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ON LIFE
AND
ON VITAL ACTION
IN
HEALTH AND DISEASE

DR. BEALE

5/-

King's College Hospital
Medical School
(UNIVERSITY OF LONDON).

Presented by

Harold Waterlow Wiltshire
M.D., F.R.C.P.,
Assistant Physician.

June 1916.

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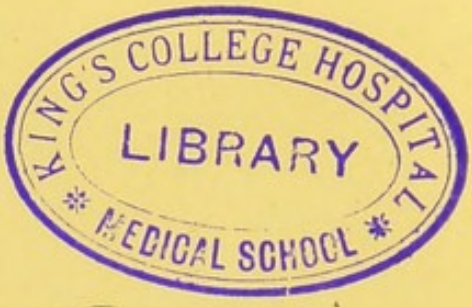

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ON LIFE

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IN

HEALTH AND DISEASE,

BEING

THE LUMLEIAN LECTURES

Delivered before the Royal College of Physicians

BY

LIONEL S. BEALE, M.B., F.R.S.,
Fellow of the College.

LONDON: J. & A. CHURCHILL.
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OUR PRESIDENT,

SIR GEORGE BURROWS, BART., M.D.,
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THE LUMLEIAN LECTURES

FOR 1875,

DELIVERED BY HIS DESIRE,

ARE DEDICATED.

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ON LIFE

AND ON VITAL ACTION

IN

HEALTH AND DISEASE.

THE nature of life is a question which has engaged the attention of the most thoughtful of every age, and was, perhaps, one of the first enigmas that philosophic man essayed to solve. For more than two thousand years, the greatest among poets, philosophers, naturalists, divines, mathematicians, and, in later days, chemists, anatomists, physicists, surgeons, and physicians, have thought and speculated and investigated in the hope of finding out what life was. But physicists, as well as those who are opposed to their conclusions, are still obliged to speak of the *mystery of life*, and we may feel quite sure that this large question will engage the attention of philosophers yet to be, and will supply a theme for many an essay, ere the problem will be finally solved.

Can there be one amongst us who, contemplating the

marvellous phenomena of man's organism from the first dawn of life to birth, and through infancy and childhood to maturity, old age, and death, has not longed to know more about the exact nature of the changes he observes and the causes of them, than he can learn at this time? And surely he who has studied and pondered over the minute changes accompanying the development and growth of tissues, the phenomena occurring in the same structures in disease, and the not less marvellous fact of their cessation at death, must have witnessed, with sorrow and disappointment, attempts upon the part of some of the most popular of our scientific teachers to revert to doctrines almost identical with those held in the time of Lucretius, to stop speculation, save in one direction only, and to force the public to believe that all these wonderful changes are mechanical—to assure us in short that these and the phenomena of all worlds—beginning, duration, and end, are to be summed up in that grotesque formula,—from fiery cloud to fiery cloud. It would be more to the point if physical authority, instead of decreeing such final solution of the great problem of being, would, with the help of physics, give a more complete answer to the question "What am I?" than has yet been obtained, and clearly show that the *why*, the *how*, and the *whither*, need no longer puzzle the understanding.

The general conclusions we may feel inclined to accept will be much affected by the particular views to which we may lean concerning the nature of the changes occurring in matter that is alive, and it will be found that vital theories cannot be fully discussed without touching upon the most profound of our thoughts. It is not, therefore, surprising,

that by the advocacy of rival doctrines, feelings should be aroused which are not favourable to the steady prosecution of scientific investigation, or compatible with calm deliberation and the discovery of truth. The discussion of such questions cannot be carried on, even in England, without warm controversy; and, occasionally, scientific ardour seems to sanction tactics, which one would suppose had emanated from the code of the political propagandist rather than from that of the searcher after scientific truth.

With a tenacity of purpose worthy of a better cause, it has been affirmed again and again that physical and chemical processes *constitute* the life of the higher animals; and, at this time, there is a considerable party who believe and teach physical doctrines of life. Nevertheless, it can hardly be doubted that of those who speak thus confidently, many are perfectly aware, that there are certain phenomena which occur in everything living that cannot be explained by physics and chemistry. No explanation is offered of the particular phenomena in question, but, in direct contravention of the principles upon which science rests, it is asserted that all phenomena are physical; some investigators apparently preferring to strengthen a party manifesting a certain definite tendency in thought, than to aim at scientific accuracy and work on in a spirit of scientific independence.

