PHASES

IN

THE DEVELOPMENTAL HISTORY OF INFUSORIAL, ANIMAL LIFE.

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PRINTED BY DESIRE OF THE PRESIDENT AND MEMBERS OF THE OLD CHANGE MICROSCOPICAL SOCIETY

FROM

" THE INTELLECTUAL OBSERVER."

LONDON.

MDCCCLXVI.

HARRILD PRINTER LONDON

PHASES IN THE DEVELOPMENTAL HISTORY OF INFUSORIAL, ANIMAL LIFE.*

THE elucidation of the mystery which surrounds the beginnings of organic life, and the discovery of the living principle which exerts so powerful an influence on all animated creation, has often and long been sought for by philosophers as well as physiologists, from the earliest ages down to the present time; but all their efforts have been in vain, and we stand in precisely the same position in regard to this subject as that occupied by the first philosopher who entered upon its investigations. Although we have not been able to throw much light on the nature of life, we find that the degree of vitality possessed by an animal is to a great extent in proportion to the degree of its organization, and we may conclude from this that there is an intimate connection between life and organization. Not that organization can create life; of this we have no instance at all, but that the principle of life, which exists in and has been given to any organic germ is only brought to maturity in accordance with the original law of its organization; and by means of this *principle of life* it is enabled to pass into a state of greater perfection, constituting what has been called, and is now recognized as the *law of progressive development*. First, let me say that I do not purpose to enter upon any inquiry into the precise nature of life, such as I have just hinted at, but rather let me on this occasion direct attention to some points of interest in the developmental history of infusorial life.

On the threshold of this inquiry a remarkable theory, and one which cannot be passed over without discussion, stares us in the face, "Whether among the smallest, and apparently the most elementary forms of organic life, the phenomenon of spontaneous generation obtains?" This question has quite recently formed the subject of careful experiment and animated discussion on the continent; the *general* opinion, however, seems to be that the lowest forms, in common with the highest, are generated by reproduction from preceding forms.

Aristotle found no difficulty in believing that worms and insects were generated by dead bodies; and to the mind imperfectly acquainted with the results of modern investigations, spontaneous generation is as easy of belief as it was to Aristotle.

* Being the substance of a Lecture, delivered to the Old Change Microscopical Society, Sept. 27th, 1866.

Do we not constantly see vegetable mould covering our cheese, our jam, our bread? Even our air-tight vessels cannot be kept free from plants and animals, where neither plant nor animal could be seen before, and where it appears impossible that their seeds could have penetrated. Where do those parasitic animals come from which are to be found in the blood, the brain, the liver, and the eye? How got they there? These questions are more easily answered on the supposition that generation can take place spontaneously; nevertheless, the weight of scientific evidence has been year after year accumulating against such a supposition, and the majority of physiologists have come to the positive conclusion that no generation whatever can occur except by direct parentage.*

And yet how difficult at times to divest the mind altogether of some such theory, when asked to account for the apparently sudden appearance in a most unlikely place, of some such extraordinary creature as that of Mr. Crosse's *acarus*. This little animal was found in a solution of silicate of potash, through which an electric current was passing, and after every care had apparently been taken to free the apparatus from every particle of dust and foreign matter. Or that noticed by Dr. Maddox on the surface of a nitrate of silver bath, which had been set by for some time: when the several bright spots in motion proved to be well-developed, highly-organized acari, looking like "miniature fat sheep."†

These, and other like remarkable instances were at one time regarded as good evidences of spontaneous generation, and afforded a simple and easy mode of getting rid of a difficulty.

The first formidable assailant of the doctrine of spontaneous generation was the celebrated Italian naturalist, Redi. In his work *On the Generation of Insects*, he proved that the worms and insects which appear in decaying substances, are really developed from eggs designedly deposited there by the mature animal. But it was thought preposterous to suppose that putrefaction could produce an insect, and this explanation was for a time rejected. But driven from the insect world, where such an hypothesis could have no chance of success, the upholders of it sought refuge in the world of infusorial and parasitic life.

Any one acquainted with the writings of Leuwenhöek will see how steadily this father of microscopy set his face against spontaneous generation, because even his imperfect instrument showed him that many of the most minute animals produced eggs, and were generated like the larger ones. Since his time

* Lewes.

