PART II.

LIFE; WHAT IT IS.—PROTOPLASM, THE MATTER OF LIFE.—PRIMARY OR SPONTANEOUS GENERATION, NATURAL AND ARTIFICIAL.—THE DIFFERENT KINDS OF LIFE.—SIMILARITY BETWEEN PLANTS AND ANIMALS.

CHAPTER III.

WHAT IS LIFE?

It may seem, at first sight, very easy to state the difference between living organized beings and bodies that are not organized and living; or, in other words, to define *Life!* But when the attempt to do so is made, many difficulties arise. One of the most obvious differences is the way in which growth or increase takes place. Inorganic bodies can increase only by the addition of other matter of a similar kind externally, as when a crystal gets larger by more material depositing upon it of the same kind and in the same form. But organized beings grow by taking matter into their interior, or stomach, and depositing it from the inside, after decomposing and changing it in many ways from what it was.

Organized, or living beings, are also usually made up of different parts, or organs, each adapted for a different use, such as the limbs and internal organs. Still, there are living beings that have no definite form, nor any separate organs, or parts, but every portion of the whole being is capable of performing every function necessary to its existence, as will be explained farther on.

One thing may be said of all living beings, that they are continually undergoing change. The substance of their bodies is being continually decomposed and got rid of in various ways, while new matter takes its place, so that the individual is perpetually changing, and yet remains the same. The repairing process is effected by what is commonly called *Nutrition*, or the digestion and assimilation of food. Inorganic bodies exhibit nothing of the kind. The question then naturally arises, whether life is caused by, or results from, organization, or whether organization results from life. To this it may be said that we know nothing of life without organization, and that we invariably see it exhibited whenever organization takes place. We find also that, just in proportion as the organization becomes complicated or perfected, so does the life, correspondingly, and when the organization is so injured or deranged that its various organs can no longer mutually interact life ceases. We are justified, therefore, in assuming that life is a result of organization, and that it is evolved by the play of the natural forces acting upon the material elements.

But as all matter does not show a tendency to organize, it becomes an interesting question what it is that determines it in special cases to do so, and what kinds of matter are most prone to organize? We find, then, on examination, that the four primitive elements, *carbon, hydrogen, oxygen, and nitrogen*, when combined in cer-

tain proportions, are those which form, as it were, *the basis of life!* Of these carbon is the only one we know in a solid form, as wood, charcoal, and diamond, while the other three we know only as gases. These elements, when so combined, form a jelly-like substance called *protoplasm*, which is nearly identical with *white of egg;* it is also sometimes called *proteine*. This primary substance may be properly considered the matter or basis of life; for a living organization can under no conditions begin without it; and when once we have it, under proper conditions, life invariably is manifested. When once formed, protoplasm is sensitive in many ways to the action of the natural forces. Heat *stiffens* or hardens it, and *electricity*, which is everywhere active, makes it *contract* or *move*, and this is probably the first vital effort or beginning of *life!* Then chemical change becomes active, and the protoplasm and surrounding bodies act upon and influence each other, whenever the conditions in which it is placed are suitable. There must be, as a rule, a certain amount of water and free oxygen present, and the temperature must not be above nor below a certain point. There are, however, certain low organizations, chiefly funguses, that are capable of developing from protoplasm, though all these conditions may not exist together. But in every case water, warmth, and oxygen are necessary to the maintenance of protoplasmic life, or, at least, to its manifestation; for without these it soon appears inert or dead. Certain forms of it, however, display an astonishing power of recuperation, or retain life, if we may so express it, with most wonderful tenacity. Thus seeds of plants, and the eggs of certain animals, may be dried and kept for many years, and yet develop or grow when placed under proper conditions. There is a little microscopic being called the *wheel animalcule*, or *rotifer*, which lives in ponds and streams, smaller than the smallest grain of dust we can conceive, and yet a perfect animal, having nerves, reproductive organs, a stomach, and even eyes. Some of these beings may be dried and rubbed into mere dust, and kept so for many years; and yet if this dust be put in water, the rotifers will immediately resume their vitality, and all their organs become as active as before they were dried; from which it will be seen that a being may still be possessed of life, though showing no signs of it, as remarked before.

Seeds and vegetable germs of all kinds, it should be observed, are composed of protoplasm, the same as animal germs, and it is but slightly different from animal protoplasm. It is probable that life, as seen in these primitive humble forms, and also in more perfect organizations, as in man himself, is only a modified manifestation of those natural forces that we see active in all forms of matter. In fact, all matter may be said to be living, and all life is fundamentally the same, whether in animals, plants, or stones; it merely differs in variety and activity according as matter is more or less combined, the higher organizations having the combined life of all the different elements and minor combinations of which they are composed. Dead or inert matter does not exist, and *vital force* is merely a modification of the universal force appertaining to all matter alike.

CHAPTER IV.

