III.—*The Development of Organisms in Organic Infusions.*

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HAVING made various experiments on the connection between animal and vegetable organisms in their lowest phases, a brief statement of them, and of the conclusions to which they lead, may not be without interest. A piece of a wine-bottle cork having been put into a small glass stoppered bottle of distilled water, two or three days afterwards, on examining the water under the microscope, I found that very fine filaments had been produced from some of the cork cells. There was no appearance of articulation in the filaments themselves, they having rounded bulging ends, by exudation from which the growth of the filaments was evidently produced. On the next examination I found that these had increased in size and length, and had become branched, and an approach was evidently being made to the cell formation. Numerous small round bodies were floating in the fluid, either separately or in masses, and there was the appearance of similar ones, either in the cells, visible through the transparent walls, or protruding from them. Some days afterwards, however, I observed on several of the stems clusters of these round bodies, resembling bunches of grapes, and at a later date some of them appeared to have become elongated and like bacteria, moved freely and irregularly, though slowly, with a jerking motion. Moreover, the cells of the fibre had become further marked, and many of them contained, or had attached to them, oval pieces of jelly-like substance. These became separated, and occasionally united in masses or chains, some of them afterwards becoming enlarged and more irregular in shape. Another curious development showed itself in a large mass of very fine filaments bearing small bodies, oval in shape, but somewhat elongated at one end. These were apparently infusorial germs, as they much resembled others developed at a later period which were clearly of this character. They were also, probably, similar to monad-like bodies which appeared to be contained in many of the cells of the fungoid growth. These "monads" gradually became active, and finally they developed into infusoria, like what I believe is an early phase of *Kolpoda cucullus*, many of them remaining for a considerable period attached by fine filaments. At the present moment the cork infusion displays all these various phenomena, animalcular life being very abundant, and there is the appearance of a new phase of vitality in the form of minute seed-like bodies, occasionally clustered together in large masses. I may mention that this cork fungus has much the appearance of the so-called "cholera fungus." The closest analogy, however, to these phenomena is to be met with in milk or cream. The changes observable in an infusion

of this kind I have described elsewhere in the following words:—
“On examining a drop of diluted cream under the microscope, we find that its globules are of various sizes, and that the smaller ones have an extremely active movement. Moreover, if a small quantity of cream be placed in water, after a few hours these smaller globules are found to have become both more active and more numerous. In the course of some days a further change takes place, many of them having taken an elongated form, and finally the cream infusion is full of animal life of a very active character.” It is at a later stage that the vegetation makes its appearance in a form exactly resembling, as I have already said, the fungus developed in an infusion of cork. There is the same formation of cells, and the apparent “budding out” from them of masses of matter resembling jelly. In another infusion these curious-looking bodies were apparently produced by elongation of the globules themselves, and they then amalgamated to form the fungoid stem. All the globules in this infusion, moreover, “sprouted,” and thus gave rise to a fungoid growth. In the cream infusion also there is produced a kind of fruit on the fungus—spherical bodies resembling the original “oil-globules”—and infusorial forms similar to those met with in the cork infusion are finally produced. This fungus appears to be a species of *Ascophora*.

These are the phenomena to be accounted for, and to simplify the matter I shall first of all state the conclusion I have arrived at as to the true explanation of them, and afterwards support this conclusion by other facts which have come under my own observation. The data are, simply, that, in the one case, from a vegetable substance—cork—and, in the other, from an animal substance—milk—both vegetable and animal organisms have been derived in such a manner as that we must suppose the higher to have sprung from the lower organism. We are, in fact, in the presence of the phenomena now explained by an increasing number of men of science as the result of “spontaneous generation,” as it is popularly called, or by virtue of what is scientifically termed *heterogeny*. I shall have a few remarks to make on this hypothesis shortly, and I will say here only that, as usually understood, this hypothesis will *not* explain the phenomena in question. Decomposition is absolutely essential to “spontaneous generation,” while here, so far from there being decomposition, every step in the process is an evolution of vitality. If we take the infusion of cork, we find that the fine filaments first developed can be traced distinctly to the cork cells, and yet these cells remain, apparently, intact, and they may be seen in the infusion undecomposed to the end of the experiment. The development is evidently from the *cell-contents*, whatever these may be. Moreover, all the further changes which take place present themselves simply in the course of this development. The