† *Quarterly Journal of Microscopical Science*, vol. ii. p. 96.

hundreds of observers have brought their contributions to the general stock, and the modes of development of plants and animals have been more and more clearly traced; and each extension of knowledge in this direction has had the effect of narrowing the ground on which the spontaneous hypothesis could possibly find a footing; and the question now comes to this: "Is it more probable that a law of generation which is well nigh universal in the organic world, should have an exception; or that our researches have as yet been so faulty that we have not as yet been able to bring this seeming exception under the law? One after another, cases which seemed exceptions have turned out to be none at all. One after another, the various obscurities have been cleared away, and it is therefore the dictate of philosophic caution which suggests that so long as we remain in positive ignorance of the actual process, we must assume that a general law prevails."*

Positive evidence would at once settle the dispute, and I take this opportunity of directing ardent and aspiring microscopists to the question, as one well worthy any amount of time and trouble; but I must tell them beforehand that every one who has hitherto made any experiments, or attentively followed those of others, has found it exceedingly difficult to devise any experiment which shall be conclusive. This arises, first, because the facts elicited admit of very different interpretations; and secondly, from numerous sources of error. "For it is quite true that there are organic beings of which we can as yet only say that there is the strongest presumptive evidence against their being exceptions to the otherwise universal law to which I have alluded. As an instance, we do not know how the *Amœba* arises, no one has even seen its eggs, or ever been a witness of its mode of reproduction; and yet we find the *Amœba* in almost every drop of rain-water, and most vegetable infusions, so that we may be perfectly certain that its ova are carried about by every breath of air." Schultze, of Berlin, devised an experiment which might have been thought to settle the question. This experiment proved that an infusion of organic substance, supplied with air driven through a strong acid, could be suffered to remain for three months without either any animal or vegetable life becoming apparent. At the end of that time atmospheric air was allowed to enter freely, and in three days the infusion was found to be swarming with animalcules.

It will be at once observed that the essential condition in such an investigation is to be quite certain that no organic germs are introduced into the liquid from without, and that there should be secured a free supply of air, carrying no

* Lewes.

organic germs; on the hypothesis that animalcules, like other animals and plants, are produced from germs or eggs, which might be in the water and yet so excessively minute as to be easily overlooked, and only awaiting the proper *conditions* for their speedy development; or, on the other hand, supposing them to be floating about in the air, they would fall into or enter any vessel containing organic matter in a state of decomposition and there develop. Schultze's experiment, then, looked very like a conclusive one, for no sooner were measures taken to destroy the germs, supposed to be suspended in the air, than the infusion was kept free from animalcules; and no sooner was the air allowed to enter in the ordinary manner than both animal and vegetable life abounded. It was thought, however, by M. Morren, that air in its passage through sulphuric acid underwent some alteration which affected its power of supporting life; and upon putting this to the test, he found that air passed through sulphuric acid was incapable of sustaining life. We have then, M. Pouchet's experiments, which are of a most imposing character. He announced that there was nothing in either Schultze's test or Morren's correction, for he declared that in following the former's experiment in every particular, and also in repeating it with fresh precautions, he could constantly find both plants and animals in an infusion in which every organic germ had been previously destroyed, and to which the air only had access after passing through concentrated sulphuric acid, or through a series of porcelain chambers kept at a red heat. M. Pouchet even goes farther than this. He determined to substitute for atmospheric air, *artificial air*; this he introduced into a flask containing an infusion of hay, the *hay* having previously been subjected for twenty minutes to a heat of 212° F. He thus guarded against the presence of any germs in the infusion or in the air. The whole was then hermetically sealed; but in spite of all these precautions, both plants and animals appeared in the infusion. He repeated the experiment with pure oxygen gas instead of common air and with similar results.

Professor Wyman instituted a series of thirty-three experiments, prepared in different ways, in which solutions of organic matter, some of them previously filtered, having been boiled at the ordinary pressure of the atmosphere for a length of time varying from fifteen minutes to two hours, were exposed to air purified by heat. In only four were the contents of the flasks unchanged when opened; in all the rest *Bacteriums*, *Vibrios*, *Ferment-cells*, *Monads*, or *Kolpoda-like* bodies were seen, some of them having ciliary movements. In nearly every instance their presence was indicated by the formation of a film, which appeared in some on the second, and in others not until the nineteenth day. The result of these experiments is, that the boiled solutions of organic matter made use of, exposed only to air which has passed through tubes heated to redness, or enclosed with air in hermetically sealed vessels, and exposed to the heat of boiling water, became the seat of infusorial life; but such experiments throw no light on the immediate source from whence the organisms in question were derived. I have shown repeatedly, as well as numerous other observers, that the air contains many kinds of organic matter, spores of cryptogams, starch granules, and other vegetable fragments, and probably also the eggs of many animalcules, all of which are floating freely about.

