CHAPTER XIII.

"Heterogenesis" or "Spontaneous Generation:" Nature of the Subject—Development of Life in an Infusion—Molecules, Bacteria and Vibrios—Doctrine of "Homogenesis" or "Biogenesis:" Nature and Definition—Historical Sketch of the Subject—Doctrines of Redi—Experiments of Needham and Buffon—"Germ Theory" of Spallanzani—Experiments of Schulze, Schwann, Schrœder, and Pasteur—Bastian's "Beginnings of Life"—Comparison of "Abiogenesis" and "Biogenesis"—Lister's Experiments—Conclusion.

THE consideration of the subjects of Development and Reproduction has taught us, or led us to believe, that the pre-existence of a parent-form, or of seeds or germs, is, in ordinary circumstances, necessary for the production of new beings or organisms. In other words, we naturally infer that existing forms of life have been derived, or have taken origin, from pre-existing forms. And such an inference is justified by the ordinary sequence of reproductive phenomena observed in both animal and plant worlds. Yet we have already seen that the paths of biological inquiry are beset with many and strange difficulties; and we have also witnessed the displacement and contradiction of many theories and beliefs, at one time quite as surely fixed, and apparently as worthy of support, as the natural and justifiable supposition that a living form must have had a pre-existing progenitor, in most cases, resembling itself.

The doctrine of "Heterogenesis" or "Spontaneous Generation," however, maintains the occurrence of the production of living beings *de novo;* that is, without the pre-existence of parent-forms, germs, or seeds. The subject before us is therefore one which possesses a great interest for the biological student, and which, in a work

like the present, may appropriately form the subject of a brief memoir.

Our aim will be most satisfactorily attained if, in the first place, we devote attention to a *resumé* of the main ideas involved in the doctrine of "Heterogenesis," and thereafter note, in historical order, the progress of this latter theory, together with that of the opposing and rival doctrine.

We have already defined "Heterogenesis" to mean 'the production, without the pre-existence of parent-forms, germs, or seeds, of living organisms;' the latter words of this definition including both animal and plant forms. And the terms "Archebiosis and "Abiogenesis" have recently been adopted as synonymous with, but also as more expressive and correct than, the older name of "Heterogenesis."

The phenomena of "Abiogenesis" have been chiefly observed in the course of the development of life in infusions of organic matter; that is, matter of animal or vegetable nature. If an infusion of this nature be prepared in the ordinary manner, and be allowed to stand for a longer or shorter period exposed to the air, it will be found on microscopic examination to teem with living forms. The organisms thus found in the infusion are, many of them, of doubtful nature, in that they cannot with certainty be referred to either animal or plant world. Others present us with forms of undoubted animal nature belonging to the *Protozoa;* whilst the higher organisms found in an infusion are included in the most highly organised class of the *Protozoa*, that of the *Infusoria* (Fig. 5); the latter term, indeed, being derived from the circumstances under which these forms are generally produced.

The changes observable in an infusion prior to the appearance of organisms of so highly organised a nature, have been carefully studied by microscopists. These preliminary phenomena are ushered in by the formation upon the surface of the infusion, of a delicate pellicle or "scum," which the microscope shows us to consist of numberless and exceedingly minute "molecular" bodies

or particles (Fig. 29, A), which exhibit molecular movements among themselves, and constitute what is known as the "proligerous pellicle" of Pouchet.

These "molecular particles" are next observed to aggregate together, and by their union to form certain staff-like bodies, to which the name of "bacteria" has been applied (B). Later still, several "bacteria" may be observed to unite together, and thus to form a jointed filamentous organism known as a "vibrio" (C, *b b*). Both "bacteria" and "vibrios" exhibit characteristic and independent movements; the former moving

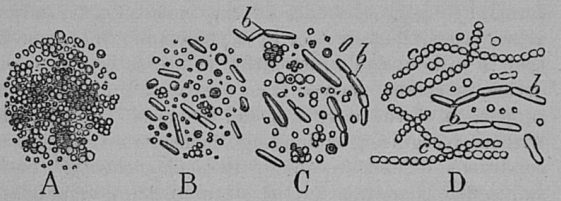

Fig. 29. DEVELOPMENT OF LIFE IN AN INFUSION.

