinous matrix or cytoblastema, and whose substance is more usually strengthened by calcareous or siliceous spicula, or a network of horny matter. As demonstrated by the present author in the chapter cited, the separate zooids or units of both the Spongida and simpler Choano-Flagellata exhibit in their developmental phenomena the closest possible affinity. These originate chiefly in either case from mouthless monadiform flagellate germs, thus exhibiting their phylogenetic relationship with the Pantostomatous Flagellata, while the adult zooids revert at will to the condition of either Rhizo-Flagellata or simple *Amœbæ*. In certain species of *Salpingœca*, as hereafter described, e. g. *S. amphoridium*, new zooids are shown to originate as amœbiform gemmules separated by division from the parent animalcule, thus completing the retracement of the line to the central or primitive ancestral stock.

In the foregoing diagrammatic scheme the line of evolution of the Spongida is made to abut upon or traverse the group of the Myxomycetes or Mycetozoa. The reasons for adopting this course require brief explanation. Formerly, and by some even yet regarded as a low order of fungi, or as a special group of organisms intermediate between animals and plants, which exhibit at one epoch of their life all the vital characteristics of the former, and at another those of the latter kingdom, their admission into the Protozoic galaxy or system will no doubt encounter objection. The evidence most recently and independently eliminated by L. Cienkowski * and Dr. A. de Bary,† concerning the structure and life-history of this most remarkable group, establishes, however, beyond question their purely animal nature. The Mycetozoa, in common with all ordinary representatives of the Protozoa, originate from minute sporuloid bodies which escape from the spore case as monadiform animalcules having a soft, plastic body-substance, a single terminal flagellum, contractile vesicle, and endoplast

* L. Cienkowski, "Zur Entwickelungsgeschichte der Myxomyceten." Pringsheim's Jahrbücher, Bd. iii., Hft. 2 and 3, 1862.

† A. de Bary, 'Die Mycetozoen. Ein Beitrag zur Kenntniss der Niedersten Organismen.' Leipzig, 1864.

or nucleus, being thus in no way distinguishable from the typical representatives of the ordinary Flagellata-Pantostomata, as met with in the genus *Monas*. By-and-by these monadiform zooids become more sluggish, subside to the bottom of the inhabited fluid medium, and for a while retaining their flagella, creep about after the manner of a *Mastigamœba*, incepting in the same way solid food-particles at any point of the periphery. The zooids in this condition may be said to represent the adult form of the Rhizo-Flagellata. Sooner or later the flagella are withdrawn, and an entirely amœboid condition is assumed. These amœboid zooids, encountering their fellows in the course of their wanderings, at once coalesce with them, and form at length by their amalgamated numbers and increase of size through the incessant increment of food, those conspicuously large masses of gelatinous consistence, characteristic of the so-called animal phase of the Myxomycetan, technically known as the "plasmodium." This plasmodium, exhibiting diverse forms in various species, may be found creeping over wet tan, rotten wood, or decaying leaves in the similitude of a colossal Amœba, or, taking a reticulate form, spreads itself over the surface of these substances, and presents under such conditions the aspect of the mycelia of various fungi. Examined with the microscope, all trace of the multicellular or multizooidal origin of the plasmodium is found to have disappeared, the entire mass exhibiting the character of homogeneous granular sarcode. A greater or less number of rhythmically pulsating contractile vesicles are discernible at various points, and a distinct circulatory motion or cyclosis of the granular plasma, sometimes in a single and sometimes in contrary directions, is exhibited within the deeper substance of the plasmodium. This phenomenon of cyclosis is most readily observed in those forms, like *Didymium serpula*, in which the plasmodium assumes a reticulate or much ramified mycelium-like outline, the motile currents of sarcode under such conditions closely corresponding with those common to the pseudopodic reticulations and ramifications of the Foraminifera and Labyrinthulina. Following upon the plasmodium state, the highly characteristic so-called vegetable phase is now arrived at. In this condition animal vitality is apparently entirely suspended, the aspect being usually that of a minute Gasteromycetous fungus, mostly stalked, and with a spheroidal, ovate, or urn-shaped capitulum or sporangium. The outer wall of this capitulum is more or less coriaceous, and is found interiorly to be densely packed with spore-like bodies, mostly held together by a dense network of delicate anastomosing fibres of a horn-like consistence. By the dehiscence of a cup-like lid or the disintegration of the walls of the sporangium, the contained spores are eventually liberated and repeat the metamorphoses just described. It is upon the external likeness to certain fungi of the quiescent sporangia of the Myxomycetes, as developed from the plasmodium, that the arguments in favour of the vegetable nature of these singular organisms have been chiefly based.

From the foregoing brief recapitulation of the developmental history of this group it is evident, however, that we have here a quiescent or resting phase preceding sporular reproduction corresponding on a compound and enlarged scale with the simple encapsuled or sporocyst state of the more ordinary Protozoa known as encystment. In both the formation of the gigantic compound plasmodium and in the development therefrom of the characteristic sporangia, these Myxomycetes exhibit certain phenomena singularly suggestive of a more or less remote affinity with the sponges. In these latter also the initial term takes the form of spore-developed uniflagellate monads, which, uniting in social colonies, form a gelatinous mass corresponding closely with the plasmodial element of the former group. In the fine horny network usually contained with the spores within the sporangium developed by the mature plasmodium, a substance is produced singularly resembling the fine horn-like elements or keratose fibre of certain sponges, while, what is still more remarkable, in certain forms spicule-like bodies composed of carbonate of lime are also developed within the substance of the walls of the sporangium, or so-called "peridium," that accord substantially in outline with the stellate siliceous spicula of the Tetthyidæ and other familiar sponge-groups. In illustration of the apparent close approximation of the Mycetozoa to the Spongida and other flagellate Protozoa, as here presumed, the lower half of Plate XI. of this volume, with its accompanying descriptions, has been devoted to a reproduction of some of the more characteristic figures given by de Bary and Cienkowski in the works quoted, that would appear to substantially support the author's views.

Two or three orders of the Protozoa, included within the section of the Pantostomata and indicating apparently an independent derivation from the central ancestral stock, have yet to be mentioned. That of the Labyrinthulida, as typified in Cienkowski's genus *Labyrinthula*, exhibits in its normal and adult condition a more or less extensively ramified or reticulate sarcode expansion upon submerged objects, corresponding to a considerable degree with the finely branched plasmodia of certain of the Myxomycetes last described. This expansion, however, does not appear to be derived from, or to be associated at any date of its existence with flagelliferous zooids, while an additional element in the form of minute ovate or spindle-shaped bodies, travelling in the directions assumed by the characteristic currents of circulation or cyclosis, is to be observed. In this last-named feature the constituent sarcode exhibits a close correspondence with that of the test-inhabiting Foraminifera, and the natural position of the group, as indicated in the diagram, would appear to be midway between the latter order and that of the Myxomycetes. The derivation of the Foraminifera themselves from the Amœbina, through such types as *Arcella*, *Lieberkuhnia*, and *Gromia*, is too patent to require prolonged notice. Of the small supplementary group of the Gregarinidæ, it remains to be remarked that it exhibits a similar type of degradation or retrograde development in association with the Amœbina as is presented by the Opalinida with relation to the normal Ciliata. All pass an endoparasitic condition within the viscera of other animals, and derive their sustenance through the direct imbibition or endosmosis of the juices of the selected host through their cuticular surface.

While the foregoing sketch suffices to indicate the leading aspects and characteristics of the Protozoic sub-kingdom generally, and to explain the view of the derivation and affinities of the various orders adopted by the author of this volume, a few other points demand brief attention. Among these, reference has yet to be made to the undoubtedly close relationship which subsists between the lowest members of the Protozoic sub-kingdom and the unicellular members of the vegetable world, and to the opinions maintained in this direction by recent authorities of note. The difficulty of indicating a clear line of demarcation that shall arbitrarily separate certain unicellular cryptogamic plants or Protophyta from the unicellular animals or Protozoa, has long been recognized, and even at the present day cannot be said to have obtained its final solution. It is, indeed, scarcely to be anticipated that any such result should be arrived at, since here, as between many other arbitrarily defined so-called natural classes and subdivisions of the animal and vegetable worlds, modern discovery is unceasingly revealing the existence of intermediate forms that, filling up the pre-existing lacunæ, further demonstrate the harmonious continuity of the entire organic series. Taxonomy, or classification, through this consideration, is necessarily reduced to a purely empirical and constantly progressive status, to an artificial means for the demarcation of those boundaries or landmarks most clearly conspicuous to our appreciation, that system recommending itself most, and having the most lasting duration, whose foundations are established upon the most simple and natural basis.

Failing to eliminate such a natural or artificial boundary line as shall serve to decisively mark out the apparently intersecting zones of animal and vegetable life, one of the foremost biologists of the age, Professor Ernst Haeckel, has elected to establish yet a third kingdom of the organic world, to which he has relegated not only all dubious types, but also many concerning whose animal or vegetable nature not so much as a doubt exists. This proposed new organic kingdom, denominated by its founder the "Protista," is, with the exception of the Ciliata, Spongida, and Tentaculifera, made to include all the members of the Protozoa embraced in the previously submitted scheme, and in addition to these, the assemblage of undoubted vegetable organisms forming the tribe of the Diatomaceæ. This attempt to cut the Gordian knot by the interpellation of a third and intermediate kingdom, is by no means happy. Even if this latter possessed in itself the elements of stability, the difficulty would be in no ways lessened, but simply augmented, as there would be now two lines of demarcation, one between the Protista and vegetable forms, and the other between the Protista and the animal series, to be defined in place of the pre-existing single one. The Protista, however, as a group separate from both the animal and vegetable kingdoms, has no real existence, there not being, with the exception of the Diatomaceæ, a single family or generic type included in Haeckel's tabular view of his new kingdom that cannot with tolerable, if not absolute certainty, be referred to the former of these two sections.

As a subordinate group of the Protista, Professor Haeckel has further proposed to found the class of the "Monera" for the reception of all those types, externally corresponding with ordinary Rhizopoda and Radiolaria, in which as yet the possession of a distinct endoplast or nucleus has not been demonstrated, and which are consequently regarded by him as exhibiting an essentially lower type of structure. The progress of modern scientific discovery has, however, so curtailed the boundaries of this supposed *Moneran* class, that further exploration in the same direction bids fair to deprive its illustrious founder of all interest in it beyond that of an empty title. Up to a very recent date the members of the extensive and important order of the Foraminifera were presumed to exhibit this specially simple structural type, and were in consequence relegated by Haeckel to, and formed the most important constituent of, his class Monera. Following Haeckel's lead, such a position among the so-called Monera is allotted to the Foraminifera in Professor Huxley's 'Anatomy of the Invertebrata,' though in a supplement to the same work (p. 658), the discovery of distinct nuclei in many genera of this order by the independent investigations of Schultze and Bütschli is alluded to as carrying with it the necessity of their withdrawal from this position.* A similar demonstration of the possession of nucleolar structures in the few remaining organisms relegated to this group will not improbably result from their further careful examination, with the assistance of the special treatment resorted to in the case of the Foraminifera. Finally, it is altogether questionable whether the presence or absence of a nucleus or endoplast can be accepted as furnishing a distinct and reliable character even for specific diagnosis. This structure, as shown at greater length in the chapter devoted to the organization of the Infusoria, is evidently in many instances an accompaniment only of the matured and reproductive phase.

Dismissing as entirely unnecessary and untenable, the proposed substitution by Professor Haeckel of an intervening kingdom of the Protista, it has been elected here to fall back upon the old lines, and to indicate as nearly as may be, the most salient features of distinction adopted, though perhaps somewhat arbitrarily, in this volume for the separation of the animal and vegetable series. The purpose of this treatise being the description and exposition of the structure and life-history of those

* The presence of nucleus-like bodies in the Foraminiferal type *Halyphysema Tumanowiczii*, Bwbk. (*Squamulina scopula*, Carter) has likewise been noted and figured by the present author in an article on the nature and affinities of this species, published in the 'Annals and Magazine of Natural History' for July 1878; such discovery being confirmed by Professor E. Ray Lankester's subsequent investigation of this form reported in the 'Quarterly Journal of Microscopical Science' for October 1879.

microscopic organisms only which exhibit easily recognized animal characteristics, some one or more tangible clues to such facile recognition have to be enumerated. The primary basis for such distinction here selected is, as in the case of the landmarks enumerated for the convenient subdivision of the Protozoic sub-kingdom itself, associated with the phenomena of nutrition. Excepting in a few small aberrant groups, distinguished mostly by their endoparasitic mode of existence, and possessing in consequence an abnormal and retrograde type of structure, all those forms referable to the animal section of the series, exhibit in a conspicuous and readily verified manner, their capacity to ingest solid particles of food, and their dependence upon such solid food ingestion for the growth and display of their various vital functions. Among the more highly organized Protozoa, a special organ of ingestion or oral aperture forms a characteristic and permanently recognizable structural feature, while in others there is no such special organ, the food being incepted indifferently at any part of the periphery, the actual process of its seizure and ingestion, or the recognition of the presence of externally derived pabula within the substance of the parenchyma or endoplasm being in these instances requisite for the satisfactory determination of the question. In those low-organized unicellular plants, on the other hand, which at first sight, on account of their closely corresponding form and motile properties are apparently indistinguishable from their animal congeners, the act of food injection is never witnessed, nor is its presence to be detected within their inner substance. Nutrition here, as among the higher ranks of the vegetable kingdom, is effected by the absorption of the requisite pabulum in a purely liquid state.

With relation to its chemical aspect, the composition of the nutrient matter assimilated respectively by animal and vegetable organisms is found again to be essentially distinct. All animal forms at present known are absolutely dependent on other proteaceous, or, so to say, "ready manufactured" organic matter for their food supply. Plants, on the other hand, while in a few exceptional cases, such as the so-called "insectivorous species" and certain fungi, capable of sustaining life on similar formed protein, manufacture this substance themselves out of the crude material distributed in the liquid or gaseous condition in the fluids which they imbibe. Plants thus fulfil the rôle of builders up or *constructors* from the inorganic of organic materials, while animals are, without exception, the *consumers* or breakers down of this same substance.

Accessory to the very important nutritive feature of distinction above submitted, there remain yet certain other characteristics that may be cited as of supplemental though subordinate utility in predicating the animal or vegetable nature of a given low-typed organism. Chief among these, and having a psychological rather than a physiological bearing upon this question, has to be mentioned the characters afforded by the respective modes of locomotion exercised by the separate representatives of these two groups in a like fluid medium. It is necessarily only between the flagellum-bearing members of these latter, including in the plant series the independent unicellular Protophytes, and the so-called zoospores or antherozooids of Algæ and Confervæ, and in the animal one chiefly the Pantostomatous and some Eustomatous Flagellata, that a difficulty in determination is likely to arise. To one accustomed, however, by a long practical acquaintance with the characteristic motions of these minute beings, there is at once recognizable a certain, so to say, method in the manner of the locomotion associated with the animal organism which is under no circumstances encountered in the case of the plant. In the latter instance, citing as examples the motile phases of *Volvox*, *Chlamydomonas*, or *Protococcus*, it will be found that they swim, as it were, blindfold through the water, stumbling and striking against their fellow forms or any other object that may be opposed to their aimless course. In the animal types, on the contrary, as illustrated by a *Euglena*, *Monas*, or *Heteromita*, there is no such absence of purpose in their movements ; tentative, well-controlled progress in various directions, and intelligent deviations, or, as it were, tackings backwards or to either side being continually displayed. Objects lying in their path are, again, carefully passed over or avoided, similar conduct being likewise observable in their encounter with comrades of the same or diverse species. Under these latter conditions there is often, moreover, exhibited a distinct appreciation of the society of their associates, this phenomenon being more especially alluded to in connection with the two forms described hereafter under the respective names of *Heteromita ludibunda* and *Chloraster marina*.

One other accessory character, scarcely yet, perhaps, sufficiently investigated for recording as an undeviating diagnostic feature of distinction, is connected with the presence or absence of the rhythmically expanding and contracting space, sometimes single and sometimes multiple, situated at various points—such position in a given specific form being invariably definite—within the cortical substance of the organism, and designated the contractile vesicle or vacuole. Among the representatives of the animal series, this structure, excepting in certain Opalinidæ, would appear to be constantly present, while in vegetable forms it would seem to be as invariably absent. From the explanation of the character and functions of this special organ or structure given in the succeeding chapter, it is reasonable to predicate that it is an accompaniment only of animal organization. As there shown, this pulsating vessel is continually replenished from the fluid element imbibed by the organism with the solid food-particles, or through the ciliary or otherwise produced currents, the same fluid often travelling towards and debouching into the vessel in question by well-defined canal-like channels. According to some observers, including Stein, contractile vesicles are common also to several undoubted plant forms, such as *Volvox* and *Protococcus*. The closest investigation in this direction on the author's part, and as accomplished with the aid of a magnifying power of 1– or 2000 diameters—which renders these structures distinctly visible in organisms of far more minute size—has, however, entirely failed to substantiate the presence of any such periodically contracting vesicles in the aforesaid and other allied types, though in many of these, irregularly formed and permanently conspicuous vacuoles or inter-parenchymal spaces, having no fixed location nor rhythmically contractile motions, were found to occur. These observations having been confirmed by repeated and most careful examination of the two generic types just named, the presence or absence of a contractile vesicle is now definitely accepted by the author as affording a ready means of distinguishing between unicellular animal and vegetable organisms. In those instances in which the possession of a contractile vesicle has been attributed to *Volvox globator*, as by Busk * and other investigators, it would appear probable that either *Uroglena*, *Syncrypta*, or some other of the several Volvox-like animal organisms formed the subject of observation.

* 'Transactions of the Microscopical Society,' p. 35, 1852.

CHAPTER III.

NATURE AND ORGANIZATION OF THE INFUSORIA.

PROCEEDING to the more immediate consideration of the special group or groups of organisms that form the subject-matter of this volume, it is in the first place scarcely requisite to observe that the title of the Infusoria as employed from the date of its earliest introduction up to the present time has carried with it a most wide and indeterminate meaning. Formerly utilized for the distinction of almost every microscopically minute aquatic organism, whether belonging to the animal or vegetable series, it is found to embrace for the most part in its more modern application several highly differentiated classes or sections of the sub-kingdom Protozoa, and in some cases, even yet, organisms whose true position should undoubtedly be among the representatives of the vegetable world. In accordance with the views held by the present author, the Infusoria as a group, even when restricted to forms exhibiting a decided animal organization only, scarcely possesses an intrinsic or coherent status, embracing as it does, though incompletely, representatives of all four of the primary natural sections of the Protozoa that have been previously enumerated. Adapted, however, as closely as possible to meet existing exigency, this same group or legion, as it may be conveniently denominated, corresponds as here embodied most closely with those three classes of the Protozoa included in the preceding tabular view of this sub-kingdom under the titles of the Flagellata, Ciliata, and Tentaculifera. In other words, it comprehends, with the exception of the typical Rhizopoda and two subordinate Flagellate orders of the Spongida and Mycetozoa, the whole of the representatives of the Protozoa. But for the limits of space at command, the first, if not the second, of these two last-named orders would likewise have been admitted and described *in extenso* on equal terms with their associated groups; its individual representatives, as explained at length in Chapter V., conforming in all essential structural and developmental details with those of that special order here distinguished by the name of the Choano-Flagellata. From the evidence already submitted, it is clearly apparent that the Infusoria, from whichever point of view selected, can be regarded as irregularly gathered excerpts only from that primary subdivision of the animal kingdom known as the Protozoa, and that no correct estimate of the affinities nor definition of the characters of its multitudinous representatives can be accomplished apart from their consideration as constituent integers of this one harmonious whole, as indicated in the diagrammatic plan and tabular view given in the preceding chapter. In order to meet present requirements, it has been found desirable, nevertheless, to institute the following definition of the Infusoria ; this, while according as far as possible with the broader principles of the above-named scheme, includes all, and those only, of the numerous and exceedingly diverse forms described in this volume.

DEFINITION OF THE LEGION INFUSORIA.

Protozoa furnished in their adult condition with prehensile or locomotive appendages, that take the form of cilia, flagella, or of adhesive or suctorial tentacula, but not of simple pseudopodia; zooids essentially unicellular, free-swimming or sedentary; naked, encuirassed, loricate, or inhabiting a simple mucilaginous matrix; single, or united in colonial aggregations, in which the individual units are distinctly recognizable; not united and forming a single gelatinous plasmodium, as in the Mycetozoa, nor immersed within and lining the internal cavities of a complex protoplasmic and mostly spiculiferous or other skeleton-forming cytoblastema, as in the Spongida. Food-substances incepted by a single distinct oral aperture, by several distinct apertures, through a limited terminal region, or through the entire area of the general surface of the body. Increasing by simple longitudinal or transverse fission, by external or internal gemmation, or by division—preceded mostly by the assumption of a quiescent or encysted state—into a greater or less number of sporular bodies. Sexual elements, as represented by true ova or spermatozoa, entirely absent, but two or more zooids frequently coalescing as an antecedent process to the phenomena of spore-formation.

The annexed plan of the further subdivision of the Infusoria into its component sections, classes, and orders is necessarily an abbreviation only of the tabular view of the Protozoa given at page 36, supplemented in the present instance, however, with a brief summary of the more essential diagnostic characters.

The general Morphology, Organography, Ætiology, Distribution, Reproductive Phenomena, and all other features associated with the group of the Infusoria as here defined may now be examined in detail, and under their respective headings.

MORPHOLOGY.

Unicellular Nature of the Infusoria.

As implied in the definitions of the Protozoic sub-kingdom generally, and of the Infusorial legion in particular, already submitted, any representative zooid or individual unit of the group now under consideration possesses according to the views supported by the author the morphological value only of a simple cell. This interpretation, originating in its substantial form with Carl Theodor von Siebold in the year 1845, was beyond doubt foreshadowed many years previously by Lorenz Oken, received further amplification at the hands of Schleiden and Schwann, and represents at the present date the most generally accepted estimate of the organization of the members of this class. From a very early period up to the present time, however, there have not been wanting authorities of more or less considerable eminence who have advocated on behalf of the Infusoria a

Tabular View of the Sections, Classes, and Orders of the Legion INFUSORIA.

Sections	Classes.		Orders.
A. PANTOSTOMATA. Oral or inceptive area distributed over the entire cuticular surface.	I. *Flagellata.* Appendages flagelliform.	Flagellum rudimentary, supplemented by an undulating membrane ..	1. Trypanosomata.
		Flagellum supplemented by lobate pseudopodia..	2. Rhizo-flagellata.
		Flagellum supplemented by ray-like pseudopodia	3. Radio-flagellata.
		Simply flagelliferous, no pseudopodic appendages	4. Flagellata-pantostomata.
B. DISCOSTOMATA. Inceptive area limited to a discoidal anterior region, but not constituting a true mouth.		Flagellum issuing from centre of collar-like extensile membrane ..	5. Choano-flagellata (vel Discostomata-gymnozoida)
C. EUSTOMATA. Inceptive area taking the form of a distinct mouth.		Flagellum single or multiple, no auxiliary cilia	6. Flagellata-eustomata.
		Flagellum associated with more or less numerous auxiliary cilia	7. Cilio-flagellata.
	II. *Ciliata.* Appendages taking the form of cilia.	Cilia distributed over the entire surface of the body, similar in character ..	8. Holotricha.
		Cilia distributed throughout, oral series of larger size..	9. Heterotricha.
		Cilia usually more or less diverse, confined to the ventral surface of the body	10. Hypotricha.
		Cilia not generally distributed, mostly limited to a conspicuous circular or spiral adoral wreath ..	11. Peritricha.
D. POLYSTOMATA. Inceptive areas distinct and multiple.	III. *Tentaculifera.* Appendages tentaculate.	Tentacles simply adhesive	12. Actinaria.
		Tentacles suctorial	13. Suctoria.

comparatively complex type of structure altogether at variance with the foregoing unicellular conception. Enumerated in chronological order, the first interpretation attributing a complex and multicellular structural type to these organisms was advanced by C. G. Ehrenberg, who in the year 1830 enunciated his celebrated Polygastric theory. In accordance with Ehrenberg's interpretation, the Infusoria, including both the simpler Flagellate and more highly differentiated Ciliate representatives of the series, were, as previously stated, distinguished by the possession of a variable number of distinct stomach-cavities, and of glandular and sensory organs of various descriptions, the affinities of the group as a whole being deemed by him as most nearly approximate to that of the Annelida. Founding their arguments upon a basis altogether independent of Ehrenberg's remarkable hypothesis, several authorities have since held the Ciliate division of the Infusoria to exhibit similar affinities with the lower or Turbellarian worms, the names of Oscar Schmidt and Diesing being most eminently conspicuous in this direction. According to the views of the last-named taxonomist, however, the Peritrichous group of the Ciliata exhibited a type of structure more nearly approaching that of the Polyzoa, Diesing's interpretation in this connection being likewise independently maintained by the elder Agassiz. The most powerful opposition to the unicellular nature of the Infusoria, such opposition being based upon the supposed nearer conformance of their structure to that of the Cœlenterata or zoophytes, is undoubtedly found in the conjoint writings of Claparède and Lachmann. A corresponding Cœlenterate interpretation of the affinities of this group, as illustrated more especially by the organization of the Vorticellidæ, has been quite recently advocated by Richard Greeff.

Among those authorities who, while contesting the unicellular nature of the Infusoria as advocated by Von Siebold, have substituted for it no definite and compensating alternative interpretation, may be mentioned the names of Perty, Lieberkuhn, and to a considerable extent also Stein. The crucial test respecting the disputed unicellular or multicellular structure of the infusorial body is undoubtedly, however, to be found associated with the phenomena of development. As pointed out more especially by Professor Haeckel in his 'Morphologie der Infusorien,' published in the year 1873, the entire life-history of an Infusorium, taken even in its most exalted grade of development, as represented by the higher Ciliata, is an epitomization only of the life-history of a simple cell. By the various modes of fission or duplicative division common to all representatives of the class, the infusorial zooid multiplies itself in a manner precisely corresponding with what obtains in the augmentation of the ultimate elements of all cellular structures. Again, in those more rarely observed, but still very generally occurring phenomena of sporular or internal gemmule-production, the sporoid body or embryo commences life as an undoubted simple cell, and retains this same morphological simplicity for the remainder of its existence. At no epoch of its history, from its pristine germination to its ultimate dissolution, is there any appearance of a multicellular constitution, or in the former instance, more especially, the formation of a distinct germinal layer or blastoderm, the one essential feature and index of all the multicellular animals or Metazoa. It is true nevertheless, although the circumstance has apparently as yet attracted but little notice, that many infusorial forms belonging both to the Ciliate and Flagellate sections of the group, exhibit in connection with that mode of reproduction characterized by the resolution of the primary cell or zooid into a number of sporular bodies, an aspect and plan of organization in no ways to be distinguished from the moruloid or primary segmental condition of the ovum of the Metazoa. Beyond this stage, however, the analogy, or, if it exists, the homology, entirely ceases; for whereas, in the Infusorium or Protozoon, each segment or unicellular component of the pseudo-morula becomes metamorphosed into a distinct and independent being, in the Metazoon, this primary independence is almost immediately obliterated through the recasting or reconstruction out of the primary segmental elements, or morula, of the true multicellular embryo with its characteristic inner and outer germinal layers or primordial tissues. In the case of the sponges, as shown later on, and notwithstanding the deceptiveness of external appearances, the production of similar pseudo-morulæ are associated both with the growth of the free-swimming swarm-gemmules or so-called ciliated larvæ, and also with the development in certain types of the characteristic ciliated chambers, or, as they are more usually designated, the ampullaceous sacs of the adult sponge.

Taking for granted that all infusorial structures possess a unicellular morphologic value only, the very extensive range of complexity compatible with such simple organization, as exhibited by the representatives of the Infusoria, has now to be considered. Among the majority of the older biologists, and with many even at the present day, the conception of a single histologic cell, or of an independent unicellular organism, differs widely from the one that is here advocated. With the former it was, and is, held, firstly, that such a simple cell or unicellular organism must have a differentiated bounding membrane, the cell-wall or primordial utricle; and secondly, that the same must contain a central denser and more highly refractive mass, or nucleus, which may or may not be associated with a still more minute segregated mass, the nucleolus. As demonstrated, however, by the later school of biologists, and among whom Professor Haeckel's name occupies a pre-eminent position, neither a distinct cell-wall nor a differentiated central nucleus forms an essential or invariable element of cell-organization, be such cell either an independent being, or unit, or an integral constituent only of a compound tissue. In accordance with the results of more modern investigation, the intrinsic value or potentiality of such a cell-structure resides neither in the cell-wall nor in the nucleus, but in the simple protein matter indifferently denominated sarcode or protoplasm, of which the cell-body is built up. With reference to the more or less highly differentiated organization of cell-structures and single-celled organisms, Professor Haeckel has recently proposed to introduce a special code of terminology. In connection with this he confers upon all those cells, or so-called plastids, in which no nucleus or nucleus-like structure is present, the title of simple cytodes, reserving that of true cells for those alone in which such a structure is distinctly represented. Both of these are again recognized by this authority as including two minor groups of equal value, distinguished by the presence or absence of a bounding membrane or cell-wall; the naked and membrane-bounded cytodes he has denominated respectively gymnocytodes and hullcytodes, and the nucleated cells in a similar manner, Urzellen or gymnocyta, and Hullzellen or lepocyta. This separation of the nucleated and non-nucleated unicellular structures generally, as applied to independent unicellular or Protozoic organisms in particular, forms the basis upon which Professor Haeckel has, as previously stated, proposed to establish his non-nucleated class-group of the Monera. In recognition of this same distinction, Professor Huxley, in his 'Anatomy of the Invertebrata,' has subdivided the Protozoa into the two groups of the Monera and Endoplastica; the former corresponding with the group of the same name as established by Haeckel, and the latter including that remaining great majority of the Protozoa in which an endoplastic or nucleus-like structure is distinctly visible. Such a distinction is, nevertheless, adopted by this author as a matter only of temporary convenience, he freely expressing his doubts as to whether it will stand the test of extended investigation. The outcome of such research since the publication of Professor Huxley's volume, has indeed fully justified the characteristic caution displayed by this eminent biologist; several of the more important groups of the so-called Monera, including more especially the Foraminifera, being now found to consist of nucleated structures conforming in all essential details with that larger section of the Protozoa from which it has been proposed to separate them. In accordance with the opinion maintained by the author of this volume, and as already intimated in the preceding chapter, the Monera, as a distinct class, has no substantial claim for retention, all the representatives of the Protozoa being held to possess a nucleus, or its equivalent, in their fully matured condition. In their earliest and immature state this important structure, the nucleus, is undoubtedly, however, often absent, the Protozoon, under such conditions only, conforming in structure with Professor Haeckel's diagnosis of a simple cytode or Moneron. That a unicellular animal may, on the other hand, be entirely destitute of a differentiated bounding membrane, or cell-wall, is abundantly evident. All such peripheral differentiation is clearly conspicuous for its absence in the whole of that section of the Protozoa here distinguished by the title of the Pantostomata, and in which food-substances are incepted indifferently at any point of the periphery. As already indicated in the preceding chapter, this simplest and homogeneous type of protoplasmic structure, the inseparable corollary of the Pantostomatous organism, is found associated with by far the larger portion of the entire sum of Protozoic structures, and embraces among the Infusoria proper, as here comprehended, no less than four out of the total of thirteen orders that make up the series.

Although the unicellular nature of the Infusoria is here fully accepted and maintained, it has yet to be admitted that in a considerable number of instances such unicellularity has become somewhat obscure. This is more especially observable among the order of the Ciliata, where we find several representatives of the Opalinidæ possessing an almost indefinite number of nucleus-like structures, a like complexity in this respect being also exhibited by the *Trachelophyllum apiculatum* of Claparède and Lachmann, and a few other Holotricha. Among the Hypotrichous order of the Ciliata, the nucleus is, again, rarely single, being more usually represented in duplicate. Other forms, such as *Loxophyllum meleagris* may be further quoted as illustrative of examples in which the nucleus exhibits a condition of modification midway between the two previously quoted series. This frequently recurring composite character of the nucleus has been seized upon by those who are unwilling to concede to the Infusoria the nature and position of unicellular structures, as affording substantial evidence in support of their objections. No single cell or unicellular organism, in their opinion, can possess more than a single nucleus, and where there is a multiplicity of such structures there must, they maintain, likewise be multicellularity! As explained more at length, however, later on, this structure, the nucleus, as encountered among independent Protozoic organisms, presents an amount of variation and complexity not met with in simple tissue cells, exhibiting more especially in the present connection a capacity to subdivide within, and independently of its surrounding protoplasm and peripheral cell-wall, where such exists. The distinction in both aspect and properties of the nucleus, as thus viewed, from its normal condition as the single central and essential constituent of a simple tissue cell, is so obvious that doubts have been naturally expressed as to whether the so-called nucleus of the infusorial body can be regarded as the precise equivalent of the structure that takes the same name in the latter instance. It has been further elected by Professor Huxley, in face of these doubts, to confer upon the nucleus, or its seeming equivalent as associated with Protozoic structures, the distinctive title of the "endoplast," and which title is accepted and for the future mainly adopted throughout this treatise.

The fundamental unicellular structure of Protozoic or infusorial organisms is masked in a yet entirely opposite direction, the obscurity arising in this instance from the imperfect separation of the zooids produced through the ordinary process of duplicative division. Familiar examples of this type of modification are afforded by the compound colonies of the Flagellata *Anthophysa* and *Codosiga*, and various Vorticellidæ, such as *Zoothamnium* and *Carchesium*, in all of which a greater or less number of the divided zooids remain intimately united with one another through the continuity of their supporting pedicles. In all of these examples it is nevertheless a matter of no difficulty to recognize the vital independence and essentially unicellular significance of each zooid produced by the binary subdivision of its predecessor. The entire colony stock, in either of the above-named or cognate cases, represents, in fact, the sum total of the process of segmentation of an original single cell. The only instances in which, so far as is at present known, there would appear to be a complete obliteration of the boundary lines that normally separate each unicellular element or vital area, is encountered in that singular type *Dendrosoma radians* belonging to the group of the Tentaculifera. In this we find a common repent stolon throwing up numerous trunks, which give rise to lateral branchlets that terminate each in a fascicle of suctorial tentacles similar to those borne by an ordinary *Acineta*. It can scarcely be maintained that we have here a simply unicellular organism ; each tentaculiferous branchlet is without doubt the equivalent of a typical *Podophrya*, or *Acineta* that has arisen from the longitudinal subdivision of a preceding zooid, and with which it has remained intimately and indissolubly connected. Through the process of imperfectly separated terminal gemmation, a somewhat parallel compound body is produced in the allied genus *Ophryodendron*, and more particularly in the new form here described under the name of *Ophryodendron multicapitata*. The *Podophrya gemmipara* of Cienkowski exhibits temporarily, during its characteristic reproductive state, a compound condition closely identical with that presented by the normal phase of the last-named species. In each of these last-named instances the derivation of the colony stock from a single primary cell or plastid, is self-evident, and notwithstanding the obliteration, or rather non-development, in the case of *Dendrosoma*, of all boundary lines between the individual zooids, their essential unicellular significance remains conspicuous.

Internal and External Differentiation.

Cuticular Elements or Ectoplasm.

The infusorial body in its simplest type of development exhibits a structural composition substantially corresponding with that of the lowest organized tissue cell or plastid, as defined in a previous page. There is no distinct bounding membrane or cell-wall, and no means of discriminating between the soft, semifluid constituents of the interior and exterior regions; it is throughout, and apart from the nucleus or endoplast, one continuous mass of granular, but otherwise homogeneous and undifferentiated protoplasm. The greater portion of the members of the several orders of the Pantostomata must be referred to this category. In the next step of advance, the outer or peripheral border of the protoplasmic mass, while not assuming the character of a distinct cell-wall or so-called cuticle, presents, as compared with the inner substance of that mass, a slightly more solid type of composition. The somewhat denser external layer may in this instance be conveniently denominated the "ectoplasm" and the softer inner substance the "endoplasm." The possession of this slightly denser ectoplastic in place of a distinct cuticular layer is evidenced in certain Pantostomata and in many Eustomatous Flagellata and Discostomata, which, while usually exhibiting a more or less characteristic normal outline, can revert at will to a pseud-amœboid and repent state, progressing then through the aid of variously modified pseudopodic prolongations. The possession of a well-differentiated cuticular layer, while regarded usually as the special attribute of the Ciliata, is common also to many Flagellata, being among these latter most conspicuously represented in such genera as *Euglena*, *Anisonema*, and *Polytoma*.

The development of a simple external or bounding membrane in addition to an immediately subjacent firmer ectoplasm, commonly styled under such circumstances the cortical layer, by no means, however, exhausts the cuticular organization of the Infusoria. As demonstrated by Professor Haeckel, it is possible, among the most highly organized representatives of this class, to recognize no less than four distinct layers or elements exterior to the soft, semifluid, central endoplasm, the same taking from without inwards the following plan of construction and arrangement. Outermost of all occurs that perfectly hyaline homogeneous layer with which the name of the true cuticle is most appropriately associated. It represents the formed, and consequently lifeless, cell-wall of ordinary plant and animal tissues, and is as an independent structure most readily distinguished in such a type as *Vorticella*, where, in addition to forming the outer envelope of the body proper, it is continued downwards, and constitutes the external, structureless, hyaline and elastic sheath of the characteristic retractile stalk. It is this structureless and transparent external layer, again, which enters into the composition of the more or less indurated dorsal shield or investing cuirass of *Euplotes* and *Peridinium;* while it is out of this same element, though as a secondary product, that we find derived the hardened cases or loricæ of *Vaginicola*, *Tintinnus*, and other Heterotricha and Peritricha. Immediately beneath the hyaline external cuticle is encountered, without exception, throughout that large section that takes its name from its characteristic ciliary organs, that comparatively firm, homogeneous, highly elastic and contractile layer, of which the cilia, or their variously modified representatives in the form of setæ, styles, or uncini, are the direct products or appendages, and which latter necessarily perforate the external cuticle in order to be brought in contact with the surrounding fluid. With reference to the special function of this element, Haeckel has proposed to confer upon it the title of the ciliary layer. Beneath this last-named layer is found developed in certain of the more highly organized Ciliata, though by no means with a large number, that peculiar hyaline and highly contractile fibrillate structure which fulfils for these unicellular organisms functions analogous with those performed by the muscular tissues of the Metazoa. In recognition of the special properties of this last-named element, it is referred to indifferently as the muscular or myophan layer, the latter one finding most favour with Professor Haeckel. Among the types in which this myophan layer is most conspicuously developed, may be mentioned the genus *Stentor*, in which it takes the form of closely set, longitudinally arranged, thread-like fibrillæ; *Spirostomum*, in which fibrillæ of similar aspect exhibit an oblique or spiral plan of disposition; and *Vorticella*, in which it forms a finely longitudinally striate or fibrillate sheet that invests the entire body, and is continued in a condensed and thread-like form down the centre of the pedicle, constituting the motile or contractile element of that structure. According to the recent investigations of Ernst Zeller, the cortical layers of the various species of *Opalina* are found under treatment with hydrochloric acid, as shown at Pl. XXVI. Fig. 9, to consist of closely approximated oblique or longitudinally-disposed muscle-like fibrillæ, though these latter by no means possess the highly contractile properties of the myophan element as represented in the preceding forms. The fourth and remaining elemental layer to be mentioned having, as far as is yet known, a somewhat limited distribution, is that associated with the production of the minute rod-like bodies possessing in some forms an apparently urticating, and in others a simply tactile property, distinguished by the name of trichocysts. The authority last quoted proposes to distinguish this as a separate trichocyst layer, though whether it possesses a sound claim for such distinction is at present somewhat doubtful, there being forms among the Flagellata, as for example the genus *Raphidomonas*, in which trichocysts are abundantly represented independently of any specially differentiated deeper cuticular layer. The genera *Paramecium*, *Amphileptus*, *Prorodon*, and *Nassula* yield examples in which these peculiar structures, described at length further on, may be most advantageously examined.

Internal Elements or Endoplasm.

In the majority of the Infusoria the central substance of the body, here denominated the endoplasm, but frequently also distinguished by the titles of the chyme-mass or parenchyma,—though not in this latter instance to be confounded with the similarly-named element of multicellular structures,—consists of a more or less fluid, clear or granular, but otherwise undifferentiated protoplasm. This endoplasm in most instances maintains a persistent or inappreciably varying status, but in a few others exhibits more or less constant molecular or circulatory motions, which in exceptional cases, such as *Paramecium bursaria*, may even assume an aspect and amount of regularity analogous in many respects to the cell-circulation or cyclosis of certain plants. The endoplasmic element does not, however, at all times present the simple homogeneous aspect portrayed in the foregoing paragraph. In a few exceptional types, such as *Trachelius ovum*, and *Loxodes rostrum*, though still more notably in *Noctiluca* and its allies, the entire substance of the internal protoplasm is so divided by the intercalation of variously developed vacuolar spaces as to assume a more or less complete reticulate or network-like character. Within the ramifications of this central network, the granular sarcode with the enclosed food-substances may or may not exhibit more or less regular circulatory movements, the general appearances and attendant phenomena here, as in the instances above cited, approximating again in a marked manner to those which may be observed in various plants. Such a composition and associated phenomena are, as pointed out by Professor Allman in his recent Presidential Address to the British Association (Sheffield, 1879), especially observable in those plant cells with large sap-cavities, met with in the stinging hairs of nettles, and other vegetable hairs, the internal lining of which projects into the enclosed sap-cavity thin protoplasmic strings or filaments; these, fusing with one another in various directions, form an irregular network, along which under a high power of the microscope a slow current of granules may be witnessed. As rightly observed by Professor Allman, the vegetable cell with its surrounding wall of cellulose is comparable under such conditions in all essential points with a closely imprisoned Rhizopod; the likeness, however, between a highly vacuolate infusorium and such an internally modified vegetable cell is still more striking.*

Among the examples in which the central endoplasm has been observed to exhibit motions other than circulatory, reference may be more especially made to the type first described by Ehrenberg under the title of *Monas vivipara*, here referred to the genus *Spumella*, and in which the entire body-substance within the periphery exhibits under high magnification an active vibratory motion of its enclosed granules that corresponds most closely with the purely mechanical or "Brownian movements" of finely divided inorganic particles.

Excreted Elements.

Under the above heading have to be assembled all those excreted products whose function it is to provide an external protective envelope for the defence of the enclosed animalcules, and the majority of the variously modified pedicles and other fulcra for support possessed by certain of the

* An independent observation in a similar direction has recently fallen within the author's experience, the type in question being the elegant marine diatom *Isthmia enervis*. The unicellular frustules of this species, collected and examined in the living state at Teignmouth, Devonshire, in July 1879, were found to exhibit an exceedingly remarkable internal structure. The characteristic olive-brown cell-contents or endochrome was found to be collected for the most part into a more or less extensive central spheroidal mass, from which radiating and frequently branched granular thread-like prolongations of the same substance extended to and united with the periphery. Submitted to high magnifying power (700 diameters) both the central mass of endochrome and its radiating prolongations were shown to be composed of an aggregation of minute brown ovate or spindle-shaped corpuscles immersed in or held together by a colourless and more fluid plasma. In the radiating and reticulate extensions from the central mass these corpuscles were sometimes quiescent, but more often were seen travelling in slow and regular order to and fro between the centre and the periphery; the general aspect under these conditions corresponded so nearly with the characteristic granule circulation of certain Foraminifera and other Rhizopoda that it was difficult to realize that it was a unicellular plant and not a Protozoon under examination. In the most actively moving cells almost the whole of the ovate corpuscles were deployed upon, and in motion along, the radiating filaments, while in the most quiescent examples both filaments and corpuscles were withdrawn into the central mass.

attached or sedentary species. Among the former are necessarily included those variable and often exceedingly beautiful vase-like or tubular structures upon which the titles of sheaths or loricæ are most usually conferred, and likewise those investments of simple mucus subservient in a similar manner as a dwelling house for the habitation and protection of the one or many animalcules who are engaged in its construction. Within the category of "excreted structures" have also most essentially to be included those hermetically closed indurated cysts or envelopes exuded by almost every known type of animalcule under certain uncongenial conditions, and also very frequently as an accompaniment of the phenomena of binary division or sporular reproduction. The excreted structures pertaining to these last-named special purposes possessing an altogether independent significance, they are treated of separately later on under the respective titles of "encystment" and "sporular multiplication."

In all of the foregoing cases it is evident that the secreted structure is the direct product of exudation or simple separation from the external layer or ectoplasm of the contained animalcule, and is indeed in many instances scarcely to be distinguished from the outermost or true cuticular element of the several layers of the ectoplasm already described at length. Instances in which the closest affinity may be said to subsist between these two structures are afforded by, and specially referred to, in the account given of the members of the genus *Lagenophrys* and of *Opercularia nutans*. In its simplest form, and yet at the same time partaking of the character of an independent exuded structure, the secreted envelope has a purely gelatinous consistence, and corresponds essentially in nature and aspect with the exuded mucilage that constitutes the common envelope of various bacterial growths in the characteristic "glœa" phase of their existence, and is similarly associated with many other low-organized plants or Phytozoa. Instances among the higher or Ciliate group of the Infusoria, in which a simple mucilaginous investment takes the place of an indurated sheath or lorica, are of comparatively rare occurrence, the genera *Ophrydium*, *Ophionella*, *Chætospira*, and certain species of *Stentor*, yielding the most prominent exceptions. Among the Flagellata such mucilaginous investments, and more especially when pertaining to colonial or sociably aggregated types, are far more frequent, such genera as *Uroglena*, *Protospongia*, *Spongomonas*, and *Phalansterium* being especially noteworthy in this direction. The transition from a simple gelatinous sheath to a comparatively hardened test or lorica is very gradual, and is well exemplified among the members of the genus *Salpingœca*, in several of which, as, for example, *S. ampulla*, the development of the highly characteristic lorica from a primary simple mucilaginous exudation has been attentively observed. The composition of the loricæ throughout the various orders and families of the infusorial class is found to exhibit a very uniform character, being represented in most cases in its matured state by a more or less brittle material, having an apparently chitinous consistence. In the majority of instances these loricæ are perfectly transparent, permitting a free view of their enclosed constructors, but in some few, and notably in association with the genera *Cothurnia*, *Vaginicola*, and their allies, the loricæ assume with age a deep chestnut hue, and are more or less completely opaque. Certain of the representatives of the foregoing group are further distinguished by their possession of a supplementary simple operculum or more complex valvular structure, which, upon the withdrawal of the animalcule, closes the aperture of the lorica, and effectually protects the animalcule from molestation from without. The greatest diversity in form exhibited by the protective cases or loricæ of the infusorial animalcules is undoubtedly met with among the more simply organized Flagellate section. Here we have several families, as, for example, the Trachelomonadidæ, Dinobryonidæ, and Salpingæcidæ, notable for the diversity of contour exhibited by the domiciliary structures secreted; those appertaining to the one last named being particularly worthy of mention, as including forms which vie for elegance in outline with the classic vases and amphoræ of ancient Greece. Within this family, and also in that of the Dinobryonidæ, more complex loricate types occur than among any as yet known Ciliata, many loricæ in such instances remaining united to one another, and forming more or less extensive branching structures, highly suggestive of the horny and chambered polyparies of the Sertularian zoophytes and Polyzoa; for these last-named aggregations of ordinary simple loricæ the distinctive title of "zoothecia" has been adopted by the author. Although it mostly happens that the texture of the lorica is purely hornlike or chitinous, it is sometimes found, as in *Codonella*, and among certain members of the genus *Tintinnus*, that a more or less considerable amount of sand-grains or other extraneous particles are incorporated within its substance. In a still more limited series of types, e. g. the genus *Dictyocysta*, sharing with *Tintinnus* a pelagic habitat, the shell or lorica is purely siliceous, variously perforate or fenestrate, and, in the absence of its characteristic occupant, is scarcely to be distinguished from the elegantly latticed siliceous shells of certain Polycystinæ. As mentioned in the account given of that family group, there are strong grounds for suspecting that the investing cuirass of certain pelagic Peridiniadæ is likewise of a siliceous nature.

The investing loricæ of the Infusoria represent by no means the entire sum of the structures produced by excretion. Among both the Ciliata and Flagellata are found compound tree-like growths or "zoodendria," that exhibit a highly complex type of organization. Reference is more especially made here to such an excreted compound pedicle as occurs in *Anthophysa vegetans*, a full account of the formation and mode of development of which is placed on record in connection with the account given of that species. In this particular type it was shown by experiment that the ramifying supporting stalk is built up by excretion, from the posterior region of the associated animalcules, of the residual particles of the substances first incepted for nutrient purposes mingled with some amount of cohesive mucus, or so altered by deglutition as to present a homogeneous, horn-like consistence; each fine longtitudinal stria recognizable in the branching stalk under normal conditions, indicating, again, the integral portion contributed towards the formation of the whole by the separate members of the terminal uvella-like colony. In certain other recently discovered forms, as, for example, Stein's new genera *Rhipidodendron* and *Cladomonas*, a more or less extensively branching tubular structure or "zooaulon" is built up, into the composition of which, in the first-named genus more especially, many hundred tubules not unfrequently enter. Each of these separate tubules represents in either case the excreted product of the single animalcule or zooid which is found occupying its distal extremity, and which is undoubtedly formed in a manner corresponding closely with that of the pedicle of *Anthophysa*, though in this instance the excretion of digested particles and mucus takes place throughout the greater portion of the area of the periphery, instead of being limited only to the posterior region of the body.

Encystment.

The phenomenon of encystment or cyst-development, briefly referred to in a preceding page, represents so important a factor in the life-history of the infusorial animalcules as to demand separate and extended notice. As there intimated, this encysting process is found to exhibit many distinct and independent phases. In the first, and most general of these, encystment may be defined as a mere conservative act resorted to by any independent infusorium in the presence of conditions unfavourable to its welfare, such as the change of temperature, or the drying up of the surrounding water, or other inhabited medium. In this simply "protective encystment," as instanced by *Paramecium*, *Trachelius*, and other free-swimming types, the animalcule loses its accustomed activity, and settling down in some chosen spot becomes, after a short duration of purely rotatory movements, perfectly quiescent. The cilia now gradually disappear, the animalcule at the same time contracts into a more or less perfect spheroidal form, and exudes from its entire periphery a soft, mucilaginous envelope, at first visible only as a delicate bounding line, but which hardening by degrees assumes the nature of a transparent, membranous or shelly capsule. Although in most instances these protective cysts present a simple spheroidal contour and smooth homogeneous surface, several prominent deviations are to be found. Thus in some instances this cyst or capsule is double-walled, the exterior wall being, as shown by Auerbach in the case of *Oxytricha pellionella*, soft and granular, and the inner one membranous and elastic. In *Stentor cæruleus*, again, the cyst (Pl. XXIX. Fig. 15) is flask-shaped, and provided at its upper extremity with a close-fitting operculum-like lid. In *Euplotes charon*, as shown by Stein, this same structure presents numerous longitudinally disposed, serrated, crest-like elevations, which communicate to the capsule a somewhat melon-shaped outline. A corresponding type of form with certain modifications, the areas between the longitudinal ridges being transversely striate or otherwise ornamented, is common to the encystments of various Vorticellidæ, while a somewhat similar one, having the elevated crests transversely placed, recurs in the Acinete type *Podophrya fixa.* In many species, such as *Stylonychia pustulata* and *Pleurotricha lanceolata*, the exterior surface of the spheroidal cyst is closely studded with more or less irregular papilliform elevations. In all these instances of simple or protective encystment, the animalcule upon the return of favourable conditions assumes once more its normal aspect, and, breaking through the walls of its temporary prison-house, resumes its customary active habits. It is undoubtedly to the possession of this simple self-protective faculty that the extensive distribution and prolonged vitality of many infusorial forms is mainly due. Where the ponds, ditches, or other tracts of fluid containing such animalcules become entirely dried up, these latter run no risk of extermination. Throwing out around them their transparent envelopes, they remain in a quiescent or torpid state until the reappearance of the previous congenial surroundings, or, taken up by the passing breeze, are wafted away in the form of dust until conditions are encountered corresponding sufficiently with those under which they originally flourished.

The encystment of the second order to be mentioned is of comparatively rare occurrence, and, instead of being associated with a simple conservative function, is an accompaniment of, or rather the prelude to, the phenomenon of multiplication by binary division, and may for this reason be most appropriately denominated "duplicative encystment." The preliminary manifestations and aspect of the constructed cyst correspond essentially with those recorded of the simply protective form; but the animalcule enclosed within its capsule, instead of resolving itself into a quiescent and inert mass, divides itself by the ordinary mode of increase by transverse fission, the two halves shortly after making their exit through the walls of the cyst, smaller in size, but in all other respects corresponding structurally with the single pre-existing zooid. Encystment of this special type, in conjunction with other noteworthy data, has been observed by Claparède and Lachmann of the Holotrichous form *Amphileptus meleagris.* As recorded in detail later on, this animalcule is essentially predatory in its habits, and is addicted to preying upon the stationary and defenceless zooids of the Vorticellidan genus *Epistylis*, in the same manner that the Myxopod *Vampyrella* feeds upon the frustules of the Diatom *Gomphonema.* In a like manner also, having gorged itself to satiety, the devouring *Amphileptus* builds its cyst on the apex of the supporting stem of its latest victim, and there undergoes the metamorphosis above described. Duplicative encystment is recorded by Stein of *Glaucoma scintillans*, and in accordance with the observations of that authority occurs also in *Colpoda cucullulus*, in combination with that variety of the process next described.

The third, and remaining form of encystment to be enumerated, closely approaches in many instances the one last mentioned, while in others it exhibits widely distinct features. Like the preceding, it is connected with the phenomena of reproduction, but the encysted animalcule multiplies itself not merely by the process of binary fission, but by the subdivision of the encapsuled mass into a greater or less number of spore-like bodies which, after a more or less prolonged quiescent state, develop to the parent form. This type of encystation may be most appropriately denominated "sporular encystment," and the cyst or capsule secreted in such instances, a "sporocyst." Details of this special mode of multiplication are given in the section devoted to the subject of reproduction, and it is only requisite here to indicate one important point in which such sporular encystment departs widely from both of the preceding kinds. In each of these latter the cyst or capsule produced is the product of a primarily single and independent animalcule, but in the one now alluded to it very frequently, though not invariably happens, that such a cyst is the product of two primarily amalgamated or conjugated zooids. In certain cases, even, as, for example, *Heteromita uncinata*, as many as three or four conjugated animalcules build up the characteristic sporocyst. This special sporular form of encystment is, with but few exceptions, limited to the Flagellate class of the Infusoria.

Locomotive and Prehensile Appendages.

All of the variously modified appendages possessed by the several orders of the Infusoria, used indifferently for the purposes of locomotion or prehension, are to be regarded as mere extensions of the body-protoplasm; sometimes, as in most Flagellata, they are produced directly from the external surface of the ectoplasm, and in others, as the Ciliata, from the deeper or cortical layer of that element. In certain Tentaculifera the characteristic tentacle-like appendages would seem to originate in close proximity to the central or endoplasmic region. With the exception of the organs last mentioned, which would appear to most nearly represent specialized modifications of the pseudopodia of the Radiolaria, the transition from one to the other of the several types of appendages borne is most distinct and gradual. In this manner, flagella can be characterized only as isolated and more or less elongate cilia; while the divers forms of setæ, styles, and uncini possessed most abundantly by the Ciliate section of the series, can be regarded as variations only, in separate directions, of similar simple cilia. Viewed from an independent standpoint, and as is requisite for the purposes of technical diagnosis, the term of "cilia" may be conveniently restricted to such short, slender, vibratile appendages as constitute the ordinary locomotive organs of a *Paramecium*, or the more or less convolute adoral ciliary wreath of a *Vorticella*. With the name of "setæ" are to be associated the slender, hair-like, more or less flexible but non-vibratile appendages that clothe the entire body of a *Pleuronema*, that are developed girdle-wise, and fulfil a special leaping function in the genus *Halteria*, or that in an isolated form constitute a hair-like caudal termination in the genera *Uronema* and *Urotricha*. "Styles" and "stylate appendages," differing from the organs referred to the last-named category in their greater comparative bulk and thickness, are most abundantly represented among the Hypotrichous sub-order of the Ciliata, being developed in well-defined groups or series on the ventral aspect of such genera as *Oxytricha* and *Stylonychia*, and being represented as a single terminal caudal style among the members of the family Dysteriadæ. Of uncini, which also occur chiefly among the Oxytrichidæ, it may be said that, except for their usually shorter and curved or claw-like shape, they coincide entirely in character and function with the ordinary stylate structures, and act in combination with them as most efficient ambulatory organs. It is undoubtedly among the members of this family group that the cilia attain their highest and most luxuriant development, in many species all of the four typical variations of these appendages being borne by a single individual. Here, too, in certain species, such as *Stylonychia pustulata*, *S. mytilus*, and *Euplotes patella*, we find the styles and setæ departing altogether from their ordinarily simple character, and assuming a more or less branched and often elegantly feathered or fimbriate character. Furthermore, as recently pointed out by Sterki, the adoral series of cilia among these Infusoria differ considerably from vibratile cilia of the ordinary type. These modified cilia are much flattened or compressed, and appropriately receive from him the distinctive title of "membranellæ."

In addition to the cilia and their various modifications as above enumerated, there have to be included in the list of locomotive and prehensile appendages now under consideration, the diverse forms of membranes, some vibratory or undulating and others quiescent, which, either as isolated structures or in combination with cilia or flagella, compass or assist in compassing the objects more usually relegated exclusively to one or other of these last-named structures. As has been previously submitted (see p. 38), an undulating membrane may be regarded from a developmental aspect as the root or primal form only of the adoral fringe of cilia; in certain other directions, however, it develops an entirely independent type of structure. Commencing with the lowly organized Trypanosomata, where it is found to constitute the sole organ of progression, it makes its next appearance as a supplementary locomotive organ in the Flagellate genera *Trichomonas* and certain species of *Hexamita*. By far the most remarkable development of a membraniform appendage in connection with the Flagellate section of the Infusoria, is undoubtedly represented by the singular infundibular membranous expansion or "collar," with its characteristic circulating currents, distinctive of the order here distinguished by the title of the Choano-Flagellata, and met with elsewhere throughout the entire organic series only in association with the class Spongida, whose intimate relationship with these Flagellata is thus indubitably established. The marvellous mechanism of this collar-like membrane, and its utility in combination with the centrally enclosed flagellum as a most efficient snare for the capture of food-substances, will be found fully discussed in the systematic description of this special group. Among the Ciliata, an equal or even greater variation in the form and functions of their membraniform appendages may be enumerated. In one remarkable type, *Torquatella*, referred, however, with some diffidence to the Ciliata, a terminal frill or collar-like expansile and contractile membrane represents the only organ of locomotion and prehension. In *Pleuronema*, *Uronema*, and *Bœonidium*, a delicate hood-shaped membrane is let down in front of the mouth when the animalcule is feeding, forming thus a bag-like trap, into which food-particles are swept by the adoral ciliary currents. In *Lembus* and *Proboscella* the same purpose is accomplished by the assistance of a more or less prolonged crest-like membrane, which is produced from the anterior extremity alongside of the adoral groove to the ventrally located oral aperture. As a supplementary element to the ordinary adoral fringe of cilia, a band-like undulating membrane is of constant occurrence in association with the Heterotrichous and Hypotrichous genera, *Condylostoma*, *Blepharisma*, *Onychodromus*, and *Stylonychia*, while in *Euplotes patella*, and in various species of the genus *Stentor*, the adoral fringe itself commences its existence as a similar simple band-like membrane. In the Holotrichous family of the Ophryoglenidæ, again, embracing some dozen genera, all of the members are characterized by the possession of a small flap or clapper-like membrane, which is enclosed within, or projects to a less or greater distance beyond the oral fossa.