Free speculation and the framing of hypotheses stimulates and encourages enquiry, and ought not to be opposed, but scientific speculation must be controlled by observation and experiment. Even purely conjectural propositions which arise from time to time in the mind, not unfrequently form the starting point of new lines of scientific enquiry. Nay, I

believe that but for the mental pleasure derived from speculation and contemplation, it is doubtful whether original observers would be able to complete the tasks they set themselves to perform, tasks often lasting for months or years, and depending upon the steady prosecution of observation and experiment, in the course of which failure, disappointment, and the consciousness of lost time will be found to make a large item in the account. Scientific men must exercise their imagination, though at the same time they must control it. Observers probably differ from one another less as regards capacity for imagining than in the judgment they display in the publication of the results of imaginative enquiry. One man, perhaps, may examine carefully and then cast away hosts of ideas that another would gladly seize upon and bring under public notice at the earliest possible moment as thoughts that ought to move the world. Any one having enthusiasm, who pursues a definite line of enquiry will naturally desire to press on into the region just beyond the limits of observation and experiment; and this tendency is advantageous, for it often leads to new discovery. But of late scientific men, boasting of their exactness, have tried to drag us into very remote regions of conjecture, and insist that we shall accept, as literally true, all they discover in their imagination concerning the potentialities of imaginary atoms.

And not only so, but it has been more than suggested that some of the facts of the imagination upon which certain very old doctrines, recently revived, are based, cannot be made evident to people generally, but are only thoroughly understood by a very limited number of privileged persons. It is, therefore, a necessity that information so distributed

should only be dispensable by a select few. But if we really study some of the hasty generalizations recently put forward, we shall find that after all they are little more than the opinions of one or two scientific speculators, having remarkable confidence in the infallible nature of their own opinions. Their unbounded faith has led many to accept their statements as literally true; and, by degrees, a powerful party has been formed. Now no reasonable objection ought to be made to a combination among those who agree in their views of nature for the purpose of spreading the truths they have discovered, and endeavouring to gain for them the greatest publicity. The more widely and the more quickly facts are spread after they have been proved to be true the better for investigators and for students. But that a few scientific men who have committed themselves to a particular set of doctrines, or that any one scientific man should, upon matters of science speak as it were *ex cathedrâ*, and declare a particular doctrine concerning the origin and formation of all things to be absolutely true, should praise in highly extravagant terms those who side with him, and stigmatise those who do not at once accept his views, or who differ from him in opinion as unworthy of credit, or as weak, or foolish, or savage cannot be right or to the advantage of science. Such a course if supported by many scientific men, and if sanctioned by public opinion, would surely be extremely prejudicial to liberty of thought and freedom of enquiry, for would it not soon lead to the establishment of a power that, instead of proposing, would decree; and, being convinced of its infallibilty, would not hesitate to promulgate it? Nay, there is manifestly, at this time, a strong desire to establish a new power in connection with science and philosophy which

would be contrary to the first principles of English thought and destructive of progress.

I venture to think that enthusiastic disciples of physical life science, have recently seized far too much of the world of life and assumed that it was their own, and have claimed privileges which do not and ought not to belong to investigators and teachers—especially the privilege of enjoying with only a very few other highly gifted persons, a monopoly of the work of extracting scientific truth from the depths of the imagination. And although some of the hypotheses now very popular, can only be understood by a very small number of scientific men, is it impossible that the facts and arguments advanced against them should be made intelligible to a very large number of intelligent persons?

Many of this College, following the noble example set by the most illustrious of their predecessors, have done their utmost to extend the boundaries of medical science, and among our number are not a few who have taken an active part in the purely scientific work of the present century. The scientific as well as the practical aspect of medicine, has ever been well represented in the College Lectures, but many circumstances seem to me to render it desirable, that those among us, who are favoured by circumstances, and have a natural bent for scientific pursuits, should do their utmost to maintain the high reputation for pure science won by their predecessors; and, as far as they have the power, hand down the honoured precepts to those who shall succeed. Such considerations, Sir, I hope may afford some justification for the course I shall take in directing attention to debated questions connected with life, which I fear may be deemed by some out of place here, in the Theatre of the Royal

College of Physicians. But I may also plead, that one who has long been a teacher of Physiology, and has had the honour of receiving a Baly Medal, may not unnaturally desire to ask this college and the profession, to consider with him phenomena of the greatest interest, and which are most intimately connected with individual life, in a state of health and disease. But above all, I have been affected by the circumstance that at this time we are overwhelmed and confused with the most conflicting statements, as regards even the simplest facts of life. We have no solid foundation upon which to build the fundamental principles of our science, for are we not, many times in each year, enjoined to accept as true, the doctrines of a purely conjectural philosophy, based upon conjectural discoveries concerning matter and atomic phenomena?