ORIGIN OF PROTOPLASM, ITS USES AND ITS PROGRESSION FROM THE INORGANIC TO THE ORGANIC WORLDS.

PROTOPLASM, as before observed, is a compound of the primitive elements, oxygen, hydrogen, carbon, and nitrogen, in certain definite proportions. Neither of these elements alone, nor any smaller number of them, can, so far as we know, form living substance nor sustain life; they must be compounded together in this particular form. All plants, and all animals, from the highest to the lowest, are made up of protoplasm, and animals are nutrified, or supported alive, by protoplasm alone,—it is the basis of their food. Animals get their protoplasmic food by eating either other animals or plants; they cannot, so far as we certainly know, make protoplasm from the primary elements: so that animal life is dependent upon vegetable life. The plant, on the contrary, forms protoplasm from the primary elements by compounding them together, and thus acts as the animal's provider, or the agent by which the primary elements are brought into a form fit for animal nutrition.

But even the plant cannot take the four elements, oxygen, hydrogen, nitrogen, and carbon separately, and form protoplasm from them. They must first combine in this way: the hydrogen and oxygen first combine and form *water;* hydrogen and nitrogen combine and form *ammonia;* oxygen and carbon combine and form *carbonic acid*. These three new substances, *water*, *carbonic acid*, and *ammonia*, will feed the plant, and by it are built up into one substance called vegetable protoplasm, which forms the bulk of its own substance, and becomes food for animals, in whom it is slightly modified and becomes animal protoplasm. We thus have:

First. The primary elements, oxygen, hydrogen, nitrogen, and carbon.

Second. These combine and form carbonic acid, water, and ammonia.

Third. The carbonic acid, water, and ammonia are used by the plant as food, and converted by it into protoplasm.

Fourth. This protoplasm, made by the plant and forming its own substance, is used as food by the animal and maintains its existence.

Fifth. The animal dies; its body decomposes, and is resolved again into carbonic acid, water, ammonia, and simple elements, upon which the plant feeds, and thus begins the round over again. It is a circle of operations never ending, but always beginning. Break the circle at any point, and the whole operation ceases at once; each part is dependent upon the other.

Now, we have always existing in nature the three elementary compounds, carbonic acid, water, and ammonia, but, as we have shown, they require the plant to

combine them together into protoplasm, so that the pre-existence of the plant seems necessary. The question then arises, Do we know of any conditions under which protoplasm is formed without plant agency? Many other organic substances have been formed artificially by the chemist, and substances very similar to protoplasm, but not the thing itself, as yet. Doubtless it is formed in nature, or has been at some former time, and when once formed, as previously shown, it organizes and forms a living being, by the action of the natural forces. The first living beings formed were, in all probability, neither plants nor animals, but between the two—what will be described farther on as *Protista*.

For a long time it was doubtful if protoplasm did exist ready formed, independent of plant life, anywhere; but the discovery of what Professor Huxley calls *Bathybius* (*deep life*) seems to prove that it does. This substance is a kind of *ooze*, or jelly, which is deposited on the bottom of the sea in certain places, and which in all essential particulars is identical with *protoplasm!* It is apparently formed naturally, by the combination of the primitive elements, or their primary compounds, independent of plant agency. A similar material is also found in stagnant ponds.

This substance, under the influence of the natural forces, separates or divides into small portions, like specks of jelly, which soon exhibit contractility, or *motion*, and thus become endowed with *life* in its simplest form. These earliest living bodies may become either plants or animals, for, as before said, there is primarily no distinction between them; but probably the first distinctly formed organisms are plants, and thus the *circle* begins to be formed, and living beings are evolved from inorganic matter by its own inherent force, to be again decomposed at death and returned to what they came from. The matter of which they are formed, and the forces they exhibit while living, are neither lost nor lessened by death, but both are returned to the inorganic world in the same quantity, but in different forms.

A thoughtful and careful observation of natural processes, then, leads inevitably to this conclusion, that the simple natural elements, oxygen, hydrogen, carbon, and nitrogen, first combine and form protoplasm, and that this, by the action of electricity, heat, and other natural agencies, begins to contract, or move, and finally becomes a living being!

Protoplasm itself varies within certain limits in its composition, having more or less of one or the other of the elements. Vegetable protoplasm, for instance, is slightly different from true animal protoplasm, and, of course, the primary simple beings formed from it will be more or less different in consequence. They will then be differently acted upon by the surrounding objects, and by each other, and thus varieties of living beings will originate. Some will also use *lime*, which is always found in sea-water, and thus form a lime shell, or case, while others will absorb *silica*, and make a stony case. In short, *variety* once begun, no matter how slight it may be, tends to increase, and living beings will gradually become more and more dissimilar. The death of the first formed simple beings also makes a richer and more abundant protoplasm, which nourishes later succeeding generations, and so disposes them to vary still more,—or progress. Finally comes in *evolution*, or that process by which surrounding agencies act upon living beings so as gradually to modify or change them, till finally, perhaps after millions of years, they become entirely different. In this way have all the living creatures on the earth, animal

and vegetable, in all probability, been produced from the first formed simple animalcules, which originally sprang from protoplasm evolved by natural agency from the inorganic elements.