It is obvious that the locomotive and prehensile appendages of the Tentaculifera, including *Acineta* and its allies, depart widely in form and function from those pertaining to the more ordinary Ciliate and Flagellate groups, approaching more nearly in this respect the pseudopodia of the Radiolaria. This affinity is more especially apparent in such types as *Ephelota trold* and *Hemiophrya gemmipara*, in the former of which none, and in the latter a portion only, of the tentacle-like organs exhibit the more frequent tubular and suctorial character, being simply prehensile, and in some instances invertile. In the genus *Ophryodendron* the single or several extensile proboscidiform tentacula, with their associated terminal fibrillæ, exhibit a complex type of structure whose true significance yet requires elucidation. Notwithstanding, however, the humble Radiolarian affinities apparently indicated by the most simply organized members of this group, it has yet to be borne in mind that the embryonic forms of all the species, as yet investigated, are more or less completely clothed with fine vibratile cilia, a circumstance which would seem to betoken an adult type of organization in advance even of that possessed by the permanently ciliate group usually accepted as representing the highest section of the Protozoic sub-kingdom. The more important bearings of the organization of the Tentaculifera in this connection will be again referred to.

Oral Aperture or Cytostome.

It is necessarily only in connection with the members of the Eustomatous section of the Infusoria, including the three orders of the Flagellata-Eustomata, Cilio-Flagellata, and Ciliata, that a true oral aperture—or, as Haeckel designates it in contradistinction to the oral opening of the multicellular animals, a "cytostome"—is met with, food-substances in the remaining sections being incepted indifferently over the whole or a more or less widely dispersed area of the peripheral surface. Where, as above indicated, such a distinct oral aperture is represented, a considerable amount of variation is found to subsist with relation to its contour and associated structure. With the great majority, the oral aperture takes the form only of a simple orifice, or of a tubular passage, through which direct intercommunication is established between the surrounding medium and the inner or deeper endoplasmic region of the animalcule's body. Most frequently this oral aperture is permanently conspicuous, but not unfrequently, as in the genera *Dinomonas* and *Trichoda*, it happens that this structure is to be detected only at the moment when food is being swallowed, its lateral walls at all other times closing so completely upon each other as to leave no passage visible. As might be anticipated, when the walls of the oral passage are loose and elastic, as in the above-named types, this orifice is capable of great distension, the food mass devoured being frequently but little inferior in size to the body of its captor. The first manifestation of a complex organization in connection with the oral aperture is indicated by a simple thickening or induration of the lining wall; this thickening in certain types, such as *Trachelophyllum apiculatum*, takes the form of well-developed longitudinal rugæ, while in others, such as *Chilomonas paramecium*, this region has been lately shown by Bütschli to be both longitudinally and transversely plicate. Among the majority of the Dysteriadæ, as also in association with many of the Prorodontidæ, a distinct corneous tube, that may be isolated from the surrounding body-plasma, is substituted for the simple indurated oral passage characteristic of the last-named series; this structural type leads again directly to that considerable assemblage of forms in which, in place of such a simple corneous tube, a tubular fascicle of rod-like teeth or stylets is enclosed within, but remains at the same time capable of protrusion at will beyond, the oral fossa, and is employed by the animalcule for the purpose of grasping and engulphing its accustomed prey. This special type of oral armature is, so far as it is at present known, possessed only by the Ciliate section of the Infusoria, occurring, however, in three out of the four leading groups or orders of this division, as represented by the genera *Prorodon* and *Nassula* among the Holotricha, *Chilodon* and *Phascolodon* among the Hypotricha, and apparently in the solitary case of *Polykrikos* in the group of the Peritricha.

The most remarkable type of oral armature possessed by the series of organisms now under consideration is, undoubtedly, met with in the *Dysteria armata* of Professor Huxley, in which the simple corneous tube or tubular rod-fascicle of its nearest associates is, as fully recorded in the description given of this specific form, replaced by a series of corneous plates and styles of such diverse and complex character that considerable doubt was entertained at the date of its discovery as to whether the organism might not be more correctly relegated to the section of the Rotifera. Following upon the oral aperture, it not unfrequently happens that a secondary tubular passage, conveniently though incorrectly termed the "pharynx"—it being in no way homologous with that structure as developed in Metazoic organisms —penetrates still deeper into the substance of the central endoplasm, and serves as a channel for the conduct of incepted food-substances to this region. An example of such a prolonged pharyngeal passage, its distal termination at the same time exhibiting a somewhat remarkable hook-like curvature, characterizes Cohn's genus *Helicostomum.* In many instances, such as *Climacostomum* and the type last named, this pharyngeal prolongation is entirely smooth throughout, while in others, such as *Nyctotherus* and *Metopus*, it is more or less distinctly ciliate. The most complex form of oral and pharyngeal organization is, however, met with in certain of the Peritrichous representatives of the Ciliata. Here, as demonstrated by Greeff, more especially in the cases of *Epistylis flavicans* and *plicatilis*, the prolonged and thickly ciliated pharynx is followed by an almost equally long but exceedingly slender and non-ciliate tubular canal, or so-called "œsophagus," whose distal termination is suspended freely in the central fluid endoplasm. At the point of junction of the pharynx with the above narrower canal-like prolongation this latter structure exhibits a peculiar bulb-like dilatation into which the food-particles fall after their passage through the wider superior portion, and are there moulded into the characteristic pellet-like masses which are to be seen regurgitating through the substance of the body. The foregoing type of oral and œsophageal organization has been recently shown by Wrzesniowski to obtain in *Ophrydium versatile*, and is apparently common to all the members of the Vorticellidan family. In the genus *Didinium*, the inner lining of the oral region can be protruded to a considerable distance, after the manner of a proboscis, for the purpose of food-capture; a like, though somewhat less pronounced, structural modification is met with in *Mesodinium.*

Anal Aperture or Cytopyge.

The results of recent investigation have tended to demonstrate that a distinct anal aperture, or as Haeckel denominates it the "cytopyge," for the discharge of fæcal substances, exists in at least all of the Eustomatous section of the Infusoria, while in not a few of the Pantostomata, such a distinct aperture is, although not distinctly developed, most clearly foreshadowed. Among these latter, reference may be made more especially to such types as *Anthophysa vegetans* and *Oikomonas obliquus*, in both of which the excrementitious particles are rejected at the posterior region of the body, and are in the former instance intimately interwoven with the substance of the branching stem. Even among the Ciliata, where this organ attains its most pronounced development, it is, except during the passage of rejectamenta, rarely conspicuous. An exception to the above rule is, however, afforded by the members of the genus *Nyctotherus*, where it is permanently recognizable as a posteriorly located thick-walled, tubular passage, that penetrates to a considerable distance into the substance of the body. As pointed out by Professor Huxley,* the tract along which the food passes in this Infusorium is so circumscribed through the delimitation of the pharynx, anal passage, and very short intermediate area of fine granular endosarc or endoplasm, that it may be not inappropriately described as possessing a rudimentary intestinal canal. In common with *Nyctotherus*, the anal orifice is more usually terminal or subterminal, but may, as in *Stentor* or *Follicularia*, have a lateral location, or as in the large group of the Vorticellidæ, it may open upon the anterior extremity in close vicinity to the oral aperture.

Contractile Vacuole or Vesicle.

In close association with the anal or excretory aperture—the functions of which it in many instances would seem to assist in performing—has to be described that early recognized organ, sometimes single and sometimes multiple, presenting in the generality of species the aspect of a clear, rhythmically expanding and contracting spheroidal space, most generally distinguished by the title of the "contractile vesicle." A very considerable diversity of opinion has been, and is even yet, maintained with relation to the true structure and function of this very important organ. By Ehrenberg it was first described as a spermatic gland; Spallanzani and Dujardin attributed to it a respiratory function; Lieberkuhn and Claparède and Lachmann recognized in it a rudimentary heart or circulatory organ; while in accordance with the views of Stein and Oscar Schmidt, the functions discharged by it are excretory and correspond most nearly with that of the renal organ of the higher animals, and the excretory water-canals of the Turbellaria. As maintained more recently by Professor Haeckel, it seems, however, most reasonable to infer that the functions performed by the contractile vesicle of the Infusoria partake of a twofold character, being both respiratory and excretory. One of the most important points for consideration in the determination of the functions of this organ, is the long-disputed question as to whether or not it maintains a free communication with the outer water. By the majority of earlier and many recent writers, including among the latter Claparède

* 'Invertebrate Anatomy,' p. 105.

and Lachmann, it has been affirmed that no such intercommunication exists, and that the organ consequently partakes of the character of a closed vessel. Among the first to arrive at a contrary decision and to declare that the contents of this vacuole were at the time of collapse or "systole" discharged externally, may be mentioned the names of Oscar Schmidt and Mr. H. J. Carter, strong confirmatory evidence in the same direction being likewise contributed by Professor E. Ray Lankester, in his "Remarks on *Opalina* and its Contractile Vesicles," published in the 'Quarterly Microscopical Journal' for the year 1870. Since that date testimony has been forthcoming from a variety of sources establishing beyond question the existence of the intercommunication above indicated, its precise pore-like character being further described and figured by Wrzesniowski in association with the genera *Enchelyodon* and *Dendrocometes*. In the last-named type, furthermore, a delicate tubular canal has been found to proceed from the spheroidal vesicle and to penetrate the thick cuticular investment. A second disputed point, almost equal in its consequence and bearings to the preceding, was for a long while connected with the precise structure of the contractile vesicle, and more especially as to whether or not it possessed a distinct bounding membrane. By Ehrenberg, Siebold, Claparède and Lachmann, and also by Mr. Carter, the presence of such a definite wall or bounding membrane to this vesicle has been maintained; a contrary view, however, being advocated by Dujardin, Perty, Stein, and the majority of recent investigators. In accordance with the opinion of these latter, no such bounding membrane exists, the vesicle in this respect presenting no higher structural differentiation than the various non-contractile or irregularly contractile vacuoles or lacunæ that occur so abundantly in the protoplasmic element of both animal and vegetable cells. The non-possession by the contractile vesicle of any bounding membrane is now amply proved through the tendency exhibited by this structure in certain species to split up into a variable number of minor vesicles, which may again unite in an irregular manner with one another. This phenomenon has been especially demonstrated by Wrzesniowski in connection with the Holotrichous type *Trachelophyllum apiculatum*. The non-occupation by the contractile vesicle of this species of a permanently fixed position has likewise been elicited by this authority, he having observed that during the discharge of fæcal matter from the terminal anal aperture the vacuole is forced backwards to a very considerable extent to permit of its free passage.

The constant and free intercommunication of the contractile vesicle with the outer water or other inhabited fluid medium, and the composition of this structure as a mere rhythmical pulsating vacuole or lacuna in the cortical layer of the ectoplasm, possessing no distinct bounding membrane, being here accepted as fully established, further details with relation to the functions and more prominent variations it assumes in various infusorial types may be proceeded with. In its simplest form, and as represented in the majority of the Infusoria, the contractile vesicle exhibits at the period of its fullest expansion or "diastole," a merely spheroidal contour, and becoming entirely lost to view at the moment of collapse or "systole." The time occupied between the consecutive pulsations of this organ is found, under normal conditions, to present a constant average among individuals of the same species, varying from a few seconds only in certain forms to over sixty or even one hundred seconds in other types. Undoubtedly, in many cases the characters afforded by the pulsations of this vesicle yield a useful accessory feature for specific diagnosis, and the registration of such characteristics, in connection with the technical description of each specific form, would be of value. Passing on to the more complex phases of this structure, reference may first be made to those types in which the otherwise simply spheroidal contractile vesicle is supplemented with two or more lateral sinuses or lacunæ, the contents of which flow together immediately upon the contraction or systole of the central vacuole and assist materially in the re-expansion of this central part. An instance in which two symmetrically bilateral accessory sinuses are combined with a central vesicle, exhibiting in this case a broadly pyriform outline, has been ascertained by the author to occur in *Urocentrum turbo*, a similar modification being likewise characteristic of the homomorphic species *Calceola* (*Peridinium*) *cypripedium* of Professor H. James-Clark. Examples in which a greater and variable number of similar lateral or peripheral sinuses are found along with the central vesicle, imparting to it under certain conditions a characteristic rosette-shaped configuration, are afforded by such forms as *Follicularia ampulla*, *Trachelophyllum apiculatum*, and *Didinium nasutum*. It is, however, in such types as *Paramecium aurelia* and *Ophryoglena flava* that this special modification of the contractile vesicle attains its most complex development. Here, it is found that the supplementary sinuses present a narrower or more linear contour, and exhibit, as a consequence of their radiate plan of disposition around the central vacuole, an elegant and highly characteristic stellate aspect. In *Paramecium* there are usually from five to seven or eight of such radiating sinuses, while in the case of *Ophryoglena*, Lieberkuhn has reported the existence of no less than thirty. Examined carefully with the assistance of the higher powers of the microscope, it has moreover been demonstrated by the authority last quoted, and also by Mr. Carter, that these lateral sinuses extend as slender radiating and frequently branching canals throughout the entire cortical layer. A still more conspicuous canal-like system that anastomoses with a main or central contractile vacuole, may obtain. This special type of organization, while occurring in a considerable number of infusorial forms, is perhaps most prominently illustrated by the various representatives of the genus *Stentor*. Here, the main and spheroidal dilatation of this organ is situated a little below the peristomal ciliary wreath, to the left hand of the ventral aspect, and closely adjacent to the anal aperture. From this spheroidal dilatation, as first pointed out by Lachmann, a single long and more or less tubular, canal-like diverticulum extends, inferiorly, down the left side of the animalcule to within a short distance of the adherent foot; while another similar canal, departing from the superior region of the same vacuole, extends in an annular form round the entire circumference of the peristome. As recently demonstrated by Wrzesniowski, an almost identical configuration of the contractile vesicle occurs in *Ophrydium versatile*, an anterior annular canal without the posterior diverticulum obtaining also in several other Vorticellidæ. Among the numerous examples in which the contractile vesicle takes the form of a simple lateral canal-like prolongation, exhibiting the normal spheroidal dilatation at its point of discharge, with occasionally one or more minor bulbous dilatations at various portions of its course, may be mentioned more especially such genera as *Spirostomum*, *Loxophyllum*, and *Climacostomum*. In a yet more considerable assemblage of species the contractile vesicular system is remarkable for what may be denominated its dispersed type of representation. With these, instead of presenting a simple, well-defined centre, with perhaps one or more associated canal-like diverticula, a variable and often indefinite number of similar independently pulsating vacuoles are developed at various separate points. It is thus that in *Paramecium* and *Panophrys* two such separated pulsating centres occur; in *Chilodon*, *Chlamydodon*, and many Acinetidæ, simple spheroidal contractile vacuoles, varying in number from three or four only to as many as twenty, are variously and mostly irregularly distributed throughout the cortical substance; while in a few rarer instances, such as *Bursaria truncatella*, *Trachelius ovum*, and the *Prorodon margaritifera* of Claparède and Lachmann, these independent contractile centres are so abundant as to be almost past enumeration. One other characteristic modification of the compound contractile vacuolar system is exemplified by *Amphileptus gigas* and certain Opalinidæ, in which an even serial or linear distribution of these vesiculæ is exhibited. In all the examples above cited the animalcules named belong to the Ciliate section of the infusorial class. A plurality of contractile centres is not unfrequently, however, associated with the representatives of the Flagellata. Examples in connection with this group are yielded by the important order of the Choano-Flagellata, among whose members two or more comparatively large posteriorly located contractile vesicles are almost invariably presented, while in certain species of *Oikomonas* and *Anisonema*, two equal-sized and in the former case alternately pulsating vacuoles have been observed by the present author. In *Anisonema acinus* and *Entosiphon sulcatum*, Stein, again, has indicated in his recently published volume that the normally single and subspheroidal contractile vesicle develops, at diastole, lobate peripheral sinuses, which impart to the entire structure a rosette-like aspect resembling that already referred to in connection with various Ciliata.

Such being the most prominent external configurations of the contractile vesicle, in both its simple and compound type of development, it yet remains to indicate the more important function in the economy of the infusorial body that it may be predicated to fulfil. Beyond doubt, the leading function of the contractile vesicular system is excretory, in the getting rid of the comparatively vast amount of fluid constantly brought into the body through the ciliary or other currents in combination with the incepted food-material. As is conspicuously evident when watching the feeding process in a *Vorticella* or other highly organized Infusorium, each spheroidal pellet or isolated fragment of incepted pabulum, regurgitated through the yielding endoplasm, is enclosed within an equal or even more extensive mass of water, and which liquid, without some special outlet for its discharge, would soon accumulate to an extent incompatible with the well-being of the animalcule. In this relation, the contractile vesicle with its tributary canaliculi and lacunæ, clearly visible in certain instances and doubtless existing in all, enacts the part of a highly elaborate and efficient drainage system, collecting the superabundant fluid from every part of the body-plasma, and discharging it after its reception into the single or several more or less spheroidal, reservoir-like centres beyond the cuticular periphery. That the considerable quantity of water thus brought constantly into intimate contact with the body-plasma, and as it were circulated throughout every portion of its substance, plays an important rôle in the reoxygenization of its molecular constituents, and thus fulfils a rudimentary respiratory function, may be likewise consistently premised, as also that by the time this same water has circulated through the animalcule's tissues, and has debouched into the reservoir or contractile vesicle from which it is eventually discharged, its chemical composition has become materially altered through both the loss of oxygen and the increment of carbonic acid and other waste material. It is possible that the pale pink hue, mostly prevalent in the contents of the expanded vesicle, owes its presence to such chemical reaction, and it presents at any rate a point worthy of future investigation.

Vacuolar spaces possessing no rhythmically pulsating properties, sometimes constant in position, at others sharing in the movements of the parenchyma, and not unfrequently exhibiting slowly contractile motions which terminate in their permanent obliteration, are constantly met with among the Infusoria. In some few instances this vacuolation, as more fully related at page 58, is developed to such an extent that the entire endoplasmic substance presents a mere trabecular or network-like appearance. This extreme type is especially prominent in the Flagellate group of the Noctilucidæ, and attains a closely parallel degree of development in the Ciliate forms *Trachelius ovum* and *Loxodes rostrum*.

Nucleus or Endoplast, and Nucleolus or Endoplastule.

These important organs, while possessing a stronger claim for consideration, perhaps, in that section specially devoted to the description of the reproductive structures and phenomena, represent in themselves such highly characteristic elemental factors, and exhibit among the various members of the class such varied characters and configuration, that their independent treatment is rendered necessary. The morphological correspondence of the nucleus or endoplast, as it occurs among the simplest and lowest organized Infusoria, with the nucleus or cytoblast of the ordinary animal or vegetable tissue-cell, is so conspicuously obvious as to render extended comment needless. Among the higher representatives of this group, it, nevertheless, manifests so wide a divergence in various directions from this simple and primitive condition as to render desirable the employment of some equally appropriate but at the same time sufficiently distinctive and independent title. This widely felt desideratum has been happily recognized and provided for by Professor Huxley, whose recently introduced term of the "endoplast" in place of that of the nucleus when applied to Infusoria or other Protozoic structures is, as previously related, adopted by the author. The simplest representative type of the infusorial endoplast, and the one which corresponds most closely with the nucleus of the ordinary organic cell, is met with most abundantly among the Flagellate section of the series, but is also represented in not a few of the higher Ciliata. In this initial phase of development it exhibits a simply spheroidal contour, and may or may not enclose a central endoplastule, the homologue of the histologic nucleolus. The first step towards a departure from this primitive condition is manifested by the tendency of the endoplast, as illustrated by the Flagellate genus *Euglena* and its allies, to lose the spheroidal and to assume a more or less ovate outline. A still more attenuate and somewhat sausage-like configuration is exhibited by the endoplast appertaining to the Ciliate genera *Balantidium* and *Nyctotherus*, a further element of divergence being here introduced, however, through the fact that the endoplastule or so-called nucleolus is not contained within the substance of the endoplast, but is adherent exteriorly to its lateral periphery: this special phenomenon, entirely opposed to what obtains with reference to the nucleolus of the ordinary tissue-cell, occurs repeatedly among the Infusoria. The most pronounced development of the elongate type of endoplast is found associated with the Peritrichous group of the Vorticellidæ, and where in many cases it assumes a remarkably attenuate, ribbon-like aspect. Such a ribbon-like or almost filiform configuration of the endoplast is more especially characteristic of the genus *Ophrydium*, and is also represented, though in a less marked degree, in the Heterotrichous form *Bursaria truncatella*. In intimate connection with the band- or ribbon-like type above described, has to be enumerated that branched variety of this structure common to many of the Suctorial Infusoria, or Acinetidæ, and also that modification of the elongate form of the endoplast, similarly band-like in the earlier stages of its development, but which in the mature condition of its existence exhibits a more or less uniform series of constrictions or strangulations. In its most characteristic phase of development, as prominently illustrated by the genera *Stentor*, *Condylostoma*, and

Spirostomum, these constrictions of the endoplast are so evenly developed as to impart to it the aspect of a symmetrical moniliform or necklace-like structure, that may be composed, as shown by Stein in the case of *Spirostomum ambiguum*, of no less than twenty-five or thirty ovate or bead-like segments. Although, as hereafter shown, each ovate element of this elongate endoplast becomes ultimately separated and represents the germ or embryo of a new zooid, any distinct separation between them is rarely recognizable during the normal and mature condition of the animalcule, each consecutive fragment being, for the most part, joined closely and intimately to the one next adjacent. In occasional instances, however, it may be observed that certain of these ovate or bead-like constituents are separated for intervals equal to about one-half of their total length, such interval being bridged over by a slender thread-like connecting filament. This special form of endoplastic configuration, occurring as an exception to the evenly moniliform type of the several last-named genera, is found to foreshadow or pretypify in a very feeble manner the normal and persistent characteristic of certain other species. Special reference is made here to the endoplastic structure demonstrated by Wrzesniowski to obtain in *Loxodes rostrum* and *Loxophyllum meleagris*. Under ordinary conditions, the endoplastic system appears to be represented in these types by a number of nodular bodies, either ovate or spherical, distributed irregularly throughout the cortical substance. Examining the same with the aid of reagents and the higher powers of the microscope, it was found, however, by this author that all of these endoplastic nodules were united to one another by a slender and transparent connecting filament—or, as it may be conveniently denominated, a "funiculus"—the distances between each constituent nodule, and consequent length of the connecting thread, in the case of *Loxophyllum*, often exceeding by many times the length of the nodules.

One important modification of endoplastic development, as yet unreferred to, is presented by those species in which this special structure actually exhibits the isolated fragmentary or multiple configuration apparently, but not really, existing in the two last-named forms. The endoplast, in this multiple or compound type of organization, is further found to present as considerable a series of variation as is associated with that of the contractile vesicle in its multiple condition previously described. Thus, in a large series of animalcules, embracing more especially the members of the Hypotrichous family of the Oxytrichidæ, this structure is invariably represented by two elongate-ovate endoplasts, the one usually situated a little in advance of, and the other a little posterior to, the centre line or transverse axis of the animalcule's body. In yet a few other forms belonging to this family group, such as the *Onychodromus grandis* of Stein, there are normally four such endoplastic elements, these, however, not unfrequently being doubled again through the redivision or fission of each component element. From this simple manifestation of the compound endoplastic formula, every phase of gradation is encountered, until at length, and notably in certain species of *Opalina*, as recently demonstrated by Engelmann and Ernst Zeller, the number of endoplastic elements almost exceeds computation, and takes the form of exceedingly minute spheroidal corpuscles associated with a central endoplastule distributed everywhere throughout the substance of the cortex. It is almost needless to remark that in each of these compound phases the infusorial endoplast differs essentially from the ordinary tissue nucleus, which is there invariably represented in its simple and single form. By those who contest the unicellular organization of the Infusoria, this frequent occurrence of a multiplicity of endoplastic elements has, as previously observed, been referred to as yielding the strongest evidence of multicellular structure. Such testimony is, however, entirely neutralized when correlated with the fact that this element has to be regarded as differing essentially in a variety of aspects from the nucleus of the simple histologic cell, one of the more important of these being its capacity to multiply indefinitely within, and independently of, the circumambient cell-wall or its equivalent. In connection with this phenomenon, and as more fully explained in the section devoted to the reproductive features of the class, the infusorial endoplast, in both its attenuate band-like, and compound aspect, has to be regarded in the light of a specialized proliferous stolon, adapted for the production under certain conditions of a greater or less number of embryonic zooids, and as a supplement to that more normal mode of increase by duplicative division or fission which resembles the only reproductive faculty possessed by the ordinary tissue-cell. One feature of importance presented by the infusorial endoplast remains to be enumerated. In accordance with the results of the most recent investigation, and in connection with which the names of Greeff and Bütschli have especially to be mentioned, it has been demonstrated beyond question that in its more complex form this structure is enclosed within a delicate and hyaline bounding membrane or pellicle, which may, perhaps, be most appropriately compared, physiologically and so far as its structureless nature is concerned, with the similarly transparent and structureless pellicle ensheathing the constituent elements of ordinary muscular tissue, known as the "sarcolemma." It is apparently of this hyaline supplemental envelope alone that the slender and transparent filamentous cords, or funiculi, are composed that hold in union with one another the otherwise disjointed fragments of the compound endoplast, as represented in the genera *Loxodes* and *Loxophyllum*.

That marked disparity of aspect and significance recorded of the infusorial endoplast, as compared with the ordinary histologic nucleus, is found to extend likewise to the nucleolus or endoplastule. In all ordinary tissue-cells this special structure is found to constitute an integral and essential constituent of the nucleus, of which organ it presents the appearance merely of a central, more solid, and opaque spheroidal fragment. With the majority of the Flagellata and some few Ciliata, such as *Pleuronema* and its allies, and many of the Chilodontidæ, a similar contour and relationship with the associated nucleus or endoplast is maintained ; but among the greater portion of the representatives of this last-named group an altogether different plan of arrangement is found to obtain. The nucleolus or endoplastule is, in these, no longer immersed within the substance of the nucleus or endoplast, but attached to its external periphery, or, it may be, completely isolated from it. Familiar instances of such simple lateral attachment of the endoplastule are afforded by the genera *Paramecium*, *Balantidium*, and *Nyctotherus ;* this phenomenon, however, attains its most conspicuous development among the Oxytrichidæ and other Hypotricha, in which the endoplast, as before stated, is usually represented in duplicate, and each independent element accompanied by a sometimes adherent and sometimes detached, minute, oval endoplastule. In *Stylonychia mytilus*, mostly pending the process of multiplication by binary subdivision, two or even three endoplastular fragments are sometimes found associated with a single endoplastic element. The most abnormal conditions and aspect of the endoplastule are perhaps, however, developed in the Hypotrichous form *Loxodes rostrum*, and in which, as shown by Wrzesniowski, the endoplastic system is represented by a dozen or more spheroidal elements, held in intimate union with each other, but at distant intervals, by a connecting thread-like cord. Within the centre of each of these spheroidal fragments a distinct central endoplastule was made visible through the employment of reagents ; while, in addition, a supplementary but external series of similar endoplastule-like bodies was found attached, in some instances singly to the external surface of the endoplast, and sometimes to the connecting cord or funiculus. In that series of Infusoria including chiefly the Vorticellidæ and Stentoridæ, in which the endoplast presents a ribbon-shaped or band-like outline, the endoplastular element is mostly represented by scattered granular fragments, one or more of which become enclosed within each of the segmental portions into which the endoplast becomes separated during the process of reproduction by internal gemmation, described later on. The several interpretations concerning the true significance of the endoplastule, as advocated by different authorities, being more fully discussed in the section devoted to the reproductive manifestations of the class, it suffices to add here that where this structure is developed externally to, or separate from, the accompanying endoplast, recent investigation has not yielded evidence in support of its fulfilling the part of a male generative organ or testis, as hitherto generally supposed, but rather indicates that its nature and import are essentially identical with those of the endoplast itself, and whose place and functions it ultimately supplies.

An approximate estimate of the innumerable modifications of the endoplast and endoplastule of the infusorial body as now enumerated may be obtained on reference to the supplementary plate (Pl. XLIX.) devoted especially to the illustration of these and kindred structures.

Colouring Matters.

Under the above denomination necessarily fall those pigmentary substances which in their diffused state impart, in many instances, a supplementary characteristic and easily recognized feature of distinction, and also those anteriorly located coloured corpuscles, of diverse size and number, so conspicuously represented in the families of the Euglenidæ and Chloromonadidæ. To these latter structures, on account of their aspect and position, a visual function was not unnaturally attributed by the earlier authorities, Ehrenberg first figuring and describing them as veritable optic organs, while at the present day they retain the title of eye-like pigment-spots. It is now, however, generally conceded that these characteristic structures are altogether innocent of the exalted function first assigned them, and that their true structure and composition are merely oleaginous or pigmentary, according essentially with the isolated coloured corpuscles possessed by numerous undoubted unicellular plants or Protophytes. The unessential nature of these bodies, and the entire absence from them of all the phenomena usually exhibited by so complex and highly organized a structure as an eye, is amply demonstrated by the exceedingly variable conditions under which they make their appearance, even among individuals of the same species. Thus, while in *Euglena viridis* one such characteristic eye-like pigment-spot represents the normal development, two or even three such corpuscles not unfrequently occur, while in yet a third series it may be entirely suppressed. Although these characteristic pigment-corpuscles are most abundantly represented among the members of the Flagellata, they occur occasionally among the Ciliate section, as prominently illustrated in the genus *Ophryoglena*, while according to Claparède and Lachmann, such a structure is likewise present in the earlier and free-swimming condition of *Freia* (*Follicularia*) *elegans*. The Flagellate genus *Distigma* would seem to be the only type among the Infusoria in which two pigmentary corpuscles are persistently developed, in all other forms a single one only being normally present. Excepting in the case of *Ophryoglena*, in which the pigment-spot is almost black, a brilliant crimson or scarlet hue is found to predominate. No trace of these supplementary coloured corpuscles have been yet recorded in association with the representatives of the Tentaculifera.

Colouring matter in a diffused state, or as forming an integral element of the entire body-substance, while not very generally developed, constitutes in certain types a conspicuous and highly characteristic feature. The Flagellate group of the Euglenidæ, distinguished for the brilliant green hue of the entire subcuticular parenchyma, affords perhaps the most pre-eminent examples of such diffuse coloration. The chlorophylloid nature of the pigmentary matter, or "endochrome" as it may be appropriately designated in these instances, is so evident that its presence has long been held to indicate their essentially vegetable nature, and but for the recent demonstration by Stein and the present author, of a well-developed oral aperture and accompanying capacity to ingest solid food, would yet furnish a solid argument in support of such interpretation. Between the green colouring matter of an *Euglena* and that of a Palmellaceous plant or protophyte, such as *Protococcus*, there would appear to be absolutely no distinction, the same substances in both cases exhibiting, furthermore, a tendency, at a certain epoch of their existence, to assume a more or less conspicuous red or crimson tint. This last-named phenomenon is especially characteristic of the type figured and described by Ehrenberg under the title of *Astasia* (*Euglena*) *sanguinea*, the rapid change of colour from green to red in which has doubtless given rise in many instances to the legendary accounts in rural districts of the conversion of standing water into blood, and has even been suggested by Ehrenberg as yielding an intelligible interpretation of that mysterious "turning of the waters into blood," which distinguished the visitation of the first Egyptian plague. Green colouring matter closely allied to, if not absolutely identical with the chlorophyll of vegetable organisms, is found, though in a more distinctly granular or less diffuse state, in many other infusorial groups. Instances in this connection are afforded by various *Peridinia*, but especially by *Paramecium chrysalis*, in which the greater part of the chlorophyll-like endoplasmic granules exhibit, as previously related, a characteristic circulatory motion. In the green variety of *Stentor polymorphus* it has been shown by Professor E. Ray Lankester that the absorption-bands yielded on examination with the microspectroscope, correspond closely with those given by the green colouring matter of *Hydra viridis* and *Spongilla*, and indicate the presence of an essentially chlorophylloid body. Various other species of *Stentor* are also remarkable for the brilliant colouring of their inner parenchyma, the pigmentary matter being distributed in a granular form throughout its substance, and exhibiting in some cases, such as *S. castaneus*, under a high magnifying power, two distinct and easily recognized tints. The most anomalous hue yet recorded is, perhaps, associated with *Stentor cæruleus*, in which the dispersed pigment-granules are of a brilliant and intense blue. Submitted to spectroscopic analysis, the absorption-bands yielded by the bodies of this species, either singly or *en masse*, were found, by the author above quoted, to differ so remarkably from those of any other known organic substance, that he has proposed to distinguish it by the suggestive title of "stentorin." *

In a number of animalcules, equalling if not exceeding what may be termed the chlorophyllaceous series, the parenchyma is found to yield a colouring matter—mostly diffuse, as in the green colour of an *Euglena*—the fundamental hue of which is brown, but varies from pale amber or orange to a deep olive. In this latter instance the aspect of the pigmentary matter closely approaches that of "diatomin" or the essential olive-brown

* "On Blue Stentorin," E. Ray Lankester, 'Quart. Journal Micro. Science,' April 1873.

colouring matter of the Diatomaceæ; while in the pale and more decidedly yellow examples, a nearer approximation is perhaps made to "phycochrome," or to the yellow colouring matter of various lower algæ. Among the most conspicuous examples of this yellow and brown-coloured series may be mentioned the majority of the Cilio-Flagellate group of the Peridiniidæ, and a very considerable proportion of the Tentaculifera or Acinetidæ. Similar yellow or olive pigment matter is likewise met with among a large number of typical Flagellata, such as *Dinobryon*, *Microglena*, and *Chrysopyxis*, but is remarkable in all these types for its limitation to two lateral band-like areas—a circumstance which has been accepted by the author as justifying their collection into the single family group here distinguished by the title of the Chloromonadidæ.

As illustrations of Ciliate forms in which the colouring hue presents abnormally marked features, reference may be made more especially to the *Leucophrys* (*Holophrya*) *sanguinea* of Ehrenberg, in which the parenchyma is of a bright crimson colour, and *Nassula ornata*, in which numerous vesiculæ of a brilliant violet tint are found distributed throughout the same element. In this latter instance, however, the colouring matter does not represent an essential constituent of the body-substance, but is due to a reaction of the associated juices upon the ingested food-material. An interesting example of the occurrence of fine granular matter, differing in colour from the surrounding protoplasm, is yielded by the *Monas* (*Spumella*) *vivipara* of Ehrenberg, in which such granules are exceedingly minute, of a bright red hue, and exhibit a constant vibratory and apparently purely mechanical or "Brownian" movement. Minute coloured granules of a brilliant crimson hue are also found embedded in the contractile element of the stem of *Vorticella picta*.

Although possessing no claim for consideration as supplementary colouring substance, it may be most appropriately remarked here that in all of the exceedingly minute collar-bearing monads, or Choano-Flagellata, a pale glaucous or fluorescent hue prevails, that assists materially in the recognition of their presence, even where the magnifying power employed is insufficient to render the characteristic membranous collar clearly visible. A similar pale green or glaucous tint is exhibited also by many species of Bacteria, and would appear to represent the predominating refractive index of abnormally minute protoplasmic bodies.

Accessory Structures—Trichocysts.

First in importance among the supplementary and non-essential elements associated with the Infusorial economy, have to be described those remarkable bodies, recurring under a variety of aspects and conditions, known as "trichocysts." These structures exist in their most characteristic form in the very cosmopolitan species *Paramecium aurelia*, taking there the form of minute and exceedingly slender rod-like bodies, or fibrillæ, crowded together and distributed in an even layer immediately beneath the cuticle throughout the whole extent of the cortex, their disposition with respect to the external periphery being everywhere perpendicular. Under certain conditions, including the application of artificial stimuli, such as weak acetic acid, these trichocysts become suddenly elongated, and their distal ends piercing the overlying cuticle stand out like fine, stiff, hair-like setæ, beyond the cilia, around the entire circumference of the animalcule, frequently becoming entirely separated from their base of attachment. The names of Ehrenberg and Oscar Schmidt are most usually associated with the earliest discovery of these special structures, the first-named authority having recorded their presence in *Bursaria* (*Panophrys*) *vernalis* so long ago as the year 1832, and in which connection they are figured and described as minute prismatic rod-like bodies embedded beneath the cilia in the body-substance. By Oscar Schmidt, in the year 1849, similar rod-like bodies were reported to occur in *Bursaria* (*Panophrys*) *leucas*, and *Paramecium aurelia*, their close correspondence with the rod-like bodies possessed by various Turbellaria being indicated. It has been recently elicited, however, by the present author that the existence of these trichocysts in *Paramecium aurelia* was discovered, and their characteristic aspect when extended figured and described, by our distinguished countryman John Ellis, more than a century ago, and at a time when microscopical science was quite in its infancy. With the imperfect magnifying apparatus employed by this investigator it was not possible to recognize the fine vibratile cilia by which the ordinary motions of the animalcule are accomplished, a circumstance which led him to attribute such a special function to the bodies in question; this, however, in no way detracts from his merit as their first discoverer. Ellis's account of these trichocysts being of high intrinsic as well as classic interest, its reproduction *in extenso* is herewith appended. After recording his discovery of the locomotive organs, or cilia which he denominates "minute fins," in various species of Infusoria, which he sagaciously compares with the natatory organs or cilia then recently described by Linnæus as characteristic of the Cœlenterate genus *Beroe*, he proceeds to say:—

"I have lately found out, by mere accident, a method to make their fins (cilia) appear very distinctly, especially in the larger kind of animalcula, which are common to most vegetable infusions, such as the Terebrella (*Paramecium*); this has a longish body, with a cavity or groove at one end, like a gimlet. By applying a small stalk of the horseshoe geranium, *G. zonale*, Linn., fresh broken, to a drop of water in which these animalcules are swimming, we shall find that they become torpid instantly, contracting themselves into an oblong-oval shape, with their fins extended like so many bristles all round their bodies; the fins are in length about half the diameter of the middle of their bodies. Before I discovered this experiment, I tried to kill them by different kinds of salts and spirits, but though they were destroyed by this means, their fins were so contracted that I could not discover them in the least. After lying in this state of torpidity two or three minutes, if a drop of clean water is applied to them, they will recover their shape and swim about immediately, rendering their fins again invisible."

From the foregoing account, as it appears in the 'Philosophical Transactions,' vol. lix., for the year 1769, there cannot be the slightest doubt that the bristle-like "fins," made suddenly to appear by the application of the acrid geranium juice, are identical with the fine setaceous trichocysts characteristic of the species described on a preceding page, any doubts that might exist upon this subject being at once dissipated on reference to the characteristic illustrations of the animalcule accompanying Ellis's description, and embodied in Table VI., Fig. 5, *a*, *b*, *c*, and *d* of the volume quoted. In the above connection John Ellis has, however, not only to be accredited with the first discovery of these supplementary structures, but, through the application of the special means by which he effected such discovery, he takes rank as one of the first to make successful use of reagents, now so widely employed in the elucidation of the more minute histology of the Infusoria. In this direction, nevertheless, and as recorded at page 114, Ellis was to some extent anticipated by another Englishman, Sir Edmund King, at so early a date as the year 1693.

The demonstration of the precise nature of trichocysts, and the connection with them of their now generally recognized and characteristic title, belongs to a comparatively recent epoch. In this instance also, however, an Englishman is to the fore, such demonstration and titular denomination having been accomplished at the hands of the present distinguished President of the Linnean Society, Professor G. J. Allman, who, in the 'Journal of Microscopical Science' for the year 1855, described at considerable length the more minute characters and phenomena presented by these bodies as met with in *Bursaria* (*Panophrys*) *leucas*. Here, as recorded by him in the publication quoted, the trichocysts, now so-called for the first time, were found to exhibit the aspect of minute fusiform bodies embedded thickly and on a perpendicular plan of arrangement, as in the manner already described of *Paramecium*. Under external irritation, such as the drying away of the surrounding water, the application of acetic acid, or forcible compression, they became similarly and suddenly transformed into long, fine, hair-like filaments or setæ, which projected from the whole periphery. The rapidity with which the transformation from the fusiform to the filamentous condition was effected, combined with the greater minuteness and transparency of the objects examined, hindered for a considerable while the recognition of the exact manner in which the process was accomplished. At length, by carefully crushing examples and isolating the trichocysts in their normal and fusiform condition, it was found that these latter, after the lapse of a few seconds, became all at once changed with a peculiar jerk, as if by the sudden release of some previous state of tension, and assumed through this change a minute spheroidal shape. After remaining in this condition for two or three seconds longer, a spiral filament was next observed to become rapidly evolved from the sphere, apparently through the rupture of a previously confining membrane, the filament winding itself with such rapidity that the eye could scarcely follow it, and being finally extended straight and rigid on the field of the microscope, under the form of a very fine and attenuate acicular crystal. In their most completely extended state these bodies were found to consist of an elongate and rigid spiculum-like moiety, acutely pointed at one extremity and continuous at the opposite end into an excessively fine filiform appendage, less than half the length of the spiculum; this second portion was usually observed to be bent at an angle upon the first, and to be more or less curved at its free end. The considerable structural resemblance that subsists between the trichocysts of the Infusoria as just described, and the cnidæ or thread-cells of the Cœlenterata or Zoophyte class, was at the time recognized by Professor Allman, and the circumstance has been cited on various occasions as producing strong evidence against the more recently advocated unicellular nature of the Infusoria. The non-validity of this argument is, however, at once made manifest on regard being given to the fact that the thread-cells, even as they occur among the Cœlenterata, do not possess the independent morphologic value of simple cells, many such being frequently enclosed within the bounding membrane of a single cellular element, and of which they are therefore to be regarded as the secreted product. In other words, as maintained by Professor Allman, " the formative Cœlenterate cell may in this respect be compared with the entire body of the Infusorium." According to Bütschli, the trichocysts in certain forms, including a species of *Nassula*, emit a filament at each extremity of the previously enclosing capsule instead of at one end only, as in the more normal case last described. This investigator has suggested that such a double emission is probably exhibited by the trichocysts of all Infusoria, and which in that case affords a means of distinction between these latter and the genuine thread-cells of the Cœlenterata; this hypothesis has not, however, been confirmed by more recent investigation. The trichocysts of abnormal size, exhibiting an entirely irregular distribution, reported by Bütschli of *Polykrikos Swartzii*, are apparently, as explained in the account given of the species, accidentally engulphed thread-cells only of some neighbouring Cœlenterate organism. Although more generally trichocysts occur, as in the cases of *Paramecium* and *Ophryoglena*, as an even and crowded series beneath the entire cuticular surface, in others, such as *Litonotus* and *Loxophyllum*, they present a limited and definite plan of distribution. Thus, in the former genus they form a conspicuous linear series confined entirely to the ventral aspect of the proboscidiform anterior prolongation, while in certain representatives of the latter they exhibit a partly linear and partly fasciculate arrangement. Although with but few exceptions the special bodies now under consideration are entirely limited to the Ciliate section of the Infusoria, Stein has recently shown that the *Monas* (*Raphidomonas*) *semen* of Ehrenberg possesses these structures variously distributed throughout the cortical region, but most abundantly along the anterior border, while a doubtful case of their occurrence in a marine Acinete form has been recorded by Lachmann. Opinions with respect to the functions of the trichocysts of the Infusoria are not entirely in accord, some relegating to them, as with the thread-cells of the Cœlenterata, an offensive and defensive, and others a simply tactile property: the balance of evidence would appear to be in favour of the former interpretation.

Amylaceous Corpuscles.

Those bodies of an apparently amylaceous or starch-like nature, included under the above title, possess a very limited distribution, occurring, so far as is at present known, only among the Flagellata and in relationship with the family of the Euglenidæ, already cited as most conspicuously distinguished for the possession of eye-like pigment-spots. In the genus *Euglena*, which is especially remarkable for the development of these structures, they are found, moreover, to present a distinct and varied form in the separate species, which consequently derive from their possession supplementary characteristics of some value for specific diagnosis. The more ordinary contour of these amylaceous corpuscles is oblong or elongate-quadrate, but varies in such types as *Euglena acus* and *E. deses* to bacillate, or even acicular. In some forms, such as *E. spirogyra* and *E. oxyurus*, there are more usually only two such corpuscles, one at each extremity, of large size, and exhibiting a more opaque centre and pellucid external zone, while in the two first-named types they are more generally numerous, and present a homogeneous and semi-opaque consistence. In certain instances they appear to multiply by division within the animalcule's body, and, contrary to the structures previously described, appear to lie loose within the central endoplasmic element, instead of being enclosed inside the cortical layer or ectoplasm. The precise nature and significance of these peculiar bodies have yet to be elucidated.

Decomposition or Diffluence.

Some remarkable phenomena connected with the manner in which, under various uncongenial conditions, the soft sarcode bodies of the Infusoria become more or less rapidly disintegrated, require brief notice. Artificially, through the addition to the water of a little ammonia or other reagent, or naturally, by permitting the same water to evaporate, certain species possessing a non-indurated integument, such as the representatives of the genera *Oxytricha*, *Trichoda*, and *Enchelys*, may be observed to fall bodily to pieces, or, decomposition commencing at one point gradually spreads throughout the entire organism, granular or globular portions becoming successively detached, until at length the entire body has been as it were consumed. At any point, however, by the addition of a fresh supply of oxygenated water, this action of decomposition may be permanently arrested, and the animalcule, or such larger portion or portions of it that remain, redevelop within the course of a few hours to the size and form of the normal zooid. In *Vorticella, Paramecium,* and other hard-skinned Infusoria a closely similar phenomenon of decomposition is manifested under like conditions through the extension at various points of the cuticle of globules of sarcode, this process, if not artificially or otherwise arrested, continuing until the entire endoplasm has become dissipated. Among the more minute monadiform animalcules a parallel form of disintegration is preceded by the assumption of an entirely irregular and mostly amœbiform contour, closely corresponding with such as accompanies the processes of fusion or encystment; the type *Monas diffluens*, figured and described later on, affords a suitable example of this last-named phase. Collectively, the very appropriate name of "diffluence" has been applied by Dujardin to these several closely identical modes of decomposition here enumerated. Similar phenomena, however, as they occur among the Ciliata were long before observed by O. F. Müller, who described them under the several titles of "molecular effusion" and "dissolution." In certain exceptional instances, including notably *Halteria grandinella* and its allies, an apparent modification of the process of diffluence is exhibited by the animalcule bursting suddenly to fragments in its mid career, without any accompanying visible causes of irritation.

REPRODUCTIVE PHENOMENA.

Binary Division or Fission.

This mode of reproduction represents not only the earliest recognized and most widely distributed, but undoubtedly that also by which under normal conditions the specific infusorial form is most abundantly propagated. As in all of the manifold structural aspects previously discussed, the infusorian body reproduces, with diverse modifications, the structural and functional features only of a simple cell, so likewise this special mode of multiplication is found to be a mere reflex of the ordinary reproductive phenomena exhibited by the cellular elements or units of all higher tissue structures. In these, from the most simple to the most complex, the increase in size or growth of the tissue is effected through the indefinite increase by binary or duplicative division of the specific type of cells of which it is composed. The astonishingly rapid growth of certain cellular tissues or structures, through such constantly repeated binary division of the constituent cells, is too familiar for recapitulation, and almost equally extraordinary figures are attained in connection with the multiplication of the independent unicellular bodies of the Infusoria through this simple process. Thus, Ehrenberg long since computed that in the case of *Stylonychia mytilus*, no less than one million of independent beings were derived through the simple and repeated fission of a single zooid in the course of ten days, while in that of *Paramecium aurelia*, he reckoned that as many as 268 millions might be similarly developed within the space of a single month. Substantial evidence of the prodigious numbers that may be produced by this simple reproductive mode is afforded by the various species belonging to both the Ciliate and Flagellate sections of Infusoria that are characterized by their sedentary and colonial mode of growth, each colony-stock under such conditions representing the sum total of the repeated binary subdivision of a primary single unicellular zooid. *Ophrydium versatile* constructs in such a manner aggregated masses, derived primarily from a single animalcule, that vary in size from that of a walnut to a child's head, while *Epistylis grandis* similarly produces on submerged plants, or the walls of an aquarium, what appear to the unassisted vision as homogeneous slime-like masses of many feet in extent. Correspondingly derived colonial aggregations, though on a somewhat smaller scale, are encountered among the several Flagellate genera *Dendromonas*, *Spongomonas*, *Phalansterium*, and *Anthophysa*, while in the group of the Spongida, that must be regarded as peculiarly modified colonial aggregations of such Flagellate types as *Codosiga* and *Phalansterium*, a composite structure is produced by a chiefly though not entirely similar process, which in many cases far exceeds in bulk the extensive colonies of the several Ciliate forms first quoted.

The phenomena of multiplication by binary division or fission are found to manifest several characteristic modifications. With the majority of species such division takes a cross-wise or transverse direction, a groove or constriction making its appearance towards the centre of the body, and becoming gradually deeper and deeper, until at length the anterior and posterior halves become entirely separated from one another, each swimming off as an independent animalcule, and such organs as might be wanting to either separated moiety becoming rapidly developed. In a somewhat smaller, but still pretty considerable assemblage of types, the process of fission is manifested in a precisely opposite or longitudinal direction. Such a plan of multiplication is more essentially characteristic of the large group of the Vorticellidæ, and those representatives of the Flagellata, in which, as with many of the former, a compound tree-like colony-stock is built up. Illustrations among these latter are especially afforded by such genera as *Codosiga*, *Dendromonas*, and *Rhipidodendron*. The compound zoothecium of *Dinobryon*, while at first sight apparently constructed by means of a similar reproductive formula, is the product of transverse fission, each anteriorly separated zooid utilizing the wall of the lorica it quits as the fulcrum of attachment of its own independently constructed domicile. The most remarkable modification of longitudinal fission is perhaps furnished by the collared Flagellate genus *Desmarella*, and in which the variable number of zooids developed by this process remain laterally attached in such a manner as to form a more or less elongate necklace-like series. In the genus *Vorticella* and its allies, as hereafter recorded, the process of fission is always preceded by the closing up and entire obliteration of the primary oral system, two new ones subsequently appearing in its place.

In a third, but comparatively very small number of Infusorial forms, neither a transverse nor longitudinal mode of fission is met with, but one that takes an entirely oblique direction. The Ciliate genera *Stentor* and *Lagenophrys*, and the new Flagellate type described in this volume under the title of *Anchomonas sigmoides*, are among the most noteworthy examples of this somewhat aberrant process. Although it usually happens that all of these various phenomena of multiplication by simple binary division now enumerated are accomplished during the active life of the animalcule, it not unfrequently happens that a quiescent or encysted condition, as described at page 63, is specially entered upon for the fulfilment of this purpose. Illustrations of this developmental phase are afforded by *Amphileptus meleagris*, *Otostoma Carteri*, *Euglena viridis*, and many other Flagellata. The appearances exhibited in certain of these cases more nearly coincide, however, with the sporular conditions discussed later on. In all instances, it would seem that the duplication of the infusorial body by the process of binary division is, as with the similar multiplication of the cells of ordinary tissue structures, accompanied, or rather preceded as an initial act, by the subdivision of the nucleus or endoplast. Other organs, such as the contractile-vesicle and oral or anal structures and appendages, are not so divided, but are independently developed in that moiety in which previous to subdivision they were unrepresented.

External and Internal Gemmation.

The phenomenon of reproduction by "external gemmation," although represented in tolerable abundance among the present organic group, occurs by no means so generally as was formerly supposed. Up to within a comparatively recent date that larger or smaller bud-like body, not unfrequently found attached to the lateral periphery of various members of the Vorticellidæ, and also the secondary pendent zooid, which, while first attached to, finally breaks away from the parental stem, were premised to be examples of such gemmation. In both of these cases, however, the so-called gemmule is derived through a modification of the process of binary fission, previously described, from an ordinary zooid, though in the former instance the association is fortuitous, and, as hereafter shown, has a peculiar significance. Instances of true external gemmation are, nevertheless, afforded by such types as *Spirochona*, and apparently also *Lagenophrys* among the Ciliata, while among the Tentaculifera, *Hemiophrya* (*Podophrya*) *gemmipera* and the various species of *Ophryodendron*, more especially *O. multicapitata*, supply prominent examples of this phenomenon. In the majority of the cases mentioned it has been recently demonstrated that a diverticulum of the endoplast accompanies the outgrowth of the body-substance, forming the characteristic bud, and becomes separated off and enclosed within the latter on its detachment from the parent stock. The most remarkable modification of external gemmation is afforded perhaps by certain Opalinidæ, in which, as exemplified by the *Anoplophrya prolifera* of Claparède and Lachmann, a long series of buds are developed simultaneously at the posterior extremity, and become successively detached from the parent zooid after the manner of the buds or "proglottides" of a cestoid worm. A highly remarkable modification of the process of external gemmation is exhibited by the Flagellate type *Noctiluca miliaris.* Here, as demonstrated more especially by the recent investigations of Cienkowski, the entire subcuticular protoplasm becomes broken up into nodular fragments which are protruded upon the external surface under various conditions of disposition, and are finally liberated from the parent sphere as simple monadiform bodies.

"Internal gemmation" in its most typical condition may be described as a modification only of the previous process. As in the latter case a portion of the endoplast is separated off and enclosed within a portion of the parent substance, but the gemmule or so-called embryo thus produced is retained within the parental body until matured, in place of remaining affixed to its outer wall. Such typical internal gemmation is most abundantly represented among the Tentaculifera, as instanced by the more ordinary *Acinetæ*, and various species of *Podophrya* and *Dendrocometes.* A modification of this form of internal gemmation is also undoubtedly represented among those numerous types of the Ciliata, such as *Stentor*, *Spirostomum*, and many Vorticellidæ in which embryos or, more correctly speaking, internal gemmules become separated from the more or less elongate endoplast, which may be properly characterized in this connection as an internal proliferous stolon. In all of these last-named cases it is, however, necessary to remark that the internal gemmules so formed are constructed entirely from the substance of the endoplast, and contain no fragment of the surrounding body-substance. In that peculiar form of reproduction recently recorded by Stein of various Euglenidæ, Anisonemidæ, and other Flagellata, in which young are produced through the enlargement and subdivision of the endoplastic element into one or more germinal masses, the phenomena manifested closely correspond with those last related, but at the same time lead the way to that more general mode of propagation among the Flagellata which is next described.

Sporular Multiplication.

Under the above-named denomination are correlated by the author all those reproductive phases connected with the assumption by the individual animalcule of a quiescent or encysted condition, accompanied by the subsequent partition of the entire primitive mass into a greater or less number of spore-like bodies. In those instances in which the sporuloid bodies so produced may be easily reckoned, and do not exceed the numbers of two, four, eight, sixteen, or thirty-two, they may be appropriately termed "macrospores," while in those instances in which there is an excess of this last-named number, and may be described as innumerable, they may be conveniently denominated "microspores." In extreme cases many thousands of these last-named bodies may be included within the parent capsule or "sporocyst," their individual calibre being so minute as to be inappreciable even with the highest constructed powers of the compound microscope. Whether microspores or macrospores, each segmented particle ultimately develops to the parent form. The demonstrated existence to any considerable extent of this sporular form of multiplication is connected with the results of the most recent investigation, many of the facts testifying to the universal prevalence of such phenomenon being now published, indeed, for the first time. Among the higher orders of the class Infusoria sporular reproduction is comparatively rare, being as yet almost unknown among the groups of the Tentaculifera, while in that of the Ciliata a few stray instances can alone be cited. It is in that lower section of the class distinguished by the flagelliform character of their locomotive appendages that spore-formation attains its most vigorous development, it representing among these, in fact, in many instances the most general and prolific form of propagation. Quoting those few instances in which spore-production in its true sense occurs among the Ciliata, mention may be made of *Colpoda cucullulus*, in which, as demonstrated by Stein many years since*—though then reported as cases of simple encystment—the encapsuled zooids became divided into two, four, or eight spore-like bodies or macrospores, each having a separate membranous investment; these give exit to animalcules of smaller size, but which in other respects preserve all the characteristics of the parent form. Phenomena closely corresponding with those related of *Colpoda* have also been observed by Mr. Carter in the Holotrichous genus *Otostoma*, and still more recently by the author previously quoted in connection with *Prorodon teres* and *Panophrys flava*. The only instance as yet placed on record in which an encysted Ciliate animalcule becomes divided into segments so numerous as to fall within the denomination of microspores is afforded by the type recently described by Fouquet under the title of *Ichthyopthirius multifiliis*, the encapsuled zooid in this instance dividing up into at least several hundred spore-like fragments. The products of these spores, when first excluded from their cyst or capsule, differ considerably from the parent animalcule, but by degrees acquire an identical aspect and character. Arriving at the Flagellate section of the infusorial class, the difficulty is rather to indicate types in which a sporuloid phase does not more or less frequently intervene. In consequence of the searching scrutiny that has been directed of late years upon this previously all but neglected group, the life-histories and reproductive phenomena of its members are in many instances more completely known than that of the more highly organized Ciliata.

* 'Die Infusionsthiere,' 1854.

The investigator, to whom credit is due for first demonstrating the sporiparous mode of multiplication among the Flagellata, and for indicating with reference to such peculiarity the close approach made by this group to the Palmellaceæ and other Protophytes, is without doubt Professor L. Cienkowski, who in the year 1865 * figured and described at length such sporular multiplication in connection with his *Monas* (*Heteromita*) *amyli*, various species of his newly founded genus *Pseudospora*, and several types of ordinary Rhizopoda. Although he discovered such developmental phenomena, Cienkowski, however, scarcely attributed to them the interpretation here adopted, the quiescent or encysted condition and transitional amœboid phases being treated by him as more essential and characteristic than the motile flagelliform bodies issuing from the spores, named by him "zoospores," and which certainly represent the typical form of expression of the species in its most mature condition. Not only, however, did Cienkowski recognize the respective natatory or flagelliform, amœboid or repent, and quiescent or sporular conditions of the above-named types, but he also witnessed the conjugation or coalescence in several instances of two or more zooids during the amœboid stage, and the construction by them of a single sporocyst. In connection with this last-named phenomenon, he sagaciously recognized the close approach made to the construction of the compound plasmodium of the Myxomycetes, at that time the subject of special observation by de Bary and himself, and to a certain extent, also, anticipated the more prominent points in the life-history of certain monadiform species revealed a few years later through the painstaking investigations of our own countrymen, Messrs. Dallinger and Drysdale. Full details of the somewhat varying phenomena presented by the diverse types examined by these two authorities being recorded in connection with the systematic descriptions of the Flagellata given further on, and among which may be more especially cited such forms as *Monas Dallingerii*, *Cercomonas typica*, and *Heteromita uncinata*, it will suffice here to indicate that Messrs. Dallinger and Drysdale established in every instance the interpolation among the ordinary mode of multiplication by binary division of a spore-producing phase, accompanied by the assumption of the individual zooid of a resting or encysted state. Preceding such encystment a transitory repent amœboid condition was usually exhibited, and was in most instances accompanied by the coalescence of two or more such amœboid units. In certain cases the sporular bodies so produced were of such a size and number as to fall under the category of macrospores, while in a few others they were of such excessive minuteness and corresponding numbers as to defy individual definition with the magnifying power of 15,000 diameters brought to bear upon them with the aid of a $\frac{1}{50}$-inch objective. These three leading phases in the life-history of a Monad, as above enumerated, and which may be respectively denominated the active flagelliferous, the transitory amœboid,

* 'Arch. f. Mik. Anat.,' Bd. i.

and the quiescent sporocyst states, the first yielding the essential and specific form, are now found to obtain throughout the majority of the Flagellata. Simultaneously with, and in many instances anterior to, the publication of Messrs. Dallinger and Drysdale's researches, corresponding phenomena had been observed and duly recorded by the present author in relation with the representatives of the Choano-Flagellata or collar-bearing section, and other more simply organized Flagellata. Like results have also accompanied his more recent investigations, while confirmatory evidence in the same direction is abundantly afforded in the magnificent volume devoted to the illustration of the Flagellata generally, lately published by Professor Stein. As examples of the persistence of the three above-named characteristic phases in the group of the Choano-Flagellata, reference may be more especially made to the systematic descriptions and accompanying figures of such species as *Salpingœca amphoridium*, *S. fusiformis*, and *Codosiga botrytis*, in all of which the transitory amœboid phase is particularly remarkable. In all those Eustomatous Flagellata which, like *Phacus* and *Anisonema*, possess an indurated cuticle, the assumption of an amœboid condition would not be possible, and the animalcule previous to encystment and spore development merely loses its flagella, and assumes a quiescent state. In *Euglena* and its allies, including *Eutreptia*, the animalcules exhibit a transitory amœbiform, or, more correctly, a gregarine-like repent state immediately preceding the process of encystment. With the representatives of the two last-named genera it is further worthy of note that the initial condition of existence on emerging from the spore is likewise amœbiform and non-flagelliferous. Among the Choano-Flagellata this earliest stage is simply flagellate or monadiform, there being no trace of the characteristic collar, while in a larger series, including the majority of the Pantostomata, such initial phase, in all but size, corresponds essentially with the parent zooid.