To the doctrines now generally taught and fast becoming very widely diffused, I am and have been strongly opposed. In certain particulars those doctrines are in conflict with views based upon well-observed facts, in relation to the growth and multiplication of every known form of living matter, and the formation of the tissues of living beings. Many observations, though repeated again and again, must be entirely erroneous if the positive statements recently made concerning the phenomena of living beings are true. It may be presumptuous, perhaps, to suggest that the conclusions arrived at by me many years ago, ought not to have been wholly ignored by authorities, who have expressed themselves in very confident language concerning the physical nature of life, but people have been informed again and again that *all* the phenomena of living beings are due to physical changes, although it has been

pointed out, that phenomena, characteristic of every kind of living matter, cannot be so explained. I have for many years pleaded in vain, that, for example, an attempt should be made to explain the movements of an amœba, or a mucus corpuscle by physico-chemical action. But, instead of being answered, I am twitted with belonging to an institution famous for its orthodoxy. Old assertions are again repeated, and it is dogmatically declared in the plainest language, that *all living things are machines*, and *that all their actions are mechanical.*

It is, therefore, right as it seems to me, now to proceed a step further, and challenge the supporters of the physical theory of life, to publicly reply to the objections urged against the statements they have made. For has not the time arrived when the facts and arguments upon both sides might be summed up and judgment given, whether the physical doctrine of life is justified by the scientific knowledge of the time in which we live; or whether on the other hand it is not a thoroughly unscientific inference, based only upon the facts of the imagination, and opposed to facts of observation?

In the physical domain, as has been well said, consequence follows its antecedent with unerring certainty. What will happen under certain given circumstances can be stated with exactness and premised beforehand. But it is not so with the living world. It has yet to be proved that every change there is a direct consequence of antecedent physical change. We cannot predicate of vital as we can of physical phenomena. We have not the certainty of physical law. Nevertheless, with amazing confidence, not, however, resulting from knowledge, some declare that the

difference is to be easily accounted for by the greater complexity of the circumstances and conditions which obtain as regards vital phenomena. When, it is affirmed, by further investigation these circumstances shall have been fully investigated, man, we are assured, will be able to define, with absolute certainty and unerring precision, the particular living form which shall result from the development, under certain given conditions, of a particle of colourless transparent matter which represents the earliest stage of being of countless numbers of very different creatures. And yet changes, characteristic of every form of living matter, have been scarcely alluded to by the upholders of this notion. It must indeed have struck many as a remarkable fact that so little has lately been said concerning the relation of life to matter. The connection between mind and body, mind and brain, mind and matter, has been very fully discussed, but the question of the connection between life and body has received far less attention, although the determination of the last is the preliminary enquiry which would naturally be presented for solution, before the nature and relations of mind were touched upon.

Surely we who have been studying life in many forms, and under varying conditions,—who have, from early age, been familiar with the tissues and structural changes occurring in man and animals, in health and disease,—ought to carefully examine the current statements about the physics of life, and try to prevent the wider diffusion of mere mechanical views, at least until it shall have been proved that they rest upon some solid foundation. We have been assured, over and over again, that we must accept a particular doctrine or nothing; but surely the alternative is not a very terrible

one, for is it not conceivable that some may prefer being stigmatised as believers in nothing to the privilege of accepting as literally true highly conjectural propositions?

Ought we not to urge those who have assumed the responsibility of teaching physical doctrines of life to publicly reveal the facts, and clearly state the arguments upon which they rely for the establishment of the doctrines they assert to be true—doctrines which seem to be based upon mere discoveries of the imagination, though they are, it is to be regretted, believed and taught in the most ancient of our seats of learning, where, strange to say, Socratic philosophy and caution are still inculcated?

Among the doctrines referred to are the following:—

The sun forms living beings.

The brain and all organs have been built by the sun.

All the actions of all things living are mechanical.

All things living are machines.

Living organisms, as well as crystals, are the products of molecular forces.

The mind, the intellect, the will, thoughts and emotions, as well as the body, were once latent in a fiery cloud.

The present world and all its inhabitants, past and present, as well as those to come, lay potentially in the matter which was once cosmic dust.

The lowest forms of living, approximate very closely to non-living, material.

Only matter and material forces—only atoms and atomic forces—have been and are concerned in the formation of all things, living as well as non-living.