In short, nothing is needed but matter, and the forces inherent in it, to account for all the life that is found on the earth, of every kind.

This is primal generation, or the first *Origin of Life!*

It should be remarked here, in relation to Huxley's *Bathybius*, that the oozy matter, so named, is almost wholly composed, in some places, of flocculent *sulphate of lime!* But, in other places, it contains more or less true protoplasmic material, as above described. It is, therefore, a variable substance, which is sometimes composed, more or less, of protoplasm.

CHAPTER V

SPONTANEOUS GENERATION, AND ONENESS OF LIFE ALL THROUGH NATURE.

In the very earliest times we find that there was a belief in spontaneous generation; that is, that under favorable conditions, living beings of certain kinds could, by natural agency, come into existence from the common elements, without being derived from parents. This was even *orthodox Church belief* for a long time, so singularly does theology change in regard to natural processes, at different periods. The Church formerly taught that only man was created directly by God, and that all other beings sprang ready formed from the earth. St. Ambrose, and St. Basil, both contended that where the Bible says, "Let the earth bring forth grass, the herb," etc., and "let the waters bring forth abundantly the moving creature that hath life," it means that the earth and the water really had the power to bring forth animals and plants. Nay, they contended further that this power remains still, and that in a similar way new plants and animals may come into existence.

Strange as it may seem, when Redi first announced that the maggots in meat were not generated spontaneously, but were developed from eggs laid by the flies, his statement was denounced by the Church as heresy! So that we see the same scientific doctrine may be heretical in one age, and orthodox in another. Let those who are afraid of modern scientific teaching remember this; it is a lesson which many should study at the present day. Men early observed that when putrefaction took place, for instance, swarms of living creatures were produced, and not looking close enough to trace how they originated, jumped to the conclusion that they were spontaneously generated. Flies especially were thought to be generated in this way, and also lice; indeed, many people even at the present day still think the same. Aristotle taught that every dry substance when it became moist, and every moist substance when it became dry, produced living creatures, if the surrounding conditions were favorable. Others of the ancient philosophers taught that all living beings originated at first in this way; Virgil actually gives directions how to produce a swarm of bees by spontaneous generation; and even so late as 1542 Cardan taught that water engendered fishes. Van Helmont went so far as to give special directions for the creation of *mice;* and Kircher informs us that he *saw* certain animals produced by the action of water on bits of the stems of plants. It was not till 1668, that an Italian scientist, named Redi, first showed that the worms and insects found in putrefying substances really came from eggs, deposited by other insects of the same kind; and, still later, by means of the microscope, Leuwenhoek and others made this yet more evident. The doctrine of spontaneous generation in consequence

fell into disfavor; but still there was a difficulty in regard to many beings, such as the worms, flukes, and hydatids found in the intestines, liver, brain, and eyes, both of man and other animals. But even these were finally traced to pre-existing parents, and it was proved satisfactorily that they are not, so far as we know, spontaneously generated.

In more modern times the improved microscope has, however, discovered to us beings much more minute, and much more simply organized, which appear under such peculiar circumstances, so suddenly, and in such astonishing numbers, that ordinary parental generation does not seem to account for them. Many eminent scientists, after careful observation and experiment, have come to the conclusion that these beings really are generated spontaneously, from protoplasmic matter. Among the most eminent of these may be named *Pouchet* in France, and *Bastian* in England. With these men it is no mere theory, but the result of careful experiment. The opponents of their views, equally eminent men, such as *Tyndall* and *Huxley*, contend that the atmosphere is full of *germs*, or organized bodies, too minute to be seen even by the most powerful microscopes, but which are really the origin of all these beings—plants and animals—supposed to be spontaneously generated. That these germs do exist there is no doubt; and it is equally certain that they often originate living organisms of various kinds where they had previously not existed. Many diseases are believed to originate in this way, both in plants and animals, and it is asserted, by those who do not believe in spontaneous generation, that if the air is carefully excluded from any kind of material already free from these germs that no life will ever originate in it.