Sexual or Genetic Reproduction.

Sexual reproduction in the broad acceptation of the term as belonging to the propagative phenomena of the higher animals or Metazoa, or, as up to within a comparatively recent date maintained by Balbiani and others to obtain among the members of the higher Ciliate section of Infusoria, and in either case involving the concourse of true and independently developed sexual cellular elements—ova and spermatozoa—remains, so far as it concerns all or any members of the class or classes now under discussion, entirely undemonstrable. Nor, the essentially unicellular nature or value of the infusorial organism, as here advocated, being once firmly and incontestably established, can a contrary verdict be anticipated! Notwithstanding, however, the apparently uncompromising verdict pronounced in the foregoing sentence, it will presently be shown that these Protozoic organisms, in essence if not in fact, fulfil a rôle of reproduction that corresponds most closely with this important function as it is met with in all Metazoic or multicellular structures. As already maintained in the description of that more common phase of multiplication which takes the form of constantly repeated binary division, the Infusoria through such mode of increase merely repeat in a separate and independent manner that process of cell-multiplication which characterises the normal growths of all tissue structures. By-and-by, however, in the case of the Metazoon or tissue organism, an epoch is arrived at when the component cells cease to exhibit their previous duplicative energy, the consequence being the gradual decay and ultimate dissolution or death of the entire organism. But for the interposition of a special and more or less periodical regenerative act, this termination of the life of the individual would also, sooner or later, involve the extinction of the race or species. Such a regenerative act, and the further survival of the race, is, however, here accomplished through the fusion or union of one of that congeries of cells out of which the compound organism is composed with one other exteriorly derived cell liberated from another organism or congeries of cells pertaining to the same specific type. The result of such fusion between these two, denominated respectively the germ-cell and sperm-cell, or, in other words, the ovum and spermatic cell or element, is the capacity conferred upon the former of once more proceeding with the duplicative process, and repeating that cycle of cell-aggregation or tissue-construction followed by the parent organism. In a precisely similar manner, the infusorial body, after repeated duplicative multiplication, arrives at a condition in which the strain or race is too exhausted for the further maintenance of this process, and without the intervention of some supplementary regenerative operation would become extinct. By, however, the coalescence or fusion of one of these individual cells or animalcules with an elemental cell or animalcule derived from a neighbouring race or strain, the capacity to continue the duplicative process is revived, and the further duration of the race secured. The two animalcules thus uniting with one another correspond to all intents and purposes with the coalescing germ-cell and sperm-cell, or ovum and spermatozoon of the higher tissue organisms, the only essential point of divergence being in the subsequent changes manifested; the organism in the latter instance exhibits a tendency to build out of the cells amassed by the duplicative process, more or less complex coherent tissues, while in the former each cell so produced maintains a separate and independent existence.

Among the extensive series of types included in the infusorial classes, the phenomenon of "conjugation," "fusion," or "zygosis," as it is variously called, and which undoubtedly represents the sexual or genetic reproductive process of the higher animals in its most simplified or elementary form of expression, exhibits certain well-defined modifications. With the majority of the more highly organized Ciliata, such conjugation has to be denominated, as compared with the form next described, transient and incomplete, being, as illustrated by the generic type *Paramecium*, accompanied by the following manifestations. Two previously independent and free-swimming zooids meeting one another, become locked together through the close application and apparently intimate union or coalescence of their two oral or ventral surfaces, the aspect presented by the united couple coinciding closely with that of longitudinal fission as it occurs among many familiar types, and for which simple reproductive process it was originally mistaken by Ehrenberg and other early writers. This process of conjugation or fusion has in the present species been observed to extend over a period of five or six days, the two united animalcules swimming about in the interim with an amount of ease and activity scarcely inferior to that exhibited by the single and independent zooids. The genera *Bursaria*, *Blepharisma*, *Chilodon*, *Cyrtostomum*, and many other forms, exhibit conjugative phenomena closely identical with those presented by *Paramecium*, while in *Stylonychia* it would appear, according to Engelmann, that both the transient and the complete form of conjugation may be met with among individuals of the same species. In the normally stationary or attached genus *Stentor* the conjugative process is also transient, the contiguous animalcules, according to Balbiani, becoming temporarily united by their anteriorly located oral areas. A similar transient conjugative act has likewise been reported to obtain among the members of the genus *Podophrya*, but, as shown by the author in the case of *P. mollis*, such apparent act is not unfrequently attributable to the less complex process of multiplication by binary division.

The form of conjugation to be next enumerated is characterized by its complete and permanent duration. Two animalcules or zooids in this case become, as it were, so completely melted or welded together, that their previous individuality is entirely obliterated. Among the Ciliate section of the Infusoria, this special complete or entire conjugative phase is almost exclusively restricted to the Peritrichous family of the Vorticellidæ, but recurs occasionally in alternation with the partial or transient one in *Stylonychia* and other Hypotricha. The most prominent development of this permanent or complete type is undoubtedly met with in the Flagellate section of the series throughout the whole of which, as at present known, it would appear to constitute the one and only conjugative process. Most usually, among these Flagellata, this complete conjugative act is accompanied with the assumption by the coalescing individuals of an outline entirely at variance with the normal specific aspect. The flagella or other appendages are in this instance entirely withdrawn, and pseudopodic processes, like those of an *Amœba* or *Actinophrys*, extended for locomotive or prehensile purposes from various parts of the periphery. Succeeding such conjugation among the Flagellata, it most usually happens that the sporular reproductive phase, described on a preceding page, is immediately entered on, though that such conjugation is not imperatively associated with this spore-production has been demonstrated by the present author, in connection with *Heteromita angustata*, and various other species. As elicited by the recent investigations of Messrs. Dallinger and Drysdale, it occasionally happens that the coalescence of three or four or more metamorphosed or amœbiform Flagellate animalcules takes the place of the more ordinary conjugation of two zooids only. In this latter instance, as illustrated by the biflagellate type *Heteromita uncinata*, a close approximation is made towards that multiple coalescing process by which out of a number of similarly metamorphosed or flagellate zooids the compound amœbiform plasmodium of the Mycetozoa is built up ; a modification of this phenomenon would also, as hereafter shown, appear to accompany the construction of the compound locomotive gemmules, or so-called "ciliated larvæ" of the Spongida.

While the interpretation of the sexual or genetic reproductive phenomena of the Infusoria embodied in the earlier portion of this present section adapts itself most nearly to the data elicited by the most recent investigators, among whom the names of Engelmann and Bütschli are especially noteworthy, it by no means represents the one regarded with the greatest favour prior to the publication of the discoveries of these authorities, nor even yet, perhaps, the one at the present day most extensively maintained. From almost the earliest epoch of their history, the probable propagation of infusorial animalcules by a sexual or genetic process analogous to that which obtains among the higher animals has now and again been suggested. Such an interpretation was thus, though inaccurately, attributed by Sir Edmund King, in the year 1693, to the ordinary process of transverse fission witnessed by him in a species of *Euplotes*, while O. F. Müller, in his 'Animalcula Infusoria,' 1786, figured and described that conjugative process or genetic union of *Paramecium aurelia* since generally admitted, so far as the external features are concerned, to be substantially correct.

Passing over, for the present, that far-fetched and long since abandoned hypothesis advanced by Ehrenberg, in which the contractile vesicle was regarded as a spermatic reservoir engaged in the continued fecundation of closely associated ova, the far more practicable and intelligent one originating with Balbiani in the year 1858 may be cited. By this accomplished investigator it was at the foregoing date first pointed out that the hitherto supposed instances of longitudinal fission, as figured and described by Ehrenberg, of *Paramecium bursaria* and other free-swimming Ciliata, had nothing to do with such a duplicative process, but were indicative of a genetic union or conjugation between two individual zooids. Balbiani further maintained that the nucleus and nucleolus during such conjugative process became transformed into veritable sexual organs, of which the nucleus or endoplast, dividing up into a number of spheroidal fragments, performed the function of an "ovary," and the nucleolus or endoplastule in the same way, after first assuming a longitudinally striate aspect, and then separating into a number of rod-like spermatic elements, fulfilled that of a testis or "seminal capsule." During the process of conjugation, lasting in this species, according to Balbiani, five or six days, the nucleoli or seminal capsules were respectively exchanged, the so-called ovules in each animalcule being thus mutually fertilized on a plan corresponding with that exhibited by the Helicidæ and other monœcious Gasteropoda. These phenomena of fusion or genetic union, first reported of *Paramecium*, were recorded by the same observer as occurring in a variety of animalcules, and were soon, so far as the external circumstances were concerned, found to obtain very generally, but under varied conditions, the union being sometimes transitory and in others permanent, throughout the whole infusorial class. Among the authorities who, after devoting themselves specially to the investigation of this organic group, have arrived at conclusions confirming the discoveries of Balbiani, and have relegated to the nucleus and nucleolus the same respective genetic functions, may be mentioned the names of Kölliker, Stein, Claparède, and Lachmann, and, in a slightly modified manner, also Mr. Carter. This last-named author, however, previous to the discoveries of Balbiani,* attributed the production of spermatic elements to the nucleus, and that of germs or ovules to the general body-substance.

An examination may now be made of those recent discoveries of Engelmann and Bütschli which have resulted in the introduction of an entirely new train of thought respecting the reproductive properties of the Infusoria. After a prolonged and independent research, these two authors have, while admitting the conjugative process, been compelled to reject *in toto* Balbiani's interpretation assigning to the endoplast and endoplastule respectively the functions of an ovary and testis. The characteristic striated aspect exhibited by the endoplastule during conjugation is declared by them to be in no way connected with the production of spermatic elements, but to represent the normal aspect of both this structure and the nucleolus of the ordinary tissue-cell prior to the act of subdivision. Nuclei, in both animal and vegetable cells, are further maintained by them, and confirmed by the observations of Hertwig and Strassburger, to frequently exhibit a similar striated appearance and general likeness to the so-called "seminal capsules" of the Infusoria. Briefly epitomized, the general conclusions arrived at by Bütschli with reference to the conjugative process of the Infusoria are as follows:—During such process the original nucleus or endoplast in both animalcules breaks up into a number of fragmentary portions, and becomes lost among the endoplasm or general body-sarcode. By-and-by an entirely new endoplast is constructed through the gradual assemblage and union with each other of fragmentary particles having a similar general derivation, this newly found endoplast being single and common to the two in such instances as *Vorticella*, where conjugation or fusion is complete and permanent, while two or more, according to the normal number, are reproduced where such conjugation is, as in *Paramecium*, partial and transient. In the case of *Stylonychia mytilus* it is further affirmed

* H. J. Carter, "Notes on the Freshwater Infusoria of Bombay," 'Ann. and Mag. Nat. Hist.,' Ser. ii. Nos. civ. and cv. 1856.

by Bütschli that the endoplast of each individual divides, during conjugation, into four fragments, which, becoming rounded into a form corresponding with the so-called "ovules" of Balbiani, are cast out of the body as "waste matter." The same destiny is likewise attributed by him to one out of the four fragments into which the endoplastule becomes divided—two remaining to represent the normal complement of these structures, and the residual one assuming first a more considerable volume and transparent aspect, and ultimately redividing and constituting the two new nuclei or endoplasts. The endoplastules in all cases preceding subdivision assumed a fusiform shape and striated character, but in no instance was an interchange of these structures between two conjugated animalcules witnessed, as was affirmed to take place by Balbiani. Qualitatively, the endoplastules of the Infusoria are regarded by Bütschli as differing in no way from the endoplasts, and into which latter, in accordance with his observations, they not unfrequently develop. The idea that embryos are developed independently from the endoplast is entirely rejected by this author, the significance attached by him to this structure being simply that of the nucleus of an ordinary animal or vegetable cell. The only reproductive faculty conceded to the Infusoria by Bütschli is that of division or gemmation, the conjugative act being associated by him only with the conference of renewed power or vital energy for the continuation of the dividing process. The superficial analogy existing between the complete conjugative process, as exhibited in the genus *Vorticella*, with the union of the ovum and spermatozoon of the higher animals, is accorded by this author, but hermaphroditism or sexual differentiation, as a constant and essential feature of the representatives of this organic group, is entirely denied. The unicellular nature of the Infusoria is necessarily maintained, in the most thoroughgoing and forcible interpretation of the term, in connection with Bütschli's foregoing exposition of the reproductive features.

Engelmann's latest independent investigations in this direction, while resulting—contrary to his earlier researches—in an entire acquiescence with the views of Bütschli, so far as the reconstructive properties of the endoplast and the total rejection of the embryonic theory are concerned, exhibit certain points of difference. Thus, although the nucleus or endoplast is regarded by him in most instances as the equivalent simply of the nucleus of the histologic cell, this same structure is in certain cases, such as *Stylonychia* and *Euplotes*, interpreted as representing a female element, while the accompanying nucleoli or endoplastules are further stated to be exchanged between two conjugating individuals, and held to exert a possible fecundating influence in the building up of the new nucleus. In the case of *Vorticella*, where conjugation or zygosis is complete, the usually smaller detached zooid, whether derived by fission or gemmation, that encounters and buries itself in the substance of a larger sessile individual, is regarded as a male zooid, and the latter sessile one as the female; in this sense the Vorticellidæ and other types exhibiting similar phenomena are deemed to be essentially hermaphrodite. Conjugation under any circumstance is, however, interpreted by Engelmann as productive of a mere revitalizing or rejuvenating power, enabling the unicellular organism to continue its normal mode of multiplication by binary division. During all conjugative processes, the disintegration and subsequent reconstruction of the endoplastic element, and the assumption by the endoplastule of a striated aspect, reported by Bütschli, is entirely corroborated.

While inclined to acquiesce with the views of Engelmann and Bütschli now briefly recorded, so far as their interpretation of the conjugative process is concerned, and, as previously intimated, to attribute to this process a chiefly revitalizing or rejuvenating function as implying the most logical possible interpretation of the reproductive phenomena exhibited by unicellular organizations, the present author is not prepared to follow these authorities in that part of their argument which involves the disassociation of the endoplast with any function beyond that possessed by the nucleus of an ordinary tissue-cell, or to deny to the Infusoria any faculty of reproduction beyond that of binary division. The one alternative is most intimately, and indeed inseparably, involved with the other, and in this connection sufficient consideration has certainly not been granted by Bütschli and Engelmann to the results practically, and not merely theoretically, obtained by other workers in the same field. That the endoplast does, under certain conditions, exhibit phenomena entirely distinct from those presented by the simple histologic nucleus, and that the Infusorial organism can propagate its kind by means other than those of simple fission, has been already demonstrated in the section devoted to external and internal gemmation, and is conspicuously manifested in such types as *Hemiophrya gemmipara* among the Acinetidæ, in which ramifying diverticula of the endoplast ascend into the anterior bud-like extensions of the body-substance and become separated off, and enclosed within the same, when the latter are severed from the parent organism; phenomena of an essentially similar kind are likewise presented by the gemmiparous *Acineta mystacina* and various species of the genus *Spirochona*. There is, further, no sufficient reason for doubting the accuracy of the observations first made by Eckhard in the year 1846, and since confirmed and extended by Claparède and Lachmann, concerning the production of internal embryos in *Stentor cæruleus* and *polymorphus*, these embryos being developed individually from a single element or node of the characteristic moniliform endoplast. Where such embryos have been reported, Engelmann and Bütschli have dismissed them as merely externally derived parasitic forms, mostly Acinetæ, referable to the genus *Sphærophrya* of Claparède and Lachmann, synonymous with Engelmann's genus *Endosphæra.* Such in many cases they undoubtedly are, and notably in those supposed embryonic forms associated by Stein with the several types *Stentor polymorphus*, *Bursaria truncatella*, and *Stylonychia mytilus*; these unmistakable parasitic forms represent, however, but a small and altogether unimportant minority. Undoubted evidence of the production of embryos through the breaking up of the substance of the endoplast is afforded, in addition to the instances already cited, by Haeckel, in his account and illustrations of the pelagic form *Codonella campanella*, and by Balbiani, in connection with his most recent investigations of the Müllerian type *Didinium nasutum*. In the genus *Euglena* and its allies, the production of embryos through the increment in size and splitting up of the substance of the endoplast has been amply demonstrated by Stein and Carter, and is confirmed also by the observations of the present author. As a last illustration of this production of germs or embryos through the subdivision of the endoplastic element, may be cited Professor Allman's account of the development of a species of *Epistylis*, communicated to the meeting of the British Association, held at Brighton in the year 1875. In this case individuals possessing a normal development of the ordinary band-like endoplast were observed to undergo encystment, the enclosing membrane becoming after the lapse of a few days so opaque as to preclude a clear view of its contents. Upon breaking the capsule open, however, it was found that the endoplast had increased prodigiously at the expense of the surrounding plasma, presenting the aspect of a long and much convoluted cord, while in still more advanced phases this cord-like endoplast had separated into a number of ciliated and free-swimming germs whose contour, as in the case of *Didinium nasutum*, most closely resembled the adult form of *Trichodina* (*Halteria*) *grandinella*. Reproductive phenomena, closely corresponding with those just described, have been recently reported by Everts of *Vorticella nebulifera*.

Before finally dismissing the subject of the production of embryos from the substance of the endoplast, a protest must undoubtedly be lodged against Bütschli's assertion that the fragments into which it becomes separated during or after conjugation, are merely cast out of the body as waste matter. Such an unprofitable destiny is not usually found associated with so essential a structure, and in place of the purely negative evidence adduced, it is equally probable, and far more logical, to presume that these detached fragments represent germs which ultimately develop to the parent forms, as in the case of the endoplastic fragments of *Stentor*, *Vorticella*, *Euglena*, and other types already alluded to. Whether or not the conjugation or fusion of two individual animalcules exerts a direct influence upon the sporular or gemmiparous reproductive phases, in addition to the more ordinary binary segmental one, is as yet scarcely determinable, though that in the first-named case it commonly, if not more usually, precedes spore-production is made evident through the investigations of Messrs. Dallinger and Drysdale, added to those of the present author, in connection with a considerable number of Flagellata.

With respect to the actual act of conjugation, fusion, or zygosis, as it is variously denominated, it is worthy of remark that where such conjugation is complete and permanent, as in the family of the Vorticellidæ, and so far as known, in all the members of the Flagellata, the coalescing units are frequently of diverse size and contour, the one larger and more rounded, and the other smaller and more attenuate. The inference to be derived from this circumstance, combined with the fact that in the conjugative process the smaller unit mostly, if not invariably, becomes absorbed by or immersed within the substance of the larger, is unavoidable. The larger unit takes the place of the female element, and in itself figuratively and physiologically represents the monocellular unimpregnated ovum ; the smaller one to an equivalent degree is identical with the male element or spermatozoon, and through its union with the female one communicates to the latter that re-vivifying influence expressed through a capacity to prolong the reproductive function, and whether that function takes the form of binary division, gemmation, or spore-production, the diœcious generative type may certainly be said to be represented in its most elementary condition. With those animalcules, on the other hand, such as *Paramecium* and *Bursaria*, in which conjugation is simply transient and incomplete, and where both conjugative factors meet and part on equal terms, both the male and female elements, if such are represented, are necessarily united in each individual zooid, and the generative system is as distinctly and essentially hermaphrodite or monœcious.

Affinities of the Infusoria to the Higher Zoological Groups.

Among the very extensive, and in some respects heterogeneous, assemblages of animal forms associated in this volume under the comprehensive title of the Infusoria there is necessarily encountered a series of races or types that not only differ very widely from one another, but which occupy, so far as it is possible to predicate, a very different rank or position with relation to the outlying representatives of the organic series. Being accepted, as already explained, as simple unicellular organisms or Protozoa, no comparisons possessing a homologic value can necessarily be instituted between the Infusoria and any members of the more highly organized and multicellular Metazoa. It remains, however, to be shown that, while no such direct homological comparisons can be established, there permeates throughout the ranks of this extensive group a substratum of superficial or homoplastic resemblances whose existence it is impossible to ignore. Regarded from this point of view, the Infusoria will be found, like an architect's puny and homogeneous clay or plaster model, to, as it were, anticipate and pre-typify the elaborate edifice of multiple and diverse materials afterwards erected or eliminated from this same primary simple plan. In yet another direction it is likewise capable of demonstration that a very considerable number of infusorial animalcules foreshadow or typify in a corresponding manner, in either their isolated or socially aggregated condition, the separate or associated cellular elements out of which the higher tissue-structures or Metazoic organisms are built up. The likeness in this last instance is necessarily far more substantial than in the preceding case, and, as the comparisons instituted are as between cell and cell or equivalent appendages of such cells, all likenesses of this description may in the strictest parlance be termed homologous resemblances. Some of the more prominent examples that fall within this last-named category may be first enumerated. Commencing with the Infusorial group, in its simplest or most lowly organized condition, or in the first place descending yet a step lower, and selecting a simple Rhizopodous Protozoon, such as an Amœba, it is impossible not to recognize that we have here the morphological equivalent or homologue of a tissue-cell in its most elementary condition, as represented by a colourless blood-, lymph-, or ganglionic-corpuscle. The likeness in this instance is, furthermore, not simply one of form; in the case of the blood- and lymph-corpuscles, reptant movements accomplished by the extension and contraction of pseudopodic appendages, and similar to those of the independent Rhizopod, are also freely manifested. It is from such a similar simple repent amœbiform body that many of the flagelliferous members of the Infusorial class take their origin, as demonstrated by the author in the case of *Euglena*, *Eutreptia*, and many Choano-Flagellata, while the retrogression to such a simple elemental type is a familiar phenomenon among the representatives of this same section immediately antecedent to the process of either encystment or coalescence. Proceeding with an examination of the flagelliferous section of the Infusoria in its normal conditions of development, we find at the bottom of the series the curious genus *Trypanosoma* distinguished in the case of *T. Eberthi* by a long attenuate body, around which is spirally disposed a most delicate frill-like membrane, whose active vibrations fulfil the function of locomotion. It is a remarkable fact that an essentially similar type of structure characterizes the exceptionally shaped monocellular spermatozoons of *Triton*, *Bombinator*, and other tailed and tailless Amphibia, as originally figured by Wagner and Leuckart, Unker, and Von Siebold. Spermatozoa in their normal and most familiar form consist merely of a more or less rounded anterior extremity or head, and a dependent flagelliform appendage or tail, and have been recently compared by Professor Huxley * to a simple cell of which the larger and more solid anterior part represents the nucleus, and the dependent tail only the very fully developed and much attenuated peripheral protoplasm. This more normal and simple form of the spermatozoal element is abundantly represented in the class now under consideration. Such simple uniflagellate types as *Monas* and *Petalomonas* exhibit in their adult state of development a type of structure essentially corresponding with that of an ordinary spermatozoon, while the *Heteromitæ*, the majority of the Choano-Flagellata, and numerous Eustomatous Flagellata commence their existence as simple uniflagellate spermatozoon-like organisms. In the case of *Heteromita lens*, as also in that of the swarm-gemmules of the flagelliferous Spongozoa, it is, moreover, noteworthy that in their initial condition of free-swimming existence the individual

* Biological Lectures, South Kensington, Session 1879–80.

unicellular zooids are aggregated together in clusters, closely resembling the sperm-bundles of various higher animals, the same being similarly derived from the repeated cleavage or fission of a primarily single unit. Illustrations of the homoplastic likeness that subsists between certain Infusoria and the more complex forms of spermatozoidal structures are afforded by the *Heteromitæ* in their adult and bi-flagellate condition, in which they resemble in a remarkable manner the so-called "zoospores" or "antherozooids" of various cryptogamic plants, while in the Polymastigous forms *Pyramimonas* and *Chloraster* the modification presented is almost identical with that which obtains in the spermatic elements of *Homarus* and other Podophthalmous Crustacea.

The next recurring structural homotype in the ascending scale as represented by independent Infusorial organisms with relation to the differentiated elements of a compound tissue-structure, is met with in the remarkable multiflagellate type discovered by Professor Haeckel, and which has received from him the title of *Magosphæra.* In this instance the isolated zooids of the normally compound globose colony present a somewhat elongate pyriform contour, and bear at their truncate anterior extremities a number of long whip-like appendages or flagella. A type of structure in all ways comparable with the zooids of *Magosphæra* is repeated in the ciliated epithelium-cells of all higher tissue organisms, from which, compared separately, they are scarcely to be distinguished. One more illustration in connection with the present line of comparison remains to be cited. Many Flagellata, such as *Spongomonas*, *Phalansterium*, and *Uroglena*, are distinguished for their excretion of a glairy gelatinous matrix, within the substance of which the separate units multiply by the process of binary segmentation, and gradually extend the limits of their common domicile. A similar building up by excretion of a common gelatinous matrix, and the extension of the boundaries of the mass by repeated fission within the same, is the essential characteristic of the cartilage cells of both Vertebrata and Invertebrata. The comparison here instituted is, however, still more striking in the case of *Nostoc* and other allied plants. In these latter the condition of simple nucleated cells, imbedded like those of cartilage cells in the midst of a common gelatinous matrix, is generally exhibited, while in that of the Infusoria it obtains only during the duplicative process.

As might have been anticipated, it is among the lower or flagelliferous section of the Infusoria only that are encountered those forms that find their counterpart in the component elements of the higher tissue-structures now enumerated; in a similar manner it will be found that those homoplastic prototypes of certain Metazoic organisms, taken as a whole, exist only among the ranks of the more highly differentiated Ciliate and Tentaculiferous divisions of the group.

Before proceeding, however, to an enumeration of these more highly differentiated homoplasts, it has to be shown that both the Flagellate and

Ciliate sections of the Infusoria share between them one typical developmental phase, which is usually regarded as an essential factor only of the Metazoa. Among all these organisms the first developmental step exhibited by the simple unicellular reproductive cell or ovum is the division of its mass by the process of segmentation or repeated binary fission, the secondary result of which subdivision is the production of a more or less spheroidal aggregation of simple cells or blastomeres, upon which has been bestowed, in reference to its mulberry-like aspect, the characteristic title of a "Morula." Such a Morula is, however, not limited to the Metazoa. As demonstrated in the chapter devoted to the reproductive phenomena of the Infusoria, certain Ciliata, such as *Colpoda*, *Otostoma*, and *Ichthyophthirius*, and an innumerable host of the Flagellata, exhibit in their developmental cycles an essentially corresponding embryonic type. In no point can the segmented cell-mass or Morula of the Metazoon and Protozoon be distinguished, and it is only in the succeeding phases of development that the distinction becomes apparent. Through the disintegration or falling to pieces of the Protozoic Morula, each individual cell or segmented element mostly commences an independent existence, while in that of the Metazoon they remain permanently united and initiate new and complex metamorphoses. Exceptional and highly instructive instances among the Protozoa, in which the Morula condition may be said to be retained as the characteristic adult life form, are afforded by the subspheroidal colony-stocks of *Magosphæra*, *Synura*, and *Syncrypta*, and in a modified manner also by the spheroidal clusters or "cœnobia" of *Anthophysa vegetans*, *Codosiga botrytis*, and other sedentary types. The compound Radiolaria, *Collosphæra* and *Sphærozoum*, &c., may also probably be correctly interpreted as modifications of the moruloid type. Although any direct comparison between the Protozoic and Metazoic organisms beyond this Morula stage would be inconsistent, certain most remarkable homoplastic resemblances invite attention. Commencing with the lowest order of the Ciliate group, and selecting as an illustration one of the mouthless Opalinidæ, it will be at once recognized that there is here presented a form which, on a simplified and monocellular scale, most distinctly foreshadows or epitomizes the structural type exhibited by the so-called "Planula," or ciliated larva, developed by Metazoic organisms, as the direct outcome of the embryonic Morula already described. Like a typical *Opalina*, these Planulæ are characterized by the possession of a more or less ovate body, which is covered throughout its surface with fine vibratile locomotive cilia. In neither case is there any trace of an oral aperture, so that both animals may be described as closed, externally ciliated sacs. In the Planula this closed sac is composed of multicellular elements, arranged in two distinct superimposed layers, the ectoderm and endoderm, while in *Opalina* the entire homoplastic counterpart is fashioned out of a single cell. It is a significant fact, however, that in this latter instance the organism has been recently demonstrated to be multinucleate, a fact in itself suggestive of latent or potential multicellular composition. In the same way that the Opalinidæ may be said to foreshadow the Planula type of organization, it might be suggested that the ordinary stomatode Ciliata, and more especially the multinucleate species, anticipate the next progressive developmental phase of the Metazoic embryo, as represented by the typical "Gastræa" or "Gastrula." The only advance in organization exhibited by this last-named type as compared with the Planula is, that intercommunication between the central cavity and the outer world is now effected through the breaking away of the apical extremity of the primitive closed sac, this apical perforation or "cytostome" constituting the primitive mouth or oral aperture.

As a rule, the Ciliate Infusorium develops, in addition to an oral orifice, a second or anal aperture, but in many it is not distinctly represented; in these the conformity to the Gastræa type is necessarily all the more complete. By Professor Haeckel, to whom the scientific world is chiefly indebted for the discovery of the three several "Morula," "Planula," and "Gastrula" developmental phases of the Metazoic series, it has been suggested that, in accordance with the laws of evolution, these successive transitory phases doubtless represent the permanent conditions of as many primitive and pre-existing Metazoic organisms, to which might be attached for convenience the hypothetic titles of "Arche-Morula," "Arche-Planula," and "Arche-Gastrula." From the foregoing data it is very evident, however, that such archetypes are even yet in existence, and may be successfully sought for among the representatives of the Protozoa.

Entering now upon an examination of those few instances in which representatives of the Infusoria appear to pre-typify, not embryonic or transient, but fully matured conditions of certain lower Metazoa, attention may be first directed to those forms, such as *Paramecium* and *Ophryoglena*, in which the subcuticular layer abounds with the minute evertile structures known as trichocysts. As already pointed out many years previously by Kölliker, Oscar Schmidt, and other authorities, the correspondence between such types and certain of the lower Annelida or Turbellaria is, so far as the general form and the possession and disposition of their trichocysts is concerned, most conspicuous, so that on a simple monocellular scale these Infusoria may be said to foreshadow or pre-typify these simple Annelids. It has been suggested by Louis Agassiz, and also by Diesing, that the typical Vorticellidæ, with their closely approximated oral and anal apertures and well-developed pharyngeal tube, indicate a considerable conformance with the fundamental organism of the Polyzoa—the last-named authority, indeed, transferring this section of the Infusoria to that series. In its originally implied sense it is necessarily impossible to maintain such a proposed affinity, but in a more remote manner, regarding such animalcules as modifications of unicellular zooids in the direction indicated, it may perhaps be accepted. While, as already intimated, *Paramecium* and its allies would appear to pre-typify the Turbellaria, another more lowly organized group of the Ciliata exhibits an entirely distinct and highly interesting affinity. The group in question is that of the Opalinidæ. The simpler members of this section have been already compared with embryonic Planulæ, but in certain of the more highly modified representatives of the family the homoplastic resemblance to the similarly endoparasitic tape-worms or Cestoidea is most marvellous. Both are distinguished for the entire absence of an oral or anal aperture, and are in this respect imperforate saccular bodies. Both occasionally develop horny hooklets or an acetabulate appendage at the anterior extremity wherewith to ensure a permanent adhesion to the internal viscera of the host infested. Both, moreover, share in common a special mode of reproduction, which, while it recurs among the higher Annelida, is met with nowhere else among the Protozoa. Reference is here made to that peculiar form of terminal gemmation exhibited by the *Opalina* (*Anoplophrya*) *prolifera* of Claparède and Lachmann, and several other allied forms, and in which a long series of buds or segments are produced at the posterior extremity, and become successively liberated, like the segments or "proglottids" of an ordinary tape-worm.

The affinities, real or apparent, of one important section of the Infusoria, that of the Tentaculifera, remain to be discussed. At first sight, this group, including *Acineta* and its allies, would seem to stand by itself and to present no special homoplastic points of agreement with any Metazoic type. It is proposed here, however, to show that in more respects than one these suctorial animalcules epitomize most conspicuously, though on a simple unicellular scale, the structural plan of the lower Hydrozoa. To illustrate this resemblance, the Hydroid Polypite in its simplest form, as represented by the so-called "Dactylozooids" recently discovered by Mr. H. N. Moseley,* to play so important a part in the life-economy of *Millepora*, *Stylaster*, and other coral-building Hydrozoa, may be selected. Such a Dactylozooid or Polypite presents the aspect of a long, slender, sinuous body, provided with numerous simple or knobbed tentacles, but is entirely devoid of any mouth or stomach. The function of these Polypites is simply to seize food and convey it to the mouth-bearing polypes or "gastrozooids." There can be little doubt, however, that these rudimentary or secondary Polypites represent the primary and independent zooids of some more ancient stock, and the question naturally arises how in such a case did they ingest food? In reply, it may be submitted that all that is needed is a perforation of the extremity of each separate tentaculum, such as normally exists in many Cœlenterata, combined with the capacity of incepting food at these orifices. It is this slight modification, furthermore, that is alone required to produce an organism fundamentally corresponding with that of an ordinary suctorial *Acineta*, and whose only means of communication with the outer world is similarly through perforations of the extremities of its prehensile tentacles. In one genus of the Acinetidæ, *Hemiophrya*, it is further worthy of remark that certain of the tentacles only, and those the inner ones, are devoted to the ingestive function, while those

* H. N. Moseley, "On the Structure of *Millepora*," 'Phil. Trans. Roy. Soc.,' vol. clxvii. (1877).

forming the peripheral series are simply prehensile, and catch and convey food to the central ones.

Should a type be discovered possessing, in addition to the peripheral or prehensile series, only one central ingestive tentacle, in place of the three or four that more usually obtain, and which would consequently occupy that position in relation to *Hemiophrya* that is maintained by *Rhyncheta* with respect to *Podophrya*, there would be undoubtedly presented an organism directly comparable with an ordinary gustatory Hydroid Polypite. The homoplastic correlation of the Tentaculifera with the Hydrozoa can be still further extended. In the compound type *Dendrosoma radians*, for example, we meet for the first time, and, as far as yet known, with the only existing instance among the Protozoa in which is produced a decumbent creeping stolon and an erect branching stalk, essentially analogous with the so-called creeping "hydrorhiza" and erect "hydrocaulus," which form the common "cœnosarc" of the ordinary Hydroid Zoophytes. The phenomena of development in this group yield yet another highly suggestive co-ordination in a similar direction. As previously stated, the larval condition of the Cœlenterata generally, including the Hydrozoa, is a free-swimming, mouthless, ciliated sac, named a Planula, with which certain of the Opalinidæ have been indirectly compared. It is a noteworthy fact that the larval condition of the Tentaculifera is also in all cases a free-swimming and mouthless ciliated sac entirely different from the parent organism, whose cilia become similarly obliterated on the assumption of the normal sedentary state.

In addition to the foregoing enumeration of the several apparent homoplastic affinities here suggested as subsisting between the various sections of the Infusoria with relation to certain Metazoa, or to the more simple elements of the same, the morphologic relationship or position of these several groups or sections with respect to each other remains to be summarized. The main lines or phyla of evolution, from the lowest and most simplified factors in the series as represented by such types as *Mastigamœba* or *Monas*, by diversely branching and frequently intercalating tracks, up to the highest members of the class, has been already discussed at length, and diagrammatically illustrated in a preceding chapter. The more intricate question, however, as to which special group or sub-order of the Infusoria generally, or of the Ciliata and Tentaculifera in particular, claims precedence as exhibiting the most highly differentiated structural type, has yet to be decided. More usually this most advanced position has been conceded to the Peritrichous sub-order of the Ciliata, including chiefly the Vorticellidæ, whose higher structural plan is held to be manifested through the reduction and concentration of the ciliary appendages so as to form a simple circular or spiral adoral wreath. Viewed also with respect to the closely approximated positions of the oral and anal apertures, and to the high organization of the pharyngeal apparatus, the evidence would appear to be altogether in favour of the Peritricha.

In certain important points, nevertheless, it will be found that another sub-order, that of the Hypotricha, commends itself equally as a candidate for recognition. It is, for instance, undoubtedly among the representatives of the genera *Stylonychia*, *Euplotes*, and other Oxytrichidæ that we find the most elaborate differentiations of the Ciliate type, certain of the numerous and diversely modified groups of appendages being severally set apart for the accomplishment of the special functions of food-collection, natation, and even ambulation. Such forms, although not indicating any homoplastic affinity, as in the previously cited cases, with the Metazoic series, undoubtedly represent the as yet known most highly specialized type of a simple unicellular animal or Protozoon, and exhibit in this respect, as compared to the other sections of the Ciliata, a type of organization parallel to that which obtains among the higher Insecta with relation to the Annelidous or Myriapodous groups of the Arthropoda. It is not, however, in either of these more highly specialized divisions that the phylum of evolution onwards and towards the yet higher groups of the organic world is to be sought. Such differentiated types represent merely the most advanced and terminal series of an entirely divergent and independent branch or outgrowth from the parent stock. In yet another point, the Hypotrichous sub-order of the Ciliata would seem to lay claim to a higher grade of organization than that possessed by the Peritricha. In their phenomena of reproduction the processes of conjugation, as exhibited by these two sections, are conspicuously distinct, being in the case of the Peritricha complete and permanent, as with the Flagellata and lower Protophytes, while with the Oxytrichidæ, and also certain Holotricha, such as *Paramecium*, the conjugative act is only transitory, the two conjugated individuals finally separating and renewing their independent existence. The approximation in the latter instance towards the genetic reproductive process of the Metazoic series, and in the former case towards the simpler vegetative one known as "zygosis," as it occurs among the lower plants, is self-suggestive, and affords an additional element for consideration in summing up the evidence in favour of the higher organization of these respective groups.

The apparent affinities of the Tentaculiferous class of the Infusoria with reference to the Metazoic series has been already discussed, but not so those that obtain between the Tentaculifera and the Ciliate division of the same group. Excepting for the data yielded by the phenomena of development, no direct relationship indeed would seem to subsist between the two, neither cilia, flagella, nor any recognizable modifications of those appendages being characteristic of the adult forms. In place of such organs these animalcules possess suctorial or prehensile tentacula, which, as explained at length on a previous page, more closely approach, in their simplest condition, the extensile ray-like pseudopodia of *Actinophrys* and other Radiolaria. The free-swimming larvæ or embryos of all Tentaculifera are, nevertheless, characterized by the possession of a more or less complete covering of cilia. These cilia are found in different genera and species to exhibit three separate plans of distribution, which are further remarkable as coinciding essentially with those three patterns of ciliary distribution exhibited by the three Ciliate orders of the Holotricha, Peritricha, and Hypotricha. Thus, the simple forms *Urnula epistylidis*, and *Acineta linguifera*, furnish examples of Holotrichous ciliated embryos; *Podophrya fixa* and *P. cyclopum*, Peritrichous; while in those of *Dendrocometes paradoxa*, *Ophryodendron abietinum*, and *Hemiophrya gemmipara*, such ciliation essentially corresponds with that of the Hypotrichous series. Paying due regard, therefore, to the morphologic axiom that the embryonic history of the higher species foreshadows or epitomizes the adult state or states of others lower in the organic scale, the deduction is unavoidably arrived at that the Tentaculiferous group of animalcules represents a series of organisms occupying a position morphologically higher than that of any of the Ciliata, and all of the leading divisions of which latter are passed through or structurally represented by the Tentaculifera during their earlier or embryonic state. It is a further noteworthy fact that the embryos presenting a Holotrichous pattern of ciliation are met with in association with the simplest representatives of the Acinetidæ, while in the most complex ones, such as *Hemiophrya* and *Ophryodendron*, it assumes the Hypotrichous type. This last-named circumstance may be cited as further correlative testimony towards the evidence already adduced in support of the higher organization of the Hypotricha as compared with the Peritricha. The innumerable intercalating relationships and affinities that serve to bind together and unite in one harmonious whole the several orders of the Ciliata, are discussed at length in connection with the preliminary definitions given of each respective subdivision of the class.

Taking the evidence now submitted in its complete form, and having regard to the innumerable intricacies exhibited in the organization and development of the class Tentaculifera, the position of the highest factor in the Protozoic sub-kingdom is herewith accorded to it, and the anticipation at the same time submitted, that future investigation will serve to establish on a still more substantial basis the affinities between this group and the more elementary factors of the Hydrozoic series.

Distribution of the Infusoria.

Although, taken as a whole, and as already intimated in general terms in the opening paragraph of this volume, the Infusoria exhibit practically no limit to their distribution, it will be found on a closer examination that many out of the various groups, families, and genera present a certain fixed order of diffusion. Among these, some may exclusively inhabit salt water, and others fresh, the several secondary conditions of both these latter elements, whether fresh or stagnant, being also productive of special forms or types. Water in its various conditions, as above indicated, by no means represents, however, the total limit of infusorial dissemination; several groups are distinguished for their exclusively endoparasitic habits, the alimentary and circulatory systems of various Vertebrata and Invertebrata, including that of man himself, being often the unconscious entertainers of infusorial guests. As the result of the most recent investigation, one considerable group is found associated with offensively putrid fish and other animal macerations, while in a totally opposite direction, as discovered by the present author, and recorded in the chapter devoted to the subject of Spontaneous Generation, the limpid water of condensed dew or falling rain as it settles on the grass provides a microcosm for the maintenance of a still more extensive series.

Passing in brief review several of the more abnormal habitats now enumerated or recorded in the succeeding chapters, those infusorial organisms distinguished for their salt-water predilections may be first noticed. Although as yet our knowledge of the marine species of Infusoria may be said to be but imperfect, many generic and family groups may be cited as belonging almost entirely if not exclusively to this category. Commencing with the higher Ciliate division, the free-swimming pelagic forms *Tintinnus*, *Codonella* and *Dictyocysta*, and the sedentary type *Folliculari a*, are especially prominent. In the last-named genus, a single fresh-water species, *F. Boltoni*, has, however, been quite recently discovered. Other genera, such as *Lembus*, *Metacystis*, and *Blepharisma*, while essentially marine, are more notably littoral or stagnant sea-water types. To this last-named group have also to be referred the two Hypotrichous family divisions of the Chlamydodontidæ and Ervilliidæ, and the three separate genera *Styloplotes*, *Uronychia*, and *Epiclintes*. Among the Cilio-Flagellata, the genus *Ceratium* is almost entirely marine; *C. longicorne* and *C. kumaonense* being the only known fluviatile forms, while the allied genera *Prorocentrum*, *Amphidinium*, and *Dinophysis* are exclusively pelagic. *Noctiluca* and *Leptodiscus* may be selected from the Flagellate section as the most conspicuous pelagic types, the several genera, *Glyphyidium*, *Anchonema*, and *Conchonema*, being in a similar manner characteristic of sea-water in its stagnant or putrid state. The section of the Tentaculifera is pretty evenly balanced between salt and fresh water habitats; two genera, *Ophryodendron* and *Ephelota*, are, however, so far as known, exclusively marine. Although the foregoing generic and family groups are here quoted as typically characteristic of the marine infusorial fauna, they are by no means cited as constituting an exhaustive summary. It will be further found that a very considerable percentage of the more ordinary fluviatile types of the Ciliata have likewise their marine representatives, and as familiar examples of which may be mentioned the greater number of genera of the extensive family groups of the Vorticellidæ, Oxytrichidæ, and Euplotidæ, not a few species among these, indeed, such as *Ophrydium versatile* and *Uronema marinum*, being notable for their indifferent salt and fresh water habitat.

In an enumeration of those animalcules whose distribution pertains to neither of the two last-named elements, but is for the most part inextricably interwoven with that of various more highly organized animal types, upon whose vital juices they are dependent for their existence, the most prominent position has undoubtedly to be awarded to the mouthless Opalinidæ. All of the various specific and generic types of this important family group are found leading an endoparasitic existence within the alimentary canals, in some instances of various Amphibia, such as newts, frogs, and toads, and in others of various aquatic Annelida, these latter being in several instances marine. Among the Peritricha, the two genera *Ophryoscolex* and *Entodinium* are notable for their limitation to the stomachal cavities of various ruminants, while the Heterotrichous form *Balantidium coli* honours the rectal passage of the human subject with its presence. Other species belonging to the last-named genus, as also its near allies *Plagiotoma* and *Nyctotherus,* limit their attentions in a similar manner to various worms and other lower Invertebrata. The two generic types *Conchophthirus* and *Ptychostomum* form noteworthy examples of the parasitic series, being both found inhabiting the mucilaginous body-slime of various terrestrial Mollusca. The more recently discovered *Ichthyophthirius multifiliis* is remarkable for its attachment to the cuticular surface of young trout, and often causes severe losses to the French fish cultivators by reason of its depredations.

Although the Tentaculiferous section of the Infusoria yields but few examples of endoparasitism, one single genus, *Sphærophrya,* is characterized by its passing the earlier stages or chief portion of its existence within the internal substance or endoplasm of various other animalcules. The Flagelliferous section of the class yields, so far as endoparasitic habits are concerned, a series of examples little inferior in extent and interest to that of the Ciliata. It is to the ranks of this group that have to be assigned the actively motile organisms recently discovered by Mr. T. R. Lewis in the blood of healthy rats, and described hereafter under the title of *Herpemonas Lewisi.* One species of *Trichomonas* has as yet been found only in fluid obtained from the human vagina. *Bodo urinarius* inhabits human urine, while the several species of *Lophomonas* infest the intestinal tracts of the cockroach and other Insecta. The two specific forms here referred to the order of the Trypanosomata undoubtedly represent the Flagellate Protozoa in their most rudimentary condition, and are respectively inhabitants of the blood of frogs and other Amphibia, and the rectal passages of ducks, geese, and other domestic poultry. As intimated in the systematic description of these types, it is possible that they represent developmental conditions of the same organism.*

Apart from the large number of Infusoria that exhibit ecto- and endoparasitic habits, it will be found that a very considerable series, while

* An extensive notice of the essentially parasitic representatives of the Infusoria is embodied in an article contributed by the present author to the 'Popular Science Review' for October 1880.

invariably attached to other living organisms, are not maintained at the expense of the essential juices of these latter, but simply occupy with respect to them the position of co-lodgers or messmates. The very appropriate title of "commensals" has been recently employed by Prof. P. van Beneden to distinguish those organisms among the higher Metazoic series which pass a similar co-associated, non-hurtful, and often mutually dependent existence, and that of "commensalism" for the distinction of the peculiar pseudo-parasitic life habits which they exhibit. As might be anticipated, the phenomenon of commensalism is exhibited among the Infusoria chiefly by those types that lead a fixed or sedentary existence, and is notably conspicuous among the Peritrichous Vorticellidæ. From these may be selected as examples various species of the several genera *Epistylis*, *Zoothamnium*, *Opercularia*, *Cothurnia*, *Scyphidia*, and *Spirochona*, a very large number of which are found in company only with certain species of aquatic Insecta, Crustacea, or Mollusca.

As free or unattached messmates or commensals, reference may be more especially made to the family of the Urceolariidæ, including *Trichodina pediculus*, notable for its intimate relationship with the fresh-water Hydra, and which position it shares with the Hypotrichous form *Kerona polyporum*. Other animalcules of the same family, exhibiting closely corresponding habits, are represented by the two genera *Urceolaria* and *Trichodinopsis*, while a near ally, *Licnophora*, has been found as yet as a commensal only of certain marine Planarians. The genus Ophryodendron, among the Tentaculifera, furnishes in the two species *O. sertularia* and *O. multicapitata* marked examples of pseudo-parasitic life, the former being a common guest of both Sertularian zoophytes and the little hairy crab *Porcellana platycheles*, while the latter, recently discovered by the author, has as yet been found attached only to the limbs and carapace of a species of sessile-eyed crustacean. Descending to the division of the Flagellata, commensalism, so far as is at present known, would appear to be most abundantly represented among the mostly sedentary collar-bearing section of the Choano-Flagellata, where it is further noteworthy that the majority are found attached, as commensals, to the peduncles or loricæ of other higher Infusoria. In this manner *Salpingœca minuta* is found in society with the flagellate type *Dinobryon sertularia*, while *Salpingœca convallaria* grows on *Epistylis anastatica*, and *Monosiga Steinii* on *Vorticella convallaria* and *Epistylis plicatilis*, itself a commensal of the common pond-snail.

While the foregoing summary of some of the more abnormal areas of distribution of the Infusoria subserves the purpose of indicating to the student and collector of this group of beings the localities in which to seek with success for certain specific or generic types, a brief space devoted to an enumeration of the most favoured habitats of the non-aberrant types will probably be welcome. In this direction it need scarcely be indicated that weedy ponds, and slowly running water, containing an abundance of aquatic plants, present both the most accessible and most remunerative hunting grounds. Arrived here, the collector should be careful to secure more especially portions of all the more finely divided plants, such as *Myriophyllum* and *Ceratophyllum*, these affording favourite fulcra of attachment for the sedentary species belonging both to the Ciliate and Flagellate sections of the class, and being especially suited in consequence of their slender contour for subdivision and transference to the glass slide or zoophyte trough for examination. Living plants, however, by no means exhaust the category of material to be secured. Dead leaves, from adjacent trees, that have fallen into the water, and are passing rapidly into decay, are often covered on their lower surfaces with the extensive slime-like colonies of *Vorticella campanula* or *Epistylis grandis*. Specimens of the almost always numerously represented Entomostraca, *Cyclops* and *Canthocamptus*, or higher crustacean forms such as *Asellus* and *Gammarus*, as likewise all larvæ of aquatic Insects, Mollusca, and even Annelida, should be brought home and diligently examined, for some one or more of the many parasitic or pseudo-parasitic species recently referred to. The family of the Daphniadæ or "water-fleas," as exceptions, are rarely the entertainers of infusorial guests.

Ponds of smaller pretensions, presenting only a superficial layer of duckweed, or stagnant ditches with a surface of brilliant green or other coloured slime, may always be visited with advantage. In the latter instance, some representative of the social Euglenidæ, or possibly Peridiniidæ, is usually to be encountered ; while in the former one the pendent rootlets of the floating duckweed will in most cases be found to support a perfect forest-growth of *Vorticellæ* and other Infusoria. Restlessly wandering among the floating leaves of this gregarious plant, numerous Oxytrichidæ, Tracheliidæ, and not unfrequently *Urocentrum turbo* will reward research, while the interstices of the decaying leaves may be examined for examples of the singular genera *Stichotricha* and *Chætospira*. In the ponds of our metropolitan parks and commons that so abound with various aquatic Ranunculi, the various species of brilliantly coloured *Stentors* or "trumpet-animalcules" are commonly met with, their social colonies often forming thin coloured incrustations on the minutely divided leaflets of the plants in question that are conspicuously visible to the unassisted eye. Lastly, in connection with fresh-water habitats, the upland ponds and marshes abounding with *Sphagnum*, *Drosera*, and other bog-plants, are rich hunting grounds that have as yet been but very imperfectly examined, and may be expected to yield a rich infusorial fauna to the investigator. As the result, indeed, of a few brief hours recently spent by the author on the outskirts of Dartmoor, the two new and highly remarkable Flagellate types, described later on under the titles of *Rhipidomonas Huxleyi* and *Spongomonas sacculus*, were obtained.

For the collector sojourning at the seaside, an almost equally unexplored hunting ground is thrown open. Some of the most prolific habitats in this instance are afforded by the living polyparies of the Hydrozoa and

Polyzoa that may be gathered at low-water mark or dredged from the sea-bottom. These in almost all instances produce an abundant harvest of *Zoothamnium alternans* and other attached Vorticellidæ, Acinetidæ, and Flagellata, being in this respect far more prolific than the neighbouring sea-weeds, though certain of the finer divided varieties of these will be found to yield their characteristic types. Many free-swimming species may be secured by a careful surface-skimming of the smaller rock-pools, and more especially such as are invaded by the sea only during the spring tides and are left undisturbed through the intervening intervals. As in pond collecting, the innumerable small Crustacea, Annelids, and other animal organisms with which the sea abounds, should be carefully examined for parasitic forms. For the capture of the less familiar pelagic types, including representatives of the families of the Noctilucidæ, Peridiniidæ, Dictyocystidæ, and Tintinnidæ, the use of a boat and muslin towing-net must be resorted to.

Concerning the geographical distribution of the Infusoria, we cannot be said at present to possess anything approaching a comprehensive knowledge. The infusorial fauna of but few countries or even districts has as yet been thoroughly investigated, while whole continents remain of which it may be said that absolutely nothing whatever is known. From such data as are at present available, nevertheless, and as might be anticipated with reference to organisms occupying so humble a position in the organic scale, it is made manifest that generic, and in many cases even specific, forms exhibit a most diffuse and practically cosmopolitan area of distribution. Thus, a number of types belonging to identical or indistinguishable specific forms are found to occur on the European continent, in England, North America, and the neighbourhood of Bombay. Arctic, temperate, and tropic climes yield, so far as at present explored, no more widely divergent types than are to be encountered within adjacent districts. Even the marine species as a rule exhibit no clear and well-defined demarcation, for the most part including the same generic and in not a few instances specific sorts identical with those obtained from fresh water.

Of the dissemination of Infusoria in time, or in other words their geological distribution, there is, as a necessary consequence of their mostly soft and perishable nature, scarcely a trace preserved. The hard coverings or loricæ of a few species have, however, been recognized by Ehrenberg in the Cretaceous deposits, and referred by him to the genera *Chætotyphla* and *Ceratium*. The siliceous loricæ of the Peritrichous genus *Dictyocysta* occur also in company with the pelagic Polycistina of the Tertiary formations, and there can be but little doubt that the Infusoria in their simplest condition represent one, if not the most ancient, of the stock-forms of the organic series. Accepting, in fact, the Spongida as representatives of the Choano-Flagellata, a subject-matter which is fully discussed in a succeeding chapter, the Flagellate section of the infusorial series is distinctly traceable through every marine deposit from the present day back to the Cambrian and even the Laurentian section of the Palæozoic epoch.

Preservation of Infusoria.

Up to within the last few years no attempts aiming at the preservation of Infusoria in a condition approaching that which they exhibit in their living state appear to have been successful. Ehrenberg and other early investigators succeeded by careful desiccation in securing some shadowy semblance of the pristine form of a few Ciliata, such as *Paramecium* and *Pleuronema*, but for histologic purposes it is scarcely requisite to state that types so preserved are practically worthless. Such progress has, however, been made within the last half of the present decade in the discovery of reagents and preservative fluids for the treatment of all organic tissues, that the securing of permanent slides of the majority of infusorial types is at the present day a mere matter of manipulation. That medium which lays claim to the foremost position in the ranks for the conservation of animalcules in their normal state, is undoubtedly osmic acid. Previously utilized as an ordinary histologic reagent, it was first recommended to the author by Professor Huxley in the year 1877 for the purpose now under consideration, and is at the present time very generally employed. Applied either in the form of vapour or as a solution in distilled water, having a strength of from one to two per cent., the results obtained are most remarkable. All structures, such as cilia, cirrhi and flagella, the internal endoplast, and in *Euglena* and its allies the colours also, are preserved, the animalcules, excepting for the absence of motion, being scarcely distinguishable from the living organisms. With certain of the more exceptionally contractile forms, such as *Stentor* and *Oxytricha*, it is, as recommended by M. A. Certes, better that the osmic acid should be employed in the direct form by placing a drop of the solution on the covering glass before laying the latter upon the slide containing the Infusoria; this plan indeed has been found by the author to be the most effectual and simple of application in the majority of instances. For the *Vorticellæ* the employment of a more concentrated solution of the acid than the one above mentioned is recommended. As pointed out by M. Raphael Blanchard,* and also by M. Certes, colouring reagents, such as hæmatoxylin, eosin, and picrocarmine,† may be advantageously used in combination with osmic acid, and assist greatly in developing the presence and form of the nucleus or endoplast. The animalcules thus killed may be fastened down as permanent preparations, without the addition of any other preservative, and afford valuable material for future reference and comparison. It will be found that the smallest and most delicate flagelliferous species are equally amenable to this course of treatment, preserving their flagella, and even, in the case of the Choano-Flagellata, their delicate sarcode collars, in a life-like form. As attested to in a succeeding chapter, the employment

* 'Rev. Internat. Sci.,' iii. 1879.

† In using this medium, the addition of one part of glycerine and one part of distilled water is recommended by M. Certes.

by the author of this medium for the investigation and preservation of the similar collar-bearing sponge-monads has been attended with the most satisfactory results. In addition to osmic acid, divers other conservative reagents, accompanied with variable success, have been recently introduced. Among these may be mentioned rectified pyroligneous acid, a drop or two of which may be applied in the same manner as the medium last described. Also, a concentrated solution of iodine prepared according to the formula prescribed in Huxley and Martin's 'Elementary Biology,' and embodied in the appended footnote.* The least portion of this fluid added to that containing the Infusoria has been found by the author to act in a manner almost identical with that related of osmic acid, and in some instances even more efficiently. This medium possesses the additional advantage of yielding no deleterious exhalations, which have to be carefully guarded against in the use of osmic acid. An equally efficient and entirely harmless medium for the preservation of Infusoria is, according to M. G. du Plessis,† afforded by a saturated solution of permanganate of potash; this last-named chemical being recommended by another authority ‡ in combination with chromic oxydichloride acid in the proportions of 25 per cent. chromic acid, 5 per cent. permanganate, and 50 per cent. water. Staining agents, such as the anilin blue or diamond fuchsin, in proportionate parts of, in the first place, one part of the anilin solution to 200 parts of distilled water, plus 800 parts of pyroligneous acid, are reported to act well in the resolution of otherwise obscure endoplastic structures. A 1 per cent. solution of acetic acid is also of important use for this purpose, but on account of its corrosive properties is not available as a medium for conservation.

In many instances, and more especially for the preservation of the retractile-stalked simple and compound Vorticellidæ, the employment by the author of very weak dilute spirit, about one part of spirit to ten of water, has been attended with the most successful results, the stems retaining under such treatment their stalks in every condition of contraction and expansion, and their ciliary discs everted as in life. According to Mr. J. E. Lord,§ the pelagic type *Noctiluca miliaris* may be preserved by mounting in cells filled simply with pure sea-water.