Milne-Edwards objected to the conclusions of Pouchet, saying, there is no proof that the hay itself had been subjected to the temperature of boiling water, it being very probable that although the furnace was at that heat, the hay, which was in a glass vessel and surrounded with air at rest, was not at anything like that temperature. On the other hand, granting that the temperature may have been reached, that would not suffice for the destruction of all the germs if they were perfectly dry; the power of resistance possessed by vegetable silicated cylindrical tubes, as hay and straw, is well known. The observations of M. Doyere prove that the *Tardigrada*, "water-bears," when thoroughly desiccated, preserve the power of reviving even after having been subjected to a temperature of 316° F. The *Vibrio tritici* will maintain its vitality for many years through all the vicissitudes of heat and cold. I have kept wheat for ten years, and still find these animals easily resuscitated; and Mr. Deane mentions a remarkable fact, "that on a particular piece of land whenever wheat is grown it is always infested with *Vibrio*, no matter what the length of time since the previous wheat crops, nor what crops have been sown in the meantime." If, therefore, animals of so complex a structure as these *Tardigrada* and *Vibrios* can resist the action of time and temperature, there is no reason for supposing that the germs of the simpler animalcules would be destroyed by them.

The Rev. Lord Sidney Godolphin Osborne, in a letter filled with interesting remarks on "Cholera and its germs," which appeared a few weeks ago in the columns of the *Times*, writes—"I know from experiment that there are 'germs' containing a principle of life, that will stand very strange usage, and yet not have that principle destroyed. Many years since I applied a certain matter to a piece of glass about four inches square. This has another very thin piece cemented close over it on three sides, leaving a space just sufficient for a thin stratum of water between the two. It has been exposed for days to the action of the direct rays of the sun, it has been kept in the dark, and sometimes has been for a year or two in a very dry place without a particle of water touching its surface. To amuse friends I have again and again allowed a little water, sometimes filtered, generally of the coldest *spring* nature, to fill up the space between the two glasses—water I had previously tested for any living organisms. I have never failed to produce, in a few hours, a most beautiful exhibition of one of the most interesting species of Infusoria, having beforehand sketched the exact creature I would produce. With the same water, in another glass tank of the same nature but not so prepared, I fail to produce anything at all until it has been left for some days, and then the creatures seen are not my old friends. I have read, not seen, that these organisms retain their vitality even when the glass has been made red hot. I don't say I believe it, but from what I have seen I think it quite possible."

I have myself found, upon subjecting the spores of *Penicillium* to the action of boiling water, twice over, that they remain uninjured, their vitality is so little impaired that on placing some of them in saccharine solutions and other substances, carefully excluded from the air, a very short time sufficed to show the presence of the characteristic mould growing up from the spots where the spores rested, and microscopic examination confirmed the character of the growth.

M. Quatrefages says, that he examined the dust remaining on the filter after ignition from some observations on rain-water, and found that the organic elements presented a confused assemblage of particles, and this continued to be the case for a few minutes after their immersion in water; but in a few hours he detected a great number of vegetable spores, infusoria, and those minute spherical and ovoid bodies familiar to microscopists, which inevitably suggest the idea of eggs of extremely small size. He also declares that he has frequently seen monads revive and move about after a few hours immersion.*

M. Pouchet's reply is, that if the air be filled with animalcules and their eggs, they will fall into any vessel of water, and as water is their natural element, will there exhibit their vitality. But if half-a-dozen vessels of distilled water, perfectly free from animalcules, be left exposed to the air beside one vessel of distilled water containing organic matter in decay, the half-dozen will be free from animalcules and eggs, but the one will abound with them. Now it is perfectly intelligible that inasmuch as organic matter is said to

* Mr. Samuelson examined the dust shaken from rags brought from Alexandria, Trieste, Tunis, Peru, and Melbourne, and found in all germs of *Monads*, *Bacteriæ*, and *Kolpoda*.

form the indispensable condition for the development of the eggs, it is only in the vessel containing such matter that the eggs will develope; but why are they not also visible *as eggs* in the other vessels? Why are not the animalcules themselves visible there as they were in the water examined by M. Quatrefages?

My reply to Pouchet's question is, that in all the vessels ova had probably been deposited, but, that they had quickly died in five for lack of nourishment. It is well known that in all organized structures, disorganization rapidly sets in, unless either some vegetable matter or a well-oxygenated medium be ready at hand to carry the ova on to maturity. And as to their not appearing in all the six vessels, I can only say that this does not accord with my experience; for upon exposing any number of bottles to the same atmospheric influences, all have given positive results, and I can only suppose that M. Pouchet either made a very imperfect and cursory examination, or his microscopic manipulation must have been greatly at fault.

A few years ago an observation made by Cienkowski, the botanist, seemed finally to settle the question of spontaneous generation, and to place the matter beyond doubt, because it caught nature in the act, so to speak, of spontaneously generating. Cienkowski's statement is as follows:—If a slice of raw potato be allowed to decompose in a little water, it will be found, after some days, that the starch cells have a peculiar *border*, bearing a strong resemblance to a cell-membrane. This shortly turns out to be a real cell-membrane, and is gradually raised above the starch grain, which then occupies the position of a cell-nucleus. Thus, *out of a grain of starch a cell has been formed under the observer's eye.* Inside this cell little granular masses are developed, which begin to contract. Finally, minute eel-like animalcules (a species of *Anguillulidæ*) are developed there, which bore their way through the cell-wall into the water.