Up to this time no one has succeeded in showing that the above propositions contain the vestige of a sub-stratum

of truth, and it would have been easy to have added several others to the above list, of which the same remark would be correct. Those who force such views upon public attention incur a serious responsibility, but I am not sure if scientific men who strongly disapprove of the course taken, and who know full well that many of the extravagant assertions now made in the name of science, and from a scientific platform, cannot be supported by facts, do not, by their silence, incur a responsibility equally grave, inasmuch as they permit arguments which they know to be unsound, to be advanced in the name of science without objecting to them.

And now, Sir, I think I cannot better show how fully sensible I am of the high honour you have conferred upon me by appointing me to deliver these lectures to the College and the profession, than by asking of you permission to resign whatever authority the position of Lumleian lecturer may have given; for I would come before you as a student who, after studying and working for many years, desires, in as plain a way and as briefly as he can, to speak of some of the things he has seen, and is anxious to indicate, as far as he is able to do so, the broad general principles which seem to be deducible from his observations.

Much of what I have to tell is simple, and will easily be understood, and there is nothing that I have found out that might not have been found out by another had the same means of enquiry been adopted, and had the work been patiently carried on for as long a time. Far from laying claim to the possession of any unusual powers or privileges of investigation, I shall be quite content if I am credited with the power of being able to see as correctly as my contemporaries.

The preparations upon which my inferences are based

have been shown to others, and not a few were exhibited in this theatre soon after they had been made. It is upon demonstration that I rely, and if I am not convinced that opponents who have never seen my specimens know much more about them than I, who have carefully studied them for hours under very high magnifying powers, on many different occasions, I hope I shall not be considered a very unreasonable and prejudiced person.

In the course of six lectures which I delivered to the College in the spring of 1861, and which were published soon afterwards, and in the course of the same year, translated into German by my friend Prof. Victor Carus of Leipzig, I directed attention to the remarkable characters of *living matter*, and pointed out how this could be distinguished throughout nature.*

I also showed that in nutrition the pabulum always gained access to the living matter, and that by and out of this latter alone tissue was formed, the very matter that was once living becoming converted into the tissue. Specimens of the living matter were exhibited, some of which were taken from the lowest organisms, and others from the tissues of the higher vegetables and animals, and from man. The varying proportion of living matter in corresponding tissues at different ages was also demonstrated in cuticle, cartilage, muscle, nerve and other tissues. The living matter was called

* As much misconception has arisen as to the exact date of my observations, on account of frequent references on the part of authorities to observations of Max. Schultze and Kühne, while mine were wholly ignored, it is only right to draw attention to the fact that Max. Schultze's "Das Protoplasma" was published in 1863, nearly two years after my lectures appeared, while Kühne's "Untersuchungen über das Protoplasma" did not appear till 1864.

germinal matter, which term has been since replaced by the short and more convenient word *bioplasm;* and the matter formed from it was termed *formed material*, because it was shown that all tissue, "intercellular substance," and matters resulting from changes in the so-called cell were formed from the bioplasm only.

It was also shown that masses of bioplasm, after reaching a certain size, usually less than the $\frac{1}{1000}$ of an inch in diameter, underwent division, and that as soon as any mass of bioplasm attained a certain definite size (which differs in different creatures and textures, but which is constant for the same) it divided, or portions moved away; and, at length, detached themselves from it. If the bioplasm were to continue to grow, the distance to be traversed by the nutrient matter, before the inmost parts were reached, would soon become so great that these would be practically beyond reach, and could not be nourished or subjected to the constant action of currents of fluid. Death would begin in the central part of such a mass, and would soon involve particle after particle as its ravages extended outwards, until the whole of the living mass was dead. There are many circumstances connected with the life of a mass of bioplasm which render its growth without division and subdivision a most improbable event. With the exception of that fanciful sheet of living matter once supposed to grow in the sea at very great depths—never seen but received in undoubting faith by the critical Strauss—that so-called Bathybius which was evolved from the depths of the imagination at a time when a primeval physical basis of all life was particularly wanted by certain advocates of evolution,—with this exception, I repeat—large masses of living matter exist not.

In man and the higher animals, it is the exception to find a single mass of bioplasm which measures as much as the one-thousandth of an inch in any direction. It is not wonderful that particles of matter so small, seeing that they are also colourless and structureless, should have been, for a long time, passed over as of little importance, and almost ignored by some anatomists. In many drawings of tissues which contain numerous masses of bioplasm, not one is represented, for it was supposed that the tissue was formed independently of such particles. But the evidence in favour of the view that it is from these small masses of living matter that all tissue grows is incontrovertible. Without them nothing characteristic of a living organism is formed. These, and not the formed tissues, are the seat of nutrition, formation, and differentiation, and in them is the the sole source of metabolic power.