A, Aggregation of particles or molecules on the surface of the infusion, forming the "proligerous pellicle" of Pouchet. B, Development of larger molecules, and production of staff-like bodies or "bacteria." C, Formation of "vibrios" (*b b*) by union of bacteria; the vibrios exhibiting independent movements. D, Later stage, showing the production of filaments or chain-like bodies (*Leptothrix*) *c c*, most probably of vegetable nature.

and turning upon their own axes; the latter wriggling through the fluid with somewhat of a serpent-like motion. At this stage, too, we may perceive the aggregation of larger molecules to produce a necklace-like or beaded filament, also exhibiting movements, and known as "leptothrix" (D, *c c*). As development proceeds, other and undoubted animal forms make their appearance in the fluid, amongst others *Amœbæ* and *Infusoria;* the process of populating the infusion, so far at any rate as complexity of organisation is concerned, generally ceasing with the appearance of these last-mentioned organisms.

The series of changes and events thus described must be borne in remembrance, since they constitute a typical case for the illustration and explanation of the doctrines, in the consideration of which we are engaged. And the phenomena thus witnessed would therefore appear to partake of the nature of those phases which have been already noticed in discussing the "molecular" origin of the tissues and cell-structures. By the advocates of the "molecular theory of organisation," the organic and vital molecules found in the infusion are accordingly considered capable of gradual aggregation in various ways to form living organisms; which latter, thus produced by the coalescence of the molecules, are said to arise "spontaneously" or by a process of "abiogenesis," that is without the intervention or presence of true ova, germs, or spores, derived from pre-existing forms. Other supporters of the doctrines and tenets of "abiogenesis," without recognising or binding themselves to accept the conditions offered by this "molecular theory," find a sufficient explanation for the origin of living organisms in a fluid infusion of organic matter, in the supposition that the living forms are produced "spontaneously;" or simply by the combination, in virtue of chemico-physical conditions and laws, of the dead, lifeless, and inert particles held suspended in the infusion. And this latter hypothesis will be readily recognised as allied in kind to those physical theories of the origin of life and vitality which we discussed at the commencement of our biological studies.

Such is a statement of the leading and essential ideas included in the doctrine of "abiogenesis;" or, as it was known to the older biologists, the doctrine of "spontaneous generation." The present aspect of the "molecular theory," it must be borne in mind, is not at all analogous to that in which we considered it, as relating to the ultimate constituents of textures and tissues. Since, in regarding the origin from a "molecular bioplasm" of cells and tissues, we assume the existence of a special force and conditions; the force being that of ordinary vitality, and

the conditions those of ordinary development. To assume, therefore, the power of molecules to spontaneously coalesce to form organic beings of definite form and organisation, is to place the "molecular theory" on a widely different footing from that in which we regard it as materially serving to explain the formation of cells and tissues after the process of development has been inaugurated and begun. In the one case we assume the pre-existence of a vital power determined by the ascertained conditions of development. In the other we regard the molecules as of themselves capable of producing and inaugurating the vital action, and of building up, in a manner utterly inconsistent with any known laws of development, the definite forms of living organisms.

As might readily be expected, the supporters of "Abiogenesis" have not had the field of controversy entirely or at all to themselves. On the contrary, they have been hotly and strenuously opposed by a second school of biologists, whose leading doctrine, in opposition to that of "Abiogenesis," has received the names of "Biogenesis" and "Homogenesis;" whilst the supporters of this latter theory have also been occasionally known as "Panspermatists."

The doctrine of "Biogenesis," in contradistinction to that of "Abiogenesis," may therefore be said to rest upon the belief and opinion that the living organisms found in infusions are produced from true ova, germs, or seeds borne by the atmosphere, or contained in the organic matter of the infusion. These germs or seeds, in either case, find in the infusion a suitable medium, and therein develop into the characteristic forms of life, of which they are the early representatives. The infusion is to the floating or contained germs what the soil is to the seed; and the contact of one with the other constitutes the necessary condition for developing the seed or germ into an adult form.