filaments increase in size and length. Their substance is gradually formed into cells, from which are thrown off certain bodies, some of which, with others of analogous character but probably of a different origin, finally and unmistakably take the infusorial form of life. The whole progress is an evolution of vitality. Exactly the same course is pursued in the changes which take place in a cream infusion, except that the organic so-called "oil-globule" is the starting-point in the phases of evolution. But if we reject the hypothesis of "spontaneous generation," or *heterogeny*, what other explanation of the phenomena can be given? It cannot be said that the germs of the fungoid growth, or of the infusoria, are introduced with the air or the water used in the experiments.* The phenomena in question completely negative this idea. Nor can we suppose that the germs of all the products are contained in the infusion itself. There is, certainly, a starting-point to which all may be traced—the contents of the cork cell in the one case, and the cream-globule in the other—but this accounts for the appearance of the first step only in the series of changes. Driven thus to a corner, the only conclusion we can draw is that the first germ is alone necessary. Given the cell-contents or the cream-globule, all the rest of the phenomena, whether they relate to animal or vegetable life, must inevitably follow, when the proper conditions of development are supplied.

In support of this view, I will now detail other experiments I have made, first, however, referring again to the fungus of the cork infusion. This we have seen was developed, apparently, not from the material of the cell walls, but from the cell-contents. Not that the cell necessarily loses its vitality immediately it becomes what Professor Beale terms "formed material." In the experiments above detailed, the cells give forth certain vital products in the course of the development of the fungus quite independent of the germs from which the infusorial life is evolved. It may be that these products themselves again combine immediately to form a vegetable structure, as I have seen several of them united endwise, and some at least of the milk-fibres had every appearance of being composed of cells thus joined and amalgamated. The cell-contents, however, are clearly the starting-point of the phenomena under review, judging from other phenomena to be now mentioned.

In France, M. Bechamp † has made experiments which establish "the natural development of bacteria in the protoplasmic parts of various plants," and he affirms that this arises from the fact that the *microzymæ*, or molecular granulations of the plant-tissue, are the germs of the bacteria. This opinion I have confirmed by the following experiments:—If a thin section of the tissue of a plant,

* We must dissent from this proposition of the author's.—ED. M. M. J.

† See 'Popular Science Review' for April, 1869.

more especially that of the leaf or flower, be examined under a microscope, it will be found to contain very numerous small spherical bodies, having apparently a free movement, these being the *microzymæ* referred to by M. Bechamp, and among them bacteria also may sometimes be seen. Moreover, if a green leaf be moistened and rubbed on a glass slide, a number of these living molecules—monads or bacterial germs—are found on the glass when it is viewed through the microscope. I have seen them come from a small piece of leaf-tissue in a perfect stream. The cells of the petal contain great numbers of these bodies, and occasionally here, as in the leaf-tissue, blotches which appear to consist of masses of them may be observed. These facts led me to examine the seeds of certain plants, when I was astonished to find *microzymæ* in great abundance, more so than in either the petal or the leaf-tissue. In fact, the contents of seeds having a “fleshy” perisperm appear to be made up almost entirely of *microzymæ*, with occasional bacteria. To see whether these were really what I suspected them to be, I placed some seeds in water, and after a few days the water was swarming with most active infusoria of different kinds, including that which I have described as a phase of *Kolpoda cucullus*. On examining the contents of the seeds themselves the same phenomenon presented itself. In one instance the bacteria had a most curious appearance. A number of them were joined together end to end, and the united body moved actively through the fluid with a peculiar undulatory motion.

In a letter in which I communicated some of these facts to ‘Scientific Opinion,’ I stated that the pollen of plants seems “to consist literally of *microzymæ* cells,” and that I had found the organic germs contained in these cells to move freely. This motion I have repeatedly witnessed, and, on one occasion, several of the pollen-cells of the common dandelion burst while in the microscopic field, and their contents were discharged and moved freely through the fluid in the same manner as the *microzymæ* of seeds. I was much struck with the resemblance between the organic molecules of the dandelion pollen-cells and those of the nettle, which I was examining on the same occasion, and I have no doubt that infusions of them would furnish similar results in either case. It is difficult to obtain the molecules of the nettle-hair without the tissue of the hair itself, which renders experiments with them less satisfactory than those with the contents of pollen-cells. The phenomena presented by the pollen when placed in water are most curious, and not the less so because these phenomena somewhat vary in different cases. A few days after placing some pollen of *Scabious* in water, I noticed a slight fluffy appearance at the bottom of the bottle. On examining this with the microscope, it was found to consist of minute filaments of a fungoid