Sir John Ellis's claim for notice as one of the earliest employers of reagents in the investigation of infusorial organisms, the medium utilized being the acrid juice of geranium leaves, has been already mentioned at page 82. Brief reference was at the same time made to the still earlier experiments, in a similar direction, instituted by Sir Edmund King, details of the methods and materials he resorted to being, however, reserved for enumeration under the present heading. Such earliest authentic record, as contributed by Sir E. King to the 'Philosophical Transactions,' No. 283,

* "Prepare a saturated solution of potassic iodide in distilled water; saturate this solution with iodine; filter; dilute to a brown sherry colour."

† 'Science-Gossip,' March 1879.

‡ T. C. in 'Science-Gossip,' May 1879.

§ 'Science-Gossip,' No. 173, 1879.

for the year 1693, embodies the following highly interesting data. Having recorded the results of the application to Infusoria, with a needle's point, of various substances producing no very important effects, he says—"Tincture of salt of tartar (*tartaric acid?*) put with them in the same manner kills them more immediately, but yet they will be first so sick or so affected, call it what you please, as you may see by a surprising convulsive motion, they will grow faint and languid apace, and you may see them fall to the bottom of the drop upon your object plate, dead but in their own shape that they were in before you applied your needle, and will neither be flat as with spirit of vitrol, nor cylindrical as with common salt liquor; but lie dead in the same shape as before you put in your needle with the salt of tartar.—Sack will kill them, but not so speedily as the other liquors."

Methods of Investigation.

To the working microscopist a hint or two will probably prove acceptable with reference to the mechanical means that may be most advantageously resorted to in the investigation of the structure and life-histories of the more minute, and comparatively unfamiliar, representatives of the Infusorial series. These, as typified by the several orders of the class Flagellata, necessarily demand in conjunction with the high-power object-glasses that are indispensable for their correct appreciation, more delicate methods of manipulation.

A chief obstacle encountered in the employment of these short-focussed lenses presents itself at the outset in the matter of penetration. However thin may be the covering glass employed, it rarely fulfils the needs of the investigator, and mostly causes both inconvenience and loss of time on account of its extreme brittleness. Where the objects under examination are attached to more solid substances, such as the stems of water plants, this rigidity and brittleness of the covering glass hampers progress in a most provoking manner, and materially restricts the limits of clear vision. The unsuitability of ordinary covering glasses for the special investigations here alluded to, was long since recognized by the present author, and a substitute provided that has been productive of the most satisfactory results. The material utilized for this purpose was no other than the one extensively employed, previous to the introduction of specially prepared glass, for the permanent mounting of microscopic objects. This substance, represented by ordinary talc as extensively used for gaselier shades, may with a little practice be split into laminæ of such extreme tenuity that they may be blown away with the lightest breath, while for perfect evenness and transparency they will compare favourably with the finest manufactured glass. With the employment of these talc-films the investigation of Infusoria with the $\frac{1}{16}$, $\frac{1}{25}$, or even the $\frac{1}{50}$-inch objectives becomes a comparatively easy task. The material in question possesses the further considerable advantages of bending readily and permitting the object-glass to be brought close down on the more remote objects in the microscopic field, while it may be cut with the scissors to any required size or shape.

In the investigation of the Flagellata, or indeed of any Infusoria in which it is sought to arrive at an accurate knowledge of the life or developmental history of any given type, it is desirable that the same individual zooid or animalcule should be continuously examined. An important mechanical obstacle that has to be overcome in the conduct of such continuous investigation, which may extend over many hours or days, results from the rapid evaporation of the water or other fluid from beneath the covering glass, combined with the necessity of keeping it constantly replenished. Various mechanical appliances for accomplishing the desired end have been introduced by Recklinghausen, Leuckart, and other Continental workers, none of these, however, being equal in efficiency to that employed by Messrs. Dallinger and Drysdale, during their famous "Researches into the Life-history of the Monads," figured and described in the 'Monthly Microscopical Journal' for March 1874. The illustrations given of this apparatus with accompanying explanations are reproduced in the plate devoted to mechanical appliances at the end of the atlas to this volume, and may be thus briefly described. It consists firstly of a plain glass stage, about the one-tenth of an inch thick, fitted so as to slide on in place of the ordinary sliding stage of the microscope. From the left-hand anterior border of this stage a projecting arm is produced which carries a socket for the reception of a small glass reservoir about 1½ or 2 inches deep. The glass stage being too thick to work through with an achromatic condenser and high powers, a circular aperture of sufficient size is cut through it, and a piece of thin glass cemented on its upper surface. A piece of blotting-paper is now cut coinciding in form with the glass stage, but slightly smaller, and with a tongue-like projection that lies along the projecting arm and dips down into the glass reservoir. A circular aperture of larger size than the covering glass employed is cut out of the centre of this paper, such aperture, where a ¼-inch cover is made use of, being preferentially the $\frac{1}{16}$ of an inch. The foundation of the moist chamber is now complete, and it only remains to provide the bounding walls. This Messrs. Dallinger and Drysdale accomplish by means of a piece of glass tubing, about 1½ inch in diameter, cut to ¾ inch in length. Across one end of this tubing a thin sheet of caoutchouc is next firmly stretched and securely tied, and a small hole perforated in its centre. The tubing with its free edge, which should be carefully ground, is now placed concentrically upon the glass stage, over the aperture in the blotting-paper, and the object-glass racked down upon the perforation in the caoutchouc. The caoutchouc should be sufficiently thin to offer no impediment to the action of the fine adjustment, while it at the same time clasps the object-glass firmly round its central perforation and in combination with the lowermost or free edge resting on the blotting-paper, constitutes a practically air-tight chamber. Everything is now in working action and it only remains to add the material to be examined and to fill the reservoir with water. The water from the reservoir soaking through the bibulous paper keeps the air-tight chamber constantly moist, and evaporating faster from its contained free circular edge, prevents loss of moisture from beneath the covering glass. The water in the reservoir will maintain the moist chamber in the above conditions for many days and will require replenishing only at distant intervals.

Where uninterrupted observation is not demanded, but simply the chronicling of the more important developmental phases of some sedentary or encysted type, and where in the interim the microscope is probably required for the examination of other objects, it will be found convenient to transfer the slides containing the animalcules to an ordinary moist chamber which may be extemporized out of a tumbler or small bell-glass inverted upon a plate containing a few folds of well-saturated bibulous paper. By a registration with a graduated scale on the mechanical stage, or by a rough drawing of the bearings of the type to be re-examined with relation to surrounding objects, it may be with facility refound for subsequent observation. An efficient moist chamber for the same purpose, and, as is often needed, for the transfer of a slide containing living Infusoria from place to place, is ready to hand in the shape of an ordinary wide-mouthed pomatum bottle, with some moistened blotting-paper at the bottom ; the height inside being a little over three inches allows the cork to be thrust down upon the slide, thus keeping it firmly in one position.

The ingenious chambers constructed by Professor Tyndall for the reception of test-tubes in connection with his experiments on atmospheric germs, fully described in the succeeding chapter, and illustrated side by side with Messrs. Dallinger and Drysdale's apparatus, at Pl. L., offer special facilities for the effectual isolation and continued examination of specific infusorial types.

CHAPTER IV.

SPONTANEOUS GENERATION.

THE solution of the yet smouldering, and but a few years since fiercely incandescent, question of "spontaneous generation" is so inextricably bound up with an extensive knowledge and correct appreciation of the vital phenomena of the microscopic beings that form the subject of this volume, that it is felt by the author that a grave error of omission would be committed were not a few pages set apart for its consideration. Spontaneous generation, "*generatio æquivoca*," or as it is now more widely designated "abiogenesis," is by no means an invention of to-day or yesterday. It dates back to the classic times of Plutarch, Virgil, and Aristotle, by which three brilliant leaders and expositors of the world's highest wisdom it was seriously maintained that eels grew out of mud, bees from putrefying flesh, and rats through the vitalizing properties of the sun's rays, without any intervening parental agency. Spontaneous generation as enunciated at the present day is the same in essence if not in fact as when evolved and launched upon the seething waters of scientific controversy over two thousand years ago. Then as now, or now as then, the point sought to be established by its exponents was or is, that organic beings can be and are under certain conditions generated or newly created out of dead organic or purely inorganic material, independently of any pre-existent parent, egg, or germ. With the revival of the arts and scientific culture which distinguished the latter half of the seventeenth century, the theory of spontaneous generation as applied to the grosser forms of animal life, and accepted as an article of creed from the days of antiquity, was attacked and finally disposed of through the labours of such careful investigators as Redi, Réaumur, and Schwammerdam. By the first-named of these authorities, more especially, the maggots found in putrid meat and hitherto supposed to be generated spontaneously, were shown by a combination of careful experiment and inductive reasoning to be the progeny only of flies which had previously deposited their eggs upon it. Reasoning from the constantly observed presence of flies round decaying meat previous to the appearance of the maggots, Redi concluded that these winged insects were the progenitors of the same, and took steps to prove it. Placing meat in a jar and covering it so carefully with paper that flies could not obtain access to it, he found that although putrefaction set in, no maggots were developed, while at the same time these organisms appeared abundantly in similar jars of meat left purposely uncovered. Substituting fine gauze for the paper coverings, the flies were soon attracted by the emanating odour, but being unable to get at the meat deposited their eggs upon the gauze, and out of which eggs minute maggots were then seen to develop. This very simple experiment by which Redi proved his case, carries with it, as presently shown, a most practical and important bearing upon the question of spontaneous generation in the modern acceptation of the term. The weapon, however, that proved of the greatest service at about this same epoch in breaking down the ancient superstitions concerning the spontaneous generation of highly organized animals, was undoubtedly the microscope, now utilized for the first time in unravelling the mysteries of nature.

With this instrument in the hands of Leeuwenhoek, Robert Hooke, Hartsoeker, and other early labourers, it was soon discovered that the hitherto deemed doubtful or spontaneously multiplying species propagated their kind perpetually through the medium of impregnated seeds or eggs, after the manner of the larger and more familiar types, and the idea of spontaneous generation, so far as such organisms was concerned, was banished to oblivion. The agency, however, which thus achieved the overthrow of this theory in one direction, paved the way for its re-establishment in another, and as it at first seemed, on an apparently far more sure and substantial basis.

Among the most important revelations of the hitherto invisible and unknown world made known with the assistance of the microscope, was undoubtedly the discovery by Leeuwenhoek, in the year 1676, of the microscopic beings that form the subject-matter of this volume. The abundant confirmation of this discovery and the intense interest manifested on all sides in so newly indicated and fascinating a field of research, necessarily entailed a speedy recognition of the extraordinary rapidity with which these minute organisms multiplied, and also of their appearance suddenly in vast numbers under auspices totally at variance with the propagative phenomena of all previously known organic forms. None of the then familiar laws of organic reproduction sufficing to explain these several phenomena, the mind naturally reverted to that interpretation of the "incomprehensible" initiated by the philosophers of antiquity, and stamped such abnormal manifestations with the brand of the miraculous.

As indicated in a preceding chapter, the theory of abiogenesis or spontaneous generation, as applied to the minute animalcules produced so abundantly in infusions, took its origin as a possible hypothesis with their first discoverer, and was upheld with more or less force by Gleichen, Joblot, and O. F. Müller. The first, however, to mould this somewhat vague idea into shape and to formulate out of it that definitive doctrine concerning the spontaneous production of the lowest organisms that with varying fortune has commanded adherents thenceforward up to the present time, was undoubtedly our own countryman Tuberville Needham, who in his 'New Microscopical Discoveries,' printed in the year 1745, and various subsequent publications, declared that infusorial animalcules were directly and spontaneously engendered from more highly organized bodies in a state of putrefaction. This bold declaration was entirely approved by Buffon, who further maintained that with respect to these organisms such a mode of generation was not only the most frequent and universal, but also in all probability the most ancient.

Such being the definite position taken up by the advocates of spontaneous generation, it was not long before it was vigorously assailed, the controversy that ensued surpassing probably in acrimony and the extent of its duration that of any yet brought within the area of scientific polemics. The earliest authority to declare himself opposed to this doctrine and to submit an intelligible interpretation of the apparently anomalous conditions of growth and reproduction of infusorial organisms, is usually held to be the Abbé Lazzaro Spallanzani, of Pavia, who in the year 1765 enunciated the opinion that such animalcules were propagated through the medium of minute germs constantly present in the atmosphere, and which fructified or developed immediately they came in contact with the conditions suitable for their growth furnished by artificial or other infusions. The atmospheric "germ theory," attributed to Spallanzani, can boast, however, of a far more remote antiquity. Seventy years prior to the time of Spallanzani (1696), an Englishman, John Harris, whose name as one of the earliest observers of infusorial life has been previously quoted, contributed to the 'Philosophical Transactions' a suggestion concerning the generation of these minute beings that is now, almost two centuries later, found to represent the true position of the case more nearly than any of the manifold interpretations brought forward between that date and the present time. In the course of his observations upon the subject of infusorial animalcules, embodied in the foregoing communication, the following paragraph occurs:—

"How such vast numbers of animals can be as it were at pleasure, produced, without having recourse to equivocal generation, seems a very great difficulty to account for. But the solving of it that way makes short work of the matter (for 'tis easie enough to say they are bred there by putrefaction), yet the asserting equivocal generation seems to me to imply more absurdities and difficulties than perhaps may appear at first sight. I wish therefore that this matter would a while imploy the thought of some ingenious and inquisitive man. In the mean time I've conjectured that these *animalcula* may be produced by one or both of the following ways. I. I have thought that the eggs of some exceeding small insects, which are very numerous, may have been laid or lodged in the plicæ or rugæ of the coats of the grain by some kinds that inhabit the same as their proper places. For that insects of the larger kinds do frequently thus deposite their eggs on the flowers and leaves of plants, has been often experimented; and 'tis very probable that the smaller or microscopical insects do the same. Now these being washed out of the seeds, by their immersion in water, may rise to the surface and there be hatched into those animals which we see so plentifully to abound there. II. Or the surface of the water may arrest the straggling eggs of some microscopical insects that were perhaps about in the air, and being fitted and prepared for the purpose, by the infusion of proper grain, or a proportionable degree of heat, may compose so proper a nidus for them, that they may by the warmth of the sun be easily hatched into living creatures . . . . and perhaps sometimes both these circumstances, and others of the like nature, concur for their production."

Making due allowances for John Harris's conception of Infusoria as the product or offspring of microscopically minute insects, it is astonishing to find how closely his two suggestions of their being primarily attached in the form of eggs to the rugæ and plicæ of the surfaces of the vegetable substances experimented on, or of their falling from the atmosphere and germinating in such suitable liquid nidus as may present itself, coincide with the actual distribution of infusorial eggs or spores as demonstrated by the most recent research.

Proceeding to an enumeration of the results obtained by the many "ingenious and inquisitive men" who, following the recommendation of John Harris, did "imploy their thoughts" upon the subject of infusorial propagation, it has to be further recorded of Spallanzani that he initiated the experiment of filling flasks with organic infusions, and after hermetically sealing their apertures and boiling their contents, showed that no life was generated in them, however long they remained in their closed condition. The Genevan naturalist Bonnet, the intimate friend of Spallanzani, adopting the same line of argument, proceeded so much further as to declare that all substances both organic and inorganic were permeated with these infinitely minute germs, and that these germs were in some cases able to resist the highest temperatures. This latter property ascribed to the organic germs was the outcome of certain exceptional cases in which, in infusions boiled and confined in flasks in the manner above indicated, living organisms were found both by himself and Spallanzani to make their appearance.

This point of the controversy being arrived at, the subject attracted such general attention that the whole world of science may be said to have divided itself into two hostile camps, the one supporting Needham's and Buffon's, and the other Spallanzani's and Bonnet's hypotheses. As rallying titles or *noms de guerre* that should serve to distinguish the adherents of these two respective camps, that of "heterogenists" was generally associated with the supporters of abiogenesis, or who, as the word implies, advocated the heterogenetic or spontaneous generation of the organisms under dispute; that of "panspermists" being applied with corresponding significance to those followers of Spallanzani who attributed the rapid propagation and distribution of Infusoria to the universal presence of their germs in the surrounding air. Among the many doughty champions who, as successors to Needham, distinguished themselves for their ardent devotion to the cause of abiogenesis or heterogeny during the earlier portion of the nineteenth century, have more especially to be placed on record the names of Lamarck, Oken, Bory de St. Vincent, and Dujardin. On the side of the "panspermists," on the other hand, appear during the same epoch those of Paul Gervais, Schwann, Schultze, and

Ehrenberg. Lamarck, one of the most fervent advocates of heterogeny, in his celebrated 'Philosophie Zoologique' (Paris, 1809), freely declared that all bodies were constantly undergoing mutations of form, some passing continually from the state of the inorganic into the organic, and others reverting from the living to the inanimate condition. Nature was further represented as thus exhibiting one continuous evolutionary cycle, and with the aid of heat, light, moisture, and electricity, as producing new organisms by direct or spontaneous generation at the initial or root terms of both the animal and vegetable kingdoms.

Almost contemporaneously with this pronunciamento of Lamarck appeared also Lorenz Oken's celebrated 'Lehrbuch der Naturphilosophie,' in which, in addition to further expounding his views initiated in the year 1805 concerning the fundamental construction of all living bodies out of vesicular or cellular elements that found their equivalents in the independent and simple vesicular bodies of infusorial animalcules, he declared himself most strongly in favour of "spontaneous generation." Oken's remarkable enunciation of these two separate principles in their mutual or interdependent aspect is thus expressed in the treatise above quoted :—

"The first organic points are vesicles. The organic world has for its basis an infinity of vesicles.—The mucous primary vesicle may in a philosophical sense be aptly called an infusorium.—If the organic fundamental substance *consist* of infusoria, so must the whole organic world *originate* from infusoria. Plants and animals can only be metamorphoses of infusoria.—This being granted, so also must all organizations *consist* of infusoria, and during their destruction dissolve into the same. Every plant, every animal is converted by maceration into a mucous mass; this putrefies, and the moisture is stocked with infusoria.—Putrefaction is nothing else than a division of organisms into infusoria, and reduction of the higher to the primary life.—Organisms are a synthesis of infusoria. Their generation is none other than an accumulation of infinitely numerous mucous points or infusoria. In these the organisms have not been at once wholly and perfectly depicted as on the smallest scale, nor contained in a state of performation; but they are only infusorial vesicles, that by different combinations assume different forms, and grow up into higher organisms.

"As the whole of nature has been a successive fixation of æther, so is the organic world a successive fixation of infusorial mucous vesicles. The mucus is the æther, the chaos for the organic world. The semen of all animals consists also of infusoria; the same may be said of the vitellus.—Every generation commences *à priori* or from the beginning. The organic substance must again be dissolved into the original chaos or mucus if anything new should originate.—Out of an organic menstruum only can a new organism proceed, but not one organism out of the other. A finished or perfect organism cannot gradually transform itself into another.—The generative juices, or semen and vitellus, are none other than the total organism reduced to the primary menstruum.—Physically regarded also, every individual originates only from the absolute, but no one out of the other. The history of generation is a retrogression into the absolute of the organic, or the organic chaos-mucus, and a new evolution from the same.—This development from mucus is only applicable, however, to the generation of the perfect organisms, but not to the origin of the organic body, or the infusorial mass. The former originate only from an organic mass that has been already formed; but the infusorial mass, as constituting the organic primary bodies, cannot have originated in the same way. It was and must originate directly from the inorganic. From whence can the organic have otherwise proceeded?—The infusorial mucus-mass originated at the moment when the earth's metamorphosis was at an end, and at the moment when the planet succeeded in so bringing together and identifying all the elementary processes, that they were all together or at one and the same time in every point.—This origin of the organic primary bodies I designate *generatio originaria*, *creation.*—But infusorial vesicles can also originate by mere division of larger organic carcases, and these can again originate as well through the combination of these secondary as of the primitive vesicles, or as it were by coagulation only. I nominate this generation *generatio æquivoca.*—There are only two kinds of generation in the world, the creation proper and the propagation that is sequent thereupon, or the *generatio originaria* and *secondaria.*—No organism has been consequently created of larger size than an infusorial point. No organism is, nor has one ever been, created, which is not microscopic. Whatever is larger has not been created, but developed."

Wild, fanciful, and bordering on the very verge of "idiotic inspiration," as Oken's utterances in connection with the above and kindred physiological problems have been most generally pronounced, our wondering admiration must, so far as the present subject-matter is concerned, certainly be accorded to the creations of this most original and master mind. Notwithstanding the inability to reconcile his views of the constant recurrent or spontaneous generation of Infusoria out of inorganic matter with our present more perfected knowledge of the vital phenomena of the class, his conception of the morphologic value and significance of the infusorial body with relation to organic life in general, and compound or tissue-forming organisms in particular, has certainly anticipated in a most clear and striking manner the views expounded as original by many eminent physiologists who have succeeded him. Giving Oken his due, to him most certainly must be accredited the origination of the cellular theory subsequently introduced by Schleiden and Schwann; for what otherwise than the equivalents of cells, the ultimate factors of all organic bodies as recognized at the present date, are Oken's "first organic points," or "mucous primary vesicles"? By his comparison of the infusorian body with such a simple mucus-vesicle or cell, he anticipates again that conception of the same adopted by Von Siebold and Kölliker, and confirmed by the most recent investigation, while in his interpretation of all higher organisms as compound agglomerations of infusorial bodies, or their equivalents, and in his declaration that organic life must have originated with these simple infusorial types, out of which again by a process of development, and *not through independent creation*, the higher forms have been constructed, is most naturally foreshadowed that grand doctrine of evolution with which the names of Lamarck and Darwin are so honourably associated.

Returning to the more legitimate subject of discussion, that of "spontaneous generation," notice must now be taken of the arguments advanced by the leading and contemporary partisans of the opposite or panspermist persuasion. Ehrenberg, one of the most ardent espousers of this latter cause, based his objections to the spontaneous form of reproduction on the many new facts concerning the organography of the Infusoria elicited through his special investigations, and which included, in his own estimation, the discovery of reproductive organs and the production of ova corresponding with those of the higher animals, and which circumstance he declared rendered the addition of an independent or spontaneous mode of growth entirely superfluous. Evidence of a far more substantial nature, and which was held at the time to be utterly subversive of the cause of the heterogenists, was that produced by Schultze and Schwann in the years 1836 and 1837. The former of these demonstrated that organic infusions after boiling might be exposed to the action of the atmospheric air for many months without developing living animalcules, provided such air passed first through concentrated sulphuric acid, which was pronounced by Schultze to destroy or devitalize the air-suspended germs. The results obtained by Schwann and the means employed were precisely identical, excepting that calcined air was substituted by him in place of sulphuric acid. An important conclusion arrived at by this investigator, as a necessary corollary of the above results, was, that the putrefaction of organic bodies was entirely dependent on the associated growth and multiplication within their substance of minute organisms, such as Infusoria and their allies.

Helmholtz in the year 1843, and Schröder in various contributions published between the years 1854 and 1859, accumulated additional evidence in favour of the panspermists, and towards demonstrating that the animalcules developed in infusions originated mainly, if not entirely, from pre-existing atmospheric germs. Among the more noteworthy experiments of Helmholtz, it was shown that a putrefying infusion, and one sterilized by boiling, might be divided from each other by means of a thin membrane only, so that the liquid masses of the two might freely intermingle through the processes of exosmosis and endosmosis without the latter one becoming tainted, as it indubitably did if the smallest portion of the putrescent fluid was added to it in its concrete form. The unavoidable conclusion derived from this experiment was that the germs existed in the putrescent infusion as actual very minute and solid particles that could not pass like the associated fluids through the intervening membrane. Following out this same line of demonstration, Schröder further showed that simple plugs of cotton-wool inserted in the necks of flasks containing organic infusions sterilized by boiling, sufficed as efficient filters for the exclusion of organic germs, and for the indefinite maintenance of the liquid in the sterilized condition. This last-named experiment is now commonly repeated; flasks of sterilized putrescible fluid being at the present moment on view at the South Kensington Biological Laboratory, which have remained for many years with a similar simple cotton plug guarding their contents from the invasion of organic germs and accompanying putrefaction.

Notwithstanding the almost overwhelming amount of evidence now adduced in contravention of the hitherto extensively upheld doctrine of spontaneous generation, a new champion of its cause was soon to the forefront, and one who has almost down to the present day laboured with all his force and much ingenuity to prove his case. This new leader of the heterogenists was no other than Dr. F. A. Pouchet, the accomplished

Director of the Rouen Natural History Museum. In the year 1847 Pouchet had already demonstrated that the multiplication of Infusoria by the process of fission was by no means so common as was ordinarily supposed, and that the astonishingly rapid increase of their numbers could not be accounted for by such simple means. It was not, however, until the year 1859 that he brought forward that new interpretation of their developmental phenomena with which his name is most eminently associated. In accordance with the representations of this author, the most important factor in the production of animalcules, independent of parental agency, or in other words by spontaneous generation, was the filmy or gelatinous skin or pellicle, that within a greater or less interval is commonly developed on the surface of putrefying infusions. According to Pouchet this superficial pellicle, designated by him the pseudo-membrane, or "proligerous membrane," was the matrix, produced through the decomposition or breaking down of pre-existing organisms, in which egg-like bodies were generated *de novo* and developed into various species of Infusoria. The idea of the germs existing in the atmosphere in sufficient quantities to produce their normal and remarkably rapid development, as held by the panspermists, was rejected by Pouchet as not only untenable, but ridiculous, he reasoning that if such abundance obtained, they would visibly interfere with the clearness of the atmosphere and produce masses comparable with the clouds themselves.

The arguments of Pouchet were not destined to remain long unchallenged. In the following year, 1860, M. Pasteur, the eminent chemist of the Parisian Conservatoire, entered the lists on behalf of the panspermists, and after several years of animated controversy with Pouchet and his partisans, accompanied by the most patient and ingenious experiments, achieved results that most completely turned the tables upon the heterogenists. Among the more prominent and positive of these must be mentioned Pasteur's actual collection of floating organic germs, mingled with inorganic particles from the atmosphere, and which sown by him in sterilized infusions, were found to develop the ordinary infusorial animalcules in abundance. It was further demonstrated by the same investigator that the atmospheric germs in question were by no means so evenly and abundantly distributed as the panspermists had previously maintained. Thus, while sterilized infusions became immediately affected, and crowded with animalcules, when exposed to the grosser and comparatively impure atmosphere of large towns, or other thickly peopled districts, he showed by direct experiment that the same infusions bore the ordeal of exposure to the clear and moteless atmosphere of the Alpine glaciers without exhibiting the slightest alteration or trace of organic life. Transporting his experimental flasks to the pure and tranquil air of those subterranean vaults or "catacombs" for which Paris is so famous, a similar exemption from organic change was observed. In a still more complete and precise manner, Pasteur also repeated and confirmed the experiments of Schwann and Schröder already mentioned, and in the long run produced so complete and logical a chain of evidence in support of the atmospheric dissemination of infusorial germs, and their derivation from similar antecedent parents, that his views were accepted by the Paris Academy as definitely solving the long contested problem in favour of the panspermists.

Banished from France, the doctrine of heterogeny or abiogenesis has yet once again, and probably for the last time, found a staunch advocate in England, the land of its birth, where, however, as presently demonstrated, such reappearance has been associated with an even more disastrous defeat than that administered at the hands of M. Pasteur. The English champion and recognized leader in these latter days of the forlorn hope of heterogeny, Dr. H. Charlton Bastian, entered the public arena in that capacity early in 1870. Already, in January of that year, Professor Tyndall approaching the subject from an entirely independent standpoint, had, as hereafter recorded, declared himself entirely in favour of Pasteur's panspermic interpretation, and it was with the view of refuting the arguments of both of these investigators that Dr. Bastian took up the gauntlet.

Divested of all irrelevant matter, the evidence elicited through his independent experiments was productive of two new arguments, which without doubt, had they remained uncontroverted, would have once more secured a substantial victory for the cause he advocated. In the first place, Dr. Bastian declared that he had succeeded in obtaining growths of bacteria, and other organic germs, from infusions remaining in hermetically closed flasks, from which almost the whole of the air had been expelled by boiling. As at this period of the controversy it was a mutually accepted axiom of heterogenists and panspermists alike that living matter in no shape or form could survive exposure to the temperature of boiling water, 212° Fahr., it necessarily followed that both this axiom and Dr. Bastian's results being substantiated, the organisms developed in the infusions after ebullition were the product of *de novo* or spontaneous generation. In the second place, he declared that all the evidence yet adduced since the date of its first announcement, concerning the existence of germs of invisible or ultra-microscopic minuteness in the atmosphere, springing from and developing to a *known* parental or specific type, was entirely negative, and as a necessary sequence totally unreliable and unworthy of credence. These two points of contention raised by the partisans of heterogeny through Dr. Bastian, viz. the unproduced proof of, firstly, the absolute existence of these prederived ultra-microscopic germs, and secondly, the capacity of such germs to withstand a temperature of 212° Fahr., represent the last tenable position held by the adherents of the doctrine of spontaneous generation, and with the carrying of that position, so far as its serious entertainment by the reasoning and scientific mind is concerned, this doctrine undoubtedly receives its final death-blow.

The two missing links in the otherwise strong chain of evidence adduced by the panspermists, and indicated in the preceding paragraph, have now to be supplied. Their production has necessarily, and as a guarantee of their reliability, to be the joint product of several independent workers, and those names which must ever remain memorably associated with their forging, are those of Professor Tyndall and Messrs. Dallinger and Drysdale. As a humble labourer at the eleventh hour only, seeking for and obtaining evidence of an independent character corroborative of the important results achieved by the foregoing authorities, the author of the present volume is, as presently shown, also in a position to subscribe his name as an additional witness for the panspermists.

Commencing with the achievements of Professor Tyndall in this special field of research, it has first to be related that his earliest association with the subject of spontaneous generation was the result of a happy accident. In the course of those physical investigations for which his name is so justly famous, he happened, while experimenting on the subject of radiant heat in relation to the gaseous form of matter, to require air that was completely free from all extraneous or floating matter, however fine. The passage of the same through alkalis, acids, alcohols, and ethers, was found insufficient to produce the purity desired; but on the other hand, air filtered through cotton-wool, air kept free from agitation sufficiently long to allow the floating particles to subside, air in a calcined state, or obtained from the deeper cells of the human lungs, proved to be effectually cleansed from all such floating substances and to be in every way suited for the purposes required. A delicate and certain method of testing atmospheres to ensure their requisite purity was also devised by Professor Tyndall. This ready test was found to be presented by a concentrated beam of the oxyhydrogen or electric lamp. Surrounding objects being in darkness, such a beam thrown across the ordinary atmosphere revealed its track in a similar manner, but to a still more intense degree, as a sunbeam shining through a minute aperture of a closed window-shutter; wherever it passed it either threw up vividly distinctly moving dust, or presented a turbid or foggy aspect, through the reflection or scattering of light of the myriads of invisibly minute particles with which the same air was laden. Passing a similar beam through air purified in either of the manners above recorded, no such interruption of its course occurred, and from one end to the other of the traversed space its route was dark, and entirely indistinguishable from the surrounding and unilluminated atmosphere.

It presently occurred to Professor Tyndall that the important results obtained by Schwann, Schröder, and Pasteur, and other notable panspermists, concerning the sterility of certain exposed infusions, were intimately associated with those pure and moteless optic conditions of the atmosphere last described. Put to the test, this inference was verified beyond his most sanguine expectations. The ordinary infusions of turnip, hay, and other organic substances were prepared in tubes, and after boiling left to their fate in carefully closed chambers of ingenious construction, whose air contents, after two or three days allowed for subsidence, were shown by the electric beam to be entirely pure and moteless. Other tubes containing a like infused material, prepared under precisely similar conditions, were placed in the ordinary air immediately adjacent to but outside the last-named chambers, and the result awaited. It was this: In the course of three or four days the tubes *outside* the chamber became turbid and swarming with Bacteria and other organisms, while those in the *inside* were as clear and sterile as on the day of preparation, and furthermore remained in the same sterile and pellucid state for several months. At the end of this period a door in the chamber wall was opened, so as to allow the ingress of the ordinary atmosphere, and within three days after such exposure they too became affected and swarming with bacterial life. One logical inference only was to be derived from these results. The Bacteria and other microscopic forms were abundantly present in their germinal state in that ordinary and dust-laden atmosphere on the outside of the closed chamber, and indicated their presence by falling into and freely developing in the suitable nidus provided for them in the exposed tubes. In the still, optically pure, and what may be correctly termed "empty," atmosphere of the closed chambers they were, on the other hand, entirely absent, though all the while, as the sequel demonstrated, beating against the outside of the door and ready to rush in by millions to carry out their work of infection and destruction immediately the portal was thrown open.

Varying his experiments in every conceivable form, a like ultimate result was arrived at. Thus, since leading heterogenists had declared that a high temperature was most suited for the production of *de novo* generation, and especially one approximating that of 115° Fahr., tubes, with infusions as before mentioned, were maintained at this temperature in one of the compartments of the Turkish Baths, Jermyn Street, for nine days without any trace of life appearing. To meet, again, the argument that certain organic infusions were more productive than others of spontaneously generated life, well-nigh the entire catalogue of animal and vegetable substances used in domestic economy, and including among the former beef, mutton, hare, rabbit, kidney, liver, fowl, pheasant, grouse, haddock, sole, salmon, cod, turbot, mullet, herring, whiting, eel, and oyster; and among the latter hay, turnips, potatoes, oatmeal, tea, coffee, hops, &c., were ransacked and severally experimented upon by Professor Tyndall, but with the same result. So long as the infusions were kept in pure and moteless air, so long did they remain pellucid and free from the slightest trace of bacterial or other life, but in all cases on exposure to the ordinary dusty and germ-laden atmosphere, they became, within three or four days at the outside, swarming with organic forms. A small pinch of dust from the laboratory floor, or a dip on a needle's-point from a previously infected infusion, was in either case found sufficient to inoculate the sterile tubes confined in the moteless chamber, though the time occupied in the development of the moving organisms in these two respective cases presented conspicuous points of divergence. Where the inoculation was produced through a needle-dip from an already affected tube the resulting contagion was almost immediate, while where dust was supplied in its dry form, two days mostly elapsed before any indication of such inoculation made its appearance. The sagacious explanation of these phenomena, given by Professor Tyndall, was that the dust supplied contained only germs in a desiccated state, which necessarily required a set time, or "period of latency," to expire before they displayed their vital properties; while in those taken from the fluid medium, these vital properties were already in their full force, permitting the organisms to increase and multiply from the first moment of their contact with the sterile liquid.

One interesting experiment bearing upon the phenomenon last described requires mention. A certain mineral solution, containing in proper proportions all the substances which enter into the composition of Bacteria, was found after inoculation with the least speck of liquid containing living Bacteria, to be always swarming and turbid with such organisms within a space of twenty-four hours; while a small pinch of laboratory dust added to the same fluid, and containing the germs in their desiccated condition, remained in contact with the fluid with impunity for many weeks. Bacteria in their living and moist condition, and those in their desiccated state, were thus shown to possess highly differentiated developmental properties. Another fact of importance, elicited by Professor Tyndall, bears reference to the want of uniformity in the distribution of bacterial and other germs in any given atmosphere. This was demonstrated through the preparation of large trays, contrived to hold as many as from sixty to one hundred tubes of infusions side by side, and on the same level. All of these exposed to dust-laden air were infallibly, after a greater or less duration of time, teeming with living organisms, but the order of their affection or inoculation was found to differ considerably, intervals of several days not unfrequently elapsing between the inoculation of closely contiguous tubes. A considerable difference was likewise found to obtain, under such conditions, in the character of the developed matter, Bacteria of different species, fungoid growths, and other organisms, variously and irregularly preponderating. Professor Tyndall happily explains these phenomena by comparing the aerial distribution of microscopic germs to the cloud-patches visible in a mottled sky; all parts of the landscape, as represented by the tray of tubes, being overshadowed in turn by these patches, but in no definite or regular sequence. It has been pointed out by Professor Huxley, that a closely corresponding simile was originally employed by Ehrenberg, who as an exponent of the atmospheric distribution of Infusoria, either as eggs or in their encysted state, likened the non-uniformity of their occurrence under such conditions to irregularly alternating days of sunshine and heavy downpour. As shown already, however, at page 120, the atmospheric germ theory originated with John Harris, more than a century prior even to the time of Ehrenberg.

That the atmosphere in its purest state may be entirely free from organic germs, had already been demonstrated by M. Pasteur through exposing infusions with perfect immunity from infection, to the open air of the Mer de Glace, which experiment, with precisely identical results, was repeated by Professor Tyndall in the vicinity of the Bel Alp at an elevation of 7000 feet above the sea, in July of the year 1877. Respecting the capacity of Bacteria and atmospheric germs to resist exposure to abnormal elevations of temperature, he found the widest divergence to obtain in materials derived from different sources or in different conditions of vitality. Where the fully developed and vitally active organisms were experimented on, contact with boiling water, or sometimes a temperature considerably below ebullition, was found sufficient to deprive them of life, but where the desiccated germinal matter was operated on, the results were as a rule entirely reversed. In some few instances these germs were so tender as to succumb to boiling for a term of five minutes, or even less, while in extreme cases they were found sufficiently obstinate to survive a similar ordeal of no less than eight hours' duration. As regards their respective "death-points," or limit of heat-resistance, Professor Tyndall suggests that the infusorial germs of the atmosphere might be conveniently classified under the following heads: "Killed in five minutes; not killed in five minutes, but killed in fifteen; not killed in fifteen minutes, but killed in thirty; not killed in thirty minutes, but killed in an hour; not killed in an hour, but killed in two hours; not killed in two, but killed in three hours; not killed in three, but killed in four hours." Several cases of survival after four, five, six, and even eight hours' boiling were met with, and as he further remarks, there is no valid warrant for fixing upon eight hours as the final limit.

The germinal dust obtained from long preserved, and thoroughly desiccated, hay was in all instances found to yield the most obstinately resisting material, and the presence of a truss of hay anywhere in the vicinity of the germinal matter experimented on, always constituted an important factor in its reduction by boiling to a condition of sterility. Notwithstanding, however, the great resistant property possessed by a large number of these germs, Professor Tyndall has shown that even the most obstinate can be sterilized or killed if certain precautions are taken in their treatment. These consist of setting aside the infusion containing them, after ebullition, in a warm room for a period of ten or twelve hours, then raising it again to, and maintaining it for a short interval at, the boiling point, repeating the process with similar intervals of rest several successive times. By these means the germs as they approach their point of final development are successively killed off in the order of their resistance, and the liquid is in the end completely sterilized.

The special chambers improvised by Professor Tyndall for the conduct of the experiments above recorded recommend themselves so strongly, on account of their simplicity of form and efficiency in action, both for further experiments in a similar direction, and for the cultivation of Infusoria generally, that an illustration of one constructed to hold six test-tubes, as given by its talented inventor, is embodied in the plate at the end of the Atlas devoted to mechanical appliances. This simply constructed apparatus consists of a square wooden chamber or box, having a glass front, side windows, and back-door. Through the bottom of the chamber test-tubes pass, packed air-tight, with their open ends protruding for about one-fifth of their length into the chamber. Provision is made through sinuous glass tubings for the free access of air from without, but through which, on account of their sinuous form, no germinal or other dust obtains admission to the central chamber. The top of the chamber is perforated by a circular hole two inches in diameter, and closed air-tight by a sheet of indiarubber. This is pierced in the middle by a pin, and through the pin-hole is pushed the shank of a long pipette, ending above in a small funnel. The shank also passes through a stuffing-box of cotton-wool, moistened with glycerine; so that, tightly clasped by the rubber and wool, the pipette is not likely in its motions up and down to carry any dust into the chamber. The four legs upon which the chamber is elevated are of sufficient height to permit of the application of a spirit-lamp, or other heat-generator, to the bases of the depending test-tubes.

Proceeding now to an examination of the more important data bearing upon the subject of spontaneous generation, obtained through the investigations of Messrs. Dallinger and Drysdale, it must be mentioned, in the first place, that the evidence elicited through their researches was arrived at from an entirely different standpoint, and, in the second place, that it fills up an important hiatus held by the heterogenists to be present in the chain of evidence adduced by Professor Tyndall. Notwithstanding that the only reasonable and inevitable inference to be drawn from the results of his experiments was that infusorial germs of exceeding minuteness were ever present in the ordinary atmosphere, and ready to germinate in the first suitable fluid medium with which they came in contact, it has been urged by his opponents that there is no direct proof of the actual presence of these countless ultra-microscopic germs, and that his evidence is therefore of an entirely negative character. But, to those who are well versed in the life-phenomena of this special class of organisms, the connection between the impalpable germinal dust gathered by Professor Tyndall from the laboratory floor or revealed by the electric beam, and the crops of animated beings produced out of it when sown in the sterilized fluid, is inductively as certain as that the celestial nebulæ, as yet unresolved into their ultimate elements by the telescope, consist of star-aggregations similar to those of the nearer and more familiar constellations.

Fortunately for the cause of the panspermists, this one weak joint in their armour, if such may be said to have been left open—this one little loophole for doubt, out of which the heterogenists have attempted at the eleventh hour to make good their untenable position—has now to be finally closed up. The propagation of infusorial organisms by germs or spores of ultra-microscopic minuteness, has been definitely and most conclusively demonstrated by Messrs. Dallinger and Drysdale, in their accounts of the life-history of various species of monads, contributed chiefly to the 'Monthly Microscopical Journal' during the years 1873 to 1875, and as described hereafter, systematically, under the specific headings of *Monas Dallingeri*, *Cercomonas typica*, and *Heteromita rostrata* and *uncinata*. As there recorded, the spores or germs of these animalcules, when first released by the rupture of their enclosing cyst, are of such extreme minuteness as to defy individual resolution with a $\frac{1}{50}$-inch objective and associated magnifying power of no less than 15,000 diameters, appearing in the aggregate under such conditions as a faintly granular fluid, having a refractive index scarcely distinguishable from the surrounding water. As germination and development progress, each individual spore, however, passes within the range of vision, and by degrees assumes the determinate size, form, and characteristics of the parent organism. The record of these reproductive phenomena of the monads in question was brought forward at the time simply as a newly discovered and interesting chapter in their life-history. Later on, however, Mr. Dallinger published in the 'Monthly Microscopical Journal' for December 1876, the results of his further investigations of these minute organisms, in which, through correlating his own discoveries with those of Professor Tyndall, he obtained some most important results.

Drying up the residual portion of a maceration or infusion containing a certain known form of monad, he had already shown that the light, porous, papier-maché-like substance resulting from such desiccation might be saved, like the seeds of a plant, and used for propagating the species at will in any suitable sterilized putrescible fluid. Working on this basis, an infusion of haddock's head, containing in abundance the so-called "Springing Monad" (*Heteromita rostrata*) and the Calycine Monad (*Tetramitus rostratus*) in the spore-producing stage, was gradually evaporated, then raised to a temperature of 150° Fahr., or 10° above that required to kill the adult form, and so reduced to a porous and highly friable condition. A small portion of this dried material, reduced to powder, was now diffused in an experimental chamber like those employed by Professor Tyndall, and the condensed beam of an oxyhydrogen lime-light being transmitted through the windows, its path within the chamber was more brilliantly marked than on the outside, indicating the preponderating existence therein of the spore-containing or germinal dust. This was now allowed to settle for a space of four hours and a half, when the lime-light still demonstrated, though in a less marked manner, the presence of the suspended dust. Ten small glass dishes, each partially filled with a sterilized fluid, were then introduced into the chamber, four of them being covered with projecting glass lids, mechanically movable, without opening the door of the chamber, and smeared with glycerine, to prevent the disturbance of any previously settled germs. At the end of twenty-four hours the lids were removed from the four covered vessels, and the whole now left undisturbed for four days. The six vessels left uncovered from the commencement being successively examined, were found in every instance to be abundantly peopled with both of the two monad forms present in the evaporized infusion, and developed from the germs diffused as dust through the air of the experimental chamber. Two days later a similar examination was made of the four remaining vessels which had remained covered, and with somewhat different results. In all these the Springing Monad was abundantly developed, but the Calycine form was found in only one of the receptacles, and then in very small numbers.

At first, this result appeared perplexing, but it occurred to Mr. Dallinger that the spores or germs of the last-named type, as in the case of the adult monad, were considerably larger than those of the former, and had, on account of their greater specific gravity, fallen to the bottom of the chamber before the removal of the covers from the four vessels last examined, and had thus been excluded from developing ; this inference was fully substantiated by a repetition of the experiment with certain modifications. On this occasion, the material used was the desiccated residuum of an infusion containing abundantly, in its sporiform condition, the simple uniflagellate type, *Monas Dallingeri*, the smallest species yet met with by him, and whose adult length did not exceed the 1-4000th or 1-4500th part of an English inch. The spores or germs produced by this animalcule were correspondingly minute, and it was consequently surmised that they would remain floating in the still air of the experimental chamber long after the subsidence of the germs of the larger types, and develop in vessels placed there for their reception at a later date. Finely pulverized and intimately mixed with material containing the larger Calycine Monad (*Tetramitus rostratus*) having an adult length of $\frac{1}{900}$ to $\frac{1}{1000}''$, these most minute germs were dispersed as before in a prepared chamber. At the end of four hours and a half, nine small glass basins were introduced, three of them remaining open and six being temporarily covered. At the end of twenty-four hours two of these covered vessels were exposed to the air of the chamber, and at the expiration of forty-two hours the remaining four were similarly exposed. After each set had been left undisturbed for five days they were examined with the following results. The first three (without covers) contained both descriptions of monads in every drop out of the sixty examined. The next two, uncovered at the end of twenty-four hours, were found in every instance to contain the smaller uniflagellate monad in abundance, but the larger one in a single drop only out of the total of sixty examined. In the remaining four vessels, uncovered after a lapse of forty-two hours, the result was that the smaller type was found abundantly in every drop, while the larger one was entirely absent. Finally, after the removal from the chamber of these last four, four more vessels of sterilized putrescible fluid were put in their places, to ascertain if any of the germs of the same type yet remained suspended in the air; but on examination five days later it was found that not a trace even of this most minute flagellate species was present in either one of the four vessels, their germs being thus demonstrated to have entirely subsided.

In addition to the highly suggestive evidence adduced through these several experiments, in demonstration of the persistency of form, and enormous capacity for atmospheric diffusion, possessed by these monads, their ultra-microscopic spores or germs are now shown to possess varying degrees of ponderosity, and it would seem by no means beyond the range of possibility, by further research, and having regard especially to the length of time occupied in the subsidence of a given type, to ascertain, by comparison with some larger and measurable variety, the exact or approximate dimensions of those germs, as yet lying beyond the defining powers of our most perfected microscopes, but instantly revealed by the searching electric beam, and which may be cultivated at will in an appropriate fluid medium.

In addition to the very important bearings upon the question of spontaneous generation embodied in the foregoing researches, Mr. Dallinger's name demands notice also with reference to some most important experiments conducted alone, and in combination with Dr. Drysdale, for the purpose of ascertaining the power of resisting high temperatures possessed by these lower forms of life in both their adult and sporular or germ condition. These experiments entirely confirmed Professor Tyndall's observations, and possessed, moreover, the additional advantage that a given and varying thermal death-point, or limit of heat-resistance, was now associated for the first time with fixed and specific monad types. Following out this line of investigation, it was thus shown that the spores of *Tetramitus rostrata* could successfully resist a temperature of 250° Fahr. (121° C.), those of *Dallingeria Drysdali* 220°, those of *Cercomonas typica* 260°, while in the case of *Heteromita rostrata* and *H. uncinata* they passed unscathed through a temperature of no less than 300° Fahr., or 148° C., which represents the highest limit that has as yet been obtained. It was further ascertained that a somewhat different result accrued according to whether the heat was applied in a wet or dry form, the spores in certain instances exhibiting a difference of as much as 10° Fahr. in this respect, and the highest being resisted when applied in the dry condition. The adult and active monads, having their constituent sarcode or protoplasm in a soft and semi-fluid state, in all cases succumbed to the comparatively low temperature, as an approximate limit, of 140° Fahr., and in many instances to one considerably lower even than this.

Some results of the author's personal investigations have now to be submitted, which tend, from an entirely independent point of view, towards the solution of the question now under discussion. Respecting Professor Tyndall's highly valuable testimony, it has been, and may yet be, objected by the partisans of heterogeny that his atmospheric germs are purely hypothetical and intangible, not having been actually seen by him, nor, what is more important, being so far connected with any recognized specific form of infusorial life. The evidence adduced by Messrs. Dallinger and Drysdale may also be cavilled at as deficient of the necessary proofs, inasmuch as the various species with which their researches are connected are peculiar to certain putrefying animal macerations only, and cannot therefore be said to fairly represent those types common to organic infusion generally, with which the phenomena of *de novo* generation have been held more especially to obtain.

Now, among these, infusion of hay has from the earliest date of the discovery of Infusoria, and the promulgation of the doctrine of spontaneous generation, been recognized as the most productive material for the artificial development of these minute beings, and as the one in which such presumed *de novo* or spontaneous generation is most prominently manifested. So far, this seeming special potentiality of macerated hay has not been made the subject of rigid and exhaustive inquiry, while the evidence recorded by Professor Tyndall concerning the extraordinary heat-resisting and infective properties of hay-derived germs in their concrete form, is no doubt accepted by the heterogenists as simply testifying to the possession by this material of such potentiality. If, however, the disciples of heterogeny flatter themselves that from this last uninvaded vantage-ground they may peradventure be able to withstand and bring discomfiture upon the advancing hosts of their opponents, the panspermists, they are destined to signal disappointment.

Within the last two years the animalcules produced so abundantly in hay-infusions have been the object of the author's special investigation, many of the new species described in the systematic portion of this volume being, indeed, the outcome of such research. Hitherto the infusorial types commonly observed in hay-infusions have been of comparatively large size, belonging to the higher order of the Ciliata, and pertaining to such genera as *Paramecium*, *Colpoda*, *Cyclidium*, *Oxytricha*, and *Vorticella*. These, however, represent numerically but an insignificant minority compared with the vast hosts of flagellate forms which abound in a hay-infusion during the earlier days of its maceration. In such infusions, watched from day to day, and produced from hay obtained from different localities, the number of types presenting themselves in tolerably regular sequence was found to be perfectly marvellous. Foremost among the generic groups putting in their appearance must be mentioned that of *Heteromita*, frequently represented simultaneously by three or four species, and including more especially the *Heteromita* (*Monas*) *lens* of O. F. Müller, *H. caudata*, and *H. gracilis*. Other genera, such as *Oikomonas*, *Dinomonas*, *Petalomonas*, *Rhabdomonas*, *Amphimonas*, *Monas* proper, *Cryptomonas*, *Hexamita*, and *Gymnodinium*, contribute likewise an almost equally considerable contingent; while Bacteria in their characteristic motile and quiescent states are invariably present, and furnish an abundant and ever ready pabulum for their more highly organized animal consociates.

The question presented to the author for solution was, from whence were derived all these myriad organisms, frequently produced in such abundance as to literally jostle each other for room in every drop of water extracted for examination? The heterogenists, including notably MM. Pouchet and Pennetier, have asserted that the highest Ciliate types present in hay-infusions, such as *Colpoda* and *Vorticella*, are generated *de novo* out of the filmy pellicle, or so-called "proligerous membrane," that in the course of a few days makes its appearance upon the surface of the liquid. This proligerous membrane, again, is further represented to be formed from the accumulated dead and floating bodies of Monads, Bacteria, and Vibrios, that first appeared in the infusion, and to constitute a kind of primordial stroma or pseud-ovary, out of the granular constituents of which, through coalescence at various points of the component particles, true eggs are developed, giving birth to such Ciliata as sooner or later appear upon the scene. The Monads themselves are treated as primary motile molecules, occupying a place midway between the organic and inorganic, and possessing motile properties most nearly corresponding with the molecular or Brownian motions of minute inorganic particles. The spontaneous derivation of these Monads from the dead and disintegrated particles of the macerated hay is regarded as too obvious to need discussion. It has been positively ascertained by the author, however, that these minute beings are derived from spores which literally encrust with their countless numbers the stalks and blades of the vegetable matter; these again being the product of pre-existing monad forms, whose active life was passed in close association with the green and growing hay under the circumstances hereafter narrated.

In order to arrive at a comprehensive insight into the life-phenomena and progressive developmental manifestations of the special group of infusorial animalcules now under consideration, hay from different localities was placed in maceration and examined continuously, from its first contact with the fluid medium, for periods varying in duration from a few days only to several weeks. The water added to the hay was of the purest possible description, and was frequently boiled for some time to prevent the introduction of extraneous germs. In all instances, the results obtained were broadly and fundamentally the same, and differed only with respect to the specific types found living together in the separate infusions. Even here, however, the general dominance of two or more special forms was notably apparent. Commencing with the first wetting and simultaneous examination of any given sample, spores of different sizes were found congregated in countless numbers, and in various orders of distribution, throughout the surfaces of the vegetable tissues. The majority of these spores were excessively minute, spherical, of the average diameter of the 1-20,000th part of an English inch, and required necessarily the employment of the highest powers of the compound microscope for the correct registration of their characteristic form and size. Sometimes these spores were to be observed collected in definite spherical heaps, but more often they were scattered in irregular-shaped patches, such patches being often again more or less confluent, and thus forming collections of considerable extent. A large number of these spores were likewise to be seen, detached from their original adhesions, freely floating in the water, or collected in masses, upon the peripheries of the small air-bubbles that had here and there become entangled between the slide and the covering glass. In this latter instance the spores exhibited a thicker and more opaque bounding wall, and manifested, as in the case of lycopodium powder, the power of resisting for some time the hydrostatic or wetting action of the water; this property had already been suspected by Professor Tyndall to be possessed by these minute bodies, but had not previously been practically demonstrated.

The hay within from four to six hours after maceration revealed, on examination of a small fragment, a considerable alteration in the character and comportment of the associated spores. Hitherto these had displayed no signs of motion, a uniform stillness reigning throughout the entire expanse of the microscopic field. Now, however, among the numbers that had become detached from their original adhesion to the vegetable matter, the majority exhibited an active vibratory motion that at first sight was scarcely to be distinguished from the characteristic "Brownian movements." The size of these motile spores corresponded with that of the quiescent ones, not exceeding the 1-20,000th of an inch in diameter, and without recourse to the highest magnifying power and the most careful adjustment of the illumination, it was not found possible to ascertain by what means their locomotion was accomplished. Examined successively with the $\frac{1}{16}$, $\frac{1}{25}$, and $\frac{1}{50}$ inch objectives of Messrs. Powell and Lealand, it was at length satisfactorily determined that each individual spore or body was furnished with a single, long, slender, whip-like organ or flagellum, whose active vibrations propelled the spherical body through the water. These minute motile corpuscles exhibited, in fact, at this early stage of their development a type of organization in all ways comparable with that of the simply uniflagellate genus *Monas*.

A highly characteristic feature of these moving spores remains to be mentioned. Although vast numbers of them were to be seen careering singly through the water, a very considerable proportion were united to each other in irregular clusters consisting of from two or three to as many as a dozen, or, as still more generally occurred, from two to as many as eight of them were joined laterally, so as to form floating moniliform or necklace-like aggregations corresponding in general aspect and mode of attachment with the normal moniliform colonies of the collared flagellate type *Desmarella moniliformis*, hereafter figured and described. If watched for a sufficient time, these clustered and serial aggregations were observed to become disintegrated, each separate corpuscle thenceforward maintaining an independent existence. In consequence of the characteristic aggregate forms primarily exhibited by this special species, it has been further found possible to definitely identify it with one of the types of animalcules described by O. F. Müller in the year 1786, and upon which he conferred the name of *Monas lens*. As figured and described by this author, the above-named species is distinguished in its more minute form by the two conditions of aggregation just enumerated, his illustrations of them being necessarily on a very small scale, and no trace being indicated or discernible with the instruments at his disposal of the characteristic locomotive flagella.

The further development of the separated monadiform corpuscles has yet to be traced. Following the assumption of the independent motile condition, an increment in the size of the constituent body, and with it a duplication of the locomotive appendage, was observed. Within twelve hours from the first submersion of the hay, many of these bodies had increased to twice their original size, measuring now the 1-10,000th part of an inch in diameter, and possessed in addition to a vibratile appendage a second flagellum which trailed posteriorly when the animalcule swam through the water, or held it anchored at will to the vegetable debris or other substances contained in the infusion. Retaining their spheroidal form and two associated flagella, they still continued to increase in bulk, until, at the end of twenty-four hours, the field was more or less crowded with biflagellate animalcules having an average diameter of from the 1-3000th to the 1-2500th part of an inch, and exhibiting in their adult state all the characteristics of an ordinary *Heteromita*. To make the history complete, these adult *Heteromitæ* were observed to increase abundantly by simple fission, as also more rarely to unite or coalesce, the product of such fusion being the assumption by the united zooids of a quiescent or encysted state, followed by the breaking up of the combined mass into a heap of minute sporular bodies corresponding with those just described, and which, like them, were subsequently released and recommenced their developmental cycle under the form of similar irregularly clustered or chain-like aggregations. *Heteromita lens*, however, represented but one, though perhaps the most constant and abundantly developed, out of a number of monad forms that were produced in the various macerations of hay examined, all of which existed, and were for the most part recognizable, in their sporular condition attached to the external surface of the vegetable tissues at the time of their immersion.

Such other spores of various descriptions were found abundantly scattered among those of the type just described, most of them, as in the case of *Heteromita caudata* and *Oikomonas mutabilis*, being of considerably larger dimensions than, and sometimes, as in the first of these two instances, presenting a contour altogether distinct from, the simply spheroidal spores of *H. lens*. In the last two instances the sporular bodies were produced by the subdivision of the parent animalcule into four, eight, or sixteen segments only, and thus conformed in character with the type designated "macrospores" in the account given of the reproductive phenomena of the Infusoria. In that of *Heteromita lens*, on the other hand, these corresponding bodies were so numerous and minute as to baffle computation, and laid claim in a corresponding manner to the appellation of "microspores." In yet other instances the encysted monads were observed to give exit to spores of such excessive minuteness, that, as in the case of several types described by Messrs. Dallinger and Drysdale, they were not individually recognizable as they escaped from the parent cyst, but presented in the aggregate, as viewed with the highest magnifying power, the aspect only of a viscid granular fluid, having a refractive index scarcely higher than that of the surrounding water. The recurrence of the various monad forms just enumerated by no means, however, exhausts the evidence of latent or pre-existing life found accompanying well-nigh every fragment of hay examined. The spores of fungi occurred in abundance, and also ciliate Infusoria, such as *Vorticella*, *Colpoda*, and *Trichoda*, in their resting or encysted state, while Bacteria were never absent. These latter, as time progressed, developed their several motile, glœa, and filamentous phases, and were repeatedly, with the assistance of the $\frac{1}{50}$-inch objective, demonstrated to increase by means of minute internally produced spores, after the manner of the co-associated monads. Some idea of the conditions under which the spores and encystments of the various animalcules present themselves in connection with hay-fibres, as viewed with a high magnifying power, may be arrived at on reference to the upper portion of Pl. XI., which, with its accompanying explanation, is devoted to the special illustration of this topic.