It was not to be expected that conclusions differing so widely from those entertained at the time by most observers, and so opposed to the general inferences concerning the nature of vital phenomena, would be accepted without the most thorough criticism. For that every conscientious worker ought to hope. I have been at all times ready to demonstrate the facts upon which my conclusions are based, and have been prepared to modify my views or abandon them if errors should be discovered, and mistakes plainly pointed out. Every student of nature must be ready to have his conclusions at least considerably modified by those who follow him, and who go over the same ground with advantages, necessarily greater than those which he, as a labourer in what was then a new field, could enjoy.

Nor can an observer, living in times when materialism

happens to be in the ascendant, at least among scientific men, and who is so unfortunate in his observations as to light upon facts which seem to him to support a view of the nature of life not in accordance with the tendency of the thought of his day, expect that his researches will be very kindly received or considerately treated. All this must be accepted, but is it not very doubtful whether the energy displayed during the last few years in pressing ill-founded and extravagant generalizations upon public attention will be of advantage, either by exciting an increased desire for scientific information, or by raising science in the esteem of well-educated persons?

It is, indeed, difficult for an observer to decide upon the course he ought to take in these days to bring his observations under the notice of other persons interested in similar enquiries. No doubt a certain humility of demeanour towards some who, I venture to think, assume an air of authority not sanctioned by custom, and not to be defended as an innovation likely to promote the interests of science, might obtain for an observer the privilege of working without serious opposition, and perhaps without much notice. But I venture to think that although a scientific man ought not to take any active steps to force his views before his contemporaries, or to gain for them the greatest possible notoriety, he may fairly expect that his results should be considered and weighed under the same advantages as those enjoyed by other members of the scientific body. Of course he should be careful not to excite opposition, but it would be unreasonable to expect him to be always making efforts to conciliate possible and probable opponents, or to passively submit to be roughly silenced by

a clique, because his views and opinions are opposed to unproved and unprovable dicta, promulgated by them.

In theory, at least as it seems to me, every worker appeals to, and ought to be protected by, scientific public opinion, which perhaps, though as yet hardly existing in England, is slowly, but it is to be hoped surely, developing itself. An observer should endeavour to accurately describe what he has seen; and, having published the results of his enquiries, should announce, in the only way open to him, that such a work has been completed, and can be obtained by those who desire to see it. It will, however, save under very exceptional circumstances, be hardly possible for him to get attention directed to his observations without some sacrifice of independence to which no real worker will like to submit, although the only alternative may be to be ignored or condemned as one not fitted to survive in the struggle for intellectual existence.

Bioplasm and formed Material.

The simple living matter of a microscopic fungus, like other forms of bioplasm, is clear, colourless, and structureless, soft, and, when growing quickly, almost diffluent. It is enclosed in a capsule of equally colourless formed material, which, however, is firm, and sometimes even hard. It varies in thickness under different circumstances. By pressure the capsule may be caused to rupture, and the bioplasm within may be squeezed out. When this simple organism is nourished, nutrient pabulum, dissolved in water, permeates the capsule of formed material, and comes into contact with the bioplasm within. The non-living matter then undergoes changes most wonderful, in the course of which it acquires the same properties and powers as the

bioplasm, already existent, possesses. The thickening of the capsule of formed material is effected by the deposition of new formed material, resulting from changes in the bioplasm upon the inner surface of the formed material already existing.

If the fungus particle is placed under favourable circumstances it will *grow*. The particle which is growing not only increases in dimensions, but, as already mentioned, manifests a tendency to separate into two or more parts. Sometimes the living matter exhibits little projections or diverticula from its surface, each of which, after a time, becomes detached and constitutes a separate particle, which may grow and divide like its predecessors. Now the phenomena I have, in very few words, imperfectly sketched —the taking up of pabulum by the living matter, and its conversion into bioplasm,—the arrangement of the elements of the bioplasm prior to the formation of the formed material, —the moving away of portions of the bioplasm from the rest, as occurs in the production of the buds or offsets,—I hold to be *vital actions*, agreeing in all essential particulars with corresponding phenomena which occur in every known kind of living matter. These phenomena differ absolutely from any actions known to occur in any kind of non-living matter whatever. They cannot be imitated, and no actions known can be fairly said to exhibit any true analogy with them. These *vital phenomena* do not characterise the formed material, for the production of this is coincident with the death of the bioplasm. As the formed material is produced bioplasm ceases to live, and no kind of formed material can *grow* and transform matter and direct its forces as living matter is known to do.