Franke, in his report of this observation, which he says he has verified, asks, "how is it possible to deny spontaneous generation here? Before our eyes a grain of starch becomes a cell, in that cell are developed living forms, which bore their way out." Again, Professor *Naëgeli* stated that he had been baffled at first in the attempt to verify this observation, but that after nearly a hundred trials he had succeeded; he appears to have confirmed all the statements made by Cienkowski; but if the phenomenon were of such rare occurrence, surely there must have been some other explanation than that of spontaneous generation.

It seemed probable that error had crept in somewhere. Cienkowski himself at length discovered the source of his own error: the membrane which seemed to form itself round the starch granule had quite another origin. He observed the little *Monads* swimming about, and noticed one of them adhere to a starch grain, spread its elastic body round it, and finally envelope it, just as the *Amœba* does its food. Thus was explained how the starch grain came to be inside a cell; and as this process was never suspected, and as the starch-grain was within a cell-wall, the idea of natural formation was inevitable, the more so as the wall seemed to grow larger and larger.

M. Pasteur, who has been the leading and most determined opponent of the spontaneous generation theory, contrived a series of experiments which met many of the arguments brought forward by Pouchet; he thought it was possible to obtain, in some place, atmospheric air so pure that it would not produce any change whatever in a putrescible liquid. M. Pouchet, Joly, and others, in their desire to meet this idea, ascended the glacier of La Maladetta, in the Pyrenees, taking with them a number of flasks, each one-third filled with an infusion of hay, which had been previously filtered and boiled for more than an hour. The air was then exhausted, and the flasks hermetically sealed. Four were then afterwards filled with air on the surface of the glacier, and four in a crevasse. The examination of four of the flasks, three days afterwards, gave specimens of *Bacteria, Monas, Vibrio, Mucidinea*, and *Amœba*. The conclusion drawn from this was that even the air of high mountains did not fulfil the conditions which M. Pasteur predicated of it. Nevertheless M. Joly said that he believed that M. Pasteur was quite right in his statement that all that was required for the production of animalcules was "air and a liquid susceptible of putrescence," and that in his opinion there is no such thing as "spontaneous generation."

M. Pasteur goes on to state that the doctrine of spontaneous generation may be expected to be constantly turning up, since it maintains a hold over us, unknown to ourselves, from its relation to the impenetrable mystery of the origin of life upon the surface of the globe. Gay Lussac's report of his examination of the method of preserving provisions for the army, was not without its influence on the minds of men on the subject now under consideration. He proved that when the air in the bottles in which substances have been well preserved is analyzed, it no longer contains oxygen, and consequently that the absence of that gas is a necessary condition for the conservation of animal and vegetable substances. He also found that grapes crushed under mercury do not undergo fermentation unless brought into contact with pure oxygen, or with common air, even in a scarcely perceptible quantity. Such experiments, made with so much exactness and care by so great a master of chemistry, have never been disputed, and other observers, following in his footsteps, have extended their researches to the organisms which arise in vegetable infusions; and all, whether partisans or opponents of the theory of spontaneous generation, admit that the smallest possible quantity of atmospheric air is sufficient, when brought into contact with a suitable infusion, to produce in a short time such changes, that there appears an incredible number of minute forms of animal life. The character of the infusion most decidedly exerts an influence over the ultimate results; as for instance when any kind of albuminous material is added to the saccharine fluid, the spores of a fungus, *Penicillium glaucum*, cover the surface in a few days; the infusions are also affected by the atmospheric conditions, whether summer or winter, by locality, whether placed inside or outside the house, in town or in country.

To sum up, and in a few words, after having carefully considered the arguments used by disputants on *both* sides of this question, I believe I am perfectly right in saying that the balance of experiment is certainly very much against the spontaneous generation theorists; but so much has been said and written on this subject, that we might, if space permitted, greatly extend our remarks. There is, however, another point deserving of notice, which appears naturally to follow an inquiry into the source of living organisms, namely, the order of their successive appearance in vegetable infusions. This point in the life history of the infusoria has already occupied the attention of many investigators: and one in particular I wish to direct attention to,—Mr. Samuelson, whose researches were carried on in conjunction with Dr. Balbiani of Paris, and confirmed by him. As might have been expected of this gentleman, he starts by asserting his utter disbelief in spontaneous generation, and then goes on to tell us that when a carefully prepared infusion of vegetable matter in distilled water is exposed to the air, the *Protozoa* which first appear in it are *Amœba:* these in a few days disappear, and are succeeded by ciliated infusoria, such as *Kolpoda, Cyclidium glaucoma*, and sometimes *Vorticella*, and these in their turn by what we have looked upon as higher forms, as *Oxytrichum, Euplotes, Kerona*, etc., consequently Mr. Samuelson thinks that *Monads* are but the larval condition of the ciliated infusoria. He also noticed the constant occurrence of *Monads* belonging to the species *Circomonas fusiformis*, or *acuminata* of Dujardin, etc., in pure distilled water after a certain exposure to the air, and this without the previous admixture of vegetable matter of any kind in the water. The same results were obtained upon shaking rags, from various and distant parts of the world, over the distilled water; other experiments were also tried, and in all cases in about three weeks he invariably obtained forms of ciliated infusoria. "The fusiform body of the *circomonas* bears a long whip-like cilium at its anterior end, and a short seta at its caudal extremity: this finally drops off, and when exposed to undue heat and light, the animal is transformed into an *Amœba.*"