From the foregoing detailed account of the life-history of one special monad type, and of the circumstances under which the spores of this and other species are found primitively attached to the macerated hay, there would appear to be little left to prove the utter untenability of the arguments adduced by the heterogenists in favour of the *de novo* generative properties of this material. One important link in the chain, nevertheless, remains to be filled up. So far it has not been shown under what circumstances these countless multitudes of spores became originally deposited upon, and attached to, the dried hay fibre, and such an absence of definite demonstration might be interpreted by the heterogenists in favour of their having been developed there spontaneously. Of the larger Ciliate species it has been frequently suggested that they are derived from animalcules carried by river inundations on to the low-lying meadow lands, and which have remained attached in their encysted state to the grass on the retreat of the overflowing waters. Such an interpretation, however, necessarily implies a local and restricted distribution only, and in no way accounts for the unexceptional and cosmopolitan distribution of Infusoria and their germs upon hay derived from whatever source. Neither, again, does the vast quantity, and definite disposition of the spores with relation to their vegetable matrix, allow of the alternative that they have simply fallen from the surrounding atmosphere, and which, in point of fact, can be no more regarded as their native or parental element than it is that of the floating thistle-down.

The mode of distribution of these infusorial spores upon the hay-fibres indicated, in characters too clear to be mistaken, that all the essential conditions of their life-cycle had been passed in close connection with it. This interpretation was arrived at inductively, and its correctness was recently put to the test, with the following remarkable results. On Saturday, October the 10th, 1879, a day of intense fog, the author gathered grass, saturated with dew, from the Regent's Park Gardens, the Regent's Park, and the lawn of the Zoological Gardens, and submitted it to microscopical examination, without the addition of any supplementary liquid medium. In every drop of water examined, squeezed from the grass or obtained by its simple application to the glass slide, animalcules in their most active condition were found to be literally swarming, the material derived from each of the several named localities yielding, notwithstanding their close proximity, a conspicuous diversity of types. *Heteromita lens* and *H. caudata* were in all three instances abundantly present, as also minute actively motile Bacteria. Other types, such as *Vorticella infusionum*, *Dinomonas vorax*, *Hexamita inflata*, *Trepomonas agilis*, and *Phyllomitus undulans*, to say nothing of a host of unidentified spores and encystments, occurred variously distributed among the three examined samples of dew-laden grass, but even these by no means exhausted the list of living forms. Two species of Rotifera, *Rotifer vulgaris* and *Theorus vernalis*, numerous *Amœbæ*, *Anguillulæ*, and various diatoms, chiefly motile *Naviculæ*, contributed their quota towards the host of active living organisms that were found peopling more especially the lower and decaying regions of the dew-moistened vegetation, the collection as a whole being undistinguishable from the ordinary microscopic fauna of a roadside pond.

The data elicited through the observations just recorded carry with them an important and far-reaching significance. In addition to the conclusive proof herewith afforded of the primary origin of germs in hay, Infusoria and other minute forms of aquatic life were thereby demonstrated to possess an area of active vital distribution hitherto undreamt of. Water in its stable and concrete form is no longer, as hitherto presumed, a requisite concomitant of such vital energy. The smooth-shaven lawn, park-land, and meadow are each and all one vast teeming city, peopled by its myriads of tiny inhabitants, heedlessly crushed under foot in our daily walks abroad. Securely housed in their spore-membranes or encystments, these microscopic beings slumber undisturbed and unconsciously throughout the dry, dusty summer days, awaiting, however, only the fall of the evening dew, or passing shower, to cast off the frail cerements that enclose them, and to re-awake to active sentient life. The mode or conditions of existence of the animalcules thus found so plentifully on the dew-, or rain-moistened grass, are obvious. As already stated, they are encountered most abundantly on the lowermost blades, coloured brown or yellow, upon which the finger of decay has already set its stamp. Here, in fact, is a plentiful banquet ever set in order for them, closely identical in character with the artificially prepared infusions of hay, and other vegetable substances, which are so speedily attended by their myriad guests. Their purpose in life, as in the case of the animalcules inhabiting artificial infusions, is to break down and convert into new protoplasmic matter this otherwise waste product. To maintain the balance here, however, and to check the too rapid increase of the herbivorous monads, we find other types, such as *Dinomonas* and various Ciliata, answering to the Carnivora among the various higher animal sub-kingdoms, developed side by side with and feeding in turn upon the plant-eating species.

The general conclusions deducible from the long array of evidence now produced with respect to the question of "spontaneous generation," or "abiogenesis," may now be briefly summarized. From every line of inquiry investigated, one and the same answer is invariably returned. Life in its most humble and obscure form, be it existent as impalpable germinal dust floating in the atmosphere, or shaken from a truss of hay, or manifested in its more active state as the minute monads, bacteria, and other organisms developed in infusions, tells everywhere the same unvarying tale. Traced backwards to its origin, or forwards to its ultimate development, each type is found by patient search to be derived, not *de novo* out of dead or inorganic elements, but from a specific parental form identical in all respects with itself, and whose life-cycle is as true and complete as that, even, of man himself.

To the scientific mind the conception that organic matter was primarily eliminated, or in other words created, out of the inorganic, is forced home as a natural and logical conclusion, and also that this transition may be a process of every day occurrence. So far, however, as such recurring or *de novo* generation is exhibited by the types of organic life dealt with in this volume, or at present known, there is no longer left a loophole for doubt. The evidence from all sides, revealed by the exhaustive light of recent research, proves conclusively that in all these cases, down to the lowest monad and bacterium, the reproduction of their kind, formerly supposed to be altogether fortuitous and irregular, conforms in every essential particular with that of the highest members of the organic series.

Accepting, in point of fact, the infusorial or protozoic spore as the physiological, though not morphological, equivalent of the ovum of all higher animals, or Metazoa, Harvey's once famous, but since discarded, aphorism "*Omne vivum ex ovo*," is found, so far as human knowledge has as yet penetrated, to dominate with equal force from one extremity to the other of nature's chain. To assert, however, that we have penetrated to and laid bare the ultimate and finite confines of the organic realm, would be an arrogant and altogether illogical assumption: a vast *terra incognita* of organic forms may still remain to be explored. As yet, the latest investigations of physiologists have pushed so far forward as to acquire an approximate, though by no means exhaustive, knowledge of the "*cellular*" as manifested by unicellular and multicellular products. Unicellular products, however, there are ample grounds for maintaining, are susceptible of differentiation to an almost unlimited extent, such differentiation being essentially "*molecular*." In the same manner that unicellular organisms are now shown to correspond with the essential or primary elements out of which all multicellular organisms are built up, so is it within the region of possibility that entities yet exist which in a parallel manner find their morphological equivalent in the constituent elements of unicellular beings, and whose composition may be therefore correctly described as simply molecular. Practically, such molecular organic entities exist in the individually invisible or ultra-microscopic germs, discharged in a semifluid state from the encystments of many monads. The embryonic condition of one form typifying the adult state of one lower in the organic scale, is of almost undeviating recurrence in the scheme of nature, and the conception, therefore, of beings possessing in their highest state of development a corresponding germinal, and yet ultra-microscopic or molecular condition, follows as a natural and almost unavoidable deduction. It is, logically, within the realms of the *molecular* alone, if anywhere, that the transition from the inorganic to the organic is to be sought. Elsewhere, throughout the entire range of *cellular* structures, the phenomena of reproduction are distinct and uniform, rendering entirely untenable and nugatory their correlation with the doctrine of abiogenesis.

One final, though indirect, result of the rigid scrutiny to which the monads, and other low unicellular organisms, have been submitted in order to solve the mystery of their generation, remains to be recorded. As conclusively proved by Professor Tyndall, Dallinger and Drysdale, Cohn, Kühne, and other investigators, such organisms in their germinal or sporular state can successfully resist exposure to temperatures that prove fatal to any other more highly organized structures, even up to and beyond the boiling-point of water. So far, therefore, as they are brought in contact with the ordinary conditions of the earth's surface they are practically *indestructible*. Nay more! as suggested by Professor Tyndall, there is no reasonable pretext for assuming that there are not germs capable of resisting far higher temperatures than those which have been hitherto subjected to experiment. Hence, among all known organic forms, the Infusoria and their allies alone would appear to possess the power of weathering the cataclysmic changes of the universe, and, secure from all influences of heat and cold, of migrating in safety through interplanetary space.

CHAPTER V.

NATURE AND AFFINITIES OF THE SPONGES.

IT is proposed to devote the present chapter to an extensive discussion of that near relationship of the sponges to certain of the Infusoria Flagellata, briefly referred to on several occasions in the course of the preceding pages. This affinity is found, indeed, upon an impartial examination of the data here collected, to be so comprehensive and thoroughgoing as to render absolutely unavoidable the correlation of this group with the typical representatives of the flagellate Protozoa. Those differences which do exist between the two groups are, in point of fact, far less essential than those which obtain between many of the subordinate sections of the ordinary Ciliate and Flagellate Infusoria; such being the case, the present work could not be considered complete if it did not embrace a more or less extensive account of the fundamental plan of organization, at least, of the Spongida. Strictly speaking, the sponges, throughout all their wealth of form and organization, are here accepted as Mastigophorous Protozoa, and it is on account only of the limited space at disposal, that their full specific enumeration and description, on a scale corresponding with that allotted to the more typical representatives of the Flagellate Infusoria, is here omitted. Under existing circumstances, it is found possible to submit a brief sketch only of those broad fundamental characters which either unite with, or distinguish the members of the sponge-tribe from their nearest allies, supplementing them with the author's personal interpretation of those somewhat obscure structural and developmental points which have been held by other authorities to indicate an affinity in a different direction. For, although it is confidently anticipated that the evidence now brought forward must materially assist in securing to the sponges, eventually, a general recognition of their intimate relationship to the Choanophorous section of the Flagellate Infusoria, it can by no means be said that such an affinity is at the present date universally recognized. On the contrary, the balance of contemporaneous scientific opinion favours the relegation of this organic group to the division of the Metazoa, though upon grounds which, plausible as they seem to be upon the surface, are fundamentally purely artificial and untrustworthy.

In order to arrive at a position permitting a thoroughgoing and impartial appreciation of the very voluminous and conflicting evidence that has been amassed with reference to the much debated affinities of the sponges, it is, before all things, desirable to commence with an examination of the earlier periods of their intelligibly recorded history, and thence to trace forwards, link by link, those consecutively recorded data which have led up to the present controversial position of the question.

As an initial step in this direction, it is worthy of remark that the conclusive demonstration of the very animal nature of the Spongida has only been accomplished within the present generation ; for while originally premised by Marsigli at the commencement of the eighteenth century, and subsequently advocated by Ellis and Solander, Montagu, and Lamarck, it was left to Grant, Bowerbank, Carter, Lieberkuhn, and Dujardin within these later limits to produce the actual proofs of their animal organization. Among the investigators just enumerated, the name of our fellow-countryman Dr. Grant may be specially singled out, as the authority who first discovered the characteristic ciliary action in sponges, as also the existence of the remarkable free-swimming ciliated reproductive bodies described at length later on. That of Felix Dujardin, however, has to be still more prominently mentioned, he having been the first to indicate that relationship between these organisms and the more ordinary Flagellate Protozoa, which with some modification is here supported. In the course of his 'Histoire des Infusoires,' published in the year 1854, this author devotes two brief pages to the nature and organization of the group now under consideration. Tearing to pieces a living fresh-water sponge (*Spongilla lacustris*), he there records that the constituent living particles will be found, on submission to microscopical examination, singly or united in groups, either floating in the water or adherent to the glass slide, and that for the most part these constituents are furnished with long vibratile filaments or flagella, similar in character to those possessed by the simplest Flagellate Infusoria or monads. These same constituent particles, he, moreover, observed to throw out lobe-like expansions or pseudopodia, and to creep about after the manner of amœbæ. This phenomenon, while possessed by the floating ones, is more especially marked in those which adhere to the surface of the glass, and in which the vibratile flagella had become withdrawn or obliterated. He also briefly alluded to the ciliated reproductive bodies of *Spongilla* and various marine sponges, and the group as a whole he declared to exhibit a type of organization comparable to associated colonies of Infusoria, possessing the united characteristics of both monads and amœbæ. Respecting the horny fibres and siliceous or calcareous spicules secreted by the various tribes of sponges, Dujardin suggested that they are analogous respectively to the branching and somewhat horn-like supporting stalk of such monads as *Anthophysa*, and to the siliceous and calcareous tests presented by the ordinary Rhizopoda.

By Mr. Carter, in November of the same year 1854,* the announcement was made of the discovery, in *Spongilla*, of so-called zoosperm-like bodies, these, however, as he afterwards admitted, representing the ordinary

* 'Ann. and Mag. Nat. Hist.,' vol. xiv. ser. ii.

polymorphic and flagellate cells first noticed by Dujardin. To a like category must undoubtedly also be relegated the so-called "spermatic elements," described by Professor Huxley in the 'Annals of Natural History' for the year 1851. Lieberkuhn * corroborated and added considerably to the details of the structure and life-history of *Spongilla* made known by Dujardin, and elicited much new evidence concerning the occurrence in this type of the motile ciliated germs, in addition to the more ordinarily occurring non-motile and so-called "seed-like bodies," first discovered by Dr. Grant, in association with various marine species, and merely recorded by Dujardin, on the authority of M. Laurent, as existing in *Spongilla.* Following upon Lieberkuhn's discoveries, must be recorded the very important contributions respecting the ultimate structure of the closely allied Indian species of *Spongilla,* contributed by Mr. Carter to the 'Annals and Magazine of Natural History,' during the years 1857 and 1859. In the first of these contributions, the entire life-history, from the indurated "seed-like body" up to the adult state, was successfully traced out, and many entirely new facts respecting the more minute histology of the sponge organism elicited. Among these it was demonstrated that the essential living constituents of the sponge-body were represented by the ciliated monad-like elements first described by Dujardin, and that they exhibited a very definite mode of arrangement. Under normal conditions, Mr. Carter found that the monad cells were congregated together so as to form a single and even layer within the interior of small spherical chambers excavated within the sarcode or mucilaginous basal substance of the sponge, and to which chambers he applied the term of "ampullaceous sacs." The additional name of ovi-cells was also given to these chambers in their earlier condition, from his having observed their development out of a pre-existing ovule-like or granular mass, this latter first passing into the normal, small, monociliated and unciliated sponge-cells which then spread over the interior surface of the so-called ovi-cell, each with its cilium directed inwards, and so leaving a cavity in the centre which finally became connected with the nearest adjacent afferent canal.

The origin of these "ampullaceous sacs," by a process of development corresponding to the growth and segmentation of an ordinary ovum, is, as hereafter shown, entirely confirmed by the investigations of the present author. Mr. Carter further demonstrated the capacity of both the ciliated and unciliated sponge-cells of the ampullaceous sacs to take in solid food in the form of minute granules of carmine distributed in the surrounding water, as also the possession by these individual bodies of contractile vacuoles and nucleus-like granules. Taken as a whole, the animal nature of *Spongilla* was now proved beyond further question, and its composition maintained to consist essentially of polymorphic monadiform or amœba-like elements, closely corresponding with ordinary monads and amœbæ, the former being aggregated together in definite order within the structureless

* Müller's 'Archiv,' Bd. i., 1856.

jelly-like sarcode, that formed the groundwork or substratum of the sponge-body. Within the central substance of this sponge-body, and also in the superficial part, called by Mr. Carter the investing membrane, were found scattered the innumerable amœba-like non-flagellate cells, as also the characteristic spicules of the species, which were reported to be secreted by the amœboid elements. Finally, the entire sponge-body was shown to be brought into intimate relationship with the external water, firstly, by a series of pore-like apertures opening or closing at will in the investing membrane, and communicating through the afferent canals with the ampullaceous sacs; and secondly, by another series of tubular channels, the efferent canals, which originating in the deeper substance of the sponge, united with each other, and finally debouched upon the large excurrent apertures or "oscula."

As a result chiefly of the very exhaustive evidence concerning the ultimate structure of *Spongilla* elicited through Mr. Carter's investigations as here briefly epitomized, the position of the sponges among the ranks of the Protozoa, and as specialized and colonial aggregations of amœboid and monadiform Protozoic beings, became almost universally accepted. It is at the same time worthy of notice, that Mr. Carter hinted at the possible correspondence of the ciliated sponge-chambers or ampullaceous sacs with the stomach-cavities of the simplest polyps, certain Planariæ, and other organisms in which the cavities receiving the injected food are also lined with cilia. In January 1859, Mr. Carter contributed a further communication to the journal already named, recording new data of interest relative to the form and structure of the essential monadiform sponge-cells, though at the same time he temporarily modified his previous views concerning the character of the ampullaceous sacs. The most important point that requires notice relates to the circumstance that he here described and figured in association with certain of the larger ciliate or monadiform sponge-cells, the existence of two "spines" or "ear-like points," which he figured and described as projecting to an even distance on either side of the base of the single whip-like cilium. A possible spermatozoic character of these so-called "spiniferous cells" was at first suggested by Mr. Carter, but subsequently abandoned through his demonstration of their capacity to take in solid nutriment. The special interest attached to the discovery by Mr. Carter of these spiniferous elements will shortly become apparent.

The earliest complete treatise of importance demanding notice bearing upon the structure and organization of sponges, is the first volume of Dr. Bowerbank's 'Monograph of the British Spongiadæ,' published by the Royal Society in the year 1864. Vast, however, as is the mass of material embodied in this and the two subsequent volumes of this work (1866 and 1874), it relates almost entirely to the structure and organization of sponges in their dried or preserved condition, and is of practical value only for the purposes of specific identification. In such preserved specimens, as there described, the essential vital elements now under discussion had become completely metamorphosed or obliterated. Excepting, in fact, his notice of the several observations of Grant, Dujardin, Carter, and Lieberkuhn, concerning the presence and disposition of the monociliated sponge-cells, Dr. Bowerbank's only personal record of their definite recognition is associated with the calcareous type *Grantia compressa*, of which species he figures and describes their characteristic tesselated plan of arrangement. In their isolated condition the separate flagellate elements are so delineated as to resemble the spermatic cells of ordinary vertebrate animals, having a small ovate body and a long and comparatively thick terminal flagellum.

With the year 1866, an important epoch in the elucidation of the structure and affinities of the Spongida was inaugurated. In June of that year was published in a condensed form in the 'Proceedings of the Boston Society of Natural History,' the results of a prolonged and painstaking investigation instituted by Professor H. James-Clark, of the Agricultural College of Pennsylvania, U.S.A., with reference to the ultimate form and composition of the monociliated cells of a calcareous sponge most nearly allied to the *Leucosolenia botryoides* of Bowerbank, and having respect to their close correspondence with the individual zooids or units of certain new forms of Flagellate Infusoria which he had recently discovered and then described for the first time. This important communication, with accompanying plates, appeared *in extenso* in the 'Memoirs' of the above-named society, vol. i. plate iii., for the year 1868. The essential feature of the new and special forms of Flagellata here introduced, numbering in all four species, and referred to the then two newly instituted genera *Codosiga* and *Salpingœca*, consisted of the fact that all of their representatives were provided at the free anterior extremity with a delicate funnel-shaped expansion of the sarcode, possessing an extraordinary amount of plasticity, which in its normal condition of expansion surrounded the base of the flagellum.

Upon this newly discovered and remarkable structural element Professor Clark bestowed the appropriate title of the "collar," and as "collared" or "collar-bearing" monads, the animalcules then and since discovered sharing a corresponding structure, are now generally known. Turning his attention to the ultimate ciliated elements of the calcareous sponge just mentioned, Professor Clark at once recognized that when viewed with a sufficiently high magnifying power they exhibited a type of organization precisely identical with that which obtained in the independent collar-bearing monads, possessing like these a similar film-like, extensile and contractile, collar-like membrane, enclosed terminal flagellum, posteriorly located contractile vesicles, and all other details characteristic of an isolated monad of his newly established genus *Codosiga* or *Salpingœca*. As indicated by Professor Clark, any one previously acquainted with the structure of *Codosiga*, but not with the sponge, would without doubt, in describing merely the congregated monads of the latter, pronounce them to be colonial and massive growths of the previously named simple Flagellata. The other elements recognized by Professor Clark as entering into the composition of the complete sponge-body, manifesting its differentiation from such a simple monad colony as *Codosiga*, were, in the first place, an externally placed and excessively hyaline, glairy, gelatinous matrix, upon the internal surface of which the characteristic flagellate cells were embedded, and secondly, the spicular bodies found immersed within the substance of this glairy matrix, and by which latter element he considered them to be secreted. Upon this common matrix he conferred the title of the cyto-blastematous layer, or "cytoblastema," in contradistinction to the internal pavement-like one composed of collar-bearing units, and which he designated the monadigerous layer. The spiculæ themselves he represented as directly comparable with the horn-like loricæ secreted, or rather excreted, as protective coverings by such genera as *Cothurnia*, *Salpingœca*, and other ordinary Infusoria.

It was at once recognized by Professor Clark that the so-called spiniferous elements of *Spongilla*, figured and described by Mr. Carter in the year 1859, were closely identical with what had been observed by himself in *Leucosolenia*, and that the two "spines" or "ear-like" points recorded by the former authority, represented actually the right and left profiles of a similar subcylindrical membranous collar. Mr. Carter's observation of these "spine-bearing" cells in a limited number of instances only is satisfactorily accounted for by Professor Clark's record of the facility and rapidity with which when disturbed this membranous collar is completely withdrawn into the general substance of the body-sarcode. With reference to the food-incepting phenomena of the sponge-monads, Professor Clark was not able to arrive at a definite conclusion. Presuming, nevertheless, from his assumed discovery of a distinct oral aperture in *Codosiga* and other Flagellata, close to the base of the flagellum, he was led to predicate the existence of a similarly located one in the case of the sponge-monads. As hereafter shown, however, Professor Clark's inferences concerning the nature and position of the oral aperture in both the independent and associated collared monads, have not been confirmed. Summing up the results of his discoveries, the views maintained by Professor H. James-Clark with reference to the position and affinities of the sponges were, that these organisms must be regarded as compound colonial forms of Flagellata, whose units, in the case of *Leucosolenia*, exhibited a type of structure essentially similar to that of *Codosiga* and *Salpingœca*, but might possibly in other instances more closely approximate to that of *Monas* (*Spumella*) *Bicosœca* or *Anthophysa*.

The entirely new light brought to bear upon the much vexed question of the affinities of the sponges, and the influence upon the scientific mind it was calculated to exert, through the important discoveries of Professor Clark, were doomed, for a time at least, to be thrown into the background, if not altogether set aside, in consequence of the almost contemporaneous introduction upon the scene of a yet more novel, and for the disciples of the doctrine of evolution, a far more fascinating interpretation of the structure and relationship of these organisms.

The following year, that of 1869, was signalized in the annals of the scientific world by the publication of Professor Ernst Haeckel's brilliant disquisition in the 'Jenaische Zeitschrift,' Bd. v. 1869 (reprinted in the 'Annals' for January and February, 1870), in which this talented author announced, in the most emphatic terms, that the sponges were more nearly related to the corals, or Anthozoarian Cœlenterata, than to any other organized beings, and that the position hitherto assigned to them among the Protozoa was fallacious, and could no longer be maintained. Practically, in the advancement of this theory, Haeckel may be said to have merely resuscitated and clothed in a new and attractive garb the moribund one that, first originating with Ellis and Pallas, was still more extensively developed by Leuckart, but rejected by the verdict of subsequent investigators. This supposed affinity, as advocated by Leuckart and his predecessors, was, however, one only of broad external isomorphic or homoplastic resemblances. In accordance with their views, each efferent or oscular area in a compound sponge-body was regarded as the equivalent of an individual polyp of a coral stock, minus in each instance the characteristic tentacles, stomachal sac, and internal mesenteries and septa that distinguish the representatives of the corals. Summing it up, such a likeness as evoked by Leuckart on the part of the sponges with respect to the corals may, borrowing a dramatic simile, be aptly compared to the play of 'Hamlet,' minus the king of Denmark. Professor Haeckel, however, disinterring and infusing new breath into Leuckart's abandoned conception, claimed for it a far wider and more deeply reaching significance. It was insisted upon by the illustrious biologist of Jena that not only a general external or homoplastic resemblance existed between the organic groups in question, but that the internal structure and histological organization of the two also coincided. Following out this line of argument, it was represented that the nutritive canal system of the sponges was both homologous and analogous with the gastrovascular system of the corals; that both the corals and the sponges were characterized by the possession of similar distinct external and internal cellular layers, or ectoderm and entoderm; and that the adult organisms were derived in either case from similar primitive diploplastic ciliated larvæ, *planulæ* and *gastrulæ*, these again being developed from ordinary segmented ova.

As may have been anticipated, this bold conception of Professor Haeckel's inaugurated for the sponges an era of most close and rigid investigation not yet ended, which has already resulted in a mass of evidence that has added vastly to our previous knowledge of the ultimate composition of these structures. None of this testimony, however, can be said to confirm precisely that interpretation of the structural or developmental phenomena insisted upon by Haeckel. In the majority of instances, indeed, it is entirely subversive of his theory. Among the earliest of the several protests against the views submitted by Professor Haeckel, reference may be made to the communications contributed by the present author to the 'Annals of Natural History' for March and August 1870. The subject on these occasions was approached more entirely from the Cœlenterate point of view, the writer being at that time officially occupied in the study, identification, and arrangement of the series of corals, recent and fossil, contained in the Natural History Department of the British Museum. Arguing from such a standpoint, it was sought to demonstrate that between the alimentary systems of the two groups in question there was nothing whatever in common; that the single, well-defined gastrovascular aperture in a coral, subservient both for the processes of ingestion and excretion, was in no ways comparable to the multifarious canal-system through which, upon every side of its periphery, the sponge-body received its nutriment, and that the assumption by Professor Haeckel of a distinct ectoderm and endoderm in the structural elements of a sponge was by no means clearly demonstrated. His claim of a distinct personality for each oscular area of a sponge-body was likewise contested, and an adhesion given generally to that Protozoic interpretation of the sponge question, then supported in the text-books of Huxley, Carpenter, and other English authorities, and manifested by the investigations of Lieberkuhn, Bowerbank, and Carter, and especially through the more recent investigations of Professor H. James-Clark already quoted. Evidence of a still more substantial nature, tending in the same direction, and emanating from one of the earliest and first authorities in this country upon sponge organization, has next to be noticed.

In October 1871, Mr. H. J. Carter contributed to the 'Annals of Natural History' the announcement of his identification, in all of the numerous marine siliceous and calcareous sponge types recently examined by him, of a structure essentially corresponding with that which he previously described as obtaining in *Spongilla*, and generally indicated their nonconformity with the Cœlenterate plan of organization insisted on by Professor Haeckel. As interpreted by Mr. Carter, the "ampullaceous sacs," or other ciliated systems, represented the only essential portion of the sponge structure, the remaining elements compared with these being entirely subsidiary. One especially weak point in Professor Haeckel's argument was further pointed out in his remarks concerning the sexuality of the sponges. In none out of the hundreds of Calcispongiæ examined by him with the microscope, Haeckel says, could he detect a trace of fecundatory male elements or zoospermia, and that therefore the bodies subserving the purposes of reproduction constantly present cannot be designated true sexual eggs or ova, but asexual germ-cells or "spores." These spores, or so-called ova, in all the sponges he investigated, Professor Haeckel, moreover, declared to be perfectly naked and destitute of membrane, like the flagellate cells from which they proceed; furthermore, he reported that in all the sponges examined by him he had never found any trace of a membrane or true cell-membrane on the cells, and that therefore all sponge structures were composed of naked cells or "gymnocytodes." As indicated by Mr. Carter, this sporidular interpretation of the reproductive phenomena advocated by Professor Haeckel was in itself completely subversive of the theory he attempted to substantiate, and, as the very essence and starting-point of which, the existence of true and normally fecundated ova, represents an indispensable condition for the evolution of the two primitive germinal layers having the significance of an ectoderm and endoderm in the ordinary and restricted acceptation of the terms. Finally, Mr. Carter directed attention to the recent discoveries of Professor H. James-Clark as indicative probably of the true direction in which the affinities of the sponges are to be sought.

Practically following up this clue, Mr. Carter, in the 'Annals' for July of the year 1871, produced a still more important contribution towards the elucidation of the structure and affinities of the sponges. On this occasion he announced that by renewed investigations, with increased magnifying power, he was enabled to entirely confirm Professor Clark's discoveries concerning the peculiar collar-like structures possessed by the monoflagellate sponge-cells, and stated that it is out of such collared monoflagellate elements that sponge organisms are more essentially constructed. While the material supplying Mr. Carter with this important confirmatory evidence was chiefly derived from the calcareous type *Grantia compressa*, other species, such as *Grantia* (*Sycon*) *ciliata*, *Leuconia nivea*, and *Clathrina sulphurea*, were found to yield substantially parallel testimony. Those elements of *Spongilla* described by himself, in the year 1859, as flagellate cells with ear-like or spine-like points, were also now recognized as indicating the same fundamental structural form in the fresh-water species. On one point only did Mr. Carter dissent essentially from the views of Professor Clark, namely, with reference to the mode of food-inception. While the last-named author attributed to the collar-bearing sponge-cells, and also to the independent collared flagellate types *Codosiga* and *Salpingœca*, the possession of a distinct mouth—not actually discerned, but supposed to be situated within the collar, close to the base of the flagellum—Mr. Carter was inclined, in consequence of the exceedingly variable or polymorphic properties of these sponge-cells, to infer that they engulfed food at any point of their periphery after the manner of amœbæ. With respect to the highly conspicuous polymorphic features of these essential sponge-cells, he further considered that they were to be regarded rather as forms intermediate between Rhizopoda and Infusoria-Flagellata than as typical Infusoria as interpreted by Professor Clark; preferentially, perhaps, they were to be accepted as a distinct and independent Protozoic group, whose component units or individuals might be appropriately designated sponge-animals or Spongozoa.

Before the close of the same year, 1871, additional but unfortunately for science, the latest evidence in this direction, a few months prior only to his much-to-be-lamented decease, was produced by Professor Clark himself. Already, in 'Silliman's American Journal' for February 1871, he had drawn attention to Cienkowski's new social monad genus *Phalansterium*, and indicated its apparent close affinity to the collared types *Codosiga* and *Salpingœca* discovered by himself, but from which they differed most essentially in the less conspicuous development of the characteristic collar, and in their social or colonial occupation of a common gelatinous matrix. This latter point more especially was cited as indicative of a still more intimate relationship with the sponges than that presented by the two last-named genera. Professor Clark further placed on record in the same serial the results of his recent investigations into the ultimate structure of the American Fresh-water Sponge, *Spongilla arachnoides* J.-Clk., the results confirming substantially, and adding considerably to, the data elicited through his previous examination of the marine calcareous type *Leucosolenia botryoides*. In this fresh-water form, however, the characteristic collared flagellate cells were found occupying definite spherical excavated chambers, corresponding with those described by Mr. Carter of *Spongilla alba* under the name of ampullaceous-sacs, which received from Professor Clark the equivalent title of the "monad chambers." Taken in its entirety, the sponge-body of this species was declared to be composed of the three following distinct and well-marked elements: Firstly, of a common, glairy, gelatinous basis, within which all the remaining constituents were embedded, and which he designated the *cytoblastema*. Although presenting the same characteristic consistence throughout, this glairy cytoblastema exhibited a separation into two distinct regions, the one consisting of a thin superficial stratum, stretched out on the points of the larger externally projecting spicula, after the manner of a tent-canvas extended upon the ends of its supporting poles. Within this peripheral cytoblastematous layer, designated by Professor Clark in its separate form the "investing membrane," there was no trace to be found of the monad-chambers. These latter, which constituted the second and most important structural element, were confined entirely to the deeper and comparatively solid substratum of the cytoblastema, and which he therefore distinguished, with relation to its contents, as the "monadigerous layer." The third and remaining essential element recognized by Professor Clark consisted of the innumerable amœbiform cells or bodies scattered more or less abundantly throughout the substance of the cytoblastema, and most conspicuously visible, in consequence of the absence of the monad-chambers, in the thin superficial stratum or so-called investing membrane. These amœbiform cells were distinguished by Professor Clark merely by the name of the "cell-elements" of the cytoblastema, but, for convenience, may be appropriately designated the "cytoblasts" or "cytodes." Like simple cytodes, they were shown, as also pointed out by Professor Haeckel, to possess no distinct cell-wall, and, unless specially focussed for, were scarcely to be distinguished from the cytoblastema in which they were embedded. Seen under the most favourable auspices, their substance was demonstrated to be slightly granular, and that they contained a subcentral, spherical, and more highly refractive nucleus or endoplast. The contours presented by these cytoblastic bodies varied greatly, ranging from simply ovate to every variety of irregular and jagged outline, and their periphery often taking the form of more or less prolonged caudiform projections, directly comparable with the pseudopodic appendages of a typical *Amœba*. In addition to these three essential elements, e.g. the transparent structureless "cytoblastema," the "collared monads," and the polymorphic amœbiform "cytoblasts," one conspicuous but non-essential structural element, as represented by the supporting or strengthening siliceous spicula, remains to be mentioned. The spicula in the sponge in question were of two sorts, large and small, and were found in either case to be confined exclusively to the cytoblastematous layer, and not to intrude into the monad-chambers; while the larger ones penetrated into the deeper substratum of this element, the smaller ones occurred only in the more attenuate peripheral region, and were evidently built up or secreted by the cytoblastema or its enclosed amœbiform cytoblasts. The exclusion here made of the secreted spicula from the category of essential elements, while a departure from the course taken by Professor Clark, is justified by the fact that sponges exist—e. g. the Myxospongiæ, including *Halisarca* and its allies—in which, while all the other three elements are fully represented, spicula or skeletal structures of any kind are entirely absent.

Among the data of importance recorded by Professor Clark concerning the organization of the separate collar-bearing elements of the monad-chambers or ampullaceous sacs, has to be particularly mentioned that he demonstrated in this type most definitely the possession by each monad of two or more conspicuously developed and evenly pulsating contractile vesicles. The location of these vesicles was found to be more towards the posterior extremity of the body, their systole and diastole being further described as on the whole extremely slow, but very distinct, if sufficient patience was used to watch them fixedly and without interruption. The last third portion of the act of systole differed in being considerably more abrupt, the vesicle appearing only at such time to contract suddenly. This latter circumstance, taken together with the constant position of the vesicles, is cited by Professor Clark as sufficing to rebut the inference that might otherwise be arrived at, and as actually insisted on by Professor Haeckel, that these vesicles were simply irregular protoplasmic vacuoles, such as occur among undoubted protophytes and various ordinary tissue-cells. Comparing the arguments adduced by Professor Haeckel, in favour of the Cœlenterate affinities of the sponges, with the actual structural composition of *Spongilla* and *Leucosolenia*, elicited by his own special investigations, Professor Clark finally arrived at the decision that the attempted parallelism between the two groups must utterly fail, the relationship of the sponges to certain Flagellate Protozoa being, on the other hand, so distinct and decisive as to forbid their logical inclusion among the representatives of any other organic class.

The year 1872 is, perhaps, more notable that any in the entire annals of sponge biography through the publication of Professor Haeckel's truly magnificent work of labour and art, if nothing more, entitled 'A Monograph of the Calcispongiæ.' This treatise, as its name denotes, embraced an exhaustive account of every known form and variety of sponge characterized by the possession of a skeleton composed of spicules of carbonate of lime, and of which the little white *Grantia compressa* of our own coast affords a familiar example. The chief interest of this monograph, however, depends upon the fact that it is made the vehicle of Professor Haeckel's more matured views concerning the near relationship affirmed by him to subsist between the sponges and the corals, and which he now sought, by means of the sponge-group monographed, to establish on a more firm and solid basis. This remarkable work has in other words to be regarded as embodying the veritable consummation of his then newly conceived and now world-familiar "Gastræa" theory, having as its aim the demonstration that all animal forms, from the sponges up to the Vertebrata, emanate in their developmental history from one single stock-form or phylum, upon which the common title of a "gastrula" is conferred. This gastrula, as formulated by Haeckel, is constructed fundamentally upon the same type as the advanced condition of the embryonic planula, having an ovate body composed of two even, separate cellular layers, the ectoderm and endoderm, and a central primitive stomach-cavity or archenteron, which communicates at one extremity with the outer world by a primitive oral orifice. From this identity of the bilaminate gastrula in representatives of the most various animal stocks, from the sponges to the Vertebrata, Haeckel, to quote his own words, deduced the common descent of these various animal phyla from a single unknown stock-form, his hypothetical gastræa, which was constructed on a plan essentially corresponding with the above-described typical gastrula. As a first step towards the successful correlation of his gastræa theory with the group of organisms now under consideration, it necessarily devolved upon Professor Haeckel to refute the more recent interpretations, still adhered to by many authorities, which relegated the sponges to the lowermost or Protozoic section of the organic series. At the least, it was to be expected that this eminent author would devote some little space to the serious discussion of the new and very important facts concerning the ultimate structure of sponges and suggestive affinities elicited through the investigations of Professor H. James-Clark and Mr. Carter. In place of this, no consideration whatever is given to their discoveries, which are brusquely dismissed with the comment that neither one nor the other of these authorities have any conception of the essence of the cell-theory. The present author is visited, for his temerity in having dared to call in question the soundness of the suggested Cœlenterate affinities of the sponges, with a far more substantial share of the learned professor's attention. "Mr. Saville Kent's attacks" upon his theory are finally summed up as incapable of refutation, since he "neither understands the arguments brought forward, nor is in general sufficiently acquainted with the structure and development of zoophytes and sponges."—The endeavour is here made to show that Mr. Saville Kent has since that time devoted his best energies to rectifying the omission in his education pointed out by Professor Haeckel, the outcome of his humble efforts in this direction being, however, scarcely conducive perhaps to the firmer establishment of that authority's hypothesis.—The most crushing shafts of Haeckel's sarcasm are undoubtedly directed against an accidental misrendering or misinterpretation, on the author's part, of some of the more abstruse questions of homology and analogy propounded as subsisting between the representatives of the two groups in question. Whatever may have been the error in this direction, the very important and significant fact remains that Professor Haeckel's exposition of the Cœlenterate affinities of the sponges, embodied in his 'Monograph of the Calcispongiæ,' is characterized by a complete abandonment of that position which he had formerly maintained with so much vehemence, and by a repudiation of that very homology he had formerly insisted on, and which was especially disputed by the present author. In order to make this significant contradiction clear, it is necessary merely to quote and compare Haeckel's oracular utterances of the two respective years 1869 and 1872. In his first notable essay, 'On the Organization of the Sponges and their Relationship to the Corals,' he says:—

"Certain sponges differ from certain corals only by a less degree of histological differentiation, and especially by the want of urticating organs. The *most essential* peculiarity of the organization of sponges is their nutritive canal system, which is both *homologous* with, and *analogous* to, the so-called cœlenteric vascular system, or gastrovascular apparatus of the Cœlenterata."

In his 'Monograph of the Calcispongiæ,' Bd. i. p. 461, his recantation, modestly interred in an unobtrusive footnote, runs as follows:—

"Whereas the near relation of the sponges to the corals, to which I formerly gave particular prominence, is to be understood *only as an analogy*, *not as an homology*, I thought at that time that I found in the radiate structure of the Sycones (*Grantia* (*Sycon*) *ciliata*) an essential morphological point of comparison with the corals; but the developmental history of the radial tubes of the Sycones, with which I only became acquainted subsequently, has convinced me that these *are not homologous* with the perigastric radial chambers of the corals."

Having abandoned his former line of defence, Professor Haeckel depends mainly, in the monograph now under discussion, upon making good his position with relation to the suggested affinities through the evidence he adduces with respect to the developmental phenomena of the Calcispongiæ. The radial aquiferous system of the adult sponge, originally paraded with so much *éclat*, when put to the test was, to use a familiar expression, found incapable of "holding water"; it now remains to be seen whether Professor Haeckel's new arguments were based upon a more firm foundation. The one essential point brought forward on this occasion relates to the composition and significance of those ciliated and motile reproductive bodies common to all sponges, first discovered by Dr. Grant, and noticed by various subsequent observers, but whose true structure and import have not yet been exhaustively investigated. In accordance with Professor Haeckel's interpretations, these bodies, or "ciliated larvæ," as they have since been more commonly designated, abundantly developed throughout the representatives of the Calcispongiæ, were all referable to one common plan, with regard both to external configuration and internal histologic composition. This common plan, as now enunciated, manifested itself externally in the possession of an evenly ovate or subpyriform contour, the broader end representing the anterior pole, as exhibited by the body in its condition of natation. Except at one point, the entire peripheral surface of these bodies was clothed with long vibratile cilia, each cilium originating from the centre of a minutely circumscribed polygonal area, to each of which was assigned the morphologic value of a single cell. The exceptional region referred to, over which the cilia did not extend, was limited to the anterior pole, from which point an axial canal was described as leading from the external surface to a central body-cavity. Round the outer edge of this apical opening were stationed a circular border of larger subspheroidal non-ciliated cells, which represented the externally protruding units of a layer of similar cells that lined in a single and continuous series the entire surface of the hollow internal cavity with which the apical aperture was continuous. Taken thus in optical longitudinal section, these bodies, as interpreted by Professor Haeckel, or borrowing from his own illustrations, as represented at Fig. 2 in the adjoining woodcut, presented the aspect of an ovate sac composed of two separate, and histologically distinct, external and internal cellular layers, the outer one being composed of more minute subcylindrical and radially disposed monociliate cells, and the inner one of a correspondingly simple layer of much larger subspheroidal and non-ciliated cells. This sac-shaped bilaminated structure Professor Haeckel denominated a "gastrula," and represented it to be the ground or stock-form from which all sponges were primarily developed. It was further insisted that the outer or so-called "dermal lamina" of this bilaminated structure represented a true external dermal layer or ectoderm, and the inner or so-called "gastral lamina" a true entoderm, as obtains in all ordinary Metazoic organisms. Launching out into the regions of hypothesis, Professor Haeckel claimed for his so-called "gastrula" a far-reaching and most important significance.

"I regard the gastrula," Haeckel says, "as the most important and significant embryonic form in the whole animal kingdom. It occurs among the sponges, the Acalephæ, the Annelida, Echinodermata, Arthropoda, Mollusca, and the Vertebrata as represented by *Amphioxus.* In all these representatives of the most various animal stocks, the gastrula preserves exactly the same structure. From this identity of the gastrula in representatives of the most various animal stocks, from the sponges to the Vertebrata, I deduce, in accordance with the biogenetic fundamental law, a common descent of the animal phyla from a single unknown stock-form, gastræa or archegastrula, which was constructed essentially like the gastrula."

Speculating still further with reference to this newly-detected keystone, Haeckel maintained that the primary stock-form of all the sponges must have been an attached, bilaminate, gastrula-like organism, in all ways com-

FIG. 1.

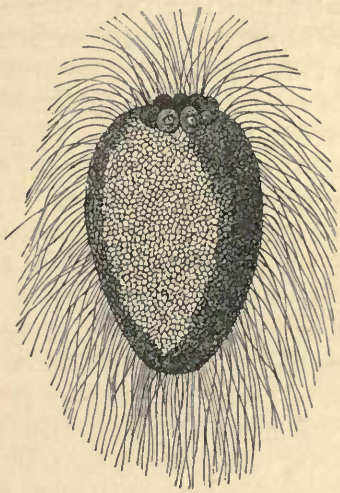
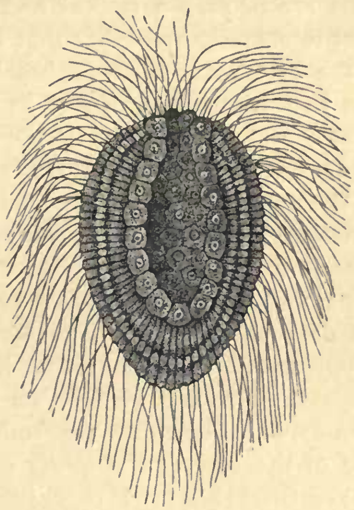


FIG. 2.



Hypothetical Ciliated Larva or so-called "*Gastrula*" of a Calcareous Sponge, *Leuculmis echinus* Hkl., as viewed, Fig. 1, superficially, and Fig. 2 in longitudinal section. In Fig. 2 an imaginary central gastric cavity, having a terminal but non-existing oral aperture and imaginary lining of subspheroidal endodermal cells, is represented. In Fig. 1 the most anteriorly developed cells of this imaginary endodermic layer are projecting around the hypothetic oral aperture.—After Haeckel, *Monograph of the Calcispongiæ*, pl. xxx. figs. 8 and 9, 1872.

parable with this typical "archegastrula," possessing a simple, double-walled, sac-shaped body, with a central stomachal cavity, terminal oral aperture, and no porous system. Should the walls be strengthened with spicula, such a type might be designated *Prosycum*, or, in its still more simplified form without any spicula, *Archespongia.* Such a typical hypothetic *Archespongia*, though not actually known to exist, Haeckel anticipated to probably possess a close ally in the singular form first described by Dr. Bowerbank under the title of *Haliphysema Tumanowiczii.* Haeckel's later and most ingenious exploits with this self-selected type will receive due notice presently.

Summing up the deductions and speculations concerning the affinities and significance of the so-called sponge-larva or gastrula, just enumerated, it is almost impossible to overrate the important and far-reaching issues involved in Professor Haeckel's interpretation of this developmental structure. Presuming his interpretation to have been substantiated, and to have received the confirmation of the many investigators who have subsequently devoted themselves to the study of this special zoologic group, the Metazoic organization and affinities of the sponges, as insisted upon by Haeckel, would undoubtedly have been established upon a firm basis. If, on the other hand, such investigation proved the existence of important errors in the interpretation rendered, neither the intimated affinity of the sponges, nor any of the many side-inferences and deductions connected with and interdependent upon such interpretation, possess further value. As a matter of fact, the crucial test applied has been productive of the most unlooked-for results, for, not only has it been shown that errors do exist, but that these are of such a radical and fundamental nature that the inference is most reluctantly arrived at that Haeckel, carried away in his ardent pursuit of the Metazoic archetype, has lost for the time his power of discrimination between matters of fact and hypothesis, and so evolved from his own inner consciousness those details that are wanting to complete and perfect his theory. This at any rate is the most charitable construction to place on the extraordinary discrepancies found to exist between even the broad structural characteristics of his so-called sponge-gastrula as reported by himself, and as since found to exist in fact by a number of independent witnesses. Without entering now into a precise and extensive account of the data elicited, it will suffice at present to state that on all sides, as demonstrated by the independent investigations of Metschnikoff, Oscar Schmidt, Barrois, F. E. Schulze, H. J. Carter, and the present author, it has been made evident that a reproductive body having the form and organization of the so-called *gastrula* or ciliated larva, as attributed by Haeckel to the Spongida, and reproduced in the foregoing woodcut, has no real existence, and that his representation of such a structure is entirely at fault in the following cardinal points. In the first place, this ciliated body never does possess two distinctly marked cellular layers comparable to a true ectoderm and endoderm; in the second place, there is neither a distinct gastric cavity nor an intercommunicating apical, oral, or other aperture as required for the confirmation of Haeckel's dictum; while, finally, the anterior and posterior poles have, as compared with what exists in nature, been exactly reversed in order to make them conform with his particular requirements. This latter circumstance is made obvious from the fact that in all instances, in both his figures and descriptions, the larger cells, which do frequently, but not invariably, occur in connection with these bodies, are stationed by him at the anterior, or his so-called "oral extremity," while in reality they are located at the posterior one. Taken altogether, it is clearly evident that the so-called "sponge-gastrulæ," described and figured over and over again in Professor Haeckel's 'Monograph,' are an entire myth, and that the superstructure of the gastræa theory, so far as it rests upon this basis, is entirely worthless. From this it is also clear that a very considerable portion of Professor Haeckel's artistically executed plates in the monograph in question are utterly untrustworthy and worse than use-less, since, accepting as infallible the representations of so high an authority, these entirely imaginary figures with their accompanying definitions have been already extensively reproduced as proven facts in many recent text-books of biology.* The glaring unreliability of Professor Haeckel's representations, in this special connection, necessarily justifies more than customary precaution in accepting as Gospel fact his evidence in other directions, wherever room is left for entertaining the slightest reasonable doubt. A case altogether to the point is afforded by his representations of the spermatozooids of various sponge species, in Plates 1, 7, 9, 11, 25, and 48 of his monograph. Scarcely three years previously, Haeckel, as already stated, declared that sponges were asexual and sporiparous, and that the careful examination by himself of hundreds of specimens had satisfied him that spermatic elements were entirely wanting throughout the class. As pointed out by Mr. Carter, the admission was in itself fatal to his Metazoic or gastræa theory as applied to the sponges, spore production being an essential property of Protozoic organisms only, and the union of true sexual elements, ova and spermatozoa, being of unvarying occurrence throughout all the higher or Metazoic groups. Tacitly, Professor Haeckel evidently acknowledged the trenchant force of Mr. Carter's argument. At any rate it is an interesting and significant fact that so-called true spermatozoa were found ready to hand and produced in abundance in Haeckel's succeeding essay on the affinities of the sponges. The celerity with which these missing elements were discovered in profusion, directly their presence was shown to be essential for the sustenance of his Metazoic theory, and in face of his previously declared incapacity to recognize them after a most exhaustive investigation, when not specially wanted, a few months earlier, is in itself a suspicious circumstance. It is just possible that these supposed spermatozoa may represent in some instances a misinterpretation of certain earlier conditions of the ordinary flagellate cells; but in one special case,† in which the actual fructification of a sponge ovum by spermatic bodies is delineated, it is difficult to resist the conclusion that the learned professor's fertile imagination—as in the case of the gastric cavity, oral aperture, and endodermic cell-layer of his sponge-gastrula—has risen to the occasion and kindled into being forms and features possessing no tangible existence.

Before proceeding to an examination of the evidence towards an elucidation of the precise structure and affinities of the sponges, accumulated through other independent sources, one later contribution of Professor Haeckel's demands brief notice. Reference is here made to his separate brochure 'Studien zur Gastræa-theorie,' published in the year 1877. While devoted generally to the exposition of his latest and most matured views upon the gastræa theory, it is specially worthy of notice as the

* E. g. "Development of Sponge, *Ascetta primordialis*," in Prof. Huxley's 'Manual of the Invertebrata,' p. 112, fig. vi.

† 'Monograph of the Calcispongiæ,' pl. 48, fig. 6.

channel selected by him for the introduction to the scientific world of what appeared to be an entirely new and remarkable little group of organisms. Professor Haeckel had previously declared, in his 'Monograph of the Calcispongiæ,' his belief that the so-called "gastrula" or "ciliated larva" of a sponge typified the permanent and adult condition of some pre-existing type which might be appropriately designated an *archegastrula*, and that probably a very close approach to this hypothetic archetype was furnished by the supposed little sponge-form first described by Dr. Bowerbank under the title of *Haliphysema Tumanowiczii.* In the 'Biologische Studien' Haeckel announces, as the results of his most recent personal investigation, the discovery of a series of forms generically identical for the most part with this type; that his former anticipations were fully verified; and that in *Haliphysema*, and its allies, the true archetype of all sponges and the entire Metazoic series was at length forthcoming. As interpreted by Haeckel, *Haliphysema* was declared to be simply an attached sac-like "gastrula," having a simple central gastric cavity, terminal orifice, and imperforate body-wall composed of two closely apposed inner and outer cellular layers, the former one or entoderm being made up of flagellate cells, corresponding with those of the ciliated chambers of the ordinary Spongida, and the outer or ectoderm being constructed out of coalescent non-ciliate cells, and in all ways corresponding with his so-called syncytial element of the more complex sponges. No spicula or other endoskeletal structures were secreted by these *Haliphysemata*, but the external layer or "syncytium" possessed the faculty of appropriating and building up a variously modified and protective test, or exoskeletal covering, out of sand-grains, sponge-spicules, or any other suitable adventitious particles found in its vicinity. For the reception of the various types described the new group-title of the Physemaria was created, its members being announced by Haeckel to belong properly neither to the sponges nor to the zoophytes, but to represent in themselves an independent order which more nearly approached the hypothetic root-form of all Metazoa, his so-called "gastræa," than any yet discovered organic type.

The various species, five in all, referred to the genus *Haliphysema* were severally distinguished by the form and composition of their respective tests or exoskeletal elements, one among these, *H. globigerina*, being specially remarkable in having its test built up entirely of the shells of Rhizopods, such as *Globigerina*, *Rotalia*, *Orbulina*, *Textularia*, and various Radiolarians, collectively indicative of a deep-sea habitat. A second generic group was referred by Haeckel to the Physemarian order, under the new name of *Gastrophysema*. Of the two species referred to this genus the one received the title of *Gastrophysema dithalamium*, while the other, *G. scopula*, was identified with an organism described by Mr. Carter in the year 1870 under the name of *Squamulina scopula*, and referred by that investigator to the group of the Foraminifera. The only essential external difference presented by *Gastrophysema*, as compared with *Haliphysema*, was afforded by the character of the test, which in the former instance consisted of two or more intercommunicating chambers in place of the single one only possessed by the last-named type. Concerning the internal structure and significance of the interconnecting cavities in *Gastrophysema,* however, a far different and most remarkable interpretation was arrived at. The different chambers were in fact declared by Haeckel to be set apart for the performance of special and independent functions. Affirming that ciliated bodies or gastrulæ, similar to those of the sponges, were found only in the proximal or basal of the two chambers of *G. dithalamium,* he relegated to this cavity the function of reproduction, and bestowed upon it the special title of the "brood-chamber" or "uterus." The succeeding or anterior of the two cavities he declared to be a true stomach, communicating with the external world through the medium of the terminal aperture designated by him the mouth. The list of structural complexity, however, by no means ended here. Among the ordinary flagellate cells of the so-called stomach-cavity, Haeckel observed, or affirms to have observed, certain ovate cells of a special nature, pronounced by him to be of a glandular character; these he accordingly figured and described as gland-cells, "Drüsenzellen."

Had Professor Haeckel's observations and interpretations concerning this newly introduced group of the Physemaria been confirmed, *Haliphysema* would undoubtedly have to be accepted as a sponge structure in its simplest known form, while in *Gastrophysema* a complexity of organization would be superadded forbidding its correlation with either the sponges or the ordinary Cœlenterata. As a matter of fact, however, the evidence more recently adduced has tended to raise the gravest doubts concerning the very existence even of such an organic group as the so-called Physemaria of Professor Haeckel.

Haliphysema Tumanowiczii and *Gastrophysema* (*Squamulina*) *scopula* have both been proved to be varieties of one form, and instead of a simple sponge, as first described by Dr. Bowerbank, to be an arenaceous or test-bearing foraminiferal type. This interpretation, first suggested by Mr. Carter, has been fully established by the present author in a paper, with accompanying illustrations, published in the 'Annals and Magazine of Natural History' for July 1878. The account and illustrations there given were derived from the examination of living specimens collected in the Channel Islands, and which in their healthy condition exhibited their true nature by the emission, from the terminal aperture of their tests, of extensive reticulate pseudopodia exhibiting circulatory currents, comparable in all ways to those of the ordinary Foraminifera. By a careful investigation of that portion of the organism contained within the test, it was likewise shown that there was no trace whatever of a lining layer of flagellate cells, as asserted by Professor Haeckel, all, throughout, being simple homogeneous or more or less granular sarcode. A similar Foraminiferal interpretation has been arrived at by Professor Mobius, with respect to a new species, *Haliphysema capitulatum*, examined by him in the living state at the Mauritius, and in which pseudopodia were seen issuing in a corresponding manner from the single terminal aperture of the spiculiferous test. This confirmation, to which the author's attention was directed, after the publication of his communication to the 'Annals,' appeared in the 'Versammlung d. deutschen Naturforscher in Hamburg,' p. 115, for the year 1876. Evidence corroborating still more strongly the results above recorded, was published, however, in the 'Quarterly Journal of Microscopical Science' for October 1879, in which Professor E. Ray Lankester, after a most exhaustive examination of duplicate specimens of *Haliphysema Tumanowiczii* remitted him by the author from Jersey, in both the living and preserved condition, entirely supports the foraminiferal interpretation, and indicates the necessity of Professor Haeckel producing some satisfactory explanation of the very antagonistic statements now on record, for which he is responsible, with reference to *Haliphysema* and its allies.

Possibly, as suggested by the present author, isomorphic forms may exist having the external contour of a *Haliphysema* and the histologic internal structure of a simple sponge; but the evidence in this direction is up to the present time altogether opposed to such a supposition. Analyzing, in fact, the by no means extensive list of Professor Haeckel's Physemarian genera, *Haliphysema* and *Gastrophysema*, scarcely a single type is left him wherewith to demonstrate the existence of such isomorphism. Thus out of his five species of *Haliphysema*, *H. echinoides* is undoubtedly, as already pointed out by Mr. Norman, the young condition of the Tethyadan sponge first described in its young and stalked condition by Professor G. Percival Wright, under the name of *Wyville-Thomsonia Wallichii*,* next described by the present author in the adult state as *Dorvillia agariciformis*,† and finally by Sir Wyville Thomson, as one of the trophies of the 'Lightning' and 'Porcupine' expedition, under the name of *Tisiphonia agariciformis*. *Haliphysema Tumanowiczii* and *H. ramulosa* are identified as undoubted Foraminifera. *H. globigerina* has been examined by Haeckel as dead, spirit-preserved examples only, and consequently under conditions in which the characters attributed by him to the typical forms would not be recognizable.

Of the genus *Gastrophysema*, *G. scopula* is demonstrated to be a Foraminifer identical with *Haliphysema Tumanowiczii*, and it so happens that *H. primordiale* and *G. dithalamium* are now alone left to vindicate the claims of the Physemaria for further scientific recognition. Even here the resemblance in every particular—setting aside the hypothetic and the utterly untenable "uterine" and "glandular" differentiations—coincides so closely with all the broad external features of some one or other of the numerous polymorphic forms of the one-, two-, three-, four-, or many-chambered spiculiferous tests of *Haliphysema Tumanowiczii*, that, unless Professor Haeckel can produce substantial testimony of their independent,

* 'Quarterly Journal of Microscopical Science,' vol. x., January 1870.
† 'Monthly Microscopical Journal,' December 1870.

and in that case amazingly remarkable isomorphism, the erasure of their names from scientific nomenclature, and also that of the entire Physemarian order, will be rendered unavoidable. Most unfortunately for Professor Haeckel, the context of his essay under discussion upon the gastræa theory in general, and upon the group of the Physemaria in particular, so abounds with direct negations and manipulations of known facts in order to adapt them to the requirements of his own hypotheses, that the verdict arrived at by the most impartial students of this question must inevitably tend to cast discredit upon his representations even where the same are possibly correct. It is thus not a little surprising to find reproduced as the larval type of *Haliphysema* in this essay, the self-same erroneous accounts and diagrammatic illustrations of his so-called "gastrula-larva" of the sponges, first formulated in his 'Monograph of the Calcispongiæ,' and submitted at page 157 of this volume.