growth, apparently from some of the pollen-cells. These filaments closely resembled the fungus of the cork infusion, and the subsequent evolution was also the same in the formation of cells, the exuding from them of bodies resembling pieces of jelly, and finally the development of infusoria. The only difference is in the character of the infusoria, which in this case have the form of *Paramecium caudatum*, rather than of *Kolpoda cucullus*, phases of which present themselves in the cork infusion. There is afterwards a development of other forms, especially a light-coloured spherical body, which spins rapidly through the fluid, and which is similar to organisms I have found in infusions of coal matter. The pollen of *Escholtzia* differed in its products from that of *Scabious* in the absence of the fungoid growth. Instead of the fluffy appearance, the bottom of the bottle was covered with a carpet of yellow substance, which adhered firmly to the glass. On examining a portion of this substance with the microscope, it was found to consist of the pollen-cells, which were apparently united by the interlacing of very fine fibres developed from them. There was, however, the presence, almost from the very first, of the same kind of infusoria as those which were finally developed in the other pollen infusion. One kind, unlike the others, was characteristic of both infusions, and I was much struck by its peculiar character, not having met with it elsewhere. It was very simple in appearance, resembling a short thick worm, without, however, any wriggling in its movements. Other pollen—that of the *fuchsia*—which I have tried, yielded results similar to those of the *Scabious*, in the development in the first place of a fungoid growth, the ultimate phenomena being the same as in both of the preceding cases. In this infusion, however, there was an extraordinary development of the spherical bodies which were produced, though in a less quantity, from the other pollen. These results are perfectly confirmed by the phenomena observed when the contents of the *anther*, which has been kept in water some time, are examined under the microscope. If the anther be crushed on a glass slide, it will be found to contain, in addition to the tissue itself, a quantity of filamentous growth, and numerous infusoria of several different kinds. In one instance I was surprised to find what appeared to be a perfect example of *Desmidiaceæ*, which was paralleled by the presence of a common species of *Diatomaceæ*, among the filaments of the infused *Scabious* pollen. I do not know how to account for the presence of these organisms in this curious situation. It may be that under the conditions named, they are sometimes developed; and on one occasion I undoubtedly found a broad fibre, having the exact appearance of an ordinary form of *Desmidiaceæ*, growing from a pollen-cell.

I have thus given a general idea of the phenomena attending my experiments, and, in conclusion, I will shortly notice their bear-

ing on the hypothesis of "spontaneous generation," or *heterogeny*, and state more fully what I believe to be the true explanation of them. When treating of the fungus of the cork infusion, I stated that the cell, from the contents of which the fungus spread, apparently remained intact. In the case of the pollen exactly the same thing is shown. Whatever organic development takes place, the material of the pollen-cell, or shell, itself remains in the same state, so far as can be ascertained. This agrees with what takes place when leaf-tissue is experimented with, the *microzymæ* from it being quite independent of the material of the cells themselves, which float about in the fluid after loss of their contents. This fact appears to me to prove conclusively, what all my experiments have tended to establish, that the organic evolution of which I have given details is not due to any process of *decomposition* of the organized substance. If so, however, it cannot be the result of "spontaneous generation." One of the fundamental requirements of *heterogeny* is the existence of a putrescent body in contact with air and water. Without *decomposition* there can be no spontaneous generation or organization, but when this is given the organic products are supposed to show themselves spontaneously—that is, without derivation from a pre-existing germ, even in the substance itself, which may, M. Pouchet declares, be reduced to charcoal, before it is infused, to ensure the destruction of all organic life. To me, however, such a notion as this is perfectly inexplicable. If the infused substance does not itself contain the germs of the future organisms, and if its organic character be thus absolutely destroyed, what remains to impress on the infusion afterwards made with it that peculiar character which gives rise to the phenomena of so-called "spontaneous generation?" Nor is the experiment of boiling the infusion more satisfactory. For, surely, if boiling will not destroy that organic character of the fluid which is absolutely essential to its presenting the phenomena in question, this operation must be equally innocuous as against the organic germs that may be present in it, although invisible. In fact, the admitted phenomena of *heterogeny* disprove, so far as I can judge, the entire hypothesis. M. Pouchet says that the granulated *pellicule prolifère*—"la plus élémentaire qu'il soit possible d'observer"—"est évidemment formée par des cadavres de Monades ou de Bactériums;"* and on the preceding page he says that this pellicule "est constamment formée, dès son origine, par d'infimes microzoaires." But whence come the first microzoaires? The heterogenist says that they appear spontaneously. But from what? Not from the fluid simply, since without the presence of the decomposing, or rather infused, substance, the phenomena would not show themselves. Not from the substance itself, adds the heterogenist, because "à l'état de dissolu-