The object of the experimenters has therefore been, to prepare different fluids, suitable for the purpose, under such conditions that all germs which might be in them, or in the air that reached them, should be destroyed, so that it could be tested whether life would then originate in them or not. Both Pouchet and Bastian have done this hundreds of times, submitting their solutions to intense and prolonged heat, and roasting and filtering the air admitted to them till it would seem impossible for anything *living* to remain, and yet in most cases living things did originate in the solutions. Their opponents contend that either the germs could stand the heat uninjured, or else they gained admission to the solutions in some unsuspected way. Experiments and counter-experiments have been made on the most extensive scale, and are still being made; for the matter is by no means decided. It has, however, been demonstrated that, if these germs do exist, they are capable of enduring a heat very far beyond that of boiling water for many hours, and yet be capable afterward of developing into living organisms. The air even in which they have been thought to be conveyed has been passed through powerful acids and white-hot tubes, and still the supposed germs, if there, remained unhurt. This in itself is a wonderful fact, and gives us a new idea of the tenacity with which life, or the capability of it, is held. It is well known, however, that many seeds, and even animal eggs, may be boiled for a long time without killing them.

It may be remarked, however, that though the existence of germs of life in the air is well established, still we have not been able to isolate and show them. It is not certain therefore that these germs are of the nature of *eggs* or *seeds*, derived from living beings. They may be only minute portions of protoplasm, floating in the air, which develop into living beings when they find a suitable fluid. The generation therefore may be, properly speaking, *spontaneous*, though originating in a germ. In other words, there may be no parentage.

The question, however, arises, How comes the protoplasm in the air? The opponents of spontaneous generation say that it is only the cast-off material of living beings, and that it would not be in the air if there were no living beings from which it could come. This view, it is evident, makes the generation not strictly a *new one*, or spontaneous, because it really depends upon life, and is, therefore, only a propagation of it in a novel manner. To be really *spontaneous*, the protoplasm itself must originate from the inorganic elements, and life must be produced in it without the intervention of previous life in any way.

A little consideration here will show that it is no more unlikely for protoplasm to originate in the *air* than for it to originate in the *sea*, in the form of *bathybius!* There are always in the air carbonic acid, water, and often ammonia, the three compounds which form protoplasm, and it would be surprising indeed, if the electric agency, always at work in the atmosphere, did not sometimes cause them to combine. We know that an electric spark will cause oxygen and hydrogen to combine and form water, and that it will also cause other chemical combinations instantaneously. We know also that lightning, or natural electricity, striking through the air, causes combinations of the elements to occur, of many kinds, as will be more fully shown farther on.

Here, then, we have a simple explanation of the origin of atmospheric protoplasm, the universal *life-germ*, which probably orginates one form of life under one condition, and other forms under other conditions. Bathybius does the same in the sea, and in this way inorganic matter combines and becomes living protoplasm, the basis of every living being, plant or animal. A little reflection will show that life in its simplest form is but little more than mere *motion*, and protoplasm can scarcely exist without becoming mobile. Imagine a little speck of this jelly-like substance formed in the air or in the sea. One part of it will harden more than another, from mere heat, or some chemical agent adjoining; then, a current of electricity will traverse it—for such currents are everywhere—and this will make it *contract!* One part however, being harder than the other, the contraction will be *unequal;* this unequal contraction will corrugate it, or draw it into channels and furrows, along which the surrounding fluids will traverse with different degrees of velocity. One part will thus gain more new material than other parts in the same time, because it has more presented to it, and there is always a tendency in matter to aggregate with that for which it has an affinity. Repulsion also comes into play as well as attraction, and between the two matter can never be at rest, or without life. The softer parts will easily extend, or stretch out, when attracted by other substances, while the denser parts will not, or will do so to a less degree, and thus motion for the purpose of attaching new material will begin, or, in other words, *nutrition* in its simplest form. Many of the lowest organisms, in fact, show but little more life than this, if any. They simply bulge out in some parts and contract in others, and attach to themselves any matter which floats near them with which they have an affinity. In this way life may, and probably does, originate spontaneously, from the inorganic elements; and probably in past ages of the world the conditions were much more favorable for this process than they are now. We know that there were periods of constant and great heat, with much watery vapor, abundant carbonic acid, and intense electric action, as will be more fully shown farther on. It would seem, from what we now know, that under such conditions life *must* have originated, to an extent, and in a degree of perfection, far beyond anything of

which we can now conceive. Those who would wish to pursue this matter further should read any good modern treatise on geology, and observe the state of the world, as shown by that science, in past ages.

We cannot judge, from what we now see, what must have taken place when the world was young, when all the natural forces were intensely active, and the elements were in what chemists call the nascent state.

That life did originate naturally, at a former period, cannot be doubted, and that it often originates even now, under certain conditions, is more than probable: and these conditions may be either natural or artificial: such, at least, is the opinion of those who believe in spontaneous generation. It should be observed further, in regard to the probable origin of *motion* in protoplasm, that all organic substances similar to this exhibit, under the microscope, peculiar movements, called the *Brownian movements*, so named after their discoverer. These movements so closely resemble those that take place in living bodies that observers are often deceived by them. These specks of organic matter will not only move, but whirl about, just like the animalcules, so that the closest attention is needed to distinguish them.