The main features of this latter theory will doubtless be familiar to many readers under the more ordinary designation of the "Germ Theory." The essential tenets of the "biogenesist" are therefore, firstly, the production

of living forms, invariably and solely from pre-existing forms, or mediately through ova, germs, or seeds; and secondly, the presence of such germs in the atmosphere and in solutions of organic matter. The other subsidiary conditions required and maintained by the doctrine of "Biogenesis" briefly consist in the preservation of the vitality of such germs, under circumstances which would destroy the vitality of ordinary and more highly organised forms of life. Such circumstances are exemplified in the degrees of extreme heat and cold, to which it is believed these germs may be subjected without destroying their vitality, which is thus of a peculiarly "potential" or "dormant" kind.

Such being the respective tenets of each of these great biological doctrines, we may now briefly trace the historical progress of the present subject, with the view of placing ourselves in a fit position to arrive at some clear conception of the relative merits of each theory.

The doctrine of "Abiogenesis" claims the priority over that of "Biogenesis" in point of age and historical or chronological pre-eminence. The ancients were strict "abiogenesists," in that they explained the production of living beings from putrefying organic material, by alleging and believing that they were generated by the decomposition and decay of the organic matter; or more simply, that life and living forms were produced *de novo* from dead or from truly inorganic material. The circumstances in which this belief originated were of the most natural description; and the explanation of the origin of living beings thus given appeared to fit accurately with these circumstances, and to leave no room for further argument or controversy regarding them. Thus, for the very typical and oft-referred-to case of the production of maggots in putrefying meat, the ancients, and even philosophers at the beginning of the seventeenth century, had a very ready and apparently exhaustive explanation. The maggots were supposed to be generated or produced from and by the simple decomposition of the decaying flesh; in other words, they were believed to be "spontaneously"

generated by the putrefactive process in the meat. And we thus observe that the doctrine of abiogenesis, in its earlier aspects, did not solely concern the production of such low forms of life as mere *Infusoria* and allied organisms. On the contrary, animals so high in the scale of being as insects, and even forms of a higher grade still, were believed to be occasionally, and in this way "spontaneously," produced.

In 1638 the doctrine of Abiogenesis may be said to have received its first check, when the experiments of Francesco Redi, a Florentine physician, demonstrated that there were other, simpler, and better explanations of the appearance of maggots in meat than the supposition of their "spontaneous" generation. Redi, directing his attention to the apparently solid facts on which the doctrine was founded, soon saw cause to dispute the validity both of the theory and of the circumstances from which it took origin. Referring to the generation of maggots in meat, he showed that, by placing gauze over the meat, the development of the maggots was prevented, although the process of meat-corruption went on as before. It was obvious, therefore, that the gauze kept back from the meat a something which formerly had free access to it; and ordinary observation soon detected that this "something" consisted merely in the eggs of flies, which were deposited in the putrefying material, and which gave rise, by a process of ordinary development, firstly to maggots, and finally to the mature forms or flies. The production of "galls" and other vegetable growths was accounted for by Redi in a similar manner; and, primitively simple though the method of his experiments may appear to be, it is nevertheless closely and essentially pursued by the experimentalists of modern times.

As might be expected, Redi's refutation of the "abiogenetic" doctrine caused no little consternation and dismay among the supporters of that theory. The refutation of a doctrine apparently so incontrovertible and so firmly rooted, served to change and alter in the most remarkable manner the current of opinion regarding abiogenesis; the

overthrow of the latter theory serving at once to found and establish the rival hypothesis of "biogenesis. And the motto and dictum of Redi, "omne vivum ex vivo," was therefore considered as the triumphant expression of a newly found and universally correct law. Whilst the aphorism of Harvey, "omne vivum ex ovo," more narrowly limits and defines the belief of the biogenesists—essentially the same in these days as it was at the birth of their doctrine—the production of life and of living beings only from pre-existing life, and most generally from the ova, seeds, or germs, of pre-existent and parental forms. Life and vitality are invariably propagated by true descent, and are never specially produced or created *de novo*. Such were and are still the tenets of "biogenesis," a doctrine which for nearly an entire century after Redi's time held the position formerly occupied by the rival and opposing theory.