Mr. Samuelson's results do not very materially differ from my own, save in one or two particulars. I have not seen the succession of generations take quite the same course, and the animal and vegetable bodies generally appear simultaneously, or so soon after each other, that it is at times difficult to decide the priority of appearance; but as my experiments have been chiefly confined to collections of rain and distilled water, *without* the addition of vegetable matter of any kind, this will materially affect the results. We are, however, quite agreed as to the wide and general distribution and great tenacity of life presented by these infusorial germs. With regard to the supposed purity of rain-water, at no time can it be taken without the numerous matters floating in the air being brought down with it, and, consequently, within a few hours after it is caught, *Protococcus pluvialis, Amœba,* and *Circomonas,* may always be found in great numbers. It is somewhat remarkable that the purest snow water, caught in a clear glass vessel, and allowed to remain well-corked, will, in the course of two or three weeks, be found to contain *Amœba* and *Circomonas,* but it rarely presents other forms of animal life; the vegetable matter completes its growth very slowly, gradually passes to confervæ, and for a time no other change is seen to take place; so that it is painfully apparent that the atmosphere in which we live and move and have our being is something more than a mixture of gases, as apparently determined by chemical analysis.

Mr. Glaisher's "*blue mist,*" which he believes to be in some way associated with our cholera visitations, certainly does not depend upon the presence of any unusually large number of spores floating about in the air. Although spores, etc., exist, as I have shown, in the atmosphere, in greater abundance about the period of such visitations, they also exist when the public health is good. And therefore it should be regarded as a mere coincidence, if certain bodies prove to be more abundant during the prevalence of epidemic disease. But this "fungus-spore" theory is no new thing, for it is upon record that rusts and mildews have sprung up so rapidly upon articles of food and clothing, as to have appeared to herald approaching plagues. A so-called "blood-rain" is said to have been the forerunner of the plague of Rome. It has been noticed, however, that the present year (1866) has been especially characterized by the prevalence of all kinds of moulds and mildews upon vegetation generally; we consequently find the air thoroughly charged with the germs of *Uredo* (smut) and *Penicillium;* and we may readily believe that the same depressing influences that render the human family subject to epidemic disease also affect vegetable life, and the weakly and sickly plant equally with the higher human creature, goes to the wall, and may ultimately furnish the nidus for a colony of parasites.

In all my collections of rain, snow, and distilled water, animal and vegetable life proceeds to one definite point, and then recedes. I have never found any go beyond *Euglena;* and unless some vegetable matter be added to the solution, no higher form of life appears; on the contrary, a retrograde condition takes place. If some kind of vegetable matter, as hay or lettuce-leaf, be added, then I find, with Mr. Samuelson, rotifers make their appearance—not otherwise. But here, again, we get no further, and the infusion requires a something more to give it a start on in life. As might be predicted, these changes are all modified, accelerated, or retarded by the action of light, heat, season, and so forth, and by the presence of any albuminoid material. If fresh-caught rain water be filtered and excluded from atmospheric influences, the appearance of both vegetable and animal life is very much delayed; but when fresh and clean rain water is exposed to the air, *Protococcus* quickly makes its appearance, and with it *Amœba*; the cells of the *Protococcus* soon throw off zoospores, and the *Amœba* take possession of the cells and feed upon the zoospores. I mention this latter circumstance, because some observers, both before and since Cienkowski, having doubtless seen the same occurrences, have stated their belief in the conversion of the contents of the cells of the *Protococcus* or *Chlamydococcus* into a free moving mass of amœboid bodies.

Mr. Carter, well known for his valuable contributions to microscopical science, was one of the first to notice and promulgate this apparently impossible transitory condition of the volvox-zoospores; but he afterwards saw fit to change his opinion, and in place of looking upon it as the conversion of the vegetable protoplasm into that of an animal, he now believes that the germ of the *Amœba* must have been included in the vegetable cell, or as a parasite made its way into its interior; and remarking upon his first statement, that *Acitenæ* are thrown off by *Vorticellæ*, he writes thus: "Seeing, then, the great analogy, if not real identity, that exists between the nature of these organisms, I would suggest that the germ of the *Acitenæ*, like the egg of the *Ichneumonidæ*, becomes encysted in the *Vorticellæ*, and lives upon its host." *

* Carter. *Note on Organization of Infusoria.* Ann. Mag. Nat. Hist. Series 3. Vol. viii., p. 207.