It is probable that the Brownian movements are merely the *first efforts*, as it were, toward life, and that they easily pass into those that we observe to be truly vital. Nature is nowhere at rest, and organic motion is only a modification of inorganic. There is no such thing as *lifeless* matter! To make this subject better understood, we will now show how living beings usually first show themselves, in the fluids used in the experiments above referred to, and then describe some of the experiments more fully.

If any animal or vegetable substance be soaked in water, so as to make an infusion of it, and this infusion be exposed to the air, within certain degrees of temperature, certain changes are always observed to take place in it.

First there forms on the top a scum, or film, called the *primary pellicle*, which is seen, under the microscope, to be made up of an immense number of small round bodies, or molecules, like grains of sand.

Next we find many of these molecules begin to lengthen in one direction, forming bodies like small threads, sticks, or wands. These are called *bacteria*.

The bacteria continue to lengthen till they form still longer thread-like bodies, called *vibriones*.

Finally, both the bacteria and vibriones begin to *move* in a serpentine manner, through the fluid.

After a time, in most cases, they all become again motionless, and finally break up into molecules, which aggregate together into a new or *secondary pellicle*.

The next stage shows us a number of small round bodies, formed from the pellicle, each one possessed of a fringe of threads or hairs called a *cilium*. These it uses like oars, and by their means paddles rapidly about in the fluid.

These *infusoria*, as they are called, are often much varied in form, but all possess the *cilia*, or hairs, with which they move about, and from which they are named *cilia*. Some of them are extremely simple in organization, while others have a *mouth* and stomach, and are more perfect every way. They are by no means all alike.

This is the order of change that is noticed in most cases where an organic infusion is exposed to the air; but it is not invariably the same in all the details.

The advocates of spontaneous generation say that this is all a natural process; that the primary pellicle and its molecules are produced by chemical change in the

infusion. The subjoined figure will show the appearance of the primary pellicle formed on the surface of an infusion of isinglass. It will be seen that the course of development is slightly different from that above described. Among the granules will be seen larger, cell-like bodies, called *paramecia viride*, some containing in the interior a spot called the nucleus, while others are without it.

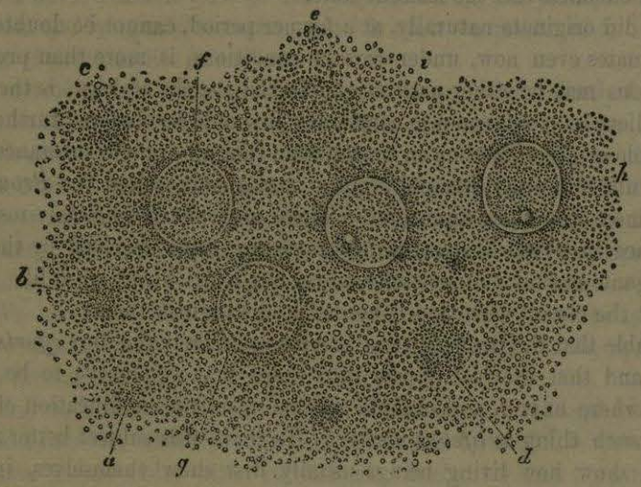

FIGURE 1.—*Mode of Origin of Paramecia, from the Primary Pellicle.*

These round bodies, or paramecia, will be seen forming, at first faintly, by the granules merely drawing together (*a*, *b*, *c*, *d*); next a clear border is seen to form around them, and finally the exterior hardens into an investing membrane, and then we have a perfect *cell* (*f*, *g*, *i*). The granules in the interior then coalesce, and begin to move round and round, having evidently organized into a living being. The slow circular motion first observed becomes quicker, and irregular, till at last the investing membrane is burst, and there issues forth a free-swimming infusorial animalcule.

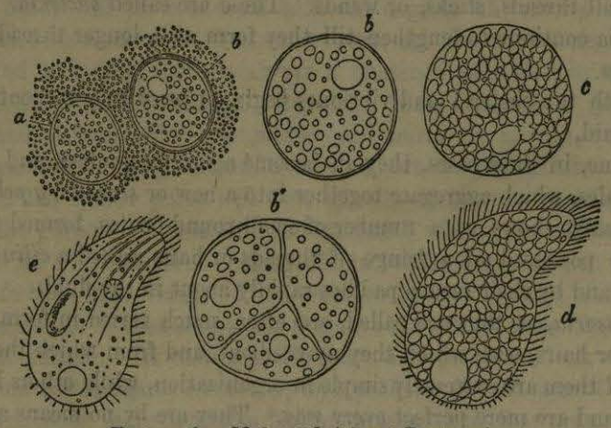

FIGURE 2.—*Mode of Origin of Paramecia.*

a. First stage of differentiation. *b*. Later stage, showing a vacuole formed. *b'*. The same still further advanced. *b''*. The same divided into three parts. *c*. A later stage; the embryo filled with large particles, and revolving. *d*. A paramecium after emerging from its cyst. *e*. Another form into which they sometimes pass.