Meanwhile the growing perfection of the microscope, and the investigation of the lower forms of life, which in Redi's time were almost totally unknown, and the further knowledge of the production of *Infusoria* and allied organisms in artificially-prepared infusions, stimulated anew the flagging energies of the abiogenesists. The next champions of this latter cause who appear before us are Needham and Buffon; who, after due experimental investigation, declared themselves as convinced of the truth of the doctrine of abiogenesis. The experiments of Needham, made in 1745, were conducted after the same method as those of Redi, but, at the same time, they more nearly and fully approach the details of the modern experimentalist.

The efforts of Needham were accordingly directed to the investigation of the conditions under which *Infusoria* and allied forms could be produced and propagated. If the *Infusoria* appear in infusions as the result of the development of germs or ova, these latter, he concluded, must be present in the infusion, or be borne by the atmosphere. And, therefore, if measures were taken to destroy the vitality of these germs or ova—the conditions of the

infusion remaining the same—no *Infusoria* should, after this treatment, appear in the infusion, and the biogenetic doctrine would accordingly be proved correct. But if, on the contrary, after this mode of investigating the subject, the animalcules were still found to be present in the infusion, then the decision would necessarily be in favour of the doctrine of abiogenesis.

Needham, considering that in a high degree of temperature the conditions necessary for the destruction of the germs were to be found, carefully boiled his infusion, and, after sealing it, again subjected it to the influence of a high degree of temperature. On opening his flasks after they had been allowed to cool, Needham found the infusion, notwithstanding its having been boiled, to teem with *Infusorial* and animalcular life. And he therefore concluded that the organisms must have been produced spontaneously from the fluid, or from the materials contained therein; since he firmly believed in the destruction by the heat of all living germs or organisms which the infusion, previously to its being boiled, might have contained. He therefore, after repeating his experiments, and with the same result, declared his firm belief in the truth of "abiogenesis."

At the same time, Buffon's theory of the production of life from "organic molecules" was promulgated chiefly as a result of the conclusions arrived at by Needham. This latter hypothesis, founded on and implying a modified belief in the doctrine of "abiogenesis," maintained that the essentially vital or life-giving properties were located in indestructible particles or "molecules," each of which had a vitality or life peculiarly its own. Buffon maintained that the body of every living organism, of whatever kind or grade, was merely a temporary aggregation of such "molecular" particles, which, liberated by the death of the organism, are once more free to enter into the combination and formation of another, and, it may be, an entirely different form. It is somewhat remarkable to find, ever and anon, the materials and ideas of an almost forgotten theory brought to light, and made to do duty,

under a fresh garb, in the establishment of a new hypothesis. There thus exists between certain recent notions of "molecules" and the ideas of Buffon a close and intimate relation, although the more modern ideas regarding them are different from the opinions of the French zoologist. The same material, however, does duty as the basis of all the "molecular" hypotheses which now and of old have been constructed and advocated.

Once more, therefore, the struggle and controversy seems to turn in favour of abiogenesis. But a new champion of the opposing doctrine soon enters the lists, and quickly throws the balance towards the biogenetic side. The Abbé Spallanzani, directing attention to the experiments of Needham, showed, in 1765, that the presence of living organisms in Needham's boiled infusions was due to want of care and skill in the method of closing his flasks. And Spallanzani demonstrated the want of care and erroneous conclusions of Needham by preparing infusions of similar kind, by closing them after an improved and different method, and by continuing the process of boiling till a higher rate of temperature than that reached by Needham was attained. The infusions of Spallanzani, so treated, were found on microscopical examination to exhibit no signs of vitality. Hence the exertions of the Abbé turned the tide in favour of biogenesis, and resulted in the foundation of his "universal germ theory," the essential feature of which was the recognition of germs borne by the atmosphere as the origin of all the forms of infusorial life.