The same inversion of the anterior and posterior apices and accompanying fallacious allocation of a gastric cavity, oral aperture, and evenly developed external and internal cellular layers, is once more repeated, the larval forms of the Physemaria being made to correspond with a like altogether hypothetic formula. The histologic characters of the essential collar-bearing flagellate cells of the sponge-body, assumed to be shared by *Haliphysema* and its allies, are again materially reduced in order to make them conform more nearly to the plan of ordinary tissue-cells, and with the morphologic and functional value of which they are alone accredited. Professor H. James-Clark and Mr. Carter had already shown that these peculiar flagellate sponge-cells exhibited a very significant Protozoic feature in the possession of two or more posteriorly located, rhythmically pulsating, contractile vesicles. In his 'Monograph of the Calcispongiæ,' Professor Haeckel grudgingly conceded and figured a single posterior vacuole, but denied to it the property of rhythmical contraction, affirming that it was a mere non-persistent and unessential lacuna developed in the protoplasmic substance of the cell. In that advanced exposition of the gastræa theory, however, embodied in his 'Biologische Studien' for the year 1877, the contractile vesicle, or protoplasmic lacuna, is improved altogether off the morphologic landscape, and the essential flagellate sponge-cell now appears with a simply nucleated but otherwise undifferentiated protoplasmic body. In two instances only does Haeckel make any concession to the antagonistic results arrived at by contemporary explorers in the same field of research, while even here these results are with a little tension made subservient to his special views. In the first place, the evidence since adduced not being confirmatory of his diploblastic interpretation of the sponge embryo, as produced by the delamination of the interior from the outer cellular layer, he now declared that essentially the same results were obtained, and the same form constructed, by the process of invagination. In the second place, the researches, more especially, of Oscar Schmidt, having elicited the fact that in many instances these ciliated bodies, as produced by the Calcispongiæ, exhibited an external conformation entirely different from his so-called "gastrulæ," Haeckel accounted for the inconsistency by declaring that in these special instances the embryonic form was represented by a distinct biogenetic type, which might be conveniently denominated an "amphiblastula."

Passing on from the foregoing brief record of the peculiar interpretations maintained by Professor Haeckel, with reference to the structure and affinities of the sponges, attention may now be directed to the facts elicited in this connection by the light of most recent research, including those adduced through the investigations of the present author. As an inevitable consequence of the very authoritative declarations of Professor Haeckel in favour of the Cœlenterate affinities of the sponges, and seeming coincidence of the evidence brought forward with these emphatic statements, the bias of late years has been altogether in the direction of substantiating their Metazoic nature, and of reconciling, with this end in view, the very conflicting structural and developmental data exhibited by the different members of this highly important group. Most noteworthy in this direction is that line of interpretation followed by Metschnikoff, Barrois, and F. E. Schulze, by whom, in both the adult and embryo sponge, the existence of three cellular layers, ectoderm, endoderm, and mesoderm, are distinctly recognized. In conformity with such interpretations, the ectoderm in the adult organism consists of a superficial layer of flattened, simply nucleated cells, closely approximated to each other, and agreeing to a considerable extent with the so-called "syncytium" of Professor Haeckel, this external element being also produced inwards, and lining the cavities of the aquiferous system. The special collared flagellate cells that line the so-called ciliate chambers are accepted as entodermic elements, while to the mesoderm is relegated the remaining interstitial portion, upon which chiefly devolves the secretion of the spicula or other skeletal structures.

In opposition to the widely supported Metazoic view founded by Professor Haeckel, adhesion is given in this treatise to that interpretation of the structure and affinities of the sponges that first originated with Professor H. James-Clark, and indicated their close relationship to the then small and insignificant little group of Flagellate Protozoa, first introduced to scientific notice by himself, and here described in a greatly extended form under the title of the Choano-Flagellata or Discostomata-Gymnozoida. The immense wealth of material that has been accumulated, both in the direction of the more minute structure of the sponges, and in the extension of our acquaintance with the above special group of Flagellate Protozoa and their allies, since the death of Professor Clark, is found on examination to support the views here adopted to the fullest possible extent. Already, in the 'Annals and Magazine of Natural History' for January and August 1878, and in the 'Popular Science Review' for April of the same year, the leading features of this advocated affinity have been submitted at considerable length. With this evidence, however, has now to be amalgamated the results of more recent research, as educed both by the author's personal researches and those of contemporaneous investigators.

Commencing with the general structural features of an adult sponge, as met with throughout the several more important groups into which the class Spongida is most naturally divided, it will be found that in any one of them, the three elements, demonstrated through the investigations of Professor Clark, constitute the actual and essential components of the sponge-body. These three, the collar-bearing flagellate monads, the hyaline and mucous-like cytoblastema, and the included amœba-like cytoblasts, will be invariably found in every sponge, more generally with superadded skeletal structures, and often with a greater or less proportional preponderance or reduction of the first, second, or third of the essential elements enumerated, but in no instance presenting an entire absence of any one of them. Out of these three elements, again, it is beyond question that the first-named, or collar-bearing flagellate monads, lay claim to the foremost position in the sponge economy, and that the two remaining ones are, as compared with them, entirely subsidiary. Separating the collar-bearing units from those two subordinate elements, as shown more especially at Pl. VIII., and comparing them with the independent collar-bearing flagellate monads, figured in Pls. II. to VI., the close identity of the two cannot possibly fail to be recognized. This likeness, furthermore, is found to be not merely general and superficial, but to extend to every point that may be enumerated. Neither is such likeness common and unimportant, or comparable to such as is usually found between ordinary tissue-cells, or to more practically illustrate the case, to such as exists between an amœba and a leucocyte or white blood-corpuscle. Amœbiform cells, indistinguishable in their isolated condition from ordinary amœbæ, recur again and again as the constituent or associated elements of the organic tissues of both vertebrate and invertebrate animals. That special modification of a simple cell, however, exemplified by the independent collared monads or Choano-Flagellata, and precisely reflected in the essential elements of the sponge-body, finds its counterpart nowhere else throughout the entire range of organic nature. While these two can be correlated and shown to harmonize with each other in every detail, it becomes self-evident that all attempts to co-ordinate either of them with any other structures are rendered nugatory, and are, in point of fact, attempts to compare that which is altogether uncomparable. In what manner the collar-bearing monads differ essentially from all other known unicellular structures, is explained at length in the section devoted to the systematic description of their order. Briefly, however, it may now be stated that the all-important distinction here insisted on is connected with that peculiar structure the "collar" and its accompanying functions. As demonstrated by the author, this "collar" is not a mere funnel-shaped expansion of inert sarcode, as might be inferred from the earliest accounts given of it, but it practically represents the most actively motile and important element in the animalcule's economy. During life, in its typical fully-extended state, a continuous stream of fine granular protoplasm is ever flowing up the exterior and down the interior surface of the collar, in all ways identical with the protoplasmic circulation or cyclosis exhibited in the extended pseudopodia of the Foraminifera and other Rhizopoda. In other words, this structure with its circulatory currents might be described as a peculiarly modified funnel-shaped pseudopodium. By direct observation the author has further demonstrated that the collar, with its characteristic currents, is an exquisitely contrived trap for the arrest and capture of its customary food, which, driven by the action of the centrally enclosed flagellum against the outer margin of the collar, adheres to it, and passes with the onflowing protoplasmic stream into the animalcule's body. The whole nutrient process, with its associated circulatory currents, as exhibited by an animalcule of the solitary genus *Monosiga*, will be at once comprehended on reference to the coloured illustration given in the frontispiece. Now, what has been described and delineated of the independent collar-bearing type *Monosiga* and its allies, is found to obtain with full force, and in the very minutest detail, in the essential collar-bearing flagellate units of a sponge-body. The collar there exhibits the same circulatory motions and is subservient, in the self-same way, as a trap for the capture of food-particles; the body, as already intimated, exhibits the same posteriorly located rhythmically pulsating contractile vesicles, the same central spheroidal nucleus or endoplast, and presents, furthermore, the most closely identical reproductive phenomena. The essential collar-bearing sponge-monads, or Spongozoa, as they have been appropriately designated by Mr. Carter, are, in fact, to all intents and purposes, collar-bearing Flagellate Protozoa, differing only from *Codosiga*, *Salpingœca*, *Desmarella*, and the various other genera included in this volume under the denomination of the Choano-Flagellata, in their special colonial mode of aggregation, and in the accessory and non-essential elements more usually, but not invariably, added in the form of skeletal structures.

An additional character, indicative of the close identity in all functional manifestations that exists between the sponge-monads and the independent collared types, remains to be mentioned. In the descriptions given of these latter, attention is frequently directed to the extreme plasticity of the individual animalcules, and the facility with which the funnel-shaped collar and flagellum is retracted at will, pseudopodium-like extensions of the body-sarcode projected, and the most polymorphic aspects exhibited. Examples of such metamorphoses, as presented by the loricate type *Salpingœca amphoridium*, may be seen at Pl. V. Figs. 5–8, and also in many other figures illustrative of this genus, and the illoricate *Codosiga* and *Monosiga*, in the several plates devoted to this interesting group. Among the collared monads of the more complex sponge-stock, not only an equal, but a far higher degree of plasticity is presented. The component sarcode of the monad's body in this latter case is apparently of thinner or more fluid consistence, permitting of rapid and protean changes of form on the slightest irritation or other stimulus. Thus, when a dissection is made of any living sponge, such as *Grantia compressa,* it is found requisite to examine rapidly with the microscope in order to witness the constituent monads with their collars and flagella in the normal condition of extension; otherwise, within the space of a few minutes, these organs are, one or both, more or less completely retracted, and their former possessors creeping about the field, or remaining congregated in clusters under conditions that render them indistinguishable from ordinary Flagellate monads, or simple amœbæ. In this latter instance, they are, indeed, identical in all respects with the amœbiform zooids or cytoblasts scattered throughout the common gelatinous central matrix or cytoblastema of the sponge-body. The more conspicuous modifications of form assumed at will by the collared sponge-monads, either with the collar and flagellum extended with the former organ alone, or with both of these two retracted, will be found abundantly illustrated in Figs. 2–38 of Pl. VIII., devoted especially to the histology of the Spongida. Among them two or three examples occur which deserve particular notice. Thus, at Fig. 17 of the plate quoted, is represented an individual monad which, after the retraction of the collar and flagellum, has thrown out innumerable long slender pseudopodia, which convey to it an appearance highly suggestive of that of the Radiolarian type *Actinophrys.* Other examples, exhibiting in a less degree the same plan of metamorphosis, are also delineated in connection with the groups or isolated examples numbered respectively 12, 14, 15, 16, 20, and 24. In Figs. 29, 30, 31, a modification in an entirely different direction is shown. Here, with the collars and flagella entirely withdrawn, as before, slender pseudopodia are emitted from the periphery, terminating in distinctly capitate extremities which recall to mind the specialized suctorial tentacles of the Acinetidæ. Recovering from the disturbing influence which has brought about any of the various metamorphoses above enumerated, the emitted pseudopodia or lobate sarcode extensions are, after a while, drawn in, and the normal form with the extended collar and flagellum again assumed. At Fig. 18 of Pl. VIII. will be found examples of such sponge-monads, which after a short tenure of a vagrant amœboid condition, have reattached themselves to a minute spiculum of the parent sponge, and resumed the customary aspect of the typical Spongozoa.

Were it not explained that these readherent collared monads belonged to a sponge-stock, it would be impossible to distinguish them from the representatives of such independent collared animalcules as *Monosiga Steinii,* represented at Pl. IV. Fig. 12. The collared sponge-monads, thus reattached, soon throw out around them a thin investing film of hyaline cytoblastema, as shown at Figs. 19, 21, and 22, and are thus capable, without any other extraneous assistance, of either repairing a mutilated sponge-stock, or of building up an entirely new one. With reference to the feeding capacities of the sponge-monads, it may be here noted, that the phenomena of nutrition are precisely identical with those exhibited by the independent collared species, the selected pabulum being arrested by the hyaline collar and carried with its circulating current into the body of the animalcule. Examples are given at Pl. VIII. Figs. 9 and 19, in which the bodies of the neighbouring sponge-monads are filled with ingested and artificially administered carmine particles. Such functions of nutrition are, however, not confined to the collared zooids; the amœbiform units or cytoblasts being equally capable, as shown at Fig. 41 of the same plate, of ingesting solid pabulum.

Examining the matter more closely, it has now to be shown that even the special differences already cited as indicating a distinction between the Spongida, independent collared monads, and ordinary Infusoria, are scarcely more substantial than those found to exist between the more conspicuously divergent representatives of the same groups or orders of the last-named section. Taking, in illustration of this analogy, the very familiar group of the Vorticellidæ, we find in *Vorticella*, or more correctly, in the stiff-stalked form *Rhabdostyla* and in the compound type *Epistylis*, the precise analogues of the solitary collared type *Monosiga* and the social genus *Codosiga*. Proceeding yet a step further, the slime-immersed colonial type *Ophrydium* is beyond doubt comparable in a like manner to the colonial slime-immersed genus *Phalansterium*. Beyond this it is not possible, as yet, to institute a direct comparison, but, supposing that a genus of colonial slime-immersed Vorticellidæ should be discovered in which the animalcules, instead of projecting directly into the surrounding water through the peripheral surface of their common matrix, as obtains in *Ophrydium*, were enclosed within chambers which communicated with each other, and with the outer water, by a system of interconnecting canals; supposing also that all the spores, germs, encystments, or other reproductive products remained embedded and developed to maturity within the common matrix, a type of the Vorticellidæ would be produced presenting a parallel to *Ophrydium* precisely identical with what actually exists between the most simple known sponge and *Phalansterium*.*

With the assistance of Plates VII. to X. it is now proposed to draw

* At the eleventh hour, while going to press, the author has had the good fortune to light upon a new and highly interesting representative of the independent collared series, that illustrates in a yet more decisive manner the close relationship of this group to the Spongida. The type in question, represented at Pl. X. Figs. 20–30, and hereafter described under the title of *Protospongia Haeckeli*, agrees with *Phalansterium*, so far as the zooids are immersed within a common gelatinous matrix or zoocytium. The characteristic collars are, however, fully developed in place of being rudimentary as in the last-named genus, while the inhabited gelatinous matrix is perfectly transparent and homogeneous instead of densely granular. Within their matrix the zooids were observed to assume various metamorphic amœboid conditions, to multiply both by the process of binary subdivision and by the partition of their entire mass into sporular elements. The resultants of the last reproductive process commence their active existence as simple, minute, uniflagellate monads, which project, as shown at Fig. 22 *b b*, from the periphery of the zoocytium side by side with the adult collared units. This interesting species which, in its mature condition, corresponds in a most remarkable and significant manner with a fragment of cytoblastema, with its enclosed collared zooids, amœbiform cytoblasts, and sporular elements, of any typical sponge-form, was obtained by the author in July 1880, in water brought from the lake in Kew Gardens.

attention to the more important structural features exhibited by the leading subdivisions of the Spongida, and especially to those points in which their close relationship to the independent collar-bearing monads figured in the five preceding plates is most prominently shown. As already stated, the collared cells or essential Spongozoa of any given sponge-body are invariably found lining special chambers excavated within the common, structureless, mucilaginous basis or cytoblastema which enters more or less considerably into its composition. These special chambers, again, are found in different sponges to exhibit a considerable diversity of contour, but, on the whole, to conform to two distinct and widely differentiated plans. In one of them it is found that the collared cells more or less completely line the entire internal cavities of the sponge, including both the afferent and efferent canal-systems. Such a type of structure, as is most prominently developed among the section of the Calcispongiæ, is illustrated in the sectional views given at Pl. VII. Figs. 3 and 4, of the interstitial canal-system and disposition of the characteristic collared monads or Spongozoa in the familiar British species *Grantia compressa*. At Fig. 3 a general view is given of the segment of a complete transverse section of this sponge, showing the characteristic disposition of the interstitial loculi with their monad linings around the common cloaca, while at Fig. 4 one complete and another incomplete loculus is considerably enlarged, proving the essential correspondence of the contained monads with the independent forms figured in the preceding plates. In the series belonging to the second structural plan, the collared cells, instead of being distributed more or less generally throughout the entire internal canal-system, are confined to certain spheroidal chambers excavated within the substance of the sponge body, these chambers being brought freely into relation with the external water through the agency of both the afferent and efferent canals. It was upon these spheroidal chambers, as first discovered in *Spongilla*, that Mr. Carter conferred the title of "ampullaceous sacs," by which name, together with that of "ciliated chambers," they have since been most familiarly known. A similar ampullaceous disposition of the collar-bearing cells is found to obtain among a very extensive series, if not throughout the majority of the Spongida, including, in fact, all the known members of the Myxospongia, the greater part of the Siliceospongia, and in accordance with the representations given by Professor Haeckel, the family of the Leuconidæ among the Calcispongiæ. The highly characteristic aspect presented by the collared monads or Spongozoa, as grouped upon this principle, will be found delineated at Pl. VII. Figs. 1 and 2, and Pl. IX. Figs. 1, 3, and 12, and is remarkable for the elegant clustered or grape-like appearance presented by the monad aggregations with their interconnecting canal-systems. In Fig. 1 of Pl. VII. is reproduced the portion of a section of the non-spiculiferous sponge *Halisarca lobularis* as delineated by F. E. Schulze, while at Fig. 2 is represented a somewhat similar section of the siliceous type *Esperia* sp., as observed by the author.

Deferring for a while the more minute account of the structure and significance of these monad-lined chambers, brief attention may be directed to certain other broad external features superficially recognizable in the various more highly differentiated sponge groups. As previously stated, in every known variety of sponge three essential elements are invariably present, namely, the collar-bearing flagelliferous cells, the mucilaginous cytoblastema, and the amœbiform cytoblasts, to which other accessory or non-essential elements may, or may not, be added. The relative proportions in which these three essential elements exist among the several sections of the Spongida, present some important differences. Among the simplest known sponge forms, as represented by the genus *Halisarca*, in which these elements occur in their pure and simple condition without any addition of spicula, horny fibres, or other skeletal structures, and where, as just stated, the collar-bearing monads exhibit the ampullaceous plan of arrangement, it will be observed, on further reference to the illustration quoted (Pl. VII. Fig. 1.) that this special system by no means occupies a largely predominating portion of the entire sponge body, a very considerable part consisting of the common gelatinous matrix or cytoblastema and its enclosed amœbiform cytoblasts. With the majority of the Siliceospongiæ, including those forms which have, either with or without siliceous spicules, a horny or keratose skeleton, an almost identical predominance of these elements is met with. Among the more characteristic representatives of the Siliceospongiæ, however, including the species of *Esperia* delineated at Pl. VII. Fig. 2, a highly characteristic modification is presented. In such as these the cytoblastema is especially remarkable for its extremely thin and pellucid consistence, this being particularly noticeable in the superficial or peripheral region, where it is supported canopywise, or after the manner of a tent-covering, from the light and efficient scaffold-work furnished by the projecting spicula. A similar type of structure is, as first pointed out by Professor Clark, highly characteristic of the fresh-water genus *Spongilla*. That combination remaining to be described, in which the proportions of the three primary structural elements exhibit a marked divergence from those just noticed, is most conspicuously developed in the section of the Calcispongiæ, and, with the exception of the Leuconidæ, would appear to be essentially characteristic of that group. As already stated, the collared cells in this section are characterized by their diffuse plan of distribution, the entire surface of the internal chambers and passages being more or less completely lined with them. In correlation with this distribution of the collared cells, it is found that the cytoblastema is, as compared with those elements, reduced to its minimum, being indeed superficially, as exhibited in the sections of *Grantia compressa* in Figs. 3 and 4 of Pl. VII., altogether inconspicuous.

A closer examination of those special points by which, in accordance with the author's views, the close affinity of the Spongida with the independent collar-bearing Discostomata is held to be substantiated, may now be proceeded with. As previously maintained, between the separate collar-bearing monads of any of the independent Choano-Flagellata and the special collar-bearing cells that constitute the one essential element of all sponge structures, there is absolutely no recognizable distinction in form, structure, and function. The body with its nucleus or endoplast, multiple contractile vesicles, and appendages as represented by the characteristic collar and enclosed flagellum, so precisely accord with each other as to defy individual identification, a circumstance which will be at once recognized on comparing these collared elements in their isolated or aggregated form, as abundantly illustrated in the Plates VII. to X. and II. to VI., devoted respectively to the morphology of the Spongida and that of the independent collared monads. The likeness, however, does not end, but practically only commences here, for, as it has now to be shown, all the phenomena of reproduction and development are likewise reducible to a corresponding type.

In order to fully comprehend and appreciate the full force of this relationship, it is requisite only to place still more intimately *en rapport*, the life-phenomena of the collar-bearing sponge-monads and those of the independent Choanophorous and ordinary Flagellate Protozoa. That the thin, structureless cytoblastema forming the common gelatinous matrix which encloses and more or less completely conceals the collar-bearing monads of the sponge-body, is the equivalent of the common gelatinous matrix of such genera as *Phalansterium* and *Spongomonas*, or, reverting to a still more familiar ciliate infusorial type, that of *Ophrydium*, is immediately apparent, and is similarly, as hereafter shown, the direct product by exudation of the included zooids. By Professor Haeckel this common gelatinous element in sponge structures is denominated the "syncytium," and treated of as an independent tissue-layer formed by so intimate a coalescence of independent constituent cells that their nuclei only are to be discerned. That a syncytium, however, in the sense assumed by Haeckel, does not exist, is abundantly proved by the testimony accumulated from a variety of sources; what he embodies under this title represents in point of fact both of those fundamental elements which receive in this volume the titles of the "cytoblastema" and "cytoblasts." It is to the existence and significance of the last-named elements that attention has now to be directed. The characteristic aspect of the cytoblasts — which occur as amœbiform bodies of variable size and contour, variously distributed and more or less completely immersed within the substance of the cytoblastema—is delineated at Pl. VII. Fig. 2 *c* and Pl. VIII. Figs. 41 to 43. Like *Amœbæ*, they are constantly undergoing a change of outline, and may also be observed to shift their position from one part to another of the inhabited matrix or cytoblastema. Oftentimes their long, slender pseudopodia, radiating towards those of their neighbours, unite together, forming under such conditions a complex network which presents, as a whole, as shown at Fig. 43, a remarkable resemblance to ganglionic corpuscles; these highly differentiated metazoic tissue-elements they may be said, in fact, to typify in both form and function.

It is undoubtedly through the stimulus received and transmitted by the cytoblasts that the characteristic contractions and expansions of the oscula, and other portions of the sponge-body, are accomplished. Strictly, however, these elements perform a more general function than that of simple nerve-ganglia, they being in addition the direct motor agents in the contraction and expansion of the general cytoblastema, and thus fulfilling the part of both nerve- and muscle-fibres. The independent existence and characteristic aspect and functions of the cytoblasts were first pointed out by Lieberkuhn,* his observations being since abundantly confirmed by the independent researches of Carter, H. James-Clark, F. E. Schulze, and many other investigators, including the author.

At first sight, the connection between these amœbiform cytoblasts and the more essential collar-bearing zooids is scarcely obvious and has not as yet, apparently, been even so much as suspected by any other authority. To arrive at a comprehension of their true significance it is only necessary, however, to refer to the life and developmental phenomena presented by the independent collared monads and Flagellate Infusoria generally. Here, both the primary and terminal conditions of the typical flagellate zooids are frequently characterized by the exhibition of a similar amœboid aspect, as is abundantly shown in the accounts and illustrations given of the life and developmental phases of the genera *Codosiga*, *Salpingœca*, *Monas*, *Oikomonas*, *Euglena*, *Eutreptia*, *Heteromita*, and a host of other forms described in this volume. The capability of the adult collared and flagelliferous spongozoa to take upon themselves a similar amœbiform character has been observed repeatedly by the author, as illustrated in a large number of figures contained in Pl. VIII., which is confirmed by the observations of Carter, F. E. Schulze, and other recent investigators, including even Professor Haeckel himself.† The amœbiform elements of a sponge-stock cannot therefore be consistently regarded even as independent structures. To all intents and purposes they are the mere larval or metamorphosed phases of the typical and essential collar-bearing zooids; the distinctive title of cytoblasts, as here adopted, being conferred upon them only as a matter of convenience. Where, as frequently occurs, the amœbiform bodies are of comparatively colossal size, the coalescence of a greater or less number of the ordinary cytoblasts has undoubtedly taken place, the phenomena in this instance being directly comparable with the building up of the huge amœbiform "plasmodia" of the Mycetozoa, or with the coalescence of a number of metamorphosed amœbiform elements as exhibited by the simple Flagellate types *Heteromita uncinata* and *H. amyli*. The import of the amœba-like masses thus constructed is likewise in all instances identical; each such aggregate mass ultimately producing, by

* "Ueber das contractile Gewebe der Spongien." Müller's 'Archives,' pp. 74–86, 1867.

† See 'Monograph of the Calcispongiæ,' Taf. 25, fig. 6: "Vier Geisselzellen welche sich in amœboide Zellen verwandelt haben." Also, Pl. VIII. Figs. 32 to 35 of this work.

segmentation, a swarm of unicellular flagellate zooids resembling those from whence they derived their origin.

The very important phenomenon of spore-production by sponges, comparable in every way with that exhibited so abundantly among the ordinary Infusoria, and which places in a still more prominent light their close connection with the typical Flagellata and Protozoa generally, has now to be described. While the occurrence of spores in various sponge-types had been noted so long since as the year 1874, its first record was contained in a communication made by the author to the Linnean Society in June 1877; further reference to this phenomenon, with accompanying illustrations, being likewise published in the author's "Notes on the Embryology of Sponges," contributed to the 'Annals and Magazine of Natural History' for August 1878. Since that time, however, much additional material has been amassed in demonstration of this special mode of reproduction, and more especially in connection with various sponge forms collected and examined by the author at Teignmouth, Devonshire, in the summer of 1879.

The types thus recently examined in the living state included more especially *Grantia compressa*, *Grantia* (*Sycon*) *ciliatum*, *Leucosolenia botryoides*, and *Leucosolenia* (*Ascetta*) *coriacea*, among the calcareous forms, and *Halichondria punicea*, *H. incrustans*, and a species of *Esperia* belonging to the siliceous series. All of these were found to yield sporular bodies in abundance, their most profuse development being, however, afforded by the calcareous type *Leucosolenia coriacea*. Here symmetrically rounded masses, irregular patches, or more or less isolated spores, of a yellow or light brown hue, were found scattered literally in thousands throughout the substance of the cytoblastema and in various stages of development. In their earliest observed condition, in which the spore-aggregations form compact spheroidal masses, these masses measured in diameter the 1–1300th, and the individual spores that only of the 1–7500th, part of an English inch. Bringing to bear upon them the high magnifying power of 2500 diameters, as obtained with a $\frac{1}{50}$-inch objective by Powell and Lealand, it was discovered that at a very early period of their development, that is in all that had arrived at twice their first noted bulk, each spore possessed a single long vibratile flagellum, and corresponded precisely in aspect with the initial phases of many of the simple monad types hereafter figured and described. Moreover, as liberated by dissection from their natural position in the cytoblastema of the parent sponge, these sporular bodies, with their vibrating flagella, were set free in the surrounding water singly, in twos or threes, or in larger social aggregations that singularly resembled the early phases of development of *Monas* (*Heteromita*) *lens*, described at page 137, and delineated at Pl. XI. Figs. 8–13. Not unfrequently, again, these motile spore-aggregations were of considerably larger size, and retained their primitive spheroidal form. Illustrations of all of these various conditions of spore-production, as observed in *Leucosolenia coriacea*, are given at Pl. X. Figs. 1–7, while, for the purposes of future reference and comparison, sections of this sponge and the other species named, exhibiting similar reproductive features, were preserved with osmic acid and other suitable media.

As a substantial proof of the derivation of these variously formed spore-masses from the typical collar-bearing units, examples were observed, as represented at Pl. X. Figs. 1*a* and 2*b*, in which these zooids had withdrawn their characteristic collars and flagella and assumed a quiescent or encysted state, while in closely adjacent examples they had become resolved into the spore-masses under discussion. Near these again, the spore-masses in their disintegrated state, or higher developmental phases, were found, as shown at Fig. 2, *d d*, scattered through the substance of the thin, transparent cytoblastema. In one point only was the character of the spore-masses, as now examined with the highest available magnifying power, found to differ from that assigned to them in their earlier record already quoted. At that time, in the case of *Leucosolenia botryoides*, a delicate capsular investment or sporocyst was presumed to exist. No trace of such an investing element could, however, be detected in *L. coriacea.* The entire body of the collared sponge-monad, after assuming a quiescent state, divides by segmentation into a mass of characteristic microspores, and these falling asunder, become distributed throughout the hyaline cytoblastema. It might have been suggested, and was indeed at first anticipated by the author, that the spore-masses, as here figured and described, might have been derived from some protozoon or protophyte which had established itself as a parasite or commensal within the canal-system of the sponge-body. The unmistakable import of these structures as integral constituents of the latter, is, however, abundantly demonstrated by their undeviating recurrence and mode of distribution in the sponge-body, even when obtained from the most remote localities.

In this connection it has to be recorded that spore-masses, presenting the same form, size, and character, have been encountered by the author without any exception in examples of *Leucosolenia coriacea*, personally collected and examined in the living state, derived from Teignmouth, Ansty's Cove, Falmouth, and other points on the Devonshire and Cornish coasts, and also from various stations in the Channel Islands. Corroborative evidence relating to this species has likewise been recently obtained from an independent and altogether unexpected source. In vol. iii. page 8, of Dr. Bowerbank's 'Monograph of the British Spongiadæ,' 1874, bodies of a precisely similar character, though connected with a different title, are described as occurring in specimens of this sponge collected in Shetland and remitted, preserved in spirit, to the author by the Rev. A. M. Norman. Dr. Bowerbank's account of these spores is as follows :—

"On examining the sponge microscopically I found it contained an abundance of gemmules. They were exceedingly numerous on the inner surface of the dermal membrane. Their form was either spherical or slightly oval; they were of a nut-brown colour, and filled with numerous spherical molecules, which were distinctly visible with a power of 700 linear. One of the largest of the gemmules measured 1–1119 inch in diameter, and the molecules within did not exceed 1–15000 inch in diameter. This gemmule had all the appearance of being in a fully developed condition. The greater portion of the other gemmules were much smaller; one, of about the average size, measured 1–1705 inch in diameter."

Unfortunately no figures are given of these bodies, but there is scarcely room for doubt that the spore-masses figured and described in this volume, and the so-called "gemmules" with their "molecular contents," as observed by Dr. Bowerbank, represent the same structures. Apparently the last-named authority attributed to these molecular or sporular aggregations the possession of a distinct investing cellular membrane, his interpretation thus according with the impression first conveyed to the author when examining them with inadequate magnifying power. In yet another calcareous type Dr. Bowerbank has placed on record his observation of somewhat similar spore-like bodies. In his account of *Leucosolenia* (*Ascortis*) *lacunosa*,* he writes:—

"The whole surface of the interior of the fistulæ and central cloacal cavity is abundantly furnished with circular nucleated cells varying in diameter from 1–5454 inch to 1–3000 inch; they are regularly disposed, and are seldom more than about the length of their diameter distant from each other. The nuclei occupy from one-third to about two-thirds of the diameter of the interior of the cell, and neither in it, nor in the cell surrounding it, is there any appearance of granules. I could not detect any of these cells in the dried specimen of the same species, nor have I ever seen similar cells in any other calcareous sponge. It is difficult, in the present limited state of our knowledge of this tribe of sponges, to determine the import of these bodies in the economy of the sponge, but it is most probable they are reproductive organs."

Correlated with the evidence just submitted in connection with the allied type *L. coriacea*, there is every reason to believe that here also spores of a closely identical type exist. Much evidence substantiating the very general occurrence of spores among the Spongida may be further adduced from the more recent publications of various Continental spongologists, though no such interpretation of the structures observed would so far appear to have presented itself to the minds of these investigators. Thus in his "Untersuchungen über Hexactinelliden,"† W. Marshall figures and describes spore-like granules as occurring separately or in spherical masses within the substance of the undifferentiated sarcode or cytoblastema of a species of *Holtenia*. C. Barrois, "Embryologie de quelques Éponges de la Manche,"‡ figures as peculiar granular cells, perhaps spermatozoa, of a species of *Isodictya*, subspheroidal and more or less elongate aggregations of spore-like bodies held together by thread-like transparent chords. This identical type has been encountered abundantly by the author on the Jersey coast, and was independently observed to exhibit a similar peculiarity. The

* 'Mon. Brit. Spong.,' vol. ii., 1866. † 'Zeit. Wiss. Zool.,' Bd. xxv., 1875.
‡ 'Ann. de Sc. Nat. Zool.,' 1876.

whole cytoblastemic element in this species is remarkably tenacious or glutinous, and is drawn out in long strings, like bird-lime, when the sponge is broken apart; the granular cells observed by Barrois are evidently the spore-masses held together in the withdrawn glutinous threads of the investing cytoblastema. The so-called "sperm-balls," figured by F. E. Schulze, in relation with the genus *Halisarca*,* would appear also to belong to the same category. The abundantly distributed subspheroidal groups of so-called coloured corpuscles figured and described by this last-named authority as imparting the characteristic yellow tint to the keratose type *Aplysina aerophoba*, † correspond remarkably with the yellow or light brown spores of *Leucosolenia coriacea*. Lastly, Metschnikoff's valuable "Spongologische Studien" ‡ embraces abundant testimony in a corresponding direction, and as is made evident at Pl. X. Figs. 8 and 9 of the present treatise, reproducing his illustrations of the so-called "mesoderm" elements of the genus *Siphonochatina*.

In anticipation of the argument that may be advanced by the adherents of the Metazoic interpretation of sponge structures, to the effect that the sporular bodies here figured and described, represent spermatic or male reproductive elements, it is only requisite to point still more emphatically to the fact that these spores distributed broadcast throughout the substance of the cytoblastema may, as ascertained by the author, be met with and traced onwards through every intermediate size and stage, from the single spheroidal spore up to the adult collared monads or amœbiform cytoblasts; the derivation of these spores through the splitting up into a granular or sporular mass of the entire substance of the matured collar-bearing zooids being correspondingly substantiated. Their phenomena of production and cycle of development are, in fact, in all ways identical with those that obtain among the typical Choano-Flagellata and ordinary Flagellata, and in all of which the spores derived by a similar segmentation of the parent body develop first a simple monadiform or amœboid phase, and after arriving at the adult state revert once more to the amœbiform condition, become quiescent, and are again resolved into minute spores. In the sponge, all these transformations and developmental processes take place within the substance of the cytoblastema, which constitutes a suitable nidus for them essentially corresponding with the gelatinous matrix or zoocytium of *Ophrydium*, *Phalansterium*, and *Protospongia*.

While the evidence so far submitted suffices to indicate the close connection of the Spongida with the typical Infusoria - Flagellata, and also explains, in connection with the phenomena last described, the manner in which the general sponge-body is, by ever progressing internal spore-production, rapidly increased in size, certain other important features connected with their reproduction remain to be recorded. Although the scattering of the spores through, and their development within, the

* 'Zeit. Wiss. Zool.,' Bd. xxviii., 1877. † Ibid., Bd. xxx., 1878.
‡ Ibid., Bd. xxxii., 1879.

substance of the cytoblastema contributes largely towards the augmentation of the common colony, it evidently does not provide for the more remote dispersion of the species. This is effected in an entirely distinct manner. In many cases, such as that of the common fresh-water *Spongilla*, such a desired result is partly brought about by the production of encapsuled gemmules, or so-called "seed-like bodies" at the time of the decadence and disintegration of the parent stock. Practically, the development of these reproductive bodies may be said to represent on a large scale a modified process of encystment closely corresponding with the production of sporangia among the Mycetozoa described on a preceding page. As winter approaches, the zooids forming the parent colony assume an amœboid state and coalescing in spheroïdal groups, secrete around them a common spiculiferous capsule, within which they remain in a torpid or quiescent state, until revivified by the return of spring and its accompanying congenial temperature. A singular inversion of this phenomenon obtains among the *Spongillæ* of tropic countries, and in which, as recorded by Mr. Carter of certain types occurring in the neighbourhood of Calcutta, the production of gemmules, or entrance upon a hibernating or quiescent state is resorted to (identically with that of many tropic fishes, such as *Lepidosiren*) as a protective provision against the summer droughts, when the tanks and reservoirs that they customarily inhabit are dried up.

The quiescent or hibernating gemmules, however, play but a minor part in the local distribution of the species compared with the actively motile reproductive bodies produced as offgrowths by sponges of apparently every denomination during their period of luxuriant growth. With these motile bodies, indeed, the quiescent or hibernating gemmules are in no ways comparable, they representing more correctly composite modifications of the temporary "protective encystments" of the ordinary Infusoria. As true reproductive gemmules only are here recognized those free-swimming bodies, the so-called "ciliated-larvæ," or "ciliated sponge-embryos," first discovered by Grant and Lieberkuhn, upon the correct interpretation of which the minds of biologists within these latter days have been so diligently exercised. It is upon these seemingly anomalous reproductive structures, moreover, that Professor Haeckel has, as already stated, conferred the distinctive title of *gastrulæ*, and sought to demonstrate the conformance of the Spongida to the Metazoic type. Without recapitulating the altogether erroneous interpretations first published, and quite recently maintained, by Haeckel concerning the form and structure of these bodies, reproduced, rather as an admonition and warning than for the purposes of edification, in the woodcut illustration with its accompanying description at page 157, a brief examination of the more reliable data accumulated through the independent investigations of Metschnikoff, Oscar Schmidt, F. E. Schulze, Barrois, and other recent authorities may be proceeded with. While one and all of them are unanimous in condemning, as entirely fallacious and untrustworthy, that special bilaminate and sac-shaped structural type attributed by Haeckel to the so-called ciliated embryos, the Haeckelian interpretation of the Metazoic affinities of the sponges has exerted so widespread an influence, and obtained such favour, that every point has been strained on all sides to reduce these reproductive structures, one way or another, to the Metazoic formula.

Unfortunately for these authorities, however, the one dissentient party to this seemingly plausible and, so far as the sponges are concerned, most honourable correlation is encountered in the very object of their solicitous attention. The ciliated sponge-embryo—or, as shown later on, it may be more appropriately denominated the "ciliated sponge-gemmule"—stubbornly resists interpretation as the exact analogue of any one of the various embryonic types prevalent among the Metazoa, and seems indeed to derive a pleasurable satisfaction from the exhibition of a varying type of structure, possessing by turns some shadowy semblance of all, but actually conforming in no single instance to any one of them. Sometimes, in fact, not only in the same order, or in the same family, but in the same genus, in the same species, and even in the same individual sponge-colony, an entire series of diversely constructed reproductive bodies may be met with.

Abundant illustration is afforded of the more important variations of form and structure found to obtain among the free-swimming sponge-gemmules, by the figures numbered 22 to 36 of Pl. IX., derived partly from the author's personal investigation, and partly from the published contributions of the various authorities previously quoted. Examined attentively, it will become apparent that this entire series exhibits, with various intermediate gradations, what may be denominated three fundamental plans of structural differentiation. Thus, in the first of these, as shown in Figs. 22, 23, and 36, such plan presents the simplest possible expression, the so-called body-wall of the more or less ovate body consisting of a simple and even layer of columnar cells, each giving origin peripherally to a single elongate cilium or flagellum. In the second series, Figs. 27 and 29, an entirely distinct and more complex plan is exhibited. Here, the cellular components of the anterior and posterior regions of the gemmule differ in both size and structure; those of the former being columnar, and bearing flagella as in those of the first series, while in the latter they are very much larger, usually more or less spheroidal, and entirely devoid of flagellate appendages. The third and highest state of complexity is arrived at in Fig. 30, where a new element is superadded in the form of a central zone of smaller rounded cells, interposed between the anterior columnar and posterior spheroidal series. It is scarcely to be wondered that the energies of talented biologists have been taxed to their uttermost to reconcile such entirely diverse structures with the typical developmental formulæ of the Metazoic embryo. By none of these, as yet, can such identification be claimed to have been successfully established; nor, on examining more closely the very discordant interpretations that have been suggested by different authorities with relation even to gemmules found in the same specific type, would there seem to be much prospect of arrival at a more definite result.

The Metazoic nature of the sponges, in deference to the authoritative dictum of Professor Haeckel, being accepted *à priori* as an article of creed, it has been rendered necessary to indicate, in one and all of those diverse so-called ciliated sponge-embryos, the existence of the two primary and absolutely essential constituents of the Metazoic embryo, the ectoderm and endoderm, as produced by the segmentation and subsequent metamorphosis of a primitive unicellular impregnated ovum. Deferring for a while the consideration of the presumed identity of this earliest or initial phase, it may be first observed that the structural type, out of the three respective series just enumerated, which has been accepted as conforming itself most conveniently to the Metazoic formula, is exhibited by that one in which the apical pole or segment of the reproductive body is composed of more minute columnar flagellate cells, and the opposite one of larger but simply subspheroidal elements. Here, as typically represented in the calcareous sponge, *Grantia compressa* (Pl. IX. Fig. 27), there certainly, at first sight, appears to be a remarkable structural correspondence with the segmented holoblastic ovum of the Mammalia, Amphibia, and various fishes, including *Amphioxus*, and numerous higher Invertebrata in which one-half of the primitive ovum, dividing more rapidly and abundantly, becomes converted into numerous minute columnar blastomeres, and the opposite half, dividing more slowly and less extensively, into fewer larger and subspheroidal blastomeres. Out of these two elemental series, distinguished respectively as the epiblast and hypoblast, the future ectoderm and endoderm are subsequently developed, the former from the minute columnar blastomeres or epiblast, and the latter from the larger blastomeres or hypoblast. The identity of the segmentation process in the Metazoic embryo and in the so-called sponge-larva being so far regarded as complete, the apparent corresponding factors in either case have also been accepted as homologous ectodermic and endodermic elements. Supposing, for the time, that these two structural elements could be consistently correlated, what should be the next step?

In the Metazoic embryo it invariably happens that either by the invagination or falling inwards, as in *Amphioxus*, upon the primitive central segmentation cavity or archenteron of the hypoblast or endodermic element, or by the encroachment upon or growing over the latter, as in the Amphibia, of the epiblast or ectodermal element, it comes to pass that the endoderm is enclosed within the ectoderm, and a bilaminate structure is produced roughly resembling the double-walled sac-like body or so-called "gastrula" of Professor Haeckel. The outer lamina or wall of this sac-like body is now the ectoderm, the inner one, closely applied to it, the endoderm. The central cavity most usually enclosed within these layers represents the primitive alimentary tract or archenteron, and the aperture placing the latter in communication with the outer world the primitive anal aperture or blastopore. The question at issue is whether similar or equivalent developmental steps are traceable in the ciliated sponge-gemmule? F. E. Schulze, writing of *Sycandra raphanus* in the year 1875, deposes that there are, giving in demonstration the figures reproduced at Pl. IX. Fig. 33. The same authority reports, however, as the result of a more recent investigation of this species, an entirely opposite plan of structure. According to his later interpretation,* it is not the larger and apparent endodermic blastomeres that become invaginated or enclosed within the more minute ectodermal elements, but, as indicated at Fig. 34 of the same plate, the latter that sink down into, and are enclosed by, the former. By Metschnikoff, a second chronicler of the developmental phases of this identical species, the so-called ciliated larvæ are described as presenting, in addition to the ordinary form having dissimilar hemispheres of large, subspheroidal, non-flagelliferous, and more minute columnar flagellate cells, examples that are made up entirely of flagellate columnar elements, which, however, towards the basal region, are of somewhat larger size. This slight modification of the first of the three structural types enumerated in a preceding page, as observed by Metschnikoff, of *Sycandra raphanus*, represents the dominant form found in other closely allied calcareous species, as also in the Myxospongiæ and the majority of the Siliceospongiæ, where the characteristic amphiblastuloid type previously considered is not known to occur. This so to say homoblastic embryonic form, produced by the entire and even segmentation of the primitive so-called ovum, and exhibiting in its characteristic state the structure and condition only of a monoblastic or simple single-cell-walled morula, with a more or less extensive segmentation cavity, does not subsequently, by direct or indirect invagination, as occurs with the monoblastic morulæ of the Metazoa, attain to the higher diploblastic formula; it cannot therefore be consistently compared with the typical and characteristic diploblastic embryo of any Metazoic organism. Nevertheless, various more or less arduous attempts have been made to demonstrate that even in this simpler monoblastic reproductive body, the essential Metazoic elements, "ectoderm," "endoderm," and in some cases even "mesoderm," are substantially represented.

By some, including Professor Haeckel, it has been suggested that the endoderm is indirectly produced through the process of delamination, instead of that of invagination, as most usually obtains. Such an interpretation, however, is entirely upset by some highly remarkable results of recent investigation. It has been shown, in fact, by Oscar Schmidt,† with relation to the calcareous type *Ascetta primordialis*, that the elements usually accepted as representing the endoderm are produced neither by delamination nor by invagination, but creep into the central segmentation cavity as separate and independent amœbiform units from the circumjacent so-called ectodermal layer, of which latter they are the metamorphosed

* 'Zeitschrift für Wissenschaftliche Zoologie,' Bd. xxxi., 1878.
† 'Archiv für Mikroskopische Anatomie,' Bd. xiv., 1877.

constituents. Sooner or later, the segmentation cavity becomes filled up with these metamorphosed, or, as Oscar Schmidt has denominated them, "wandering cells," which breaking their way through the posterior pole, ultimately appear as a projecting heap in this region, and thus convey to the entire organism an aspect closely corresponding with the normal amphiblastuloid type. It is through the medium of these projecting metamorphosed cells that the young sponge becomes fixed to its selected fulcrum of support, and that the further development onward to the characteristic adult sponge-stock is initiated. Some of the most characteristic representations of the phenomena last described, as given by Oscar Schmidt, will be found reproduced at Pl. IX. Figs. 36–38. The remarkable and important data, first elicited by the last-named authority, have been entirely confirmed by the later researches of Metschnikoff,* in connection with both *Ascetta primordialis* and various other widely separated sponge-forms. Proceeding still further, however, this investigator maintains that in these types not only the so-called endodermic, but special mesodermic (spiculiferous) elements are likewise produced by a similar developmental process.

The task of reconciling all of the various developmental formulæ now enumerated as exhibited by diverse, or, it may be, by even a single sponge type, with one or any of those that typically characterize the Metazoic embryo, is obviously almost hopeless: it now remains to be seen whether or not more substantial progress in the interpretation of the affinities of the sponges by means of the so-called ciliated larvæ can be accomplished in a totally distinct direction. Presuming that the account given by F. E. Schulze of *Sycandra raphanus* represented the typical and constant form and process of development—though practically such is very far from the case—Mr. T. M. Balfour, one of our leading authorities in this country on embryologic matters, has quite recently, January 1879, contributed to the 'Quarterly Journal of Microscopical Science' the results of his own analysis of the evidence so far adduced. The verdict he arrives at, while not proceeding to the full length advocated by the author of this volume, is noteworthy for its marked bias in a similar direction, and for its deviation in an essential manner from that Metazoic interpretation hitherto most generally acquiesced in by Continental biologists.

Mr. Balfour's expressed views in this connection are so important as to demand quotation *in extenso*. After enumerating the chief features of the developmental history of *Sycandra raphanus* as last reported by F. E. Schulze, he thus proceeds:—

"The first point in the development of *Sycandra* which deserves notice is the character of the free-swimming larva. The peculiar larval form, with one half of the body composed of amœboid granular cells, and the other of clear ciliated cells, is nearly constant among the Calcispongiæ, and widely distributed in a modified form amongst the Fibrospongiæ and Myxospongiæ. Does this larva retain the characters of an ancestral type of the Spongida, and if so, what does its form mean?

* 'Zeitschrift Wissenschaftliche Zoologie,' Bd. xxxii., 1879.

It is, of course, possible that it has no ancestral meaning, but has been secondarily acquired. I prefer myself to think that this is not the case, more especially as it appears to me that the characters of the larva may be plausibly explained by regarding it as a transitional form between the Protozoa and Metazoa.

"According to this view, the larva is to be considered as a colony of Protozoa—one half of the individuals of which have become differentiated into nutritive forms, and the other half into locomotor and respiratory forms. The granular amœboid cells represent the nutritive forms, and the ciliated cells represent the locomotor and respiratory forms. That the passage from the Protozoa to the Metazoa may have been effected by such a differentiation is not improbable on *à priori* grounds, and fits in very well with the condition of the free-swimming larva of the Spongida.

"While the above view seems fairly satisfactory for the free-swimming stage of the larval sponge, there arises in the subsequent development a difficulty which at first sight seems fatal to it. This difficulty is the invagination of the ciliated cells instead of the granular ones. If the granular ones represent the nutritive individuals of the colony, they, and not the ciliated cells, ought most certainly to give rise to the lining of the gastrula cavity, according to the generally accepted views of the morphology of the Spongida.

"The suggestion which I would venture to put forward in explanation of this paradox involves a completely new view of the nature and functions of the germinal layers of the adult sponges. It is as follows:—When the free-swimming ancestor of the Spongida became fixed, the ciliated cells by which its movements used to be effected must have to a great extent become functionless; at the same time the amœboid nutritive cells would need to expose as large a surface as possible. In these two considerations there may, perhaps, be found a sufficient explanation of the invagination of the ciliated cells and the growth of the amœboid cells over them. Though respiration was, no doubt, mainly effected by the ciliated cells, it is improbable that it was completely localized in them; but the continuation of their function was provided for by the formation of an osculum and pores. The ciliated collared cells which line the ciliated chambers, or in some cases the radial tubes, are undoubtedly derived from the invaginated cells; and if there is any truth in the above suggestion, the collared cells in the adult sponge must be mainly respiratory, and not digestive, in function, while the normal epithelial cells which cover the surface of the sponge, and in most cases line the greater part of the passages through its substance, must carry on the digestion. If the reverse is the case, the whole theory falls to the ground. It has not, so far as I know, been definitely made out where the digestion is carried on. Lieberkuhn would appear to hold the view that the amœboid lining cells of the passages are mainly concerned with digestion, while Carter holds that digestion is carried on by the collared cells of the ciliated chambers. If it is eventually proved by actual experiments in the nutrition of sponges that digestion is carried on by the general cells lining the passages, and not by the ciliated cells, it is clear that neither the ectoderm nor entoderm of sponges will correspond with the similarly named layers in the Cœlenterata and the Metazoa. The invaginated entoderm will be the respiratory layer, and the ectoderm the digestive and sensory layer; the sensory function being probably mainly localized in the epithelium on the surface, and the digestive one in the epithelium lining the passages. Such a fundamental difference in the germinal layers between the Spongida and the other Metazoa would necessarily involve the creation of a special division of the Metazoa for the reception of the former group."

It is very clear, after a perusal of Mr. Balfour's views as above enunciated, that the claims of the Spongida for admission into the ranks of the typical Metazoa, and more especially for correlation with the Cœlenterata, as advocated by Professor Haeckel, rests upon the most shallow and insecure foundation. It is likewise evident that in Mr. Balfour's estimation the sponges retain a close kinship with the Protozoa, and are at the outside an intermediate group between the Protozoic and Metazoic sections. Proceeding yet further, it is maintained by the present author that the structure and relationship of the Spongida is altogether Protozoic, and that the phenomena exhibited by the life and developmental history of the ciliated reproductive bodies now under discussion are, equally with the structural composition of the adult sponge, reducible to and capable of correct interpretation only in association with a Protozoic standard.

Before proceeding to an examination of the evidence that can be adduced in support of this declaration, a passing note may be made of one or two of the points involved in Mr. Balfour's argument. In the first instance, the so-called larval sponge form distinguished by Haeckel by the title of an "amphiblastula," and consisting of one hemisphere of amœboid, and the other of flagellate cells, cannot, as Mr. Balfour suggests, be accepted as the typical and ancestral form of these bodies, it occurring only, and then not persistently, in the group of the Calcispongiæ; a still simpler type having all the cellular constituents alike in form and character, and thus presenting a closer structural conformance to a simple vesicular morula, is mostly dominant. The important issue at stake, recognized by Mr. Balfour, relating to the digestive functions of the amœboid and flagellate elements of both the adult and embryo sponge, can fortunately be completely disposed of, and in such a manner as, on Mr. Balfour's own admission, demonstrates that neither the so-called ectoderm nor endoderm of Spongida will correspond with the similarly named layers in the Cœlenterata and other Metazoa. Nutrition and digestion are, in fact, accomplished by *both* the collared flagellate and the amœboid cells, a circumstance which would require for their strict correlation with the equivalent Metazoic elements, the possession of nutritive functions by both the ectodermal and endodermal layers.

Passing now to a consideration of the interpretation of these special reproductive sponge structures maintained in this volume, it may be affirmed to be substantially identical with that submitted by the author in the 'Annals and Magazine of Natural History' for August 1878, previously embodied in the communication made to the Linnean Society in June 1877, and as extensively confirmed by subsequent investigation. The fact of the case is, that in almost every one of the accounts and illustrations given by contemporaneous authorities, that which may unhesitatingly be pronounced to represent the most important and significant structural element in these reproductive bodies, has been persistently ignored. The omission referred to is the fundamental composition of the free-swimming sponge-embryos of collared flagellate zooids, in all ways identical with those that line the interstitial cavities, and constitute the essential factors of the adult sponge. The so-called ciliated sponge-larva is, it is here maintained, in its typical phase of development, not an individual germ or larva, but a motile swarm-gemmule, consisting of a more or less ovate colonial aggregation of typical collared zooids, as shown at Pl. IX.

Figs. 24 and 25, which represent phases of these reproductive structures, as observed by the author in the common calcareous sponge *Grantia compressa.* The collars left out—and it is admitted that without much care and patience in examination they are, like the collars of the independent collared monads and Spongozoa, most difficult to recognize—the structure accords completely with that vesicular, moruloid embryonic type so abundantly figured and described by Oscar Schmidt, F. E. Schulze, and Metschnikoff. Neither of these biologists appear to have detected the existence of that important element, the collar. That such a structure, however, positively exists, does not rest only upon testimony submitted by the present author, it being substantially confirmed by the independent investigation of Barrois, and even Haeckel. The former of these two authorities indicates, though feebly, the possession of collars by the motile reproductive gemmules of *Halisarca lobularis*, while Professor Haeckel still more clearly denotes their existence in his representations of his so-called ciliated larvæ or gastrulæ of the calcareous sponges *Leuculmis echinus* and *Sycyssa Huxleyi.* With both Haeckel and Barrois, however, the collared cells have apparently no significance beyond that of ordinary ciliated epithelium, the special function of the funnel-shaped collar, and its import with relation to both the sponge-monads and the entire order of independent organisms described in this volume under the title of the Choano-Flagellata, being as yet unrecognized.

It is not only in connection with the simpler moruloid type of the ciliated sponge-gemmule that its fundamental composition out of typical collar-bearing zooids is made manifest. A like interpretation applies with equal force to that seemingly more complex amphiblastuloid type upon which an agreement with the Metazoic embryologic formula has been most powerfully upheld. This may be demonstrated in connection with the identical sponge-form, *Grantia compressa*, cited in the previous instance. As shown at Pl. IX. Figs. 26–29, this amphiblastuloid reproductive body may, furthermore, present three very distinct developmental phases. It may, as in the first instance, Fig. 26, exhibit typical collared cells in the posterior or basal hemisphere, and simply flagellate ones in the anterior one; in a second case, Fig. 27, the basal elements may be simply amœboid and the anterior flagellate, this representing indeed the characteristic condition under which the amphiblastuloid type has been most extensively figured and described. A modification of this type, in which the basal amœbiform units project irregularly from the periphery, is shown at Fig. 29. In the third and remaining form, Fig. 28, the basal elements are also amœboid, but the anterior ones, in place of being simply flagellate, bear also characteristic hyaline collars. These three are, in fact, progressional phases only of one and the same fundamental amphiblastuloid type, the latter again being an unevenly developed variation only of the simpler and homogeneously constructed moruloid form. In the moruloid type, Figs. 22 to 25, the development of the collared units has progressed evenly throughout the entire series, while in the three amphiblastuloid ones above enumerated, it exhibits various phases of unevenness which may be thus explained. In all three, the posterior half has developed considerably in advance of the anterior one, but exhibits in the first figure its typical composition of collar-bearing monads; in the other two, on the other hand, the posterior basal elements have passed from the collar-bearing to the amœboid state, and coalesced more or less extensively with each other. In a like manner, the elements of the anterior half in both of the Figs. 26 and 27 represent the immature and simply flagellate phases of the collared zooids, but which in Fig. 28 have acquired their characteristic adult form. The life-history and various developmental phases of the free-swimming ciliated sponge-gemmules are, in fact, epitomizations only of the phenomena already described of the collared zooids of the adult sponge-stock. Here, as there, the essential constituents, or collared zooids, of the colonial aggregation, commence life as simple flagellate units, which, after attaining their typical adult form, assume successively an amœboid and quiescent state, and give rise by minute sporular subdivision to a further progeny of collared zooids. As a clear indication of the common origin and significance of both the moruloid and amphiblastuloid sponge-gemmules, with their various modifications, it needs only to be recorded that every one of these seemingly distinct structures has been met with by the author in a single sponge-stock of *Grantia compressa*, and also in *Leucosolenia botryoides* and *Grantia* (*Sycon*) *ciliatum*, as obtained both in the Channel Islands in the years 1877–8, and on the South Devon and Cornish coast in 1879. From the last examined examples, furthermore, sections containing these gemmules in abundance, treated with osmic acid, have been successfully preserved for permanent reference and comparison. It is, moreover, in connection with the first-named sponge-form (*Grantia compressa*) that Barrois has reported the occurrence of that variety of the amphiblastuloid gemmule, in which a ring of intermediate non-flagellate cells are developed equatorially between the typical flagellate and amœboid series. The latter elements, as shown at Pl. IX. Fig. 30, are of somewhat abnormal size, and, as in many other of the examples figured, are far too large to have represented individually a primarily single collared zooid. This phenomenon, as also that of the presence of the equatorial girdle of smaller cells in the example cited, admits of simultaneous explanation. The equatorial girdle, in fact, may be interpreted as representing an anterior ring of amœboid cells metamorphosed from the typical collared units at a slightly later date than those of the posterior area, and which latter have become still more obscurely transformed and increased in size, though lessened in number, by coalescence. It is by a similar process of retrogression to an amœboid type, and the more or less extensive union or coalescence of amœboid zooids that the ciliated gemmules themselves originate.

In addition to the various symmetrically constructed moruloid and amphiblastuloid modifications of the ciliated sponge-gemmule already enumerated, it has yet to be recorded that it very commonly happens that these structures present an altogether irregular and asymmetrical contour. Illustrations of such irregular formations, as figured by Oscar Schmidt, of *Grantia* (*Sycandra*) *compressa*, and as observed by the author, will be found reproduced at Pl. IX. Figs. 32 and 35. Such asymmetrically developed gemmules may retain fundamentally the moruloid or amphiblastuloid structural type, being in the one case composed entirely of similar and in the other case of dissimilar constituents. The fact that these various irregularly formed gemmules are by no means of rare occurrence, may be accepted as furnishing supplementary evidence in demonstration of the non-correspondence of these sponge-gemmules, or so-called ciliated larvæ, with the embryos of the typical Metazoa, and in which latter organic series the production of asymmetrical germs is quite exceptional. One of the strongest arguments furnished in support of the essentially Protozoic significance of these reproductive bodies is, undoubtedly, afforded by the independently contributed testimony of Oscar Schmidt and Metschnikoff, by both of whom it is shown that in the case of *Ascetta primordialis*, the component flagellate elements of the moruloid gemmule assume quite independently an amœboid condition, and retiring separately into the central segmentation cavity, undergo their further metamorphoses. Ultimately, these separately retreating amœbiform units completely fill up the central cavity, and burst through the posterior region of the ciliated body, project at this extremity, and so produce in a roundabout manner a pseudo-amphiblastula. It will be at once recognized that while this peculiar developmental phenomenon of the sponge-gemmule exhibited by *Ascetta primordialis*, is altogether opposed to anything that obtains among the Metazoic series, it is at once reconcilable with a Protozoic interpretation. With their near allies the simple flagellate or collared monads, e.g. *Phalansterium*, *Spongomonas*, and *Protospongia*, parallel phenomena, including the assumption by the adult zooids of an amœboid state, and their retreat within the common gelatinous cytoblastema-like matrix, or zoocytium, represents the normal reproductive process.