Bioplasm of Bacterium.

The living matter of the bacterium is probably the lowest, simplest form of bioplasm in nature. The entire organism is so minute as to be difficult of investigation. In 1864 I carefully examined bacteria under the one-fiftieth of an inch object-glass, and was able to demonstrate that, like the lower fungi, the bacterium consisted of bioplasm, with a layer of formed material upon its surface, as was proved by carefully crushing a very large bacterium while under observation. The membrane was ruptured, and not only was the bioplasm seen to escape, but it exhibited vital movements when free from its envelope.

Bacteria are for the most part elongated and of an oval form, and frequently the little staff-like particle exhibits a transverse line, or is constricted at or near the centre, indicating a tendency to divide at this point. In this way the division and multiplication of already existing particles take place. Bacteria vary much in size, some being as much as the one-three-thousandth of an inch in length, others so minute as to be visible only with the aid of the $\frac{1}{50}$ of an inch object-glass. I have figured some less than the $\frac{1}{10,000}$ of an inch in diameter.

The germs from which the little particles spring are far more minute, and more difficult to identify. They appear as minute specks, the largest of them exhibiting a circular outline, and probably being spherical. The smallest are too minute to be discerned with the highest magnifying powers at our command. If a specimen of fluid, in which these particles are rapidly growing and multiplying, be carefully examined, many new points will be observed to appear

from time to time. After watching with great care for a considerable time a given spot, I have assured myself that new particles actually come into existence; and that one does not, after intently watching for a time and concentrating the attention upon a certain space, merely see one coming into view after another, as star after star.

The material in which the minute germs of bacteria are embedded, and which, at least in part, consists of formed material produced by the bacteria, is much softer than the matter of which the capsule of fungi consists. It is perhaps almost as soft as mucus. I believe that even the most minute bacterium germ is surrounded by a layer of such soft formed matter, in which very minute particles of bioplasm divide and subdivide before they attain even the $\frac{1}{100000}$ of an inch in diameter. When, therefore, bacteria, in an early stage of development, dry, it is not possible to identify them. When moistened the dry mass swells up, and the bioplasm in the soft mucus-like matter grows, each particle producing a fresh investment of formed material; and then, if the conditions are favourable, the germs either at once divide and sub-divide for a time, or grow into perfect bacteria, which move freely and grow and multiply in this more advanced stage of development.

It would be difficult to say where bacteria germs do not exist. In air, in water, in the soil, adhering to tiny particles of every kind—in every region of the earth, from the poles to the equator, they are to be found. At all periods of the year they retain their vitality. Extreme dryness does not destroy them, and they withstand a temperature far below the freezing point. Under adverse circumstances they remain dormant, and are not destroyed

by a degree of heat which is fatal probably to every other living organism. Dr. Bastian tells us that living germs of bacteria are destroyed at a temperature of 160°, but others are of opinion that at least, under certain circumstances, bacteria germs do not die at 212°, and may increase and multiply after having been exposed to this degree of heat.

In the substance of the tissues—nay, in the cells of almost all plants, and in the interstices of the tissues of many animals, bacteria germs exist. I know not what part of the body of man and the higher animals is entirely destitute of particles which, under favourable circumstances, develop into bacteria. Upon the skin and the surface of mucous membranes they exist in profusion, and they abound in the mouth and in the follicles and glands. Changes in the process of digestion are soon followed by the multiplication of bacteria in every part of the alimentary canal, and within a few hours countless millions may be developed. They multiply in the secretions, under certain circumstances, almost as soon as these are formed, and I have adduced evidence to show that bacteria germs exist even in healthy blood. In the very substance of some cells I have seen them, and in many cases, in which little granules have been discerned in connection with bioplasts, there is reason to believe that some of them are really bacteria germs, passive as long as the higher life is maintained in its integrity, but ready to grow and multiply the instant a change favourable to them and adverse to us shall occur.

As the germs of bacteria are found in healthy tissues and organisms, and grow and develop into bacteria when dis-

integration and decay occur, we shall not be surprised at their existence in disease. Bacteria prey upon morbid structures and upon the substances resulting from the death of morbid bioplasm. They are found in great number among pus-corpuscles which have ceased to live, and they grow and multiply with great rapidity in fluids which contain disease germs as soon as these begin to lose their specific powers and to undergo decomposition. In the tissues and fluids of the body altered by fevers, they are abundant and exist, as is well known, in many instances during life. In the evacuations of cholera, and not only of cholera, they are very numerous, and in the columnar epithelium of the small intestine I have found many. In all parts of the bodies, in the fluids and amongst the solid tissues of animals destroyed by cattle plague, bacteria were present in varying number.