Ciliated infusoria are better organized, or more advanced, than bacteria or vibriones, and we seldom see them in the primary pellicle; but in the second they are abundant, probably because it is now richer in organized material, from the death and decomposition of the more simple beings first developed.

The cilia, or hair-like threads, which all these animals possess, are probably used ooth as oars, to move the body within the surrounding fluid, and also as arms with which they reach any small portions of nutritious matter near them.

The simpler beings—bacteria, vibriones, and monads—which come first in the primary pellicle, have no cilia; but the monads have a long tail, usually called a *flagellum*.

It should be observed, however, that this order of succession is not invariable; for sometimes we have all these forms appear at once, and they pass so rapidly into one another that the process can scarcely be seen.

The beings thus produced are *ciliated* infusoria of various forms, as shown in the following figure.

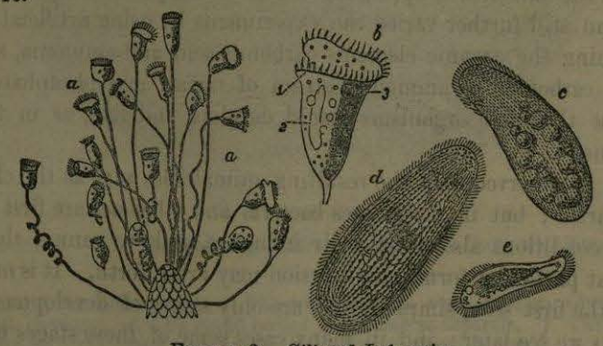

FIGURE 3.—*Ciliated Infusoria.*

a. A group of vorticella. *b*. A single vorticella more highly magnified. *c*. A kolpoda. *d*. A paramecium. *e*. Enchelys. The paramecium *d* is seen to be changed from the globular form, and is approaching that of *c*, the kolpoda.

All these beings result from changes in the paramecium, which begins from a simple aggregation of the granules of the primary pellicle, one change following the other. The air may be necessary to the change, but the advocates of spontaneous generation deny that any so-called germs are in any way necessary, or, if they be, that they are anything more than particles of naturally formed *protoplasm*, not necessarily derived from any pre-existing organism.

The *Panspermists*, as they are called, of course contend that the germs are essential, and that they are all derived from pre-existing beings, of the same kind as those that grow in the fluid. There is no proof of the existence of these germs, and each one must judge for himself as to the probability, or otherwise, of their existence, after reading the account of the experiments referred to.

Pouchet, Bastian, and others, have made infusions of *hay*, *turnip*, *cheese*, *animal muscle*, and various other organic substances. These they introduced into small glass bulbs, with very long fine necks, drawn out to mere points; then the solution was *boiled*, sometimes for hours, and, while boiling, the thin neck was melted together by a blow-pipe, or hermetically sealed.

Of course it would seem that no germs could be left alive in the solution after this prolonged heating, nor could any pass into the bulb from the air, because the hot steam was all the time rushing out, till the instant they were closed.

Nevertheless, when these glass bulbs were left undisturbed, sooner or later, all the changes above described often took place, the same as if they had been in the open air, and the same living beings appeared.

The experiment was varied in every possible way, and with all kinds of infusions, almost always with the same results.

To show that the ordinary air was not really necessary, Pouchet even made *artificial air*, by mixing oxygen and nitrogen gases in the proper proportions, and still the same results followed. In other cases the air was passed through white-hot metal tubes, and the infusion was heated, under pressure, till far beyond the heat of boiling water; but it made no difference: the pellicle and the infusoria appeared after a time just as before.

Pure oxygen even was used, instead of air, and many of the bulbs, after being sealed, were *again boiled*, for several minutes, to kill anything which might possibly have got introduced; but in spite of all these precautions, in due time the same changes occurred, and the animalcules appeared, in most cases, just as they do in the open air.

Dr. Bastian still further varied the experiments by using artificial chemical mixtures, containing the organic elements carbonic acid and ammonia, such as oxalate of ammonia, carbonate of ammonia, cream of tartar, and phosphate of ammonia. Even in these the same organisms would develop, and live, as in the natural organic infusions.

It should be observed that the resulting animalcules vary as the character of the infusion is varied; but in most cases bacteria and vibriones are first formed. The surrounding conditions also exert their influence, and we cannot therefore always predicate what particular forms any infusion may bring forth. It is more than probable that all the first seen, simple forms, are only stages of development of the more perfect beings we see later; and in many cases some of these stages may be missed, so that we see the being in its final form without its having gone through the first and simpler forms.

If horse-hair be left in stagnant water, it will usually be found associated with thousands of small worms in a very short time, and uninformed people think the hair is changed into the worms, which they therefore call *hair-snakes!* They are however only a kind of worm, which lives naturally in such places, and which probably finds the hair a good breeding-place. If it were not there they would breed on something else, as they ordinarily do. They develop from eggs or by division.