The highly important evidence that demonstrates the thoroughgoing Protozoic affinities of the sponge with relation to the primary origin and development within the parent sponge-stock of the free-swimming ciliated gemmules, has yet to be submitted. The initial condition of these reproductive structures, as conceded unanimously by the independent testimony of every investigator, takes the form of an amœbiform body, varying in size from the 1–3000th to the 1–200th of an English inch, and presents a considerable likeness to the primary condition of an ordinary ovum. With, however, the interpretation of the significance and subsequent evolution of this amœbiform structure that is most generally advocated, the author has to declare himself entirely at issue. In accordance with this more widely accepted view, the amœbiform body is a true ovum, developed separately and independently in the interstitial substance of the sponge, and afterwards fecundated by spermatozoa independently generated within the same sponge-body.

Had such a process of production and development been actually substantiated, the Metazoic affinities of the Spongida would undoubtedly be capable of considerable development, but, as a matter of fact, no substantial proof of the existence of any such process has been as yet adduced. The evidence available for the gauging of this important question favours, on the other hand, an entirely opposite conclusion. It is here maintained, indeed, as first suggested in the author's communication to the 'Annals of Natural History' for July 1878, that the amœboid oviform bodies are not independent products of the adult sponge-stock, but simply retromorphosed collar-bearing zooids that have retreated within the cytoblastema, and assumed, as is common to them after passing their matured collar-bearing stage, an amœboid condition. It is these amœboid units that through coalescence with their fellows attain by degrees the comparatively colossal proportions they present in their most advanced phase of development, and then by the process of segmentation produce the characteristic moruloid or amphiblastuloid ciliated gemmule. There is in this process of evolution no concourse of male and female or true ova and spermatozoa as occurs among the Metazoa, but the phenomena exhibited are in all ways identical with those that obtain among the most simple Flagellate Infusoria, such as *Monas* and *Heteromita*, in which the typical flagellate zooids, passing the zenith of their adult condition, enter into an amœboid state, and coalescing in pairs, or even socially, give rise by segmentation to a new generation of flagellate units. On a yet larger scale, and in a manner more closely corresponding with what obtains among the Spongida, identical phenomena, as described at page 42, are encountered in the group of the Myxomycetes or Mycetozoa. The only fundamental point that distinguishes the segmentation process in the two groups of the Spongida and ordinary Flagellata is that, whereas in the more simple Flagellata the products of such segmentation are scattered apart throughout the inhabited fluid medium, and maintain an independent existence, in that of the sponge-gemmule these flagellate units are intimately bound to one another at the time of their exodus from the parent colony-stock, and remain associated within their subsequently developed common gelatinous matrix or cytoblastema for the whole term of their existence. Substantial corroboration of the opinion here maintained that the reproductive sponge-gemmules, or so-called ciliated larvæ, are the product of the coalescence or fusing with one another of a large number of metamorphosed collared zooids, and that they are not independently generated after the manner of true ova, is afforded by the circumstances under which they are naturally met with in the tissues of the parent sponge-stock. In this connection, both in accordance with the author's experiences, and as distinctly shown in the figures given by all the more notable investigators of this organic group, it is invariably found that these bodies are, as shown at Pl. VII. Fig. 1, produced first in the deeper and consequently older portion of the sponge-stock, and that where abundantly developed they monopolize its interstitial substance to the exclusion of the ampullaceous sacs or other combinations under which the collared zooids may be characteristically distributed. These latter have, in fact, after attaining maturity, assumed the amœboid state, and, abandoning their normal position, coalesced extensively with one another after the manner of various ordinary Flagellata, the outcome of this process being the more or less regular segmentation of the united mass and production of the characteristic ciliated gemmule. Regarded from such a point of view, this ciliated reproductive structure is in no sense an egg, or its derivative, but represents a coherent aggregate of monadiform swarm-spores, or, as it may be most appropriately denominated, a "swarm-gemmule."

In addition to the characteristic ciliated reproductive bodies or swarm-gemmules just described, there remain to be discussed certain other complex bodies, generated within the interstitial sponge-substance, that, as first suggested by Mr. Carter, take their origin by an essentially identical developmental process. The structures here referred to are the so-called "ampullaceous sacs" or spheroidal ciliated chambers characteristic of *Halisarca*, the greater portion of the keratose and siliceous sponge-forms, and some few calcareous species. It has been ascertained by the author in the case of *Halisarca Dujardinii*, a species of *Isodictya*, and various other types, that these structures are also, as shown at Pl. IX. Figs. 4–9, originally developed from the segmentation of a primitive amœboid body produced, as in the former instance, by the coalescence of more or fewer metamorphosed collared zooids. Such segmentation is in this instance, however, entirely even, and results in the production of a perfectly spheroidal moruloid body having a somewhat extensive central segmentation cavity. The only difference that characterizes the more advanced condition of the ampullaceous sacs is manifested by the fact, that while in the case of the free-swimming ciliated gemmules the constituent collared zooids are so developed that their collars and flagella are directed peripherally or away from the central segmentation cavity, in the case of the ampullaceous sacs they take an opposite direction, their flagella and collars being projected into this cavity. As with the ciliated gemmules, the component zooids, before acquiring their characteristic collars, present a simply flagellate condition, their aspect at such stage being represented at Pl. IX. Fig. 11. Immediately prior to this simply ciliate condition the individual units are amœbiform and non-flagelliferous, and held together circumferentially by a thin film of structureless cytoblastema ; often, as shown at Pl. IX. Fig. 10, they are considerably isolated. In their more matured state the collared zooids cohere laterally to one another, and, excepting at the afferent and efferent apertures, present no break or interruption. Taken in optical section, so as to avoid these openings, a matured and typical ampullaceous sac presents, in fact, the exceedingly elegant and symmetrical structural form illustrated by Fig. 1 of the plate just quoted. Isolating some half-dozen cell-units from this complete section, as shown at Pl. IX. Fig. 2, a monad aggregation is produced that corresponds in a most remarkable manner with the characteristic moniliform colony-stocks of the free-swimming marine collared type *Desmarella moniliformis*, S. K., represented at Pl. II. Fig. 30, a fresh-water variety of which genus has been since figured by Professor Stein under the title of *Codonodesmus phalanx*. The symmetrical pattern of the ampullaceous sacs just described is, however, by no means persistent. In many sponges a greater or less number of these primitively spheroidal chambers, abutting upon one another, coalesce together, and so form altogether irregularly shaped cavities that may ultimately be of very considerable extent.

In his 'Spongiologische Studien'* Metschnikoff has quite recently drawn attention to certain structural elements in *Halisarca Dujardinii* that have hitherto escaped notice. These structures, upon which he bestows the name of "rosette-cells," consist of small subspheroidal groups of cells, usually eight or sixteen, that are developed independently within the interstitial substance of the adult sponge, and also within the central cavity of the free-swimming ciliated gemmules, in this latter case being the product, by segmentation, of the metamorphosed and increeping zooids from the peripheral region. Some of the more characteristic representatives given by Metschnikoff of these rosette-cells are reproduced at Pl. IX. Figs. 15–17, the two last of these exhibiting the existence of flagellate appendages. It so happens that these newly-reported rosette-cells supply, most opportunely, an important link in the organization of certain Spongida, recognized by the author some years since, but which, pending the production of corroborative evidence, has not hitherto been brought forward. Closely identical cell-aggregations have been thus observed in a variety of sponge-forms, being found more especially abundant, however, in blood-red examples of the same type, *Halisarca Dujardinii*, collected on the Jersey coast and examined in the living state in the month of February 1878. At this time of the year none of the characteristic ciliated swarm-gemmules were present; but in cutting sections, numbers of spheroidal uvella-like groups of typical collared monads were liberated, and were likewise observed united to the cytoblastema, entering largely, in combination with the ampullaceous sacs, under such conditions into the formation of the general substance of the sponge-stock. While in their most typical and matured condition the constituent zooids of these independent rosette-shaped groups were provided with collars and flagella, and in all respects resembled those lining the ampullaceous sacs, in less matured examples they were simply flagellate, and in still earlier conditions possessed no appendages whatever, the larger examples being then indistinguishable from the morula-like cell-aggregates out of which the ampullaceous sacs are themselves developed. There can be but little doubt that these structures observed in the Channel

* 'Zeitschrift für Wissenschaftliche Zoologie,' Bd. xxxii., 1879.

Islands examples, and as exhibited in their various developmental phases at Pl. IX. Figs. 18-21, are identical with the so-called rosette-cells lately described by Metschnikoff; the descriptions and delineations of them as given by him being, however, deficient in one important point—that of the possession by each constituent unit, in its matured condition, of the characteristic collar. This oversight is, however, altogether what might have been expected when it is found on examining his text and plates illustrating the histology of various calcareous and siliceous sponge-forms, that that important structure is not, except in one doubtful instance, either figured or alluded to.

The true significance of the special rosette-like aggregations remains to be discussed. Their derivation through the coalescence and segmentation of a greater or less number of amœbiform units, as in the case of the larger ciliated gemmules, and that of the ampullaceous sacs, was ascertained by the author, their close correspondence with the former of these two structures being thus made especially apparent. Their only distinction from the ciliated gemmules subsists, in fact, in their much smaller size, through being derived from the fusion of a small number of zooids only, and their retention of a spheroidal uvella-like contour, without any development, by separation from each other, of an extensive cleavage cavity. It would seem to be by no means improbable that the rosette-shaped aggregations, thus derived from the fusion and segmentation of a smaller number of the typical collared cells, represent in the one direction a more primitive form of the ciliated reproductive gemmule, and in another the more primitive mode of grouping of the typical collared zooids in the colonial sponge-stock. As already stated, and as shown at Pl. IX. Fig. 21, these spheroidal groups were found attached to and projecting from the cytoblastema into the adjacent canal-systems in the case of *Halisarca*, and contributed largely, in combination with the ampullaceous sacs, to the composition of the general substance of the compound body. It is quite probable that sponge-forms exist, or have existed, in which such a disposition alone of the collar-bearing zooids represents the normal and characteristic type of structure. A close approach to this has in fact already been observed by the writer in connection with a siliceous-spiculed sponge, further investigation, however, being desirable for its complete exposition. Should anticipations in this direction be confirmed, it will certainly admit of a yet closer approximation of the sponges to the independent Flagellate Infusoria than is now attempted. For in such a case, a sponge-stock having its essential collared zooids so disposed that they project simply in the form of uvella-like clusters into the interstitial canal-system, and whose motile reproductive bodies consist simply of similar, but detached, uvelloid clusters, would in all ways be comparable to a colony of *Codosiga botrytis* or *Anthophysa vegetans*, in which, instead of developing a branching stem, the spheroidal clusters or "cœnobia" of associated zooids extended around them, and remained immersed within, a common gelatinous matrix, or "zoocytium," such as actually exists in the several genera *Spongomonas*, *Phalansterium*, and *Ophrydium*, taking there the place of a dendritic pedicle. In *Anthophysa vegetans*, furthermore, as shown at Pl. XVIII. Figs. 2, 4, 5, the propagation of the species by the detachment of entire uvelloid masses corresponding essentially with the rosette-like clusters of *Halisarca*, is well substantiated. A still more pertinent comparison in this direction may, however, be instituted between the rosette-gemmules of *Halisarca Dujardinii* delineated at Pl. IX. Figs. 19 and 20, and the monad aggregate of *Codosiga botrytis* reproduced from Stein's drawings at Pl. IV. Fig. 6.

Summing up the entire evidence now submitted with reference to the structural and developmental phenomena of the Spongida, and correlating it with that embodied in this volume relative to those of the independent Choano-Flagellata and other Flagellate Protozoa, scarcely a shadow of doubt even is admissible concerning the intimate and thoroughgoing relationship that subsists between one and the other. The primary and essential element of the apparently complex sponge-stock is the assemblage of collared flagellate zooids that inhabit its interstitial cavities under various plans of distribution. Individually, these collared zooids correspond, structurally and functionally, in every detail with the separate collared units of such genera as *Codosiga*, *Salpingœca*, and *Protospongia*. The collar in either case presents the same structure and functions, exhibits the same circulatory currents or cyclosis, and acts in a precisely similar manner as a trap for the capture of food. The body contains an identical centrally located spheroidal nucleus or endoplast, and a corresponding, posteriorly located, series of rhythmically pulsating contractile vesicles. The developmental and reproductive phenomena are also strictly parallel. Both originate as simple amœbæ or simple flagellate monads exhibiting no trace, in their earliest developmental phase, of the subsequently acquired characteristic collar. Both again, after passing matured age, withdraw their collar and flagellum, and assume an amœboid state. Then, coalescing or not with their fellows, they enter upon a quiescent or encysted condition, and breaking up into a greater or fewer number of sporular bodies, provide for the further existence and distribution of the species. Among the independent collared types this sporular progeny, except in *Protospongia* and *Phalansterium*, is scattered through the surrounding water, while in the sponge they are retained within the common gelatinous matrix, or cytoblastema, and assist in the extension of the common colony. More exceptionally, for the purpose of securing the local distribution of the species, the coalescing amœbiform zooids of the sponge-stock, derived from the metamorphosed collared zooids, form by repeated segmentation a pseud-embryo, or so-called ciliated larva, of considerable size, whose cell-constituents when analyzed are found to consist of typical collared zooids, resembling those from whence they previously originated, and presenting similarly in their earliest phase of existence a simply flagellate structural type. In their most characteristic form, these reproductive bodies or cell-aggregates consist of a uniform series of collared zooids, but by irregular growth one half may arrive at or pass maturity in advance of the other, the product then being a compound structure presenting a close correspondence with that phase of development of the Metazoic ovum known as the amphiblastula. Since, however, these bodies are in no way comparable with the Metazoic ovum—not being the product of the concourse of true sexual elements—the above likeness is simply homoplastic, and the body as a whole, consisting as it does of an aggregation of numerous independent zooids, may be most appropriately denominated a "swarm-gemmule." While no direct approach to the production of a similar compound gemmule occurs among the typical Infusoria-Flagellata, as at present known, something much akin to it obtains in the protophytic type *Volvox globator*, which liberates from its interior, free-swimming gemmules that take the form of spherical aggregations of biflagellate daughter-cells. In their isolated state, on the other hand, the swarm-gemmules of the sponge-stock are directly comparable with the free-swimming subspheroidal colony-stock of the flagellate Infusoria *Synura*, *Syncrypta*, and *Uroglena*, or with the attached subspheroidal clusters of *Codosiga* and *Anthophysa*.

In certain respects, as already pointed out at page 41 *et seq.*, a very remarkable and suggestive analogy in the direction of the Spongida is furnished by the Protozoic group of the Myxomycetes or Mycetozoa. Here we find the essential elements consisting primarily of independent flagellate zooids possessing a spheroidal endoplast, contractile vesicles, taking in solid nutriment, and presenting other characters in common with the ordinary Flagellata. Passing their matured flagellate condition these now assume an amœbiform condition and coalescing in large numbers, as in the case of the Spongozoa, form a colossal amœbiform mass, the plasmodium, not unlike the cytoblastema of a sponge with its amœbiform contents, out of which by a species of encystment the characteristic fungus-like sporangia are developed. These sporangia are to a considerable extent comparable with the hibernating encystments or so-called "gemmules" of *Spongilla* and other sponges, and subsequently, through the process of segmentation, become resolved into innumerable minute spores, which again give birth to a host of flagellate monadiform zooids resembling those from whence they originally sprang. It is further remarkable and suggestive of some distant affinity with the Spongida, that the network of fine interlacing threads, or "capillitium," that frequently binds the enclosed spores together, closely corresponds with the fine horny fibre of the keratose sponge-series ; while in the substance of the outer wall or "peridium" of the sporangia of some Mycetozoa, such as *Didymium nigripes* and *D. serpula* (see Pl. X. Figs. 30 and 31), calcareous deposits resembling sponge spicula are developed.

It is clearly manifest that in a very singular manner, and to a marked extent, the developmental phenomena of the Spongida are productive of composite structures, the swarm-gemmules or so-called ciliated larvæ, which bear the closest superficial resemblance to the segmented ovum and primary form and disposition of the component blastomeres of the Metazoic embryo. Penetrating beneath this superficial likeness, however, the points of analogy are found to diverge and vanish altogether. No Metazoic embryo, and no Metazoic structure, whatever, is distinguished by the possession of collared flagellate cells, with their attendant properties and functions, as found to exist respectively in these ciliated reproductive bodies, in the essential monadiform constituents of the adult sponge, and among the independent Discostomatous Flagellata. It is this one important histologic element, the collared cell with its attendant physiologic functions, that so closely unites together the two sections of the Spongida and independent Discostomata or Choano-Flagellata, while it isolates them at the same time from the members of every other organic group. Were the interstitial canals and chambers of the sponge-stock lined with cells possessing no contractile vesicles, bearing simply flagella, or corresponding with ordinary ciliated epithelium, and yet capable of ingesting solid food-matter, the grounds for removing this organic section into the Metazoic series would apparently be based on a surer foundation and some analogy would be presented with the simpler Hydrozoa and many Turbellaria, where, as shown by Kölliker and Kleinenberg, the endoderm cells lining the alimentary canal develop long flagella or pseudopodic processes, and it would appear, engulf food-substances after the manner of Amœba. Even here, however, the hypothetical analogy would be entirely delusive, the matured sponge-stock being the sum total, not of the concourse of sexual elements, but of the essentially Protozoic process of spore-development.

In the fashioning of the motile ciliated gemmules, or pseud-embryos, upon the plan of the Metazoic morula and amphiblastula, and in the peculiar arrangement and separation of the constituent flagellate and amœboid factors of the adult sponge, nature would certainly seem to have marshalled her forces preparatory to crossing the border from the Protozoa to the Metazoa, and so far as a transitional group between the two series can be predicated, it is probably realized in the section of the Spongida. The step, as a complete one, however, is by no means accomplished in this group. As is at once made manifest by a closer insight, the sponges remain in every detail of structure, function, and development, typical and thoroughgoing Protozoa. Their position in, and affinities among, the several groups of this sub-kingdom are evidently close to, and inseparable from, that of the naked and independent Discostomata or Choano-Flagellata, and which, having due regard to the clearly defined laws of organic evolution, must be recognized as the ancestral progenitors or archetypes of all sponge-forms. The phylogeny or backward passage, again, from these independent collared types to the simpler monadiform Flagellata, is made apparent not only in the matured condition of such a form as *Phalansterium* —where the collar is rudimentarily developed—but also in the ontogeny or individual life-history of all other collar-bearing zooids, and which, whether they belong to the simple and independent Choano-Flagellata or to the interstitial system of a complex sponge-stock, commence existence as similar collarless uniflagellate monads.

CHAPTER VI.

SYSTEMS OF CLASSIFICATION OF THE INFUSORIA ADOPTED BY VARIOUS AUTHORITIES FROM THE TIME OF O. F. MÜLLER TO THE PRESENT DATE.

CONSIDERABLE advantage being derived from an examination and comparison of the various systems of taxonomy or classification that have at different epochs been adopted with relation to the assemblage of organisms described in this treatise, the more important are herewith submitted *in extenso.*

Commencing with the earliest essay at such systematic tabulation, as included by O. F. Müller in his 'Animalcula Infusoria' published in the year 1786, and reproduced at page 199, one is at once struck by the important influence that was exerted in its formulation by the then rudimentary condition of the optical appliances at the disposal of this authority. Thus, the entire series of seventeen genera embraced in his scheme are separated into two leading groups or sections distinguished by their exhibition or not of distinct locomotive appendages as viewed with the imperfect microscopes of that day. It is now well known, however, that every one of these, with the single exception of *Proteus*, possesses either well-developed cilia or flagella. That exceptional type, with the five Müllerian genera *Volvox*, *Vibrio*, *Gonium*, *Cercaria*, and *Brachionus*, are necessarily eliminated from the several classes and orders of the Infusoria as comprehended at the present day, the remaining eleven, though considerably limited in their significance, being still retained. The number of specific types included in Müller's system, deducting the Rotiferæ, Phytozoa, and other extraneous forms, closely approaches two hundred.

With Ehrenberg's 'Die Infusionsthiere,' a far more extended series of organisms, and corresponding elaboration of the classificatory system adopted (see pages 200 and 201), is introduced. The supposed possession by all typical Infusoria of a distinct oral aperture and numerous gastric cavities, is, as stated in a previous chapter, the foundation-stone of his system, subordinate to which the presence or, as in the case of Müller's system, presumed absence of locomotive appendages, the character of these appendages, and location of the oral and excretory apertures, receives attention. The number of true infusorial forms included in Ehrenberg's magnificent treatise may be set down as approximating three hundred and fifty, which are included in sixteen family and eighty generic groups.

Felix Dujardin's 'Histoire des Zoophytes Infusoires,' published in the year 1841, is mostly notable for the distinction given to the Flagellate section of the Infusoria, many members of which, bearing new generic titles, were now for the first time figured and described with considerable accuracy. These Flagellata, while included in Order III. of his classificatory system given at page 202, were not, however, invested with any specially distinctive title.

C. T. Von Siebold's scheme, reproduced at page 203, bearing the date of 1845, and already referred to at length at page 20, is chiefly remarkable for its subdivision of the Infusoria into the two primary groups of the Astomata and Stomatoda; the former including the Opalinidæ and all the Flagelliferous types, and the latter all the ordinary Ciliata.

The next system demanding notice is that of Maximilian Perty, embodied in his work 'Zur Kenntniss kleinster Lebensformen,' published in the year 1852. In this treatise marked progress is made upon the classificatory schemes previously noticed. The entire series of infusorial forms are included in one primary sub-kingdom designated the *Archezoa*—in all essential respects synonymous with the Protozoa of Von Siebold—and its representatives separated into the primary sections of the Filigera or Phytozoida and Ciliata, which practically correspond with the Flagellate and Ciliate subdivisions as recognized at the present day. Twenty-six family and one hundred generic groups are comprehended in Perty's classificatory table (see pages 203 and 204), the number of species incorporated falling short, however, of that made known by Ehrenberg.

Claparède and Lachmann's extensive work, 'Études sur les Infusoires,' published as a complete treatise in 1868, but which had previously appeared as separate contributions to the 'Memoirs of the Institute of Geneva' during the years 1858 to 1860, next demands attention. In this for the first time we find the Infusoria definitely restricted to the limits within which they are circumscribed in this volume, the leading subdivisions of the entire series included closely corresponding also, as shown at page 205, with those here accepted as affording the most convenient and natural arrangement. By promoting, in point of fact, the three orders of the Infusoria distinguished by these authorities by the titles of the Flagellata, Suctoria, and Ciliata, to the rank of classes, retaining meanwhile their fourth group of the Cilio-Flagellata as a subordinate order only of the class Flagellata, the main basis of arrangement of the extensive series of forms noticed in this treatise is at once arrived at. It is to be regretted that Messrs. Claparède and Lachmann did not bestow upon the ordinary Flagellate division the same attention which they gave to the three remaining groups. But two or three forms only referable to this important section are described, the order as recognized by them not being even so much as tabulated. The most important improvements upon the earlier classificatory schemes accomplished by Messrs. Claparède and Lachmann, consist of the introduction of the two groups of the Suctoria and Cilio-Flagellata, the former being compounded chiefly of forms previously maintained by Stein to be metamorphic conditions of various Vorticellidæ, while the latter one comprised only the family group of the Peridiniidæ.

The classification of Diesing, a compiler and not an independent investigator, of the present group of organisms, is reproduced (see page 206 *et seq.*) so far only as relates to the Flagellate series, he exhibiting a keener appreciation of their most salient diagnostic characters than had been displayed by any previous authority. Taking on trust the dictum of Ehrenberg, this writer, unfortunately, fell into the error of ascribing to every member of this group the possession of a distinct oral aperture, which structure is abundantly shown in this manual to have no definite existence among a very considerable series. Diesing's peculiar views respecting the affinities of certain of the Ciliata and Protozoa generally have been referred to at length at page 25 of Chapter I.

Professor Stein's system, which may be cited as representing the most advanced views of Continental biologists with reference to the classification and taxonomy of this highly interesting organic group, demands more extensive notice. In its concrete form, as reproduced at pages 209 and 210, such a tabulated list has not yet appeared, it being composed of the scheme relating to the Ciliata only, embodied by Stein in the second volume of his 'Organismus der Infusionsthiere,' published in the year 1867, to which is prefixed the list of families with included genera contained in the preface to his recently issued volume, illustrative of the Flagellata, published at the close of the year 1878. As previously remarked, no diagnoses or descriptive accounts of the numerous families, genera, or species so abundantly and admirably figured in this volume have as yet appeared, nor is any attempt made to subdivide the series as a whole into subordinate sections or orders. Critical remarks can consequently under present circumstances be passed only upon his proposed family grouping of the respective genera. In this connection, exception is here taken, in the first instance, to Stein's admission among the ranks of the Flagellate Infusoria of the several family groups of the Volvocina, Chlamydomonadina, and Hydromorina, whose representatives, with one or two exceptions, must undoubtedly, as first insisted by Von Siebold, be referred to the vegetable kingdom. Their claim for admission to Stein's scheme is, while the inevitable sequence of the very shallow basis upon which he considers the proof of their animal organization to be substantiated—that only of the possession of a nucleus and contractile vesicle—by no means supported by the verdict of such modern authorities as Cohn, Sachs, and Pringsheim, by all of whom *Volvox* and its allies more especially are relegated without hesitation among the lower Algals or Palmellaceæ. The broad distinction insisted upon by these writers as subsisting between unicellular plants and animals is identical with that already submitted by the author at page 36 *et seq.*, namely—the capacity of such animal forms to incept and digest food-matter in its solid state, and the corresponding absence of such an ingestive faculty in all vegetable organisms.

With scarcely an exception, none of the generic types included in Stein's three family groups just cited possess this ingestive property, and are consequently here refused admission within the essentially zoologic section of the Infusoria.

With reference to the remaining twelve Flagellate family groups included in Stein's classificatory system, some few, such as those of the Dendromonadina, Spongomonadina, Craspemonadina, Bikœcida, and Chrysomonadina, beyond doubt contain genera that exhibit well-marked natural affinities. Others, such as his Monadina, Astasiæ, and Scytomonadina, comprise the most incongruous elements, mouthed and mouthless, uniflagellate, biflagellate, and multiflagellate animalcules being indifferently intermingled. *Phalansterium*, a uniflagellate collared monad, is interpolated amongst the otherwise natural biflagellate group of the Spongomonadina, and with which, excepting for the secretion of a similar gelatinous zoocytium, the animalcules possess nothing in common. *Poteriodendron*, again, while represented in the figures given and accompanying index as possessing a collar homologous with that of *Codosiga* and its allies, but somewhat differently situated, instead of being placed among the Craspemonadina, is included in the family group of the Bicosœcidæ. Stein's apparently inconsistent location of *Poteriodendron* is nevertheless important, since it entirely supports the views concerning this type expressed on a succeeding page, and where it is held by the author to be actually a biflagellate organism closely allied to *Bicosœca* and synonymous with the *Dinobryon petiolatum* of Dujardin and the *Stylobryon petiolatum* of De Fromentel. The separation of the two genera *Epipyxis* and *Dinobryon* from all the other generic groups of the Chrysomonadina, with which in structure they fundamentally agree, is entirely artificial.

The scheme proposed by Stein for the subdivision into groups or orders of the Ciliate section of the Infusoria, such orders being distinguished by the titles of the Holotricha, Heterotricha, Hypotricha, and Peritricha, leaves, so far as our present knowledge extends, nothing to be desired, and is cordially adopted in the present work.

The system introduced by the author, and adopted for the purposes of classification and taxonomy throughout this treatise, alone awaits notice. Its chief features of distinction, as connected with the several schemes previously enumerated, are naturally connected with the class Flagellata, upon which the author's attention has for many years past been more exclusively concentrated. The result of such investigation has been the discovery of forms differing so widely from the previously known representatives of this group, that the introduction of new distinctive titles having the value of Orders, and carrying with them as thoroughgoing a significance as the foregoing ordinal appellations of the class Ciliata, has been rendered necessary. The broad grounds upon which these new orders are established—chiefly based upon the modifications exhibited by the oral system and appendicular structures—have been already discussed in Chapters II. and III., and are also succinctly indicated in connection with the abbreviated diagnoses of the subordinated family and generic groups in the tabular forms prefixed to the succeeding descriptive accounts of each more important group. So far as practical, the family names given in the systems of the earlier authorities quoted have been retained, with the simple adaptation of their terminal syllables in conformance with the recommendations of the British Association contained in their "Rules for Zoological Nomenclature" issued in the year 1878. In face, nevertheless, of the vast augmentation of specific types collected from every available source, many of them now figured and described in this volume for the first time, a corresponding increase of the number of family and generic titles has been unavoidable. Taken in their entirety, no less than nine hundred infusorial species, distributed among about eighty family and three hundred generic groups, are embraced by the author's system, being a sum total of more than double the number included in any previous treatise.

O. F. MÜLLER, 'Animalcula Infusoria,' 1786.

INFUSORIORUM DIVISIO METHODICA.

I. ORGANIS EXTERNIS NULLIS.

* *Crassiuscula.*

Gen. 1. MONAS: punctiforme.
„ 2. PROTEUS: mutabile.
„ 3. VOLVOX: sphæricum.
„ 4. ENCHELIS: cylindricum.
„ 5. VIBRIO: elongatum.

** *Membranacea.*

Gen. 6. CYCLIDIUM: ovale.
„ 7. PARAMÆCIUM: oblongum.
„ 8. KOLPODA: sinuatum.
„ 9. GONIUM: angulatum.
„ 10. BURSARIA: cavum.

II. ORGANIS EXTERNIS.

* *Nuda.*

Gen. 1. CERCARIA: caudatum.
„ 2. TRICHODA: crinitum.
„ 3. KERONA: corniculatum.
Gen. 4. HIMANTOPUS: cirratum.
„ 5. LEUCOPHRA: ciliatum undique.
„ 6. VORTICELLA: ciliatum àpice.

** *Testâ tecta.*

Gen. 7. BRACHIONUS: ciliatum apice.

C. G. EHRENBERG, 'Infusionsthiere,' 1836.

SYNOPSIS OF THE TWENTY-TWO FAMILIES OF THE INFUSORIA.

						Family.
A. No intestine, *Anentera*.	No appendages (*Gymnica*).	Form persistent.	Fission complete.	Illoricate		I. *Monadina.*
				Loricate		II. *Cryptomonadina.*
			Fission incomplete, forming social colony-stocks.	Dividing in every direction, loricate, forming globose aggregates		III. *Volvocina.*
				Dividing in one direction, forming thread-shaped aggregates	Illoricate	IV. *Vibrionia.*
					Loricate	V. *Closterina.*
		Form changeable.	Illoricate			VI. *Astasiæa.*
			Loricate			VII. *Dinobryina.*
	Root-footed (*Pseudopoda*).	Illoricate				VIII. *Amœbæa.*
		Loricate	Protruding many pseudopodia from a single opening			IX. *Arcellina.*
			A single pseudopod projecting from one or each single aperture			X. *Bacillaria.*
	Ciliated (*Epitricha*).	Illoricate				XI. *Cyclidina.*
		Loricate				XII. *Peridinæa.*
B. With intestine, *Enterodela*.	Aperture single (*Anopisthia*).	Illoricate				XIII. *Vorticellina.*
		Loricate				XIV. *Ophrydina*
	Two apertures at opposite ends (*Enantiotreta*).	Illoricate				XV. *Enchelia.*
		Loricate				XVI. *Colepina.*
	Apertures diversely placed (*Allotreta*).	Illoricate	Mouth with a projecting proboscis, no tail			XVII. *Trachelina.*
			Mouth without a proboscis, tail developed			XVIII. *Ophryocercina.*
		Loricate				XIX. *Aspidiscina.*
	Apertures ventral (*Catotreta*).	Illoricate	Possessing simple cilia only			XX. *Colpodea.*
			Possessing locomotive organs of diverse form			XXI. *Oxytrichina.*
		Loricate				XXII. *Euplotina.*

EHRENBERGIAN GENERA INCLUDED IN THE FOREGOING SYNOPSIS.

FAMILY.		
I. MONADINA	Genus	1, *Monas*; 2, *Uvella*; 3, *Polytoma*; 4, *Microglena*; 5, *Phacelomonas*; 6, *Glenomorum*; 7, *Doxococcus*; 8, *Chilomonas*; 9, *Bodo*.
II. CRYPTOMONADINA	"	1, *Cryptomonas*; 2, *Ophidomonas*; 3, *Prorocentrum*; 4, *Lagenella*; 5, *Cryptoglena*; 6, *Trachelomonas*.
III. VOLVOCINA	"	1, *Gyges*; 2, *Pandorina*; 3, *Gonium*; 4, *Syncrypta*; 5, *Synura*; 6, *Uroglena*; 7, *Eudorina*; 8, *Chlamydomonas*; 9, *Sphærosira*; 10, *Volvox*.
IV. VIBRIONIA	"	1, *Bacterium*; 2, *Vibrio*; 3, *Spirochæta*; 4, *Spirillum*; 5, *Spirodiscus*.
V. CLOSTERINA ..	"	1, *Closterium*.
VI. ASTASIÆA	"	1, *Astasia*; 2, *Amblyophis*; 3, *Euglena*; 4, *Chlorogonium*; 5, *Colacium*; 6, *Distigma*.
VII. DINOBRYINA ..	"	1, *Epipyxis*; 2, *Dinobryon*.
VIII. AMŒBÆA	"	1, *Amœba*.
IX. ARCELLINA	"	1, *Difflugia*; 2, *Arcella*; 3, *Cyphidium*.
X. BACILLARIA	"	(DESMIDIACEÆ); (DIATOMACEÆ); *Acineta*.
XI. CYCLIDINA	"	1, *Cyclidium*; 2, *Pantotrichum*; 3, *Chætomonas*.
XII. PERIDINÆA	"	1, *Chætotyphla*; 2, *Chætoglena*; 3, *Peridinium*; 4, *Glenodinium*.
XIII. VORTICELLINA ..	"	1, *Stentor*; 2, *Trichodina*; 3, *Urocentrum*; 4, *Vorticella*; 5, *Carchesium*; 6, *Epistylis*; 7, *Opercularia*; 8, *Zoothamnium*.
XIV. OPHRYDINA ..	"	1, *Ophrydium*; 2, *Tintinnus*; 3, *Vaginicola*; 4, *Cothurnia*.
XV. ENCHELIA	"	1, *Enchelys*; 2, *Disoma*; 3, *Actinophrys*; 4, *Trichodiscus*; 5, *Podophrya*; 6, *Dendrosoma*; 7, *Trichoda*; 8, *Lacrymaria*; 9, *Leucophrys*; 10, *Holophrya*; 11, *Prorodon*.
XVI. COLEPINA	"	1, *Coleps*.
XVII. TRACHELINA ..	"	1, *Trachelius*; 2, *Loxodes*; 3, *Bursaria*; 4, *Spirostomum*; 5, *Phialina*; 6, *Glaucoma*; 7, *Chilodon*; 8, *Nassula*.
XVIII. OPHRYOCERCINA ..	"	1, *Trachelocerca*.
XIX. ASPIDISCINA ..	"	1, *Aspidiscus*.
XX. COLPODEA	"	1, *Colpoda*; 2, *Paramecium*; 3, *Amphileptus*; 4, *Uroleptus*; 5, *Ophryoglena*.
XXI. OXYTRICHINA ..	"	1, *Oxytricha*; 2, *Ceratidium*; 3, *Kerona*; 4, *Urostyla*; 5, *Stylonychia*.
XXII. EUPLOTINA	"	1, *Discocephalus*; 2, *Himantophorus*; 3, *Chlamydodon*; 4, *Euplotes*.

F. Dujardin, 'Histoire des Zoophytes Infusoires,' 1841.

Section I. ASYMMETRICA.

Order I. Infusoria without visible Locomotive Appendages.

Family 1. Vibrionina : Gen. *Bacterium*, *Vibrio*, *Spirillum* (*Spirochæta* Ehr., *Spirodiscus* Ehr.).

Order II. Infusoria provided with Variable Expansions.

„ 2. Amœbina : Gen. *Amœba.*

„ 3. Rhizopoda : Gen. *Arcella* (*Cyphidium* Ehr.), *Difflugia*, *Trinema*, *Euglypha*, *Gromia*, *Miliola*, *Cristellaria*, *Vorticilialis.*

„ 4. Actinophryina : Gen. *Actinophrys* (*Peritricha* Bory, *Podophrya* Ehr.), *Acineta*, *Dendrosoma.*

Order III. Infusoria provided with one or more Flagelliform Appendages.

Family 5. Monadina : Gen. *Monas*, *Cyclidium*, *Cercomonas*, *Amphimonas*, *Trepomonas*, *Chilomonas*, *Hexamita*, *Heteromita* (*Bodo* Ehr.), *Trichomonas*, *Uvella* (*Polytoma* Ehr.), *Anthophysa.*

„ 6. Volvocina : Gen. *Volvox*, *Pandorina* (*Eudorina* Ehr.), *Gonium* (*Pectoralina* Bory), *Uroglena* (*Syncrypta* Ehr.).

„ 7. Dinobryina : Gen. *Dinobryon*, *Epipyxis.*

„ 8. Thecamonadina : Gen. *Trachelomonas* (*Chætotyphla* Ehr., *Chætoglena* Ehr.), *Cryptomonas* (*Cryptoglena*, Ehr.), *Phacus*, *Crumenula*, *Prorocentrum*, *Diselmis* (*Chlamydomonas* Ehr.), *Anisonema*, *Plœotia*, *Oxyrrhis.*

„ 9. Euglenina : Gen. *Peranema*, *Astasia*, *Euglena* (*Raphanella* Bory, *Amblyophis* Ehr., *Chlorogonium* Ehr.), *Colacium*, *Distigma*, *Zygoselmis*, *Heteronema*, *Polyselmis.*

„ 10. Peridinina : Gen. *Peridinium* (*Glenodinium* Ehr.), *Ceratium.*

Order IV. Ciliate Infusoria.

„ 11. Enchelina : Gen. *Acomia*, *Gastrochæta*, *Enchelys*, *Alyscum*, *Uronema.*

„ 12. Trichodina : Gen. *Trichoda*, *Trachelius*, *Acineria*, *Pelecida*, *Dileptus.*

„ 13. Keronina : Gen. *Halteria*, *Oxytricha* (*Uroleptus* Ehr., *Urostyla* Ehr.), *Kerona* (*Stylonychia* Ehr.).

„ 14. Plœsconina : Gen. *Plœsconia* (*Euplotes* Ehr., *Discocephalus* Ehr., *Himantophorus* Ehr.), *Chlamydodon*, *Diophrys*, *Coccudina*, *Aspidisca*, *Loxodes.*

„ 15. Ervilina : Gen. *Ervilia*, *Trochilia.*

„ 16. Leucophryina : Gen. *Spathidium*, *Leucophrys*, *Opalina.*

„ 17. Paramecina : Gen. *Lacrymaria* (*Straulema* Bory, *Phialina* Ehr.), *Pleuronema*, *Glaucoma*, *Kolpoda*, *Paramecium*, *Amphileptus*, *Loxophyllum*, *Chilodon*, *Panophrys*, *Nassula*, *Holophrya*, *Prorodon.*

„ 18. Bursarina : Gen. *Plagiotoma*, *Ophryoglena*, *Bursaria*, *Spirostoma*, *Kondylostoma.*

„ 19. Urceolarina : Gen. *Stentor*, *Urceolaria*, *Ophrydium*, *Urocentrum.*

„ 20. Vorticellina : Gen. *Scyphidium*, *Epistylis*, *Opercularia*, *Vorticella*, *Vaginicola.*

Section II. SYMMETRICA.

Genus *Coleps.*

C. T. von Siebold, 'Lehrbuch der Vergleichenden Anatomie,' 1845.

Class INFUSORIA.

Order I. ASTOMA (no oral aperture).

Family 1. Astasiæa : Gen. *Amblyophis*, *Euglena*, *Chlorogonium*.
„ 2. Peridinæa : Gen. *Peridinium*, *Glenodinium*.
„ 3. Opalinæa : Gen. *Opalina*.

Order II. STOMATODA (with a distinct oral aperture).

„ 4. Vorticellina : Gen. *Stentor*, *Trichodina*, *Vorticella*, *Epistylis*, *Carchesium*.
„ 5. Ophrydina : Gen. *Vaginicola*, *Cothurnia*.
„ 6. Enchelia : Gen. *Actinophrys*, *Leucophrys*, *Prorodon*.
„ 7. Trachelina : Gen. *Glaucoma*, *Spirostomum*, *Trachelius*, *Loxodes*, *Chilodon*, *Phialina*, *Bursaria*, *Nassula*.
„ 8. Kolpodea : Gen. *Kolpoda*, *Paramecium*, *Amphileptus*.
„ 9. Oxytrichina : Gen. *Oxytricha*, *Stylonychia*, *Urostyla*.
„ 10. Euplota : Gen. *Euplotes*, *Himantophorus*, *Chlamydodon*.

Maximilian Perty, 'Kleinster Lebensformen,' 1852.

Sub-Kingdom ARCHEZOA.

Class INFUSORIA.

Section I. PHYTOZOIDIA (Filigera).

Family 1. Dinobryina : *Dinobryon*.
„ 2. Volvocina : *Syncrypta*, *Volvox*, *Sphærosira*, *Pandorina*, *Synaphia*, *Gonium*, *Hirmidium*.
„ 3. Monadina : *Heteromitus*, *Amphimonas*, *Tetramitus*, *Trichomonas*, *Mallomonas*, *Pleuromonas*, *Trepomonas*, *Spiromonas*, *Cercomonas*, *Monas*, *Menoidium*, *Chromatium*, *Acariæum*, *Polytoma*, *Uvella*, *Anthophysa*.
„ 4. Astasiæ : *Euglena*, *Astasia*, *Peranema*, *Colacium*, *Eutreptia*, *Chlorogonium*, *Zygoselmis*, *Dinema*.
„ 5. Thecomonadina : *Chætotyphla*, *Trypemonas*, *Chonemonas*.
„ 6. Cryptomonadina : *Cryptomonas*, *Phacotus*, *Anisonema*, *Phacus*, *Lepocinctis*.
„ 7. Peridinida : *Ceratium*, *Glenodinium*, *Peridinium*.

SECTION II. CILIATA (non-vibratile, slightly contractile cilia).

Family 8. ACTINOPHRYINA: *Actinophrys*, *Podophrya*, *Acineta*.

A. *METABOLICA* (*highly contractile and changeable in form*).

,, 9. OPHRYOCERCINA: *Trachelocerca*, *Lacrymaria*.

B. *MONIMA* (*contractile, but without jerking action or alteration of contour*).

,, 10. COLEPINA: *Coleps*.

,, 11. EUPLOTINA: *Euplotes*, *Himantophorus*, *Coccudina*, *Aspidisca*.

,, 12. COBALINA: *Alastor*, *Plagiotoma*, *Leucophrys*, *Opalina*.

,, 13. OXYTRICHINA: *Stichotricha*, *Mitophora*, *Oxytricha*, *Urostyla*, *Cerona*.

,, 14. TRACHELINA: *Trachelius*, *Harmodirus*, *Amphileptus*, *Loxophyllum*, *Dileptus*, *Pelecida*, *Loxodes*.

,, 15. TAPINIA: *Acropisthium*, *Acomia*, *Trichoda*, *Cyclidium*, *Bœonidium*, *Opisthiotricha*, *Siagontherium*, *Megatricha*.

,, 16. APIONIDINA: *Ptyxidium*, *Colobidium*, *Apionidium*.

,, 17. CINETOCHILINA: *Glaucoma*, *Cinetochilum*.

,, 18. DECTERIA: *Cyclogramma*, *Chilodon*, *Nassula*, *Prorodon*, *Habrodon*.

,, 19. APHTHONIA: *Pleuronema*.

,, 20. HOLOPHRYINA: *Holophrya*, *Enchelys*, *Spathidium*.

,, 21. PARAMECIINA: *Ophryoglena*, *Panophrys*, *Paramecium*, *Blepharisma*, *Colpoda*.

,, 22. BURSARINA: *Bursaria*.

C. *SPASTICA* (*contractile, form changeable, with a jerking action*).

,, 23. URCEOLARINA: *Stentor*, *Spirostomum*, *Cœnomorpha*, *Urocentrum*.

,, 24. OPHRYDINA: *Ophrydium*.

,, 25. VORTICELLINA: *Vorticella*, *Scyphidia*, *Epistylis*.

,, 26. VAGINIFERA: *Vaginicola*, *Cothurnia*.

CLAPARÈDE AND LACHMANN, 'Études sur les Infusoires,' 1858–1860.

ORDER I. FLAGELLATA. (Not tabulated.)

ORDER II. CILIO-FLAGELLATA.

Family 1. PERIDININA: *Ceratium*, *Peridinium*, *Dinophysis*, *Amphidinium*, *Prorocentrum*.

ORDER III. SUCTORIA.

„ 2. ACINETINA: *Podophrya*, *Sphærophrya*, *Trichophrya*, *Acineta*, *Solenophrya*, *Dendrosoma*, *Dendrocometes*, *Ophryodendron*.

ORDER IV. CILIATA.

„ 3. HALTERINA: *Strombidium*, *Halteria*.

„ 4. COLEPINA: *Coleps*.

„ 5. TRACHELINA: *Loxophyllum*, *Amphileptus*, *Trachelius*, *Loxodes*, *Trichopus*, *Chilodon*, *Nassula*, *Prorodon*, *Enchelyodon*, *Urotricha*, *Holophrya*, *Enchelys*, *Trachelophyllum*, *Phialina*, *Lacrymaria*.

„ 6. DYSTERINA: *Huxleya*, *Œgyria*, *Dysteria*, *Iduna*.

„ 7. COLPODINA: *Glaucoma*, *Pleuronema*, *Cyclidium*, *Colpoda*, *Paramecium*.

„ 8. BURSARINA: *Ophryoglena*, *Bursaria*, *Frontonia*, *Metopus*, *Lembadium*, *Balantidium*, *Kondylostoma*, *Plagiotoma*, *Spirostomum*, *Leucophrys*, *Stentor*, *Freia*, *Chætospira*.

„ 9. TINTINNODEA: *Tintinnus*.

„ 10. OXYTRICHINA: *Aspidisca*, *Campylopus*, *Schizopus*, *Euplotes*, *Stylonychia*, *Stichochæta*, *Oxytricha*.

„ 11. UROCENTRUM: *Urocentrum*.

„ 12. VORTICELLINA: *Trichodina*, *Lagenophrys*, *Vaginicola*, *Cothurnia*, *Ophrydium*, *Gerda*, *Scyphidia*, *Epistylis*, *Zoothamnium*, *Carchesium*, *Vorticella*, (*Spirochona*).

R. M. DIESING, 'Revision der Prothelminthen.' Abtheilung Mastigophoren, 1865.

Sub-Order MASTIGOPHORA.

TRIBUS I. MASTIGOPHORA ATRICHOSOMATA (*Corpus nudum*).

Fam. I. MONADINEA.

Sub-Fam. I. **Monadinea haud loricata.**

* *ACERCOMONADINEA* (*Corpus ecaudatum*).

† *Os terminale* (*Acrostomata*).

MONOMASTIGA (*Flagellum unum*).

Animalcula monima. Gen. *Monas*, *Uvella*, *Anthophysa*, *Microglena*, *Glenouvella*.	Animalcula metabolica. Gen. *Peranema*, *Amblyophis*, *Colacium*.

DIMASTIGA (*Flagella duo*).
Gen. *Isomita*, *Dimastix*, *Glenomorum*, *Trepanomonas*.

TETRAMASTIGA (*Flagella quatuor*).

Animalcula monima. *Pyramimonas*.	Animalcula metabolica. *Polyselmis*.

POLYMASTIGA (*Flagella* 6, 10, *aut numeroso*).
Gen. *Chloraster*, *Spondylomorum*, *Phacelomonas*, *Lophomonas*.

†† *Os in pagina ventrali* (*Hypostomata*).

MONOMASTIGA.

Animalcula monima. Gen. *Plagiomastix*.	Animalcula metabolica. Gen. *Pyronema*.

DIMASTIGA.

Animalcula monima. Gen. *Heteromita*, *Chilomonas*, *Polytoma*, *Glenopolytoma*.	Animalcula metabolica. Gen. *Zygoselmis*, *Heteronema*.

Genera insufficienter cognita, *Gorgostomum*, *Doxococcus*, *Menoidium*.

** *CERCOMONADINEA* (*Corpus caudatum*).

† *Os terminale* (*Acrostomata*).

MONOMASTIGA.

Animalcula monima. Gen. *Bodo*, *Thaumas*, *Dicercomonas*.	Animalcula metabolica. Gen. *Astasia*, *Euglena*.

DIMASTIGA.

Animalcula monima.	Animalcula metabolica.
Gen. *Amphimonas.*	Gen. *Chlorogonium.*

†† *Os in pagina ventrali* (*Hypostomata*).

Gen. *Trichomonas.*

Sub-Fam. II. **Monadinea loricata.**

† *Os terminale* (*Acrostomata*).

α. *CORPUS LORICO INSTRUCTUM.*

MONOMASTIGA.

Animalcula monima.	Animalcula metabolica.
Gen *Cryptomonas*, *Petalomonas*, *Ophidomonas*, *Crumenula.*	Gen. *Lepocinctis.*

DIMASTIGA.

Gen. *Diseeræa*, *Diplotricha*, *Anisonema*, *Cryptoglena.*

TETRAMASTIGA.

Gen. *Phacotus*, *Carteria.*

β. *CORPUS URCEOLO CIRCUMDATUM.*

MONOMASTIGA.

Animalcula monima.	Animalcula metabolica.
Gen. *Lagenella*, *Trachelomonas*, *Chætotyphla*, *Chætoglena.*	Gen. *Dinobryon.*

Genus insufficienter cognitum, *Epipyxis.*

DIMASTIGA.

Gen. *Chonemonas.*

†† *Os inferum* (*Hypostomata*).

Gen. *Oxyrrhis.*

Fam. II. VOLVOCINEA.

* *VOLVOCINEA ECAUDATA.*

MONOMASTIGA.

Corpus urceolo inclusum vel lacerna involutum.

Gen. *Pandorina*, *Eudorina*, *Syncrypta.*

DIMASTIGA.

Synœcesium subglobosum.

Gen. *Stephanosphæra*, *Glœococcus*, *Chlamydomonas*, *Chlamydococcus*, *Volvox.*

Synœcesium tabulare.

Gen. *Gonium*, *Glenogonium.*

Genus insufficienter cognitum, *Trochogonium.*

Synœcesium lineare.

Gen. *Hirmidium.*

** *VOLVOCINEA CAUDATA.*

Gen. *Uroglena.*

Genus insufficienter cognitum, *Synura.*

TRIBUS II. MASTIGOPHORA TRICHOSOMATA (*Corpus ciliatum*).

Fam. III. MALLOMONADINEA.

Sub-Fam. I. **Mallomonadinea haud loricata.**

Gen. *Mallomonas.*

Sub-Fam. II. **Mallomonadinea loricata.**

Gen. *Prorocentrum.*

Fam. IV. PERIDINEA.

† *Os terminale* (*Acrostomata*).

MONOMASTIGA.

Gen. *Heteroaulax*, *Gonyaulax*, *Glenoaulax.*

†† *Os in pagina ventrali* (*Hypostomata*).

MONOMASTIGA.

* *Lorica sulco transversali antrorsum vel retrorsum collocato.*

Gen. *Proaulax*, *Amphidinium*, *Dinophysis.*

** *Lorica sulco transversali in medio fere corporis collocato.*

Gen. *Peridinium*, *Glenodinium.*

DIMASTIGA.

Gen. *Dimastigoaulax.*

F. Stein, 'Organismus der Infusionsthiere,' Abtheilung III. (Flagellata), Heft 1, 1878.

Class I. FLAGELLATA.

Family 1. Monadina : *Cercomonas*, *Monas*, *Goniomonas*, *Bodo*, *Phyllomitus*, *Tetramitus*, *Trepomonas*, *Trichomonas*, *Hexamita*, *Lophomonas*, *Platytheca*.

„ 2. Dendromonadina : *Dendromonas*, *Cephalothamnium*, *Anthophysa*.

„ 3. Spongomonadina : *Cladomonas*, *Rhipidodendron*, *Spongomonas*, *Phalansterium*.

„ 4. Craspemonadina : *Codonosiga*, *Codonocladium*, *Codonodesmus*, *Salpingœca*.

„ 5. Bikœcida : *Bikœca*, *Poteriodendron*.

„ 6. Dinobryina : *Epipyxis*, *Dinobryon*.

„ 7. Chrysomonadina : *Cœlomonas*, *Raphidomonas*, *Microglena*, *Chrysomonas*, *Uroglena*, *Syncrypta*, *Synura*, *Hymenomonas*, *Stylochrysalis*, *Chrysopyxis*.

„ 8. Chlamydomonadina : *Polytoma*, *Chlamydomonas*, *Chlamydococcus*, *Phacotus*, *Coccomonas*, *Tetraselmis*, *Gonium*.

„ 9. Volvocina : *Eudorina*, *Pandorina*, *Stephanosphæra*, *Volvox*.

„ 10. Hydromorina : *Chlorogonium*, *Chlorangium*, *Pyramidomonas*, *Chloraster*, *Spondylomorum*.

„ 11. Cryptomonadina : *Chilomonas*, *Cryptomonas*, *Nephroselmis*.

„ 12. Chloropeltidea : *Cryptoglena*, *Chloropeltis*, *Phacus*.

„ 13. Euglenida : *Euglena*, *Colacium*, *Ascoglena*, *Trachelomonas*.

„ 14. Astasiæa : *Eutreptia*, *Astasia*, *Heteronema*, *Zygoselmis*, *Peranema*.

„ 15. Scytomonadina : *Scytomonas*, *Petalomonas*, *Menoidium*, *Atractonema*, *Phialonema*, *Sphenomonas*, *Tropidocyphus*, *Anisonema*, *Colponema*, *Entosiphon*.

F. STEIN, 'Organismus der Infusionsthiere,' Heft 2, 1867.

Class II. CILIATA.

ORDER I. HOLOTRICHA.

Family 1. OPALININA: *Opalina*, *Hoplophrya*, *Anoplophrya*, *Haplophrya* (*Discophrya*).

„ 2. TRACHELINA: *Amphileptus*, *Loxophyllum*, *Loxodes*, *Trachelius*, *Dileptus*.

„ 3. ENCHELINA: *Trachelophyllum*, *Tracheloccerca*, *Phialina*, *Lacrymaria*, *Enchelyodon*, *Enchelys*, *Coleps*, *Plagiopogon*, *Perispira*, *Urotricha*, *Actinobolus*, *Holophrya*, *Prorodon*.

„ 4. PARAMÆCINA: Sub-Fam. *a*, Paramæcina: *Cyrtostomum*, *Nassula* (*Liosiphon*, *Cyclogramma*, *Acidophorus*), *Paramæcium*, *Colpoda*, *Ptychostomum*, *Conchophthirus*, *Isotricha*. Sub-Fam. *b*, Leucophryina: *Colpidium*, *Leucophrys*, *Panophrys*.

„ 5. CINETROCHILINA: *Ophryoglena*, *Glaucoma*, *Cinetrochilum*, *Pleurochilidium*, *Trichoda*, *Cyclidium*, *Plagiopyla*, *Pleuronema*, *Lembadion*.

ORDER II. HETEROTRICHA.

„ 1. BURSARINA: *Plagiotoma*, *Metopus*, *Nyctotherus*, *Balantidium*, *Bursaria*.

„ 2. STENTORINA: *Freia*, *Stentor*.

„ 3. SPIROSTOMEA: *Climacostomum*, *Spirostomum*, *Blepharisma*, *Condylostoma*.

ORDER III. HYPOTRICHA.

„ 1. PERITROMINA: *Peritromus*.

„ 2. CHLAMYDODONTA: *Chilodon*, *Opisthodon*, *Trichopus*, *Phascolodon*, *Chlamydodon*, *Scaphidiodon*.

„ 3. ERVILIINA (Duj.): *Huxleya*, *Trochilia*, *Ervilia* (*Dysteria*, *Iduna*).

„ 4. ASPIDISCINA (Ehr.): *Aspidisca*.

„ 5. EUPLOTINA (Ehr.): *Uronychia*, *Styloplotes*, *Euplotes*.

„ 6. OXYTRICHINA: *Urostyla*, *Epiclintes*, *Kerona*, *Stichotricha*, *Uroleptus*, *Gastrostyla*, *Pleurotricha*, *Onychodromus*, *Stylonychia*, *Oxytricha*, *Psilotricha*.

ORDER IV. PERITRICHA.

„ 1. HALTERINA (C. & L.): *Strombidium*, *Halteria*.

„ 2. TINTINNODEA (C. & L.): *Tintinnopsis*, *Tintinnus*.

„ 3. CYCLODINEA: *Mesodinium*, *Didinium*, *Urocentrum*.

„ 4. GYROCORIDA: *Gyrocorys*.

„ 5. URCEOLARINA: *Trichodinopsis*, *Trichodina*, *Urceolaria*.

„ 6. VORTICELLINA (Ehr.): *Astylozoon*, *Gerda*, *Scyphidia*, *Vorticella*, *Carchesium*, *Zoothamnium*, *Epistylis*, *Opercularia*.

„ 7. OPHRYDINA (Ehr.): *Ophrydium*, *Vaginicola*, *Cothurnia*, *Lagenophrys*.

„ 8. SPIROCHONINA: *Spirochona*.

„ 9. OPHRYOSCOLECINA: *Entodinium*, *Ophryoscolex*.

Classificatory System adopted in this Volume.

Sub-Kingdom PROTOZOA.

Legion INFUSORIA.

Class I. FLAGELLATA vel MASTIGOPHORA.

Order I. TRYPANOSOMATA.

Genus 1, *Trypanosoma*.

Order II. RHIZO-FLAGELLATA.

Genus 1, *Mastigamœba;* 2, *Reptomonas;* 3, *Rhizomonas;* 4, *Podostoma.*

Order III. RADIO-FLAGELLATA.

FAMILY.

I. ACTINOMONADIDÆ: Genus 1, *Actinomonas.*

II. EUCHITONIDÆ: Genus 1, *Euchitonia;* 2, *Spongocyclia;* 3, *Spongasteriscus.*

Order IV. FLAGELLATA-PANTOSTOMATA.

I. MONADIDÆ: Genus 1, *Monas;* 2, *Scytomonas;* 3, *Cyathomonas;* 4, *Leptomonas;* 5, *Ophidomonas;* 6, *Herpetomonas;* 7, *Ancyromonas.*

II. PLEUROMONADIDÆ: Genus 1, *Pleuromonas;* 2, *Merotricha.*

III. CERCOMONADIDÆ: Genus 1, *Oikomonas;* 2, *Bodo;* 3, *Cercomonas.*

IV. CODONŒCIDÆ: Genus 1, *Codonœca;* 2, *Platytheca.*

V. DENDROMONADIDÆ: Genus 1, *Physomonas;* 2, *Cladonema;* 3, *Dendromonas;* 4, *Anthophysa;* 5, *Cephalothamnium.*

VI. BIKŒCIDÆ: Genus 1, *Hedrœophysa;* 2, *Bicosœca;* 3, *Stylobryon.*

VII. AMPHIMONADIDÆ: Genus 1, *Goniomonas;* 2, *Amphimonas;* 3, *Deltomonas.*

VIII. SPONGOMONADIDÆ: Genus 1, *Cladomonas;* 2, *Rhipidodendron;* 3, *Spongomonas;* 4, *Diplomita.*

FAMILY.