* 'Hétérogénie,' p. 355.

tion complète dans les liquides qui la renferment, le microscope le plus perfectionné n'y démontre absolument rien." This, however, is the weak point of the hypothesis, which has that purely *negative* basis on which it is impossible to build with safety. Thus, it does not at all follow that the organic germs are absent simply because they cannot be discerned. It might as well be said that, before the invention of the microscope, infusoria themselves did not exist, since they were then invisible to the unassisted eye. The presence of a decomposing organic substance, however, shows clearly how these germs may exist in the infusion, although invisible, before the formation of the *pellicule prolifère*. For although the substance itself may be so completely dissolved that it cannot be discovered, the particles of which it is composed must be present in the fluid, and if so, since there is nothing to show that they lose their organic character, why may not the germs of the future infusoria thus exist? In the infusions of vegetable pollen, well defined rings, which doubtless are examples of the organic *pellicule*, make their appearance long after the development of the fungi and infusoria.

The conclusion I have come to on this question, judging from the above experiments, is simply that the infusorial germs are identical with the particles of the decomposing substance of which the infusions are made. The monads and bacteria, whose *cadavres* make up the *pellicule prolifère*, are exactly the same, in every respect, apparently, as the monads and bacteria which exist in the seeds of plants, and which give rise to the infusoria subsequently discovered in these seeds and in the water in which they are placed. Even the pollen-cell is full of the *microzymæ* from which the monads and bacteria of the tissue are formed, and infusoria are no less abundant when the conditions necessary for their development are supplied. To the same category, without doubt, belong the so-called oil-globules of milk, which also, as we have seen, furnish numerous infusoria. The character of these globules is shown clearly by their relation to the corpuscles of the blood; it having been proved that milk-globules, if injected into the arterial system, finally take the form and character of the blood-corpuscles, which may themselves probably undergo the same process of development as the former exhibit when infused.

In these various facts we see a connection between the animal and vegetable kingdoms much more fundamental than has hitherto been supposed. The peculiar position occupied by infusorial germs in the tissue, the pollen, and the seeds of plants, shows that the latter are absolutely dependent on the former for their development, if not for their very existence; and, in fact, it seems to me that whether the final result shall be animal or vegetable, depends wholly on the conditions under which such germs are brought to maturity. Their nature is probably allied to that of the infusoria

into which they will, in the absence of a vegetable organism, usually be developed, although under other conditions the appearance of a fungoid growth may ensue. Or, it may be said, that the development of the organic germs in question *may* end in the formation of infusoria, but that before reaching this point it may be arrested, there being simply the formation of fresh "germs," the substance of the original ones appearing from time to time as a fungoid growth, the cell-contents of which are supplied by the renewed germs themselves.

Many curious facts bearing on this subject have been recorded by microscopists. Such are the phenomena noticed by Dr. Hartig and Mr. Carter, the former of whom affirms that "Amœba may be produced by the transformation of the 'antherozoids' of Chara, Marchantia, or Mosses; and that, in their turn, they become metamorphosed, first into Protococci or other unicellular Algae, and then into articulated Algae."* There is no improbability in these changes, if the hypothesis I have advanced be correct. In fact, the phenomena observed by Dr. Hartig are perfectly analogous to those I have described—the development of low animal forms from supposed vegetable germs. I say "supposed," for the antherozoids of all the simple plants appear to me to be purely *infusorial* germs, and they may, I have little doubt, be as readily developed into infusoria as the contents of ordinary vegetable seeds. I have myself obtained the Amœba under curious circumstances. If *coal* be powdered and placed in water, a peculiar microscopic vegetable growth will, after a while, be found to have been developed, and still later numerous crystalline or jelly-like excrescences and tube-like protuberances which have a perceptible movement make their appearance. In an infusion of this description which I have had for several months, I have met recently with several examples of a beautiful form of Amœba, and also others of a much larger kind, which moved about among the coal vegetation, to which it adhered. At one extremity only did those changes of form take place which are necessary to the progress of the Amœba; there being towards the other a circular marking, probably the contractile vesicle, and forward movement being effected by the protrusion of a broad limb, or rather "lip," of a much lighter colour than the body itself, and at the margin of which I distinctly caught sight on one occasion of the vibration of small cilia. The development of this creature, unless it was introduced with the water of the infusion, which I do not believe, strongly supports the view I have taken that there is an intimate connection between the initial phases of animal and vegetable life.

* But see note in Dr. Carpenter's work on the Microscope, 3rd edit., p. 357.