The controversy at this point, however, assumed a new and entirely different aspect to that which had formerly characterised it. The birth of an improved chemical science opened up a *chemical* aspect which had formerly been unknown; and it was now assumed or suggested that the non-development of life in the infusions of Spallanzani might possibly be due to the influence of chemical changes induced by the process of boiling. And similarly followed the assertion that fermentation and putrefaction were changes of a chemical nature, and were not caused by the

presence of certain living and organic forms. The former of these views with regard to fermentation was held in modern times by the late Baron Liebig, whilst the latter opinion is as strenuously advocated by Pasteur.

Schulze and Schwann, in 1837, disposed of the chemical objections to Spallanzani's experiments, by allowing only air filtered through strong chemical solvents, such as sulphuric acid and caustic potash, or air passed through red hot tubes, to reach the infusion. The oxygen of the air, which was considered so necessary to the development of life, and which in Spallanzani's experiments was thought to be affected by the process of boiling, was accordingly allowed to reach the infusion. The chemical uniformity of the air was thus preserved intact, but at the same time it was deprived of the organic germs, which Spallanzani had maintained were the cause of the development of life in the infusion; and after being so treated, the infusions displayed no signs of vitality. And Schrœder and Dutsch, in 1854, substituting simple cotton-wool for the chemical solvents of Schulze and Schwann, showed that air filtered through such a medium was incapable of developing living organisms.

The investigation and discovery, by De la Tour, of the "yeast plant" (Fig. 20, *n*) as the cause of fermentation, chiefly occasioned the hot controversy already referred to, as to the nature of the fermentative and putrefactive processes; a controversy which, however, was satisfactorily settled in favour of De la Tour's view and discovery, by the experiments of Helmholtz, who proved, in the years 1843-44, that the mere separation by a thin membrane, of a putrescible fluid from one which was actually undergoing the process of fermentation and putrefaction, was sufficient to prevent the extension of the process to the former portion of the liquid. And in this way, he demonstrated, that if the cause of fermentation were purely chemical, there was no reason why the former fluid should not exhibit the same series of actions and phenomena as the latter and already fermenting fluid, since the purely

chemical conditions were the same in both. This experiment, therefore, showed that in all probability the cause of fermentation lay in the peculiar phenomena accompanying the development of living organisms within a fluid fit for their propagation; and the analogy between the development of such organisms and the production of *Infusoria* and allied forms in an infusion is at once apparent. Hence, the present stage of the controversy resulted in the demonstration, that the essential *materies* of fermentation, and in all probability of that necessary for the development of infusorial life also, existed in a state which was most nearly "particulate;" that is, consisting of minute "particles" of organic matter; which particles, like seeds in a fit and appropriate soil, were developed in the infusions into certain adult and specific forms.

The progress of the doctrine of biogenesis was thus exceptionally rapid and brilliant, and up to the present time its career has been no less striking. M. Pasteur's researches (1862) into the production of living organisms in infusions, and his demonstration of the "particulate" and specific nature of the germs or particles which give origin to forms of life in such media as infusions, and also within the bodies of higher animals and plants, are to be regarded as exemplifying some of the most important contributions to the support and establishment of the biogenetic doctrine. Whilst latterly Professor Tyndall has shown us that the existence of such particles in immense quantities in the ordinary atmosphere, is no longer a matter merely of conjecture, but one of absolute certainty and proof.

In the present day, therefore, the rival doctrines still oppose one another as of yore. And whilst the doctrine of biogenesis has been thus advancing towards complete demonstration, the interests of abiogenesis, and more especially during latter years, have not been neglected by ardent supporters. The record of progress in the demonstration of abiogenesis as a doctrine worthy of support has not, it is true, been so brilliant as that of the opposing theory; but the doctrine has not lacked

able advocates, who fail to see in the "germ theory" or in allied hypotheses, a sufficiently reasonable explanation of the occurrence and development, under certain circumstances, of the lower forms of life.