To my mind this view scarcely admits of a doubt, and it is clear that the young of the *Amœba* in some manner find their way into the cell, just as it is on the point of breaking up, and so become developed in a situation where they are at once provided with a due amount of nourishment for the support of their earliest state of existence. I must not, however, omit to say that no less an authority than Dr. Hicks still holds to the former opinion, and fully believes, after many careful observations, that these bodies, which move freely about in the cell, ever changing their position, protruding and retracting portions of their membranous walls, exactly as the *Amœba* do, are really and positively what they appear to be, animals belonging to the class of *Rhizopoda*. He further observes, that after the amœboid bodies have begun to shift about in the cell, for every such moving body there was a corresponding empty space; and he cannot suppose it possible that any parasite could enter the cell from without, but that every examination tends to confirm his opinion that the amœboid organism is really the product of the metamorphosis of a mass of vegetable protoplasm.

Another careful observer, Mr. Archer, of Dublin, has also recorded the development of amœboid bodies in the cells of *Stephanosphæra pluvialis*; he looks upon the phenomenon as analogous to that which is known as occurring in one of the stages of development of the *Gregarinida*, the encysting stage; the central nucleus and vesicle disappear, and after a certain time "the mass breaks up into a series of rounded portions, which become elongated and slightly pointed at each end, constituting a little body which has been called a 'pseudo-navicella,' from its striking resemblance to the Diatomaceous navicula; the capsule next bursts, and the pseudo-navicellæ are scattered, and pass out of the body of the creature which they inhabited." *

Dr. Hicks believes that he has seen the young volvox pass into an amœboid state; in other words, the conversion of the protoplasm of a vegetable cell into an animal. He says, "Towards the end of the autumn the endochrome mass of the volvox increases to nearly double its ordinary size, but instead of undergoing the usual subdivision, so as to produce a *macrogonidium*, it loses its colour and regularity of form, and becomes an irregular mass of colourless protoplasm, containing a number of brownish granules."†

* Huxley.

† I have continuously had the volvox under the microscope during the past summer and autumn, and made more than a hundred examinations without having once seen anything approaching to the form of an *Amœba* in the interior of the cell.

The final change and ultimate destination of these curious amœboid bodies have not yet been made out; but from Dr. Hicks's previous observations, made on similar bodies developed from the protoplasmic contents of the cells of the roots of mosses, "which in the course of two hours become changed into ciliated bodies," he thinks it very probable that this is designedly the way in which these fragile structures are enabled to retain life, and to resist all the varied external conditions, such as damp, dryness, and rapid alternations of heat and cold. "The philosophic mind," observes Mr. Carter, "takes up this line of argument." No one can at first sight witness the changes which take place, almost like a dissolving view, in the protoplasm and chlorophyll of *Chlamydococcus*, *Eudorina*, and in that of the cells of the *Algæ* generally, and during which they pass from their original form into that of a rhizopod, without inferring that the form produced is merely another one of that which preceded it, and not an absolute change. Hence my description of the fancied passage of the vegetable protoplasm into *Actinophrys*."*

Passing on to the consideration of another stage of this inquiry, we must be struck with "the remarkable powers of multiplication by fission and gemmation which many of the group exhibit; within the last few years the investigations of Müller, Balbiani, Stein, and others have shown that these minute creatures possess a true process of sexual reproduction, and that the sexual organs are those which have been hitherto denominated the 'nucleus' and 'nucleolus.'"† And ultimately it will be found that the infusoria have a life history as important as that of the higher classes of animals. Dr. Grant in 1851 recorded the presence of ova in one of the marine sponges (*Tethya*), thus showing that the Protozoa formed no exception to the other sub-kingdoms of animals in the possession of these essential elements. Five years later his observations were corroborated by Lieberkühn, in the case of one of the fresh-water sponges. Even then the existence of the generative elements still remained to be demonstrated in the Infusoria. Ehrenberg, it is true, had drawn particular attention to the "nucleus," and some others took note of certain minute filaments, but there these observations rested. Now, however, the whole aspect of this subject is changed, and for the vagueness which, four or five years ago, charac-

* The circumstances under which the moss-roots should be placed to show these phenomena, are to float any common moss on a glass of water in the shade; and when the radicles thrown out are of a considerable length, they may be removed to the slide and examined. Care must be taken not to expose them to too much light and heat."—Dr. Hicks's *Quarterly Journal of Microscopical Science*, 1862, p. 103.