Germs so minute as those of bacteria are constantly passed over, seeing that until they have grown somewhat it is hardly possible to identify them. This circumstance has led some to suppose that they are really formed anew from non-living matter, or from a substance in a transition state, which is neither living nor dead. But such a view is not supported by facts at present known, nor is there anything to justify any other conclusion than that all matter is either living or not living.

Living Matter Structureless.

As far as can be ascertained by examination, under an amplifying power of 5,000 diameters, living matter throughout nature is colourless and *structureless*. Of course it may be mysteriously suggested that living matter may nevertheless possess structure though no one can see it. Water *may* possess structure, but in such a suggestion the word "structure" has a meaning assigned, different from that which is implied when the "structure" of tissues is referred to. No "structure" which can be conceived to exist in bioplasm can possibly account for its properties and actions. Neither is it in the least degree probable that, could we magnify it to any extent conceivable, any "structure" would be revealed, or that from the appearances described we should be able to explain how tissue and other things were formed from bioplasm, or why one kind of bioplasm forms dog, another sheep, and another man.

All the evidence I can collect is in favour of the conclusion that the powers of bioplasm do not depend in any way upon characters that can be fairly termed structural, and I cannot help fearing that some of my contemporaries, biassed by previous education and influenced by the pressure put upon them by one or two scientific authorities, have consented to adopt views which, they will find, cannot be supported by facts or argument.

Not only does living matter exhibit no indications of structure, but the highest known form of living matter could not be distinguished from the lowest, and the lowest is not more unlike non-living matter than is the highest. One is, in fact, just as near and just as far from inorganic matter as the other. It has been said that certain organisms only

differ from a fragment of albumen by their granular character, but the statement is not correct. In the first place a granular appearance is not characteristic of living matter. If granules are discerned in it, they are not essential, and are at least as likely to be lifeless as they are to be living particles. Living matter is, in fact, as free from granules as a fragment of the purest albumen. Secondly, the differences between any fragment of albumen and any living particle are enormous—but of a kind quite distinct from that suggested in the above statement.

If a portion of pure bioplasm be carefully examined with the highest powers at our command, and under the most favourable circumstances as to illumination, it will be found to be entirely devoid of granular character. Clear, transparent and colourless, there will not be discernible in any part of it the faintest indication of structure. Nay, if motionless, its presence can only be recognised by the fact of it being a very little less perfectly transparent than the fluid which surrounds it, and by its refracting property being slightly different from that of the medium in which it lives.

The suggestion so often made that the relation between living and non-living matter is a close one, is as entirely groundless as the further suggestion that before very long the exact nature of the relation between the two will be cleared up, and the chasm between the living and the non-living bridged over. Neither is there anything to justify the statements made for the purpose of inducing people to believe that the non-living passes into the living by insensible gradations of some kind. There are many characters in which the living differs absolutely from any form of non-living matter yet discovered. One broad essential character

distinctive of all living particles is a remarkable capacity of movement which has not been adequately accounted for, and I therefore propose to direct your attention to the movements peculiar to living matter.

Of Vital Movements.

Every form of living matter exhibits certain movements, the nature of which has not been determined. The remarkable movements of the common amœba, of the mucus corpuscle, of the pus-corpuscle, and of the white blood corpuscle, are familiar examples of vital movements, and these can be seen and studied by anyone who can use an object-glass magnifying 500 diameters or upwards. But every nutritive act, every form of increase and multiplication, each kind of growth, the production of buds or offsets, the development, the formation and increase of every tissue, involves active movement of the particles of which living matter is composed. Vital movements affect every form of living matter, from the very lowest, supposed, by some, to have been formed direct from the non-living, to the very highest which is concerned in the development of man; but in certain instances only can the movement be actually seen to occur under the microscope. By very slight alteration of the conditions existing during life the movements may be caused to cease, but in many cases in which no movement has been seen, we have other evidence that it has occurred. Vital movement, there can be no doubt, accompanied the first dawn of life, and will continue to characterise living matter to the end of time. In fact vital movements are essential. Their cessation is coincident with the cessation of life. Without them life is not conceivable; and it is equally impossible to conceive any form

of matter not in a living state, which manifests movements like those which characterise life.

I propose to consider the subject of vital movements under the four following heads, viz. :—

1. Vital movement which may affect every part of a mass of living matter.

2. The movement of the constituent particles of a living mass, which takes place in a direction from centre to circumference.