IX. HETEROMITIDÆ: Genus 1, *Heteromita*; 2, *Colponema*; 3, *Spiromonas*; 4, *Phyllomitus*.

X. TREPOMONADIDÆ: Genus 1, *Trepomonas*.

XI. POLYTOMIDÆ: Genus 1, *Polytoma*.

XII. PSEUDOSPORIDÆ: Genus 1, *Pseudospora*.

XIII. SPUMELLIDÆ: Genus 1, *Spumella*.

XIV. TRIMASTIGIDÆ: Genus 1, *Callodictyon*; 2, *Trichomonas*; 3, *Dallingeria*; 4, *Trimastix*.

XV. TETRAMITIDÆ: Genus 1, *Tetramitus*; 2, *Tetraselmis*; 3, *Chloraster*.

XVI. HEXAMITIDÆ: Genus 1, *Hexamita*.

XVII. LOPHOMONADIDÆ: Genus 1, *Lophomonas*.

XVIII. CATALLACTIDÆ: Genus 1, *Magosphæra*.

Order V. CHOANO-FLAGELLATA vel FLAGELLATA-DISCOSTOMATA.

Section I. DISCOSTOMATA-GYMNOZOIDA.

I. CODONOSIGIDÆ: Genus 1, *Monosiga*; 2, *Codosiga*; 3, *Astrosiga*; 4, *Desmarella*.

II. SALPINGŒCIDÆ: Genus 1, *Salpingœca*; 2, *Lagenœca*; 3, *Polyœca*.

III. PHALANSTERIIDÆ: Genus 1, *Phalansterium*; 2, *Protospongia*.

Section II. DISCOSTOMATA-SARCOCRYPTA (*Spongida*).

Order VI. FLAGELLATA-EUSTOMATA.

I. PARAMONADIDÆ: Genus 1, *Paramonas*; 2, *Petalomonas*; 3, *Atractonema*; 4, *Phialonema*; 5, *Menoidium*.

II. ASTASIADÆ: Genus 1, *Astasia*; 2, *Colpodella*.

III. EUGLENIDÆ: Genus 1, *Euglena*; 2, *Amblyophis*; 3, *Phacus*; 4, *Chloropeltis*; 5, *Trachelomonas*; 6, *Raphidomonas*; 7, *Cœlomonas*; 8, *Ascoglena*; 9, *Colacium*.

IV. NOCTILUCIDÆ: Genus 1, *Noctiluca*; 2, *Leptodiscus*.

V. CHRYSOMONADIDÆ: Genus 1, *Chloromonas*; 2, *Chrysomonas*; 3, *Microglena*; 4, *Cryptomonas*; 5, *Nephroselmis*; 6, *Stylochrysalis*; 7, *Uvella*; 8, *Chlorangium*; 9, *Hymenomonas*; 10, *Chrysopyxis*; 11, *Epipyxis*; 12, *Dinobryon*; 13, *Synura*; 14, *Syncrypta*; 15, *Uroglena*.

FAMILY.

VI. ZYGOSELMIDÆ: Genus 1, *Eutreptia*; 2, *Zygoselmis*; 3, *Distigma*; 4, *Cryptoglena*; 5, *Sterromonas*; 6, *Dinomonas*.

VII. CHILOMONADIDÆ: Genus 1, *Chilomonas*; 2, *Oxyrrhis*.

VIII. ANISONEMIDÆ: Genus 1, *Heteronema*; 2, *Diplomastix*; 3, *Anisonema*; 4, *Entosiphon*.

IX. SPHENOMONADIDÆ: Genus 1, *Sphenomonas*.

Order VII. CILIO-FLAGELLATA.

I. PERIDINIIDÆ: Genus 1, *Hemidinium*; 2, *Gymnodinium*; 3, *Melodinium*; 4, *Glenodinium*; 5, *Peridinium*; 6, *Ceratium*; 7, *Dinophysis*; 8, *Amphidinium*; 9, *Prorocentrum*; 10, *Dimastigoaulax*.

II. HETEROMASTIGIDÆ: Genus 1, *Heteromastix*.

III. MALLOMONADIDÆ: Genus 1, *Mallomonas*.

IV. STEPHANOMONADIDÆ; Genus 1, *Stephanomonas*; 2, *Asthmatos*.

V. TRICHONEMIDÆ: Genus 1, *Trichonema*; 2, *Mitophora*.

Class II. CILIATA vel TRICHOPHORA.

Order I. HOLOTRICHA.

I. PARAMŒCIIDÆ: Genus 1, *Paramœcium*; 2, *Loxocephalus*; 3, *Placus*; 4, *Conchophthirus*.

II. PRORODONTIDÆ: Genus 1, *Prorodon*; 2, *Nassula*; 3, *Cyrtostomum*; 4, *Isotricha*; 5, *Holophrya*; 6, *Otostoma*; 7, *Helicostoma*.

III. TRACHELOPHYLLIDÆ: Genus 1, *Trachelophyllum*; 2, *Enchelyodon*; 3, *Urotricha*.

IV. COLEPIDÆ: Genus 1, *Coleps*; 2, *Plagiopogon*; 3, *Polykrikos*.

V. ENCHELYIDÆ: Genus 1, *Enchelys*; 2, *Metacystis*; 3, *Perispira*; 4, *Anophrys*; 5, *Colpoda*; 6, *Tillina*.

VI. TRACHELOCERCIDÆ: Genus 1, *Trachelocerca*; 2, *Lachrymaria*; 3, *Phialina*; 4, *Maryna*; 5, *Lagynis*; 6, *Chœnia*.

VII. TRACHELIIDÆ: Genus 1, *Trachelius*; 2, *Amphileptus*; 3, *Loxophyllum*.

VIII. ICHTHYOPHTHIRIIDÆ: Genus 1, *Ichthyophthirius*.

FAMILY.

IX. OPHRYOGLENIDÆ: Genus 1, *Ophryoglena*; 2, *Panophrys*; 3, *Cyclotricha*; 4, *Trichoda*; 5, *Lembadion*; 6, *Leucophrys*; 7, *Colpidium*; 8, *Plagiopyla*; 9, *Meniscostomum*; 10, *Chasmatostomum*; 11, *Pleurochilidium*.

X. PLEURONEMIDÆ: Genus 1, *Pleuronema*; 2, *Cyclidium*; 3, *Uronema*; 4, *Bœonidium*.

XI. LEMBIDÆ: Genus 1, *Lembus*; 2, *Proboscella*.

XII. TRICHONYMPHIDÆ: Genus 1, *Trichonympha*; 2, *Pyrsonema*; 3, *Dinonympha*.

APPENDIX.

XIII. OPALINIDÆ: Genus 1, *Opalina*; 2, *Anoplophrya*; 3, *Discophrya*; 4, *Hoplitophrya*.

Order II. HETEROTRICHA.

I. BURSARIIDÆ: Genus 1, *Bursaria*; 2, *Bursarella*; 3, *Balantidium*; 4, *Nyctotherus*; 5, *Metopus*; 6, *Metopides*; 7, *Plagiotoma*.

II. SPIROSTOMIDÆ: Genus 1, *Condylostoma*; 2, *Blepharisma*; 3, *Spirostomum*; 4, *Climacostomum*.

III. STENTORIDÆ: Genus 1, *Stentor*; 2, *Follicularia*; 3, *Chætospira*.

IV. TINTINNODÆ: Genus 1, *Tintinnus*; 2, *Tintinnidium*; 3, *Vasicola*; 4, *Strombidinopsis*.

V. TRICHODINOPSIDÆ: Genus 1, *Trichodinopsis*.

VI. CODONELLIDÆ: Genus 1, *Codonella*; 2, *Tintinnopsis*.

VII. CALCEOLIDÆ: Genus 1, *Calceolus*.

Order III. PERITRICHA.

I. TORQUATELLIDÆ: Genus 1, *Torquatella*.

II. DICTYOCYSTIDÆ: Genus 1, *Dictyocysta*.

III. ACTINOBOLIDÆ: Genus 1, *Actinobolus*.

IV. HALTERIIDÆ: Genus 1, *Halteria*; 2, *Strombidium*; 3, *Mesodinium*; 4, *Acarella*; 5, *Arachnopsis*; 6, *Didinium*.

V. GYROCORIDÆ: Genus 1, *Gyrocoris*; 2, *Urocentrum*.

VI. URCEOLARIIDÆ: Genus 1, *Trichodina*; 2, *Urceolaria*; 3, *Cyclochæta*; 4, *Licnophora*.

VII. OPHRYOSCOLECIDÆ: Genus 1, *Ophryoscolex*; 2, *Entodinium*; 3, *Astylozoon*.

FAMILY.

VIII. VORTICELLIDÆ: Sub-Fam. I., VORTICELLINA: Genus 1, *Gerda*, 2, *Scyphidia*; 3, *Spirochona*; 4, *Stylochona*; 5, *Rhabdostyla*; 6, *Pyxidium*; 7, *Vorticella*; 8, *Carchesium*; 9, *Zoothamnium*; 10, *Epistylis*; 11, *Opercularia*. Sub-Fam. II., VAGINICOLINA: Genus 1, *Vaginicola*; 2, *Thuricola*; 3, *Cothurnia*; 4, *Pyxicola*; 5, *Stylocola*; 6, *Platycola*; 7, *Lagenophrys*. Sub-Fam. III., OPHRYDINA: Genus 1, *Ophionella*; 2, *Ophrydium*.

Order IV. HYPOTRICHA.

I. LITONOTIDÆ: Genus 1, *Litonotus*.

II. CHLAMYDODONTIDÆ: Genus 1, *Phascolodon*; 2, *Chilodon*; 3, *Loxodes*; 4, *Opisthodon*; 5, *Chlamydodon*; 6, *Scaphiodon*.

III. DYSTERIADÆ: Genus 1, *Iduna*; 2, *Dysteria*; 3, *Cypridium*; 4, *Ægyria*; 5, *Trochilia*; 6, *Huxleya*; 7, *Trichopus*.

IV. PERITROMIDÆ: Genus 1, *Peritromus*.

V. OXYTRICHIDÆ: Genus 1, *Psilotricha*; 2, *Kerona*; 3, *Trichogaster*; 4, *Urostyla*; 5, *Onychodromus*; 6, *Amphisia*; 7, *Holosticha*; 8, *Plagiotricha*; 9, *Epiclintes*; 10, *Stichochæta*; 11, *Stichotricha*; 12, *Strongylidium*; 13, *Uroleptus*; 14, *Stylonethes*; 15, *Allotricha*; 16, *Pleurotricha*; 17, *Gastrostyla*; 18, *Opisthotricha*; 19, *Oxytricha*; 20, *Histrio*; 21, *Actinotricha*; 22, *Stylonychia*.

VI. EUPLOTIDÆ: Genus 1, *Aspidisca* (*Glaucoma*; *Microthorax*); 2, *Uronychia*; 3, *Euplotes*; 4, *Styloplotes*.

Class III. TENTACULIFERA.

Order I. TENTACULIFERA-SUCTORIA.

I. RHYNCHETIDÆ: Genus 1, *Rhyncheta*; 2, *Urnula*.

II. ACINETIDÆ: Genus 1, *Trichophrya*; 2, *Podophrya*; 3, *Hemiophrya*; 4, *Solenophrya*; 5, *Acineta*.

III. DENDROCOMETIDÆ: Genus 1, *Dendrocometes*.

IV. DENDROSOMIDÆ: Genus 1, *Dendrosoma*.

Order II. TENTACULIFERA-ACTINARIA.

I. EPHELOTIDÆ: Genus 1, *Ephelota*; 2, *Actinocyathus*.

II. OPHRYODENDRIDÆ: Genus 1, *Ophryodendron*; 2, *Acetinopsis*.

CHAPTER VII.

SYSTEMATIC DESCRIPTION OF THE INFUSORIA FLAGELLATA.

Class I. FLAGELLATA.

ANIMALCULES bearing one, two, or more long, lash-like flagella, which mostly represent the sole organs of progression, but are occasionally supplemented by cilia, pseudopodia, or other locomotive or prehensile appendages. Oral or ingestive system varying in character; definite, diffuse, or indistinct. One or more contractile vesicles almost invariably represented. Multiplying rapidly by binary fission and by the subdivision of their entire body-mass into sporular elements. The sporular reproductive process often preceded by the complete fusion or conjugation of two or more adult zooids.

The title of the Flagellata, as distinctive of a large and important series of infusorial types, was employed almost simultaneously by Johannes Müller and F. Cohn about the year 1853; it is practically synonymous with that of the Filigera introduced one year previously by M. Perty, and with the Mastigophora of R. M. Diesing.

Although thus receiving their characteristic name at a comparatively recent date, the members of this class were known to the majority of the earlier writers, being abundantly figured and described in the works of O. F. Müller, and C. G. Ehrenberg, while a first intelligible record of their existence is undoubtedly contained in Mr. John Harris's account of little fish-like animals (*Euglena viridis*) communicated to the 'Philosophical Transactions' for the year 1696, reproduced at pages 9 and 10. By these earlier authorities, however, the flagelliform organs were almost altogether overlooked, and it was not until the employment of more perfected instruments having a comparatively high magnifying power, at the hands of Felix Dujardin and Maximilian Perty, that these appendages were extensively recognized as representing the essential organs of locomotion, or their number, character, and mode of insertion made use of for the purpose of generic diagnosis. Much even then remained to be discovered with relation to their more minute organization. While Ehrenberg had declared that all these flagellate organisms possessed a distinct mouth, and in most instances numerous gastric cavities, Dujardin made the entire absence of an oral aperture a leading distinction of the Order III. or Flagelliferous section of his 'Zoophytes Infusoires.' So much uncertainty has prevailed, again, respecting the claims of the Flagellata for recognition as animal organisms—their external shape and mode of locomotion corresponding so closely with those of many undoubted unicellular plants or Protophytes, and with the spermatic elements, "antherozooids" or "zoospores," of the higher Cryptogamia—that almost down to the present time biologists have refused to admit them among the ranks of the typical Infusoria. The more perfect insight into the structure and life-history of the representatives of this class, obtained by the assistance of the higher magnifying glasses of recent construction, has, however, practically revealed in them the existence of an entirely new world of microscopic organisms, possessing the most evident animal attributes, and exhibiting with relation to each other an even more extensive range of structural variation than is met with among the hitherto more familiar Ciliate section of the Infusorial series.

The foremost place amongst those who by their original investigations have contributed most substantially towards our more correct knowledge of this previously comparatively neglected group, must undoubtedly be awarded to Professor Stein in connection with the recently published third volume, Part I., of his magnificent folio series devoted to the description and illustration of infusorial organization. As he himself justly remarks, this volume represents the most important of the three now issued, it dealing exclusively and on the most liberal and comprehensive scale with the class now under consideration. So far, however, Stein's volume is complete with reference only to the illustrations contained in the twenty-four magnificently executed plates, the one hundred and fifty-four pages of text that precede them being devoted chiefly to an exhaustive review of the work achieved by earlier investigators, with relation to both flagellate animal and vegetable organisms, and to a discussion of the claims of the innumerable forms he figures for comprehension among the animal series. A full description of the types there illustrated is reserved for a much looked forward to, but as yet unpublished, second part.* All the species delineated by Stein in the treatise quoted are represented as seen under the high magnification of from 600 to 1200 diameters and upwards, and which is indeed absolutely requisite for gaining a correct estimate of the often highly complex organization of these exceptionally minute beings. As now shown by Stein, numbers of these Flagellata possess not only a well-developed oral aperture, but frequently in addition an extensive pharyngeal dilatation, and in some cases even a buccal or pharyngeal armature comparable to that found in various higher Ciliata. Among the more important features of Stein's work may be also mentioned his comprehension of numerous types belonging to the collared series, first discovered by Professor H. James-Clark—here included in the order Choano-Flagellata, and his acquiescence, through such discovery, with the views maintained by Professor Clark, and supported by the author, respecting the affinities of the sponges. The limits assigned to the Flagellata by Professor Stein differ essentially from those recognized in this treatise. As already notified at page 197, the fundamental basis upon which he establishes this class relates merely to the presence of a nucleus and contractile vesicle, without any reference to food-ingesting properties, the result of such lax definition being the admission of such types as *Volvox*, *Gonium*, *Protococcus* (*Chlamydococcus*), and numerous other forms of whose essential vegetable affinities there is scarcely room for doubt. It is indeed contested by the author (see page 47) whether the types just enumerated possess contractile vesicles; the inability to detect such structures in numberless examples investigated with the greatest care, being accepted as a conclusive proof of their vegetable nature.

A conspicuous feature of the reproductive phenomena of the Flagellata is manifested by the tendency of almost all the forms to multiply, in addition to the ordinary process of binary fission, by encystment and the subsequent breaking up of their entire body-mass into sporular elements, such mode of reproduction being precisely parallel with what obtains among the unicellular plants or Protophytes. Sometimes the spores so produced are few in number and of conspicuous size, meriting the title, as here applied to them, of "macrospores"; while in other instances they are altogether innumerable, and of such minute calibre as to defy individual definition, even with the assistance of the highest magnifying powers of the compound microscope; the sporular bodies under such conditions being appropriately designated "microspores." It is further worthy of notice that the production of microspores is more usually preceded by the genetic union or coalescence of two, or it may be many, independent zooids, while that of macro-

* As a consequence of the present unfinished condition of Stein's monograph, the diagnoses of the innumerable new generic and specific types it embodies, given in this manual, have been framed by the author on the broad characters only indicated in Stein's drawings. The many deficiencies in these diagnoses which must necessarily exist can be supplied only at the hands of the original discoverer of the forms figured.

spores commonly follows upon the simple encystment of a single animalcule. The recognition of these important reproductive phenomena is chiefly due to the recent painstaking investigations of Messrs. Dallinger and Drysdale, whose researches in this direction are fully recorded in the descriptive accounts given of *Monas Dallingerii*, *Cercomonas typica*, *Tetramitus rostrata*, *Dallingeria Drysdali*, and several species of *Heteromita*.

With reference to the variously modified characters of the oral system, and of the locomotive and supplementary appendages, the class of the Flagellata may be conveniently subdivided into primary sections or Orders as below :—

A. Ingestive area diffuse.	Flagellum rudimentary, supplemented by an undulating membrane	ORDER I. TRYPANOSOMATA.
	Flagellum supplemented by lobate pseudopodia	„ II. RHIZO-FLAGELLATA.
	Flagellum supplemented by ray-like pseudopodia ..	„ III. RADIO-FLAGELLATA.
	Flagella representing the sole organs of locomotion ..	„ IV. FLAGELLATA-PANTOSTOMATA.
B. Ingestive area discoidal, limited to the anterior region ; no true mouth.	Flagellum issuing from the centre of a collar-like extensile membrane	„ V. CHOANO-FLAGELLATA.
C. Ingestive area constituting a true and distinct mouth.	Flagellum not supplemented by cilia	„ VI. FLAGELLATA-EUSTOMATA.
	Flagellum supplemented by a more or less highly developed ciliary system ..	„ VII. CILIO-FLAGELLATA.

Order I. TRYPANOSOMATA, S. K.

Animalcules flattened or lamellate, one or more of the lateral borders forming a frill-like undulating membrane by the vibrations of which progress is effected; one extremity sometimes attenuate and somewhat resembling a flagellum. Oral or ingestive area undefined.

Two species only, representing but a single genus, can be as yet referred to this newly established order. So far as it can be at present determined, these two endoparasitic types would seem to lie at the base of all the succeeding more typical sections of the Infusoria Flagellata and Ciliata. Although no positive flagellum is present, the growth of such an organ is evidently foreshadowed in the slender tag-like appendage of *Trypanosoma sanguinis*, while, on the other hand, the undulating membranous border, constituting the essential organ of locomotion, may without hesitation be regarded as closely, if not absolutely, homologous with the similar undulating frill-like border present in the earlier developmental phases of *Stentor*, *Euplotes*, and other higher Ciliate types, and which eventually splits up to form the characteristic adoral fringe.

GENUS I. TRYPANOSOMA, Gruby.

☞ Animalcules free-swimming, compressed; one side produced as a thin, undulating, frill-like border; the anterior extremity sometimes produced as a long tag-like or flagellate appendage. No distinct oral aperture.

Occurring in the blood of Amphibia, and within the intestinal viscera of domestic poultry.

Trypanosoma sanguinis, Gruby. PL. I. FIGS. 1 AND 2.

Body compressed, semilunate, twisted; the convex border membranous and undulating, with its margin deeply toothed; the posterior extremity of the body portion pointed and curved inwards, the opposite one produced into a long tag- or tail-like appendage which almost equals in length the remainder of the body; surface of the body coarsely striate longitudinally; endoplasm or parenchyma slightly granular; endoplast ovate, central. Dimensions, 1–600″.

HAB.—Blood of the frogs, *Rana esculenta* and *R. temporaria*.

This species was first introduced to scientific notice by Gruby, who described and bestowed upon it the name here given in the 'Comptes Rendus' for November 1843. More recently this animalcule has been figured by Professor E. Ray Lankester in the 'Quarterly Journal of Microscopical Science' for October 1871, under the title of *Undulina ranarum*, its identity with Gruby's type being, however, subsequently admitted.

Professor Lankester's account given of the characteristic aspect and movements of this singular animalcule, in the serial quoted, is as follows:—"In making examinations of the blood of frogs, I have now and then met with the interesting little parasite drawn in the woodcut. When I first saw it, in some blood from a frog last summer, I took it for a very active white blood-corpuscle, since it is a very little smaller than one of the red corpuscles of the frog's blood. On using, however, a higher power (No. 10*a* immersion, of Hartnack), I made out its infusorial nature, though, on account of the great activity of its movements, I was long uncertain as to the nature of its locomotive organs. Numerous specimens occurred in the blood of a frog (*Rana esculenta*), examined at Leipzig in March last, and by the use of a small quantity of acetic acid vapour I was able to kill the little creature without injuring it, and then to make out its structure. It was seen to be a minute pyriform sac, with the narrower end bent round on itself somewhat spirally, and the broader end spread out into a thin membrane, which exhibited four or five folds, and was produced on one side into a very long flagellum. The wall of the sac was striated coarsely, as in *Opalina;* and the direction of the striæ on the two sides of the sac, as seen one through the other, showed that the small end of the sac was twisted as well as bent over on itself. A pale, clear nucleus and a very few granules were also seen. In life the broad membrane undulates vigorously in a series of waves, the flagellum taking part, and presents then a deeply toothed appearance. The movements produced by the activity of this membrane tend to urge the animal in a wide circle. The opposite extremity of the sac twists and untwists itself to a small extent also during life. The series of waves of the undulating membrane are not incessantly in one direction; after a certain time they change to the opposite direction, and then resume their original direction, an alternation of from right to left, and from left to right being kept up. When minute traces of acetic acid vapour are passed into the gas-chamber where this infusorian is, it soon becomes affected; the undulations become deranged, starting from both ends simultaneously and meeting in the middle, and at length ceasing."

Trypanosoma Eberthi, S. K. PL. I. FIGS. 3–6.

Body flattened, and semilunate when at rest, its convex membraniform border serrated or presenting a beaded aspect; straight, lanceolate, and pointed at each extremity when in motion, not produced at either end into a tag-like prolongation; the membranous border often spirally convolute around the thicker central portion, the entire body assuming under such conditions an auger-like aspect. Length 1–1760″.

HAB.—The intestinal viscera of various domestic poultry.

It is proposed to distinguish, under the above title, the organism figured and described by Dr. J. Eberth in Siebold and Kölliker's 'Zeitschrift' for the year 1861, p. 98, as a new infusorial form inhabiting the intestinal viscera—chiefly the cæcum and ileum—of ducks, geese, and other domestic poultry. No name is there bestowed upon it, and its accordance to a considerable extent with the *Trypanosoma sanguinis* of Gruby, and *Amœba rotatoria* of Meyer is acknowledged. Its distinction from Gruby's type is clearly manifested, however, by the entire absence of the anterior filamentous or tag-like appendage which forms so conspicuous a characteristic of that species, and which is so prominently figured in Professor Lankester's more recent delineation here reproduced. If the above-named structure in *T. sanguinis* is to be regarded as the analogue or rudiment of a true flagellum, it would appear almost desirable to create a new generic title for the reception of the present more simple form. On the other hand, however, a further investigation may not impossibly demonstrate that both this and the preceding type are but transitional phases of the same specific form, which, in common with many higher endoparasitic organisms, requires the association of two distinct hosts for the full development of its life-cycle, and exhibits under each condition an altogether distinct aspect. In this manner it may be proved hereafter, though only submitted now as a suggestion, that the flagellum- or filament-bearing *Trypanomonas sanguinis*, as found in the blood of the frog, represents the adult condition of the more minute *T. Eberthi*, which would probably be swallowed by the amphibians or their tadpoles, in company with the discharged fæces of the water-fowl. Or again, though this seems less likely, *T. sanguinis* may represent the larval condition, which being devoured with its host, the frog, by the water-fowl, may develop in the intestine of the latter to *T. Eberthi*.

Yet another interpretation may be suggested relative to the true nature and significance of the present species of *Trypanosoma*. It is, as already stated at page 100, a noteworthy fact that the spermatic elements of many Amphibia correspond structurally in a remarkable manner with the representatives of the present species as figured by Eberth. The long, slender bodies of such spermatozoa are, as first pointed out by Wagner and Leuckhart in the year 1837, and as still more fully demonstrated by C. T. Von Siebold,* supplemented throughout their length by a delicate frill-like border, developed straight along or in a spiral manner around it throughout the whole extent or greater part of its total length. Quite recently it has, moreover, been shown by Mr. Heneage Gibbes,† that the spermatozoa of the Mammalia possess also, though in a less developed degree, corresponding supplementary membranes. The high import attaching itself to this structural feature of Amphibian spermatozoa just described is obvious. It necessarily renders it quite possible that the form discovered by Dr. Eberth, and here provisionally accepted as an independent infusorial species, may ultimately prove to be the spermatic elements of frogs and other Amphibia, which, as commonly happens, have been devoured by the water-fowl, and retained their vitality while passing through its viscera.

Order II. RHIZO-FLAGELLATA, S. K.

Animalcules progressing by means of pseudopodic extensions of their sarcode after the manner of the ordinary Rhizopoda, but bearing at the same time one or more flagellate appendages ; oral or ingestive area diffuse.

* "Ueber undulirender Membranen," 'Zeit. Wiss. Zool.,' Bd. ii., 1850.

† "On the Structure of the Vertebrate Spermatozoon," 'Quart. Jour. Mic. Sci.,' No. lxxvi., Oct. 1879.

The some half a dozen species as yet known that may be consistently referred to this order, intimately connect with each other the two classes of the Rhizopoda, as represented by the Amœbina, and the typical Infusoria-Flagellata. In accordance with the number and character of their flagelliform and pseudopodic appendages they admit of the following generic grouping:—

GENERA OF RHIZO-FLAGELLATA.

Flagellum single, anteriorly situated.	Repent	Body amœbiform, pseudopodia emitted from all parts of the periphery	Genus 1. *Mastigamœba*.
		Body monadiform, pseudopodia emitted only from the ventral surface	,, 2. *Reptomonas*.
	Sedentary, with radiating digitiform prolongations ..		,, 3. *Rhizomonas*.
Flagella multiple, inconstant in number and position			,, 4. *Podostoma*.

GENUS I. MASTIGAMŒBA, Schulze.

Animalcules repent, amœba-like, changeable in form, emitting pseudopodia from all parts of the periphery, the anterior extremity bearing a single, long, non-retractile, lash-like flagellum.

Mastigamœba aspera, Schulze. PL. I. FIG. 21.

Body when extended oval, depressed, pointed anteriorly; pseudopodia cylindrical, unbranched, digitiform, diverging in somewhat regular order from the lateral margins of the periphery, those at the posterior extremity of the body shorter than the others, emitting extremely fine ray-like sarcodic projections, similar to those of *Amœba* (*Pelomyxa*) *villosa;* flagellum issuing from the pointed anterior extremity, about equal in length to the body; entire external surface, including more especially the pseudopodia, beset with exceedingly minute refringent rod-like structures which communicate to it a hispid aspect. Contractile vesicles two in number, situated near the posterior extremity. A subspheroidal endoplast-like structure developed anteriorly; endoplasm enclosing numerous reddish-yellow spherules and colourless granules. Length of body 1–150″.

HAB.—Pond water.

Excepting for its smaller size and the presence of the anteriorly developed flagellum, the representatives of this species correspond in a remarkable manner with the *Dinamœba mirabilis* of Dr. Joseph Leidy, as recently figured in his magnificent monograph of the Freshwater Rhizopods of North America.

Mastigamœba simplex, S. K. PL. I. FIG. 30.

Body when extended usually widest and rounded at the anterior extremity, tapering posteriorly; pseudopodia irregular in shape, simple, lobate, or furcately branched, not differentiated from one another as in *M. aspera*, usually directed backwards; flagellum antero-terminal, about twice the length of the body; external surface entirely smooth; contractile vesicle anteriorly situated; endoplast spherical, subcentral; endoplasm transparent, colourless. Length of body 1-2000″.

HAB.—Pond water.

Deprived of its terminal flagellum, this species would seem closely to agree both in aspect and size with the *Amœba lacerata* of Dujardin. Like that form, the pseudopodia are altogether irregular in shape, and present a laciniate or ragged outline. The movements of this animalcule in the water are tolerably active, it creeping rapidly forwards over the surface of submerged objects by the continual rolling to the front of the granular contents of the body-sarcode in a manner identical with what obtains among the ordinary amœbæ; the long, whip-like flagellum is at the same time vigorously flourished in advance or thrust around in every direction, as though seeking for suitable food-substances. These latter when met with, are whipped backwards by the action of the flagellum, and striking against some portion of the periphery of the body, are at once engulfed by the soft yielding sarcode. On one occasion an example was observed dragging a *Navicula* almost equalling itself in size by an abnormal thread-like extension of one of its pseudopodia, as shown in the illustration given. The Protozoon figured and described by Bütschli under the title of "eine geisseltragender Rhizopode," * is apparently almost identical with this form; but the pseudopodia, in accordance with his illustrations, are smaller and more slender, and the flagellum, in comparison, is considerably longer.

Mastigamœba monociliata, Carter, sp. PL. I. FIGS. 22 AND 23.

Body amœboid, variable in form; pseudopodal extensions irregularly lobate, the posterior extremity having a brush-like villous tuft, anterior flagellum equalling the body in length. Dimensions unrecorded.

HAB.—Fresh water. Bombay, H. J. C.

This species is briefly described by Mr. H. J. Carter † as a new species of *Amœba*, upon which he proposes to confer the title of *Amœba monociliata*. From *Mastigamœba simplex*, which it most nearly resembles, it may be distinguished by the tuft of villi at the posterior extremity.

Mastigamœba ramulosa, S. K. PL. I. FIGS. 19 AND 20.

Body when extended elongate-ovate, about one and a half times as long as broad; the entire peripheral surface bearing subequal shortly branched pseudopodic prolongations, neither these nor the general surface of the body having secondary hispid pseudopodia; flagellum exceeding the body in length; endoplast spherical, subcentral; contractile vesicle posteriorly located. Length 1-400″.

HAB.—Marsh water.

This animalcule has as yet been met with by the author on one occasion only, being then found in marsh-water from the neighbourhood of Le Marais, Jersey, associated with the Ciliate types *Spirostomum ambiguum* and *Litonotus fasciata*. The conspicuously branched character of the abundant pseudopodia serves to distinguish it readily from either of the preceding species, and communicates to it as a whole an aspect suggestive of a minute Nudibranch, such as *Eolis* or *Dendronotus*. Like these molluscs, the little animalcule, under any disturbing influence,

* 'Zeit. Wiss. Zool.,' Bd. xxx. Heft 2, 1878.

† 'Ann. Nat. Hist.,' Jan. 1864.

immediately contracts into a subspheroidal contour, as shown in Pl. I. Fig. 20. It was observed that the granule circulation, conspicuously indicated in the central substance of the body-sarcode, did not extend into the branched pseudopodic extensions, neither on any occasion were these last-named appendages withdrawn entirely within the periphery.

Doubtful Species.

The free-swimming flagellate amœbæ, described by Tatem in the 'Monthly Microscopical Journal' for June 1869, appeared at first sight to require a position in or adjacent to the genus *Mastigamœba*, but the result of a recent investigation into the life-history of innumerable Pantostomatous Flagellate species, has inclined the author to regard the forms there figured and described as merely metamorphosed amœboid phases of some such type as *Monas fluida*.

Genus II. REPTOMONAS, S. K.

(Latin, *repto*, to creep; *monas*.)

Animalcules repent, but slightly changeable in form, bearing a single anterior flagellum; locomotive pseudopodia produced only from the repent or ventral surface.

The limitation of the pseudopodia to the ventral region, and the conservation by the body, taken as a whole, of a persistent contour, distinguish this genus from *Mastigamœba*, which it otherwise closely approaches.

Reptomonas caudata, S. K. Pl. I. Figs. 31–33.

Body monadiform, elongate-ovate, somewhat inflated posteriorly; flagellum slender, exceeding the body in length, produced from the apex of the narrower and slightly pointed anterior extremity; a long, trailing, caudiform pseudopodium continued backwards from the posterior end of the ventral surface, and numerous similar but smaller pseudopodia emitted irregularly from the whole surface of this region; contractile vesicle single, situated near anterior extremity; endoplast spherical, subcentral. Length, exclusive of caudal pseudopodium, 1–1200" to 1–750".

Hab.—Hay infusions, and among naturally decaying grass.

This as yet single discovered species of the newly instituted genus *Reptomonas* was obtained by the author in tolerable abundance from a hay infusion made at St. Heliers, Jersey, in February 1879, a closely similar, if not absolutely identical, specific type having also been met with among wet grass gathered in the Regent's Park in October of the same year, and under the circumstances narrated at length at page 140. During progression the anterior extremity of the animalcule is usually elevated in the manner shown at Pl. I. Fig. 31, the flagellum meanwhile vibrating vigorously in all directions in search of food. On one occasion, as delineated at Fig. 33, a Bacterium thrown by the vibrations of this organ against the anterior margin was at once secured by an outflowing wave of the peripheral sarcode, and rapidly passed into the interior of the body. In many respects the animalcule here described presents a considerable resemblance to the *Cercomonas crassicauda* of Dujardin, as reproduced from Stein's work at Pl. XIV. Figs. 15 and 16. That type, however, in common with all the representatives of the genus *Cercomonas* as here accepted, is a free-swimming or natatory, and not a repent form.

GENUS III. RHIZOMONAS, S. K.

(Greek, *rhiza*, root; *monas*.)

Animalcules monadiform, adherent to submerged objects by root-like pseudopodic extensions of the posterior region; the anterior extremity bearing a single lash-like flagellum.

Rhizomonas verrucosa, S. K. PL. I. FIGS. 26 AND 27.

Body subspheroidal, its general surface bearing throughout even sized, conical pseudopodic elevations whose length nearly equals one-half the diameter of the body; similar but somewhat longer conical pseudopodia produced from the posterior extremity, and rooting the animalcule to the selected point of attachment; flagellum slender, its length equalling twice the diameter of the body; contractile vesicle single, subspherical; endoplast not observed. Diameter 1–1500″.

HAB.—Hay infusions.

This remarkable form was obtained by the author from the hay infusion that yielded *Reptomonas caudata*. In its normal and fixed condition the vibrations of the flagellum are so rapid and powerful as to maintain the entire body in a state of active tremor—after the manner of the wings of many moths when hovering—thus rendering it exceedingly difficult to recognize its true form and proportions. This energetic motion becomes, however, even yet more pronounced when, either voluntarily or through a disturbance of the infusion, the animalcule is set free in the surrounding water. Under these circumstances it tumbles over and over or to and fro in apparently the most aimless and excited manner, allowing but an occasional and momentary distinct glimpse of either its body or flagellum. In very many instances it was observed that the attached animalcules, either singly or in associated groups of three or four, were immersed within a granular mucilaginous sheath apparently exuded from their own bodies, and out of which the long, powerful flagella alone projected. Such a solitary ensheathed zooid is delineated at Pl. I. Fig. 26.

GENUS IV. PODOSTOMA, Claparède & Lachmann.

Animalcules amœba-like, changeable in form, emitting pseudopodic prolongations, the free extremities of which are capable of further extension into long, thread-like, and actively motile flagella.

The single species upon which this genus is founded represents the most perfect known gradational form between the two classes of the Rhizopoda and Infusoria-Flagellata. Unlike *Mastigamœba*, to which the second place in this category may be allotted, the lash-like organ or flagellum is constant neither in its presence or position, but shares with the pseudopodia the capacity of being emitted from or withdrawn into the substance of the body at any point of the periphery; two or more of these organs may, moreover, be simultaneously extended from a single animalcule, while in *Mastigamœba* the flagellum is single and persistent as regards both its position and existence.

Podostoma filigerum, C. & L. Pl. I. Figs. 28 and 29.

Body repent or freely floating, highly polymorphic, almost spherical when contracted, substellate with attenuate pseudopodic prolongations when extended ; the distal terminations of the pseudopodia produced as long, thread-like, vibratile flagella, which are capable of contracting in a spiral manner, or of being entirely withdrawn into the substance of the pseudopodium; contractile vesicle single, endoplast distinct, subspheroidal. Length of extended body 1–500″.

Hab.—Fresh water, among aquatic plants.

Overlooking the presence of the flagellate appendages, this animalcule, as remarked by Claparède and Lachmann, closely resembles in its stellate condition the *Amœba radiosa* of Ehrenberg, while at other times, in its contracted state, it might be as easily mistaken for *A. diffluens*. Any food-particle arrested by one of the flagellate appendages is immediately withdrawn with the latter into the substance of the pseudopodium that carries it, a slight depression momentarily marking the point of entrance. Bütschli,* while recently proposing to identify Ehrenberg's *Amœba radiosa* with this type, has sought to demonstrate that the radiating pseudopodia of the former are capable of similar attenuate prolongation in the form of flagella. An intimate acquaintanceship with the *Amœba* named inclines the author, however, to regard the two as distinct, and that Bütschli must have had Claparède and Lachmann's type, and not Ehrenberg's, under examination. In the latter species, however finely attenuate may be the extensions of the pseudopodia, they never assume the form and functions of vibratile and spirally contractile flagella. This decision is entirely confirmed by an examination of the exhaustive figures and accompanying description of *Amœba radiosa* embodied in Professor Leidy's monograph of the North American Rhizopoda, previously quoted.

Order III. RADIO-FLAGELLATA, S. K.

Animalcules emitting numerous ray-like pseudopodia, after the manner of the Radiolaria, and provided at the same time with one or more flagellate appendages ; no distinct oral aperture. Mostly marine.

The several genera referred to this newly instituted Order of the Flagellata form two natural and well-differentiated groups. In the one—that of the Euchitonidæ—we find types which, except for the presence of the characteristic flagellum, are not to be distinguished from the ordinary representatives of that typical Radiolarian group known as the Polycystinæ; while in the second one—that of the Actinomonadidæ—are presented forms that most intimately unite the more typical flagellate monads with the Heliozoan group of the same Radiolarian class. Since it is now demonstrated of all the other leading groups of the Radiolaria so far investigated, that their initial conditions take the form of simply flagellate monadiform zoospores, it may be consistently predicated that in the two above-named family divisions is permanently retained that primitively developed locomotive organ which among the more ordinary Radiolaria becomes aborted at an early epoch of their existence.

The direct metamorphosis, observed by the author, of a flagelliferous zooid into an adult Radiolarian type of structure, as exemplified in the genus *Actinophrys*, will be found illustrated at Pl. I. Figs. 9–11. As first observed, see Fig. 9, the monadiform germ closely corresponded in appearance with the *Peranema globulosa*

* "Beiträge zur Kenntniss der Flagellaten," 'Zeit. Wiss. Zool.,' Bd. xxx., 1878.

of Dujardin. In the midst of its natatory course it was observed to project blunt digitiform processes from all sides of the periphery, as shown at Fig. 10. Its motions now became more sluggish, the flagellum was completely withdrawn, and then suddenly, as though by magic—the bursting of a rocket or other firework affording perhaps the most suitable comparison—fine ray-like pseudopodia were shot out in every direction, and the animalcule was at once metamorphosed into a typical *Actinophrys*. According to Cienkowski, the monadiform germs or so-called "zoospores" of the Radiolarian type *Collosphæra spinosa*, Hkl., are furnished with two subequal flagellate appendages. An account of Cienkowski's investigations in this connection, translated from the German, is published in the 'Quarterly Journal of Microscopical Science,' vol. xi., No. xliv., 1871.

FAMILIES AND GENERA OF RADIO-FLAGELLATA.

Fam. I. *Actinomonadidæ*. Animalcules naked, no exoskeleton or central capsule.	Animalcules free-swimming or attached posteriorly by a thread-like pedicle		1. *Actinomonas*.
Fam. II. *Euchitonidæ*. Animalcules with a siliceous test or lorica, and an indurated central capsule.	Test external to capsule with cyclic chambers ..		2. *Euchitonia*.
	Test external to capsule simply trabecular.	External trabecular lattice-work more or less evenly ovate ..	3. *Spongocyclia*.
		External trabecular lattice-work forming arm-like processes ..	4. *Spongasteriscus*.

Fam. I. ACTINOMONADIDÆ, S. K.

Animalcules ovate or spheroidal, fixed or freely motile, entirely naked, possessing neither an indurated test nor a central capsule; fine ray-like pseudopodia projecting from all parts of the periphery, supplemented at one point by a long vibratile flagellum.

Genus I. ACTINOMONAS, S. K.

(Greek, *actis*, ray; *monas.*)

Animalcules ovate or spherical, uniflagellate, free-swimming, or attached posteriorly by a temporarily developed thread-like pedicle; endoplasm soft and plastic, emitting ray-like pseudopodia from all points of the periphery; food-particles attracted by the vibrations of the flagellum, and then seized by the pseudopodia and introduced into the substance of the body at any part of its circumference; endoplast and contractile vesicles usually conspicuous.

The two species upon which the new genus *Actinomonas* is here founded represent some of the most remarkable and interesting types of the class Flagellata. Divested of their radiating pseudopodia, there is nothing to distinguish them from the typical members of the genus *Oikomonas*, while by the retention of the pseudopodia and removal only of the terminal flagellum, a form is produced scarcely distinguishable from the stalked Radiolarian recently described by F. E. Schulze under the title of *Actinolophus pedunculatus*. Through this generic type, in fact, the two Protozoic groups of the Radiolaria and the Infusoria-Flagellata would appear to be as effectually bridged as are the last-named group and the ordinary Rhizopoda by the several genera, *Mastigamœba*, *Rhizomonas*, *Reptomonas*, and *Podostoma*.

Actinomonas mirabilis, S. K. Pl. I. Fig. 18.

Body subspherical or ovate, seated on a slender pedicle, which usually equals two or three times the diameter of the body; endoplasm transparent, slightly granular; flagellum very long and slender, extended rigidly and arcuately in advance; pseudopodia equalling in length the diameter of the body, very numerous, radiating from all points of the periphery; contractile vesicles two in number, situated close to each other in the posterior region of the body; endoplast spherical, subcentral. Diameter 1-2000″.

Hab.—Salt water.

Several examples of this interesting type were met with at St. Heliers, Jersey, in May of the year 1878, in a jar of sea-water preserved for some weeks, containing various protozoa and hydroid zoophytes collected on the adjacent coast. At first sight the aspect presented by these animalcules so closely resembled that of the ordinary members of the genus *Spumella* or *Oikomonas*, with, perhaps, some little extra haziness around the peripheral margin, that they were nearly passed over as such, and it was not until the aid of a more powerful object-glass was brought to bear upon them that their true nature became apparent. It was then demonstrated that the hitherto hazy environment of the periphery of the body consisted of fine, closely-set, slender pseudopodia radiating in every direction, agreeing in form and structure with those of *Actinophrys*, *Actinolophus*, or any other typical Radiolaria, and subservient to a closely similar function. Through its possession of a long terminal flagellum, however, *Actinomonas* possesses considerable advantages over such a type as *Actinolophus*. While the last-named form has to wait patiently for the advent of food-particles within grasping reach of its tenacious pseudopodia, *Actinomonas*, by the vibrations of its flagellate appendage, draws towards it all such substances floating in the vicinity, and throws them back among the pseudopodic processes, by which they are immediately seized and dragged into the substance of its body. The capture and ingestion of food-matter in this manner, at all parts of the circumference, were witnessed on several occasions. Physiologically, the extended peripheral pseudopodia of *Actinomonas* are closely analogous to the extensile sarcode collar of the Choano-Flagellate order hereafter described, a similar trap-like function, in combination with the flagellum, being common also to that diversely modified pseudopodic structure. The developmental and reproductive phenomena of this remarkable type have yet to be determined.

Actinomonas pusilla, S. K. Pl. I. Figs. 7 and 8.

Body subspheroidal; pedicle equal to, or very slightly exceeding in length, the diameter of the body; flagellum slender, extended rigidly and arcuately from the apical extremity; pseudopodia equalling in length the diameter of the body, projected from all parts of the periphery, much less numerous than in the preceding species. Diameter of body 1-3250″.

Hab.—Salt water.

This species may be distinguished from the preceding by its more minute size, the shorter comparative length of the pedicle, and the considerably less numerical development of the radiating pseudopodia. It was obtained in some abundance in sea-water containing *Zoothamnium dichotomum* attached to *Fuci*, remitted to the author by Mr. Thomas Bolton from the Birmingham Aquarium in February of the present year (1880). It was observed that the specimens often attached themselves to the neighbouring vegetable debris by several radiating pseudopodia simultaneously, as shown at Fig. 8, as well as by the temporarily modified posterior one that usually fulfilled the office of a pedicle. Disengaging themselves from their single or several points of attachment, the animalcules were frequently seen to swim freely in the water with great rapidity after the manner of *Oikomonas* or *Spumella.*

Fam. II. EUCHITONIDÆ, S. K.

Animalcules free-floating, secreting a variously constructed cancellate siliceous test or lorica, which is distinguished by the invariable presence of a central differentiated capsule; ray-like pseudopodia extending from all parts of the periphery, supplemented anteriorly by a comparatively large and well-developed flagellate appendage. Entirely pelagic.

As the members of this family possess characters that unite them more intimately with the typical Radiolaria than with the ordinary Flagellata, a description of each specific form is not included in this treatise, but a brief diagnosis only of a characteristic representative of each generic group.*

GENUS I. EUCHITONIA, Haeckel.

Test siliceous, consisting of a flattened, biconvex, cyclically chambered, central capsule, with radially developed projecting arms, which are disposed in the same plane and chambered cyclically in correspondence with the central disc; the interspaces between the radiating arms filled in by a loose, unsymmetrical, siliceous network.

Euchitonia Virchowii, Hkl. PL. I. FIG. 24.

Central capsule discoidal, with from two to three concentric chamber-cycles; radiating prominences three in number, their length slightly exceeding the diameter of the central disc, the two anterior slightly narrower than the single isolated median posterior one, and basally united; cyclical chambers, of which the radiating arms are composed, varying from four to six in number; flagellum massive, equalling or exceeding the length of the test, projecting from the angle between the two anterior arms. Diameter of the central capsule 1–375''.

HAB.—Pelagic: Messina.

In addition to the foregoing type, as many as six other specific forms are referred by Haeckel to the genus *Euchitonia*, in his magnificent monograph 'Die Radiolarien,' Berlin, 1862, under the respective titles of *E. Bœkmanni*, *E. Gegenbauri*, *E. Krohnii*, *E. Muelleri*, *E. Leydigii*, and *E. Kœllikeri.*

GENUS II. SPONGOCYCLIA, Haeckel.

Test siliceous, consisting of a central capsule composed of concentric and symmetrical chamber-cycles, surrounded by an irregular, sponge-like lattice-work of siliceous trabeculæ, this sponge-like lattice-work not developed peripherally into distinct arm-like processes.

* Professor St. George Mivart recognizing the important distinction furnished by the presence of flagella in the three genera included in this family division, has proposed ('Linnean Society's Journal,' vol. xiv., No. 74, 1878) to separate them from the ordinary Radiolaria as a distinct section of the "Flagellifera."

Spongocyclia charybdæa, Hkl. Pl. I. Fig. 25.

General contour of test escutcheon-shaped, flattened and angular anteriorly, slightly widest centrally, tapering and obtusely pointed at the posterior extremity; central capsule composed of from seven to fourteen concentric chamber-cycles, its diameter equalling one-half of the entire test; flagellum stout, exceeding the length of the test, projecting from the centre of the anterior border. Length 1–72″.

Hab.—Pelagic: Messina.

Additional species, figured and described by Haeckel, are distinguished by the respective titles of *Spongocyclia cycloides*, *S. elliptica*, *S. orthogona*, and *S. scyllæa.*

Genus III. SPONGASTERISCUS, Haeckel.

Test siliceous, consisting of a central discoidal capsule composed of concentric and symmetrical chamber-cycles, surrounded by an irregular trabeculate siliceous lattice-work, as in *Spongocyclia*, but which, in place of being simply subcircular or escutcheon-shaped, is developed into distinct angular arm-like processes, which lie in the same plane as the flattened central disc.

Spongasteriscus quadricornis, Hkl.

Central capsule circular, flattened, composed of from eight to sixteen concentric chamber-cycles, radiating arm-like processes four in number, subequal, triangular, forming two basally united pairs at the anterior and posterior regions, their length equal to one-third of the diameter of the central disc; flagellum projecting from the notch between the anterior pair of angular processes. Diameter of central disc 1–96″.

Hab.—Pelagic: Messina.

One additional species is described by Haeckel under the title of *Spongasteriscus tetraceras.*

Order IV. FLAGELLATA-PANTOSTOMATA, S. K.

Animalcules simply flagelliferous, having in their characteristic adult state no supplementary lobate or ray-like pseudopodic appendages; oral or ingestive area entirely undefined, food-substances being incepted indifferently at all points of the periphery.

Among the typical Infusoria-Flagellata, this order may be said to represent the lowest and least specialized, it being directly allied through the small group of the Rhizo-Flagellata, previously described, with the Amœban order of the Rhizopoda. Many of the generic and specific forms at present referred to this section must be regarded as occupying therein a purely provisional position, it not being improbable that the animalcules, upon further acquaintance, may be found to possess a distinct oral aperture, and thus demand transfer to the succeeding order of the Flagellata-Eustomata. While again, in a very considerable number of instances, the ingestion of food-substances at all points of the periphery has been directly observed, it would seem highly probable that where neither this phenomenon nor the presence of an

FAMILIES AND GENERA OF FLAGELLATA-PANTOSTOMATA.

A. PANTOSTOMATA-MONOMASTIGA. Flagellum single.

Family.	Characters	Genus.
I. MONADIDÆ. Animalcules naked, usually free-swimming; flagellum terminal, no pedicle or caudal appendage.	Entirely free-swimming. — Globose or ovate. — Anterior border rounded. — Polymorphic	1. *Monas.*
	Entirely free-swimming. — Globose or ovate. — Anterior border rounded. — Persistent in shape	2. *Scytomonas.*
	Entirely free-swimming. — Globose or ovate. — Anterior border truncate or excavate	3. *Cyathomonas.*
	Entirely free-swimming. — Fusiform or acicular, persistent in shape	4. *Leptomonas.*
	Entirely free-swimming. — Vermicular — Spirally twisted, form persistent	5. *Ophidomonas.*
	Entirely free-swimming. — Vermicular — Polymorphic and highly flexible	6. *Herpetomonas.*
	Adherent at will by the single trailing flagellum	7. *Ancyromonas.*
II. PLEUROMONADIDÆ. Animalcules naked, tailless; flagellum lateral or ventral.	No trichocysts	8. *Pleuromonas.*
	With trichocysts	9. *Merotricha.*
III. CERCOMONADIDÆ. Animalcules naked, with a tail-like caudal filament.	Attached or free-swimming, caudal filament retractile	10. *Oikomonas.*
	Attached or free-swimming, caudal filament non-retractile	11. *Bodo.*
	Entirely free-swimming, never attached	12. *Cercomonas.*
IV. CODONŒCIDÆ. Animalcules loricate.	Loricate, erect, stalked or sessile	13. *Codonœca.*
	Lorica decumbent	14. *Platytheca.*
V. DENDROMONADIDÆ. Animalcules illoricate, with an oblique frontal border; mostly social and constructing tree-like zoodendria; flagella unequal, one long and one short.	Solitary, attached by a thread-like pedicle	15. *Physomonas.*
	Associated on a simple or branching pedicle or zoodendrium. — Animalcules attached simply to termination of zoodendrium. — Zoodendrium flexible, thread-like	16. *Cladonema.*
	Associated on a simple or branching pedicle or zoodendrium. — Animalcules attached simply to termination of zoodendrium. — Zoodendrium rigid and erect	17. *Dendromonas.*
	Associated on a simple or branching pedicle or zoodendrium. — Animalcules attached in clusters to termination of zoodendrium. — Zoodendrium more or less flexible, opaque, and composite	18. *Anthophysa.*
	Associated on a simple or branching pedicle or zoodendrium. — Animalcules attached in clusters to termination of zoodendrium. — Zoodendrium rigid, hyaline and homogeneous	19. *Cephalothamnium.*
VI. BIKŒCIDÆ. Animalcules inhabiting horny loricæ, front border oblique; flagella uneven, one long and one short.	Loricæ solitary — Sessile	20. *Hedræophysa.*
	Loricæ solitary — Stalked	21. *Bicosæca.*
	Loricæ united serially and forming a compound polythecium	22. *Stylobryon.*
VII. AMPHIMONADIDÆ. Animalcules naked, free-swimming, or attached singly and permanently by the posterior extremity, or by a tail-like filament; flagella even.	Free-swimming, anterior border oblique	23. *Goniomonas.*
	Sedentary — Attached by a thread-like pedicle	24. *Amphimonas.*
	Sedentary — No distinct pedicle	25. *Deltomonas.*

B. PANTOSTOMATA-DIMASTIGA. Flagella two in number.	VIII. SPONGOMONADIDÆ. Animalcules symmetrically ovate, mostly social and secreting variously modified protective coverings; flagella of even length.	Animalcules inhabiting a branching tubular zoothecium: Tubules of zoothecium separate	26. *Cladomonas.*
		Animalcules inhabiting a branching tubular zoothecium: Tubules of zoothecium more or less extensively united	27. *Rhipidodendron.*
		Animalcules inhabiting a common mucilaginous or granular zoocytium	28. *Spongomonas.*
		Animalcules inhabiting separate horny loricæ	29. *Diplomita.*
	IX. HETEROMITIDÆ. Animalcules naked, free-swimming, or temporarily attached by the posterior flagellum.	Flagella distinct throughout. Ovate: No ventral groove	30. *Heteromita.*
		Flagella distinct throughout. Ovate: With a distinct ventral groove	31. *Colponema.*
		Flagella distinct throughout. Body elongated, spirally twisted	32. *Spiromonas.*
		Flagella basally united	33. *Phyllomitus.*
	X. TREPOMONADIDÆ. Animalcules free-swimming, entirely unsymmetrical.	Insertion of flagella widely separated	34. *Trepomonas.*
	XI. POLYTOMIDÆ. Animalcules ovate, free-swimming, with an indurated external envelope, multiplying by endogenous subdivision.	Adherent at will by a basal flexure of the flagellum	35. *Polytoma.*
	XII. PSEUDOSPORIDÆ. Animalcules repent and natatory, flagella even.	Animalcules polymorphic, endoparasitic	36. *Pseudospora.*
C. PANTOSTOMATA-POLYMASTIGA. Flagella three or more in number.	XIII. SPUMELLIDÆ. Flagella three in number, diverse, one long and two short.	Animalcules attached by a temporarily developed pedicle	37. *Spumella.*
	XIV. TRIMASTIGIDÆ. Flagella three in number, subequal.	All three flagella vibratile	38. *Callodictyon.*
		Two flagella vibratile, one trailing	39. *Trichomonas.*
		One flagellum vibratile, two trailing: Free-swimming or adherent	40. *Dallingeria.*
		One flagellum vibratile, two trailing: Entirely free-swimming	41. *Trimastix.*
	XV. TETRAMITIDÆ. Flagella four or five in number.	Four flagella: Animalcules naked, polymorphic	42. *Tetramitus.*
		Four flagella: Animalcules loricate	43. *Tetraselmis.*
		Five flagella, one vibratile, four reflected	44. *Chloraster.*
	XVI. HEXAMITIDÆ. Flagella six in number.	Four anterior flagella vibratile, two posterior ones adherent	45. *Hexamita.*
	XVII. LOPHOMONADIDÆ. Flagella numerous, animalcules solitary.	Animalcules solitary, endoparasitic	46. *Lophomonas.*
	XVIII. CATALLACTIDÆ. Flagella numerous, animalcules forming social colony-stocks.	Animalcules united in spheroidal clusters, pelagic	47. *Magosphæra.*

oral aperture has been detected, e. g. *Herpetomonas*, *Polytoma*, *Hexamita*, and *Trichomonas*. that the animalcules derive their nutriment, as in the case of the Opalinidæ, by the direct absorption, at all points, of the proteaceous material held in solution in the fluid media they inhabit. Whether this latter be the hæmal or perivisceral fluid of a higher animal, an animal maceration, or a vegetable infusion, protein in its concentrated and more or less diffused condition is invariably present, and its direct absorption under such circumstances by the contained unicellular animalcules would be strictly analogous to the alimentary process as performed by the individual cell-units of the intestinal tract of all the more highly organized Metazoa. These beings, in fact, live continually immersed within a, so to say, ready prepared bath of nutritive broth, and require no display of energy beyond the passive one of assimilation or endosmosis for the satisfying of their creature wants. So far, a group of Flagellata presenting the physiological characteristics here submitted, has been entirely overlooked, its representatives being simply collated with the ordinary mouthed or mouthless species. Even Stein, in his recently published monograph,* erroneously represents such unmistakable Pantostomatous forms as *Oikomonas*, *Spumella*, and *Anthophysa* as possessing a well-defined oral aperture.

The *Flagellata-Pantostomata*, in common with the order of the Eustomata, may be conveniently divided into three minor sections or sub-orders, with reference to the number of flagellate appendages, as indicated in the foregoing schedule.

A.—Pantostomata-Monomastiga

(one flagellum only).

Fam. I. MONADIDÆ, Ehrenberg.

Animalcules naked or illoricate, entirely free-swimming; flagellum single, terminal; no distinct oral aperture; an endoplast or nucleus and one or more contractile vesicles usually present.

Genus I. MONAS, Müller.

Animalcules free-swimming, exceedingly minute, globose, ovate, or elongate, plastic and unstable in form, possessing no distinct cuticular investment; flagellum single, terminal; food-substances incepted at all parts of the periphery, not provided with a distinct mouth; a nucleus or endoplast and one or more contractile vesicles mostly conspicuous; multiplying by longitudinal or transverse fission, or by encystment and the subdivision of the entire substance of the body into a less or greater number of sporular elements.

Inhabiting salt and fresh water, especially abundant in infusions.

In the genus *Monas*, as here delimited, are included the simplest known forms of the typical Infusoria-Flagellata. Its specific representatives exhibit, so far as at present discernible, no higher degree of organization than that of mere specks of more or less granulate and vacuolar nucleated protoplasm, and possess as a locomotive appendage a single thread-like vibratile flagellum. Their extreme simplicity of contour, combined with their very minute size and apparent absence of all readily appreciable differential characteristics, necessarily renders it an exceedingly difficult task to discriminate between the innumerable so-called species that have from time to time been referred to this genus. A large proportion of these latter are without doubt

* 'Infusionsthiere,' Abth. iii., 1878: Der Flagellaten.