† Huxley.

terized all attempts to explain anything like a generative function in the Infusoria, we have substituted, by Balbiani, a clear and complete survey of their leading phenomena. The Infusoria have long been known to multiply by spontaneous fissure, gemmation, and the production internally of various formed bodies, which many observers have described under the name of "embryos." The phenomena of "encysting," "conjugation," etc., which these minute bodies frequently exhibit, and the relation, real or supposed, between such processes, and their various modes of propagation, have from time to time afforded matter for no little controversy. M. Balbiani's investigations, however, derive additional interest from the very complete manner in which they have been carried out. As an instance of this, he states that in his examination of *Paramœcium aureliæ* he could not look upon them as conclusive until he had succeeded in extracting uninjured some of the eggs from the parent body, and had subjected them to the action of the surrounding water; when he saw each egg resolve itself into two portions, the smaller being enclosed within the larger, then by employing reagents, acetic acid and iodine, he produced the changes more rapidly; and in this way again and again obtained abundant proofs of the truth of each observation. So much then for Dr. Balbiani's researches on the phenomena of reproduction among the Infusoria, which have added most valuable information to our former meagre knowledge of these interesting forms of organic life.

The case of the Infusoria is, in some respects, comparable to the fertilization of Orchids, which Darwin has investigated with so much care, and rendered doubly interesting by showing how highly complicated are the contrivances by which among this beautiful and extensive group of hermaphrodite plants, fertilization is accomplished, and that, save in a few exceptional instances, self-fertilization is almost impossible. Comparing the Infusoria with Orchids, we may see that their fecundation is effected by constant dissimilar elements produced in different individuals; and in both cases the details of the process are curiously varied in their several tribes.

In 1819 Chamisso detected the mode of reproduction of the *Biphoræ*, and coined the term, "Alternation o Generations."* He found that the isolated *Salpæ* only produced chained-salpæ, and then only by gemmation; whilst the chained-salpæ produced isolated ones, and only by ova. The discovery of the now well-known life history of the *Medusæ* was next made by Saars and Siebold; it was shown that the *Medusa aurita* deposits an egg, which gives rise to a polyp,

* This term is more generally associated with the name of Steenstrup, the well-known author of a learned and valuable treatise on the subject.

which grows by gemmation and fissuration, and produces from a single individual several small Medusæ, which again in their turn produce ova. Other phenomena were soon collated with these, as the fissiparous generation of Annelidæ, the various processes exhibited by certain Spongidæ and Infusoria. In 1845, T. Müller described the remarkable larvæ of the *Echinodermata*, from whose viscera the future perfect being is thrown off by a process of gemmation; and the researches of Kuchenmeister and Van Beneden afterwards fully illustrated the remarkable migrations and metamorphoses of the Helminthoid worms. "In the *Distoma* the embryos have at first the form of ciliated monads, these are metamorphosed into Gregarinaform worms, and in the interior of each of the latter, numbers of *Cercariform*, or tailed animalcules, are developed, which ultimately become true Distomata."

Quatrefages and Professor Goodsir, however, look upon all this as simply a part of the process of growth, comparable to the growth of a lost or mutilated limb in the Crustaceæ. The gemmation of the Hydra, the medusification of the Polyp, the peculiar virgin-propagation of the Aphis, the segmentation of the Nais, the gradual development of the Echinoderm within its Phitean larva, and all similar instances, are regarded as mere phenomena of *growth*, and not as illustrations of the *Parthenogenesis* of Owen. And this view is now held by nearly all biologists. We might even go a step further and point out that recent investigations have established the wide spread existence of *polymorphism*. One of the fungi has been known to possess six different kinds of fructification; the *Uredo* exhibits four, and others might be named, which were formerly looked on as distinct species.

In some of the gemmiparous animals new creatures are at times multiplied to an almost incredible extent by simple mechanical division. I have seen, after breaking away an Actinia from the side of my aquarium, a number of small pieces of the foot-stalk left adherent to the sides of the vessel; all of which fragments became in a few days perfectly-formed young Actiniæ. The *Hydra viridis* may, as we know, be divided longitudinally, or transversely, into several parts, and each part will become a perfect polyp; or if a wound be made in the body of the animal, a new one sprouts from the site of the injury.

"The gemmiparous form of generation is met with in a large variety of animals. It exists in the Infusoria, Entozoa, Polypi, Medusæ, Annulata and Tunicata. In the *Nereis* a constriction first appears in the tail of the animal, immediately behind which the head of a new *Nereis* is developed, and the posterior division becomes separated from the anterior, or parent, as a perfect animal. In this form of reproduction animals are formed, not from ova, or from the fission of primary reproductive cells, but from secondary or derivative germ-cells, placed in reserve in the tissues of these animals. The same process occurs in the *Triton* or the lobster, when a broken-off claw or tail is replaced, the new formation springs from derivative germ-cells placed in the claw or tail—that is, a reserve of derivative germ-cells, not wanted for use in the general development, is deposited in these different parts of the body."*

Professor Goodsir believes that "the regenerative faculty does not reside at any part of the claw of the lobster indifferently, but in a special locality at the basal end of the first joint. This joint is almost filled by a mass of nucleated cells surrounded by a fibrous and muscular band."