In one of Bastian's experiments he boiled some dry hay in water at 120° to 130° for three hours; then put some of the infusion in a wide-mouthed bottle under a bell jar, which perfectly covered it. In three days this infusion was quite muddy-looking, and covered with a thin pellicle, portions of which were examined with the microscope and found to contain numerous *monads*, each about the *three-thousandth of an inch* in diameter, the pellicle itself being formed chiefly of *bacteria*, with some torulæ (yeast plant). Patches of the pellicle, however, were seen of different sizes, of a whitish color, evidently made by the granules of the pellicle undergoing some change in these places. These patches, in consequence of what resulted from them, were called *embryonal areas*, or *life spots*. They gradually separated from the general mass, and the substance contained in them began to have a different look. Eventually it aggregated into distinct round bodies, like cells, which finally assumed the forms of monads. When this stage was reached, the aggregated patch seemed to spontaneously resolve itself, and the monads became free, as seen below.

These monads were seen in perfect clouds, most of them with long tails, or flagellums, and they gradually increased in size and varied somewhat in appearance, having more the look of *amœbas* (which will be described farther on). In fact, the change from the monad to the amœba could be plainly seen, and sometimes took place very rapidly, the animal losing its tail, and becoming a mere sac, which could

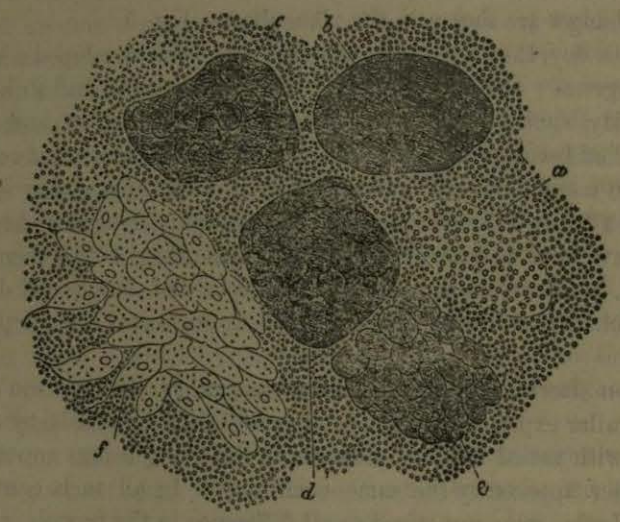

FIGURE 4.—*First Stage of Hay Pellicle, forming Life Spots and Monads.*

a. The first stage, the white patch. *b*. The second stage. *c* and *d*. More advanced stages, the round bodies just showing. *e*. The round bodies beginning to separate. *f*. The fully developed monads, resulting from the breaking up of the collection of round bodies.

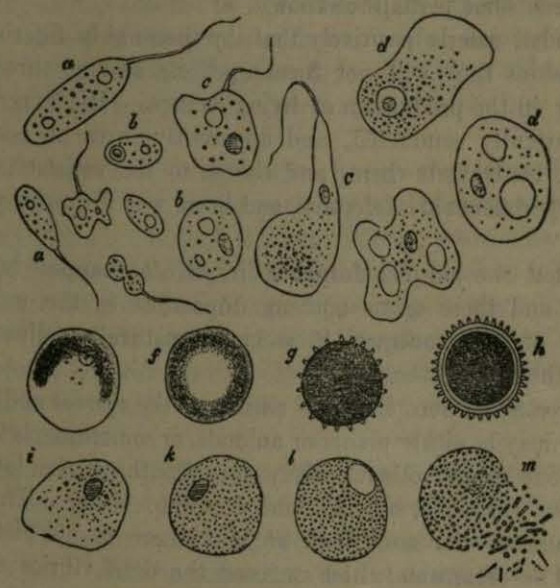

FIGURE 5.—*Second Stage of Hay Pellicle: Monads changing to Amœba.*

a, a. Monads in different stages. *b, b*. Monads which have lost their tails. *c, c*. Monads being transformed into amœbas. *d, d*. The amœbas perfectly formed. *e, f, g*. Different stages in the encysting of an amœba. *h*. One encysted. *i, k, l, m* show the various stages by which an amœba develops into a germ vesicle, and finally bursts (*m*), giving issue to a swarm of bacteria.

protrude false limbs. On the seventh day there were many thousands of perfect amœba, and on the eighth day they were as numerous as the monads.

This change from monad to amœba was often very rapid, one hour sufficing in many instances. Some of the amœba remained motionless and became encysted, or enclosed in a sac, while others, filled with germs, burst and gave forth swarms of bacteria.

All these changes are shown in the plate above—Fig. 5.