The experiments of abiogenesists have generally been conducted with a view to show that, notwithstanding the presence of conditions—such as those of great and long-continued heat—unsuited, and otherwise considered fatal to the existence and development of living or organic germs, living organisms may still be found to be developed in infusions of organic matter. And these organisms, they maintain, originate *de novo* from the molecules of the contained fluid or substance; an assumption tantamount to the belief that vitality can be created, or may spring into existence independently, and without the pre-existence of vitality or of living forms.

Thus the issue between the biogenesist and abiogenesist narrows itself to the belief, on one side, that the organic germs and particles are capable of withstanding a much greater temperature than is generally supposed or admitted; whilst on the other side it assumes the phase of an opinion against the possession of such powers by organic germs, or primarily against the specific nature and universal existence of germs. And in conjunction with these two points a third must be included, that of a belief in the "spontaneous" origin of living forms, through processes which may be deemed physical or chemical, or physico-chemical in nature.

For and against these various points much evidence has been brought to bear. The most important contributions to the side and opinions of abiogenesists which of late years have appeared, are those of M. Pouchet and Dr. H. Charlton Bastian. M. Pouchet may be ranked amongst the foremost pioneers of abiogenesis; and his elaborate experiments have been chiefly directed to the refutation of those of Pasteur. Pouchet seems to incline to the belief that the organisms developed in infusions derive their characteristics from the particular fluids in which they are produced; a fact in part explicable to the

biogenesist, by the supposition that certain germs or organisms may flourish best in particular media. Dr. Bastian, in his recent work, entitled the "Beginnings of Life," seeks to show that the doctrine of abiogenesis holds a more philosophical status than that of biogenesis. The experiments detailed in this work are many of them of the most complicated and novel description; and whilst it is permissible to offer a few general observations on these and allied experiments, and also on the conclusions deduced therefrom, it must also be borne in mind that further research is required before perfect confirmation or contradiction of Dr. Bastian's views can be affirmed. The battle in the present day between abiogenesis and biogenesis is therefore one of the most keenly-contested which the history of any science has ever witnessed. Not only have we the highest authorities in biology ranked on either side, but the most complicated apparatus is now called into requisition by both parties. And thus the warfare is waged, with the circle ever narrowing itself; each step in the sequence of proof and demonstration being as hotly contested as if all the issues of biology and the kindred sciences were dependent upon the result of the battle.

The experiments of Dr. Bastian were conducted according to the method we have already pointed out. Infusions of organic matter were subjected in flasks to great and continued heat; the flasks were then hermetically sealed, and again subjected to a continuance of a high rate of temperature; and, after being allowed to stand for a longer or shorter period, the contained infusions were examined, with the very general result of finding living organisms developed therein. And such results Dr. Bastian has obtained even from solutions or infusions of *inorganic* nature—such as solutions of phosphate of soda, or of ammonia, and also from solutions of tartar emetic; this latter condition, that of a purely *inorganic* solution, being, so far as we are aware, of an entirely novel kind in the history of experimental research into the phenomena of biogenesis. Then, also, Dr. Bastian

has found that if infusions be of a sufficient strength, and of a highly fermentable kind, infusorial life is developed "*in vacuo*." And following up the same line of observation and experiment as that pursued by Dr. Bastian, we find Dr. Burdon Sanderson asserting that "liquids which contain no particle distinguishable under the highest powers of the microscope, can often be proved to possess the property of evolving microzyms (bacteria, etc.) after being boiled in sealed flasks without contact with external media."

The chief considerations which militate against the validity of the abiogenetic doctrine in general, and against that of the experiments from the results of which it would seem to derive a large measure of support, appear to consist primarily, and from *a priori* reasoning, in the fact that the conditions under which the development of Infusoria is expected and alleged to take place are thoroughly opposed to the exhibition or development of life. An inorganic solution, for example, presents us with a condition which, primarily, we would consider to be wholly unfavourable and unsuited to the exhibition and development of any living forms whatsoever; even allowing that they were capable of being produced by molecular combination, under physical conditions, or in any other way consistent with abiogenetic belief. The very occurrence of organisms in such an infusion, therefore, militates against the theory supported by Dr. Bastian, since the mere conditions for the development of life required by the physicist himself, are wanting in such a case.