With respect to the Hydra, its reproduction is indifferently by gemmation or by true ova. The young hydra from the egg is identical in structure and character with that produced by budding. Nearly all writers now regard gemmation and generation by ova as two essentially distinct processes; nevertheless, the identity of the results is clearly seen in Mr. R. Crouch's observations on the Sertularian Polyps. "At certain seasons of the year," he says, "they produce cells much larger than those of a more permanent character. These are at first composed of the granular pulp of the stem, afterwards the pulp becomes furrowed, and finally formed into cells. After a short period they separate from the parent, and undergo the process of development. If these cells attain a certain size they are developed into eggs: if, on the other hand, they are stunted by cold, or otherwise interfered with, they are formed into polyps, while, if from further unfavourable circumstances they are rendered still smaller, they grow into branches, and thus we see that, according to circumstances, different organs are capable of being eliminated from the same structure."

It appears, then, that there are three forms of reproduction, fission, gemmation, and generation by ova; in other words, "*Fissiparous*, when a cell spontaneously divides into two or more: *Gemmiparous*, when a plant or animal sends forth young branches from its stem; *Oviparous*, when the young are produced from seeds or eggs." If we endeavour to arrange the known facts of reproduction, proceeding from the simple to the more complex, we must begin with a very simple process; namely, that of a single cell spontaneously multiplying itself by subdivision. In all the albuminous, starchy, or gelatinous matter called *protoplasm*,* a single cell appears, it assimilates

* Huxley's *Lectures on Comparative Anatomy.*

† πρῶτος, first, πλάσμα, formative substance.

more and more of the fluid portions of the protoplasm, and then divides into two parts, perfectly symmetrical; these two quickly divide into four, eight, or sixteen, and so go on multiplying until a number of cells is produced, each cell being attached to its fellow by its wall, but capable of a separate existence. By this process of subdivision, a single cell of *Protococcus nivalis* (Red snow plant) has been known to redden in a single night vast tracts of snow, and the *Bovista giganteum* is estimated to produce in one hour no less than four thousand millions of cells. Ehrenberg computed the increase of the infusorial animalcule, *Paramœcium,* at two hundred and sixty-eight millions in a month. This simple mode of reproduction is certainly identical with that of growth of both plants and animals of a higher type.

If we ascend a step we reach the second form of reproduction, namely, the union of two *similar* cells, termed by botanists *"conjugation."* This consists in the coalescence of two similar cells to form a new starting point from which multiplication may proceed. Instead of two cells in the same filament we may have two cells in contiguous filaments coalescing, but in each case it is the union of two similar cells. From the fission of one cell into two, and the conjugation of two similar cells, we pass to the third mode of reproduction, namely, *generation by ova,* or the union of two dissimilar cells, and for the production of the more complex organisms, the union of germ- with sperm-cells is indispensable.

By these several separate modes of reproduction we must admit that there is nothing more marvellous in an animalcule producing several millions of its kind, than in a plant constructed by as many cells, each produced by a process identical in every way. In the development of the tissues of the animal body, the newly-formed cells increase by division: and become determined in their growth by the character of the secretion elaborated within the walls of those previously existing. The formation of the more complex animal tissues takes place in the same way as that already noticed in plants, with this difference, that the mother cell contains a nucleus, within which is seen a very minute body called a nucleolus. The nucleus has the power of appropriating, or drawing in, a certain portion of the surrounding material, protoplasm or sarcode, enlarges and ultimately divides into two perfect cells. From the aggregation of such cells we have the animal body built up in all its complexity.

We have thus far traced the development of organic life through some very curious and highly interesting stages, and we have seen that life, in all cases, whether in the highest or lowest forms, depends upon perfection of organization for development and maintenance; but it must not therefore, as we said before, be supposed that it is altogether the result of organization, for death may occur without any trace of organic lesion to account for it. Nevertheless, the extent of organization necessary to the enjoyment of life is apparently very small indeed. A simple cell constitutes the entire organism of such plants as the *Chlamydococcus* or the *Palmella cruenta*, or even an animal, as the *Amœba*, and in these and such like simple structures resides a vital principle on which its integrity depends. But whatever the *extent* of organization may be, its perfection is essential and necessary to the maintenance of life; for, as we now know, the seed which has been dormant a thousand years will, if its organization be perfect, spring into activity when planted; but if crushed, its living principle is destroyed, and it will no longer germinate. Thus it is exemplified that to those minds familiarized with the phenomena of life, as manifested by the simpler organisms, the microscope "is not the mere extension of a faculty, it is a new sense."

HARRILD, PRINTER, LONDON.