On the ninth day, the pellicle had a darker color, and developed a large number of brown *fungus* germs; portions of it also began to separate, and sink to the bottom. On the tenth day, similar changes had progressed much further, and a large number of the amœba had become encysted. In this stage they somewhat resembled a drop of oil in a thin membrane, and when perfect had the appearance seen at *g*, being surrounded by a fringe of short hair-like cilia, the color being dark brown. Many of these finally gave birth to brown fungus bodies, like those before mentioned.

Here, then, we have monads, amœba, bacteria, and fungus, all developing from the same pellicle and from one another. In fact, one seems imperceptibly to change into the other.

The infusion afterward underwent numerous other changes, too confused for us to follow. Similar experiments have been made by the hundreds, by different experimenters, and with varied results. Sometimes the living beings appeared, and sometimes not, under apparently the same conditions. In all such contradictory cases there was, no doubt, some unnoticed small difference in the process, and, in a matter of so much delicacy, it is very difficult to always conduct an experiment with every little detail exactly the same.

It is possible that the electrical condition of the atmosphere, or of surrounding objects, may have an influence, and so may light, changes of temperature, and various other influences, some perhaps unknown.

Professor Tyndall asserts positively that, by thoroughly filtering the air which acts on the infusions they will not form a pellicle, and go through the ordinary changes resulting in the production of living beings. His experiments appear to have been very carefully conducted, and apparently prove his assertion true. Dr. Bastian, however, controverts them, and shows, to the satisfaction of his friends, that Tyndall's experiments are defective, and in no way disprove spontaneous generation.

It is certain that the simpler forms of life do often appear in a very incomprehensible manner, and there seems nothing impossible in the way of spontaneous generation; but, on the contrary, it seems to naturally follow from a careful consideration of the facts in the case.

It should be remarked here that the nature of the *vibrios* and *bacteria* is quite uncertain. They may be either plants or animals, or something between them, capable of becoming one or the other. Many scientists think the lower organisms are neither animal nor vegetable, but may develop into either. The plant and the animal both commence the same, and at first there is no distinction whatever between them. The organisms which succeed the dead vibrios appear to be more distinctly animal, and those which succeed them are animal beyond doubt. These, again, are succeeded by others still more perfect, so that there is a regular progress upward, beginning with inorganic matter. It has been objected to the theory of artificial spontaneous generation that, in all the experiments, some organic matter

had to be used to make the infusion, and that, as this had to be obtained from some organic being which existed before, there was no *new start!* And this is quite true; for though it was dead organic matter when used, still it could not have been had at all if there had not been a living being before. Chemists, however, now form organic substances of different kinds in their laboratories from inorganic material, and the number of these substances so made artificially is increasing every day. In fact, the general opinion among chemists is, that we shall, by-and-by, form artificially every organic substance known, even the food we eat, and not be dependent upon agriculture, or other animals, for it, as we are now. It will be quite possible, therefore, to first make the organic matter artificially with which the infusion is made, and thus the whole process becomes artificial from the start, and the life produced will be truly spontaneous, or independent of parentage in any way.

As an instance of how spontaneous generation, as it is called, may be affected by the conditions under which the experiment is conducted, reference may be made to a communication by Mr. Downes and Mr. Blunt, to the Royal Society, England. These gentlemen found that when glass tubes were filled with an organic infusion, such as those used by Dr. Bastian, and some placed in the light while others were left in the dark, only those in the dark became cloudy, and developed bacteria; while those left in the light did not.

It is evident from this that light is unfavorable to those changes in organic matter, or protoplasm, which result in the development of bacteria, and probably other infusoria.

With chlorophyl (the coloring matter of leaves), which may be called green protoplasm, it is exactly the reverse; for this forms only in the light, and best in the full sunlight.

It is probable that the same speck of protoplasm, therefore, may become plant or animal, according as it is affected by light during its first stages of growth.

In regard to the nature of the germs, as they are called, floating in the air, which, when they fall into organic solutions, appear to be the origin of bacteria, these gentlemen remark that they may be considered simply as *isolated cells*, or minute protoplasmic masses.

Professor Tyndall may be quite right when he says that infusorial animals never develop in any solution, if the air be perfectly excluded from them, or even if it be only perfectly filtered. Indeed, his experiments prove this. When he conducted them in the rooms of the Royal Institution, in London, it was scarcely possible, with every care, to prevent infusoria appearing in the solutions; but when exactly the same experiments were performed in purer country air, they did not appear. The inference he draws is this—that in the city the germs are so numerous that it is not possible to exclude them all, but in the country there are so few that they can easily be kept out.

To show that these germs do float about in the air, he filtered it through cotton-wool, and in this way got air perfectly free from them, which had no effect on any organic infusion. The same result followed if the air was only left for some time perfectly still, in a box. All the germs then settled down, on the bottom and sides, which were wet with glycerine to hold them fast. The air thus clarified would not affect the solutions any more than that passed through the cotton-wool.

Still, granting all this, it does not follow that the so-called germs are like eggs, or seeds, derived from living beings. They are probably only specks of protoplasm