Or, on the other hand, admitting the suitability of the preliminary conditions in the infusion, it might reasonably be doubted if the exceedingly high and continued rate of temperature to which the infusions were subjected, can be compatible with the development of living beings: yet we are informed that the development of life was as great in the infusion so treated as in one which had not been subjected to heat at all. The appearance of living organisms to such an extent, and under such conditions, would therefore seem to afford grounds for the belief in

the possession by the infusorial germs of greater powers of resistance to rigorous conditions, than, from previous experience, could have been conceived.

The actual existence of organic germs in the atmosphere, and in fluids of all kinds, has now been placed beyond the possibility of doubt. Whether the doctrine of abiogenesis and of the "spontaneous" origin of living forms be proved true or not, the fact that the atmosphere is the medium for the conveyance of vast quantities of organic germs, is insusceptible of controversion or of modification in any way. And the unavoidable admission of this fact constitutes a certain and significant argument of primary importance in favour of the ordinary and "biogenetic" development of these germs into infusorial and other forms of life. The abiogenesist, in the face of this fact, is placed in the position not only of an opponent to the belief in the actual existence of organic germs, but also to the idea of the connection between such germs and the lower forms of life; and to the consequent production of the latter by a process of ordinary development, in infusions of organic or even of inorganic material.

In connection with this latter point—namely, that of the connection between the forms of life found in infusions, and the organic germs of the atmosphere and fluids—it may be mentioned that Professor Lister has lately demonstrated, in the clearest possible manner, these important relations. This ingenious experimenter has thus shown that many of the organisms declared by abiogenesists to be produced by "spontaneous generation," are in reality the early or embryonic forms of certain fungi, which Mr. Lister has had the satisfaction of developing from germs; and these fungi were traced throughout their entire cycle of development. A fungus appearing in an organic solution on exposure to the atmosphere, was thus observed to produce "spores," which, after separation, gave rise to "young plants like the parents;" and other "spores," of precisely similar kind and origin, were seen to multiply by budding like

the Yeast plant or *Torula* (Fig. 20, *n*). The recognition of the transitional nature of the "spores," and of these alternating phases of development, thus supplies the connecting links between the organisms found in infusions and the germs from which they originate.

Mr. Lister has also observed the presence of slender filaments, which "were seen to break up into bacteria;" whilst the filaments themselves were noticed to be produced from spores, "indistinguishable from those of the fungus." These new and startling facts with reference to the origin of Bacteria (Fig. 29), and the knowledge that certain forms of life found in infusions actually represent stages in the life-circle of a fungus, place the controversy on an entirely new footing, and, at the same time, advance in an important degree the interests of "biogenesis."

A further and opposing consideration to the doctrine of abiogenesis, and one to be taken in consideration with the preceding remarks, is found in the fact that the lower forms of life, and presumedly their germs also, are capable of withstanding a long continuance of a very high rate of temperature. Hence, where the abiogenesist obtains a *positive* result in his treatment of an infusion—namely, that of the presence of infusoria, etc.—the biogenesist can assert his belief, susceptible of abundant demonstration, that a high rate of temperature is not inconsistent with the development of infusorial life from germs or spores, which are thus of a semi-indestructible nature. If, therefore, we are offered the choice of believing, on the one hand, that the organisms developed in a fluid subjected to such rigorous conditions as those we have described, spring from germs contained in the fluid, but which possess the power of resisting a very high rate of temperature; or, on the other hand, that the contained organisms are produced from a combination of the inorganic constituents of the infusion, and without the pre-existence of vitality, one can hardly think that the cautious discernment of a logical mind will hesitate in its choice of the former belief as that most

consistent with the ordinary experience of life, and best in accordance with the dictates of scientific knowledge and research.

The remaining and final considerations, which may be enforced in concluding the present subject, have reference, firstly, to the *nature* and subsequent history of the organisms developed in the infusions of Bastian and other experimenters; and, secondly, to *conditions of life* and vitality in even high forms of animal life, which bear an analogous relation to those conditions which we believe the microscopic germs of the lower forms of existence to present.

The organisms found by Dr. Bastian and others in prepared infusions were chiefly of a vegetable nature; the animal forms being limited to those of the lowest grade, many of which are hardly distinguishable from true plant-organisms. We thus observe the remarkable and noticeable absence of the higher and *Infusorial* forms which appear in such abundance in ordinary organic infusions. The forms of life found present in the rigorously treated infusions are therefore almost entirely of a vegetative kind; and, as such, may be regarded as presenting us with a lower type of vitality than truly animal forms. Consistently, then, with this lower vitality, we may presume their greater indifference to the conditions in which the infusions were placed; and hence the greater chance of such organisms being preserved, whilst the more highly organised forms would be destroyed.

Regarding the subsequent history of the forms assumed to be "spontaneously" produced in infusions, it is a fact worthy of note that they are observed to reproduce themselves after the ordinary modes of reproduction, and through the ordinary processes of development. These infusorial forms thus reproduce their like in exactly the same manner as when they occur in a natural state. And the mere occurrence in these forms of thoroughly normal reproductive processes, affords an argument of weight against the supposition of their "spontaneous" production by any of the modes included under the

doctrine of abiogenesis; whilst it also tends to impress more firmly upon us the uniformity of natural actions and laws.

We thus never witness in the after-history of these infusorial forms the occurrence of any abnormal or unusual processes of reproduction. The irruption into the circle of continuous and transmitted vitality does not seem to be repeated or again evinced in the subsequent history of these organisms. Nor can abiogenesis afford any explanation why organisms supposed to be thus spontaneously thrown into the world of being, should be capable of reproducing their like after ordinary and normal methods. And whilst the occurrence in these forms of the ordinary reproductive processes thus serves as an argument against their "spontaneous" production, the fact also goes to support the opposing doctrine of "biogenesis," in that it argues for the "cyclical" nature of the great vital processes, and for the invariable repetition, in the life-history of an organism, of the process by which itself was produced.

Finally, when we consider that in animal forms of an organisation so high as that of the *Rotifera* or "wheel-animalcules" (Fig. 3), we find a most remarkable exhibition of "dormant" or "potential vitality," our ideas of the conditions under which life and the vital force may be preserved and manifested assume an extended character, by aid of which we may draw several highly important conclusions with reference to the subject before us.

We have already remarked, in considering the nature of "potential vitality" (Chapter II.), that the *Rotifera* may be dried up from the pools by the heat of the summer sun, and in this mummified condition may be blown about as mere dust-specks for a considerable period, until the addition of a little moisture once more places them in possession of all their pristine and original vital powers.

The *Rotifera* which thus possess so wonderful a vitality, it must be borne in mind, are very far above the *Infusorian* animalcules in organisation; and we must further note that

it is not the mere eggs or germs which are thus subjected to so rigorous conditions, but the adult and mature Rotifers, in all their structural perfection and functional activity. And if the vital energies of creatures ranking so high in the scale of being, be thus capable of withstanding the influence of conditions so much at variance with the ordinary laws of vitality, we cannot, after such considerations, regard the exhibition of potential vitality on the part of the mere germs of much more lowly-organised forms, as of so unusual or extraordinary a kind. The experimental conditions already referred to, when considered relatively to the organisation of the *Confervoid* spore or germ of the lower animal organism, are not more rigorous than those to which the high organisation of the adult Rotifer is subjected.

A belief in the doctrine of Biogenesis, and in the invariable transmission of vitality, is thus shown to be of a decidedly more philosophical nature than that in the opposite theory of Abiogenesis; involving, as does the acceptation of the latter doctrine, the assumption of actions and conditions unwarranted by the general teachings of a uniform biology, and especially by the ascertained laws under which vital force and living material are respectively exhibited and conserved.