3. Movement of one portion of a mass of living matter from the rest.

4. The movement of a mass of living matter from one place to another.

Lastly, there are certain movements which are indirectly due to the vital movements of bioplasm such as ciliary action, some movements connected with nerve action, the movement of certain solid particles in cells, &c., but these will not be discussed here, as I desire to restrict myself, as far as possible, to the consideration of the nature of the intimate changes in living bioplasm only. Nor shall I enter into a discussion concerning the nature of "contractility," which has, by some, been considered to be vital in the same sense as the movements which I am about to describe. I have, however, adduced reasons for removing contractilty from the category of vital movements. I shall, therefore, only remark that contractility as it occurs in muscle is essentially distinct from the changes now to be discussed, and I may state that I have referred to this part of the subject in my work on "Protoplasm," 3rd edition, page 209. The original paper was published in the Transactions of the Microscopical Society for 1866.

1. *Vital Movements which may affect every part of a mass of Living Matter.*

These movements are undulatory in character, and may be seen in many forms of living matter. The wave-like movement gives rise to continual changes in the thickness of the mass, which, as a whole, may remain quite stationary. If the margin of the mass of living matter be studied, its outline will be observed to continually alter; a slight bulge at one place, a slight depression at another. In a few moments, perhaps, the part which projected will recede, and that which was depressed will become prominent, but with no regularity, with no alternation of movement. Such changes may be seen continually proceeding over every portion of a mass, in some cases occurring very quickly, in others so slowly that a specimen must be watched intently in one spot for some minutes, or the observer will fail to discern any change. In the amœba these movements are distinct enough, and can be studied without difficulty. The matter which moves is perfectly transparent and structureless. Granules suspended in it may be moved, but they are not the cause of the movement. Wave-like movements may be seen in young epithelial cells. I have seen them in epithelium from the throat and from the bladder of man, and I think there can be no doubt that they take place in living matter generally. In the white blood corpuscle they have been studied by many. I have given a description of the movements as they occur in the mucus corpuscle and in the pus-corpuscle, and have appended figures showing the changes observed during the course of a few seconds. I conceive that it is by movements of this kind that the little

masses of bioplasm near the surface of the brain, which I believe are concerned in mental operations, act upon the delicate nerve fibres which are in contact with all parts of their surface. These are, I believe, the instruments through which the will operates upon the nerve-apparatus, by which its mandates are rendered evident.

2. *Movements of the Constituent Particles of a Living Mass which take place in a Direction from Centre to Circumference.*

The actual movements referred to under this head cannot be seen, for they may take place slowly, and affect particles too small to be seen with the highest powers. But that motion in the direction indicated does occur seems to me to be conclusively proved by the fact that in some spherical masses of growing bioplasm, which are increasing rapidly, a new centre (nucleus) appears in the very centre of the mass. After this has grown for a time another new centre (nucleolus) appears in the centre of the first. The new growth originates centrally, and a newer growth still more centrally. This involves a movement of constituent particles outwards. Now if bioplasts, in which this change is actually proceeding, be coloured with an ammoniacal solution of carmine, which in some instances may be effected in a few seconds, the remarkable fact will be observed that the new centres have been stained most deeply, although these are situated at the greatest distance from the surface in contact with the coloured solution. All "nuclei" and "nucleoli" are new centres of growth, and invariably consist of living matter. An oil globule may be formed in bioplasm, and may be called a nucleus or a nucleolus, but the formation

of such a body is of no importance. It ought never to have received the name of nucleus, and no one ever pretended that all nuclei were of this nature. True nuclei and nucleoli were considered of little importance, but if the evidence in favour of the view of their nature, here advanced, is correct, and I believe it to be incontrovertible, nuclei and nucleoli must be regarded as *vital centres* which have originated in centres of living matter already existing.

The movement outwards of the constituent particles of bioplasm is, I venture to think, the circumstance which determines the flow of the nutrient fluid in the opposite direction. The non-living pabulum, I think, flows to the centre of the particle of bioplasm. Certain of its constituents there begin to live, and then move outwards towards the circumference, their place being taken by new matter which reaches the centre.

3.—*Movement of one portion of a mass of Living Matter from the rest.*

This form of vital movement can be seen without any difficulty. A bulge appears upon the surface of a mass of bioplasm. This gradually increases and becomes pear-shaped. The projecting portion of the living matter moves away from the general mass, with which, however, it may remain connected for some time by a narrow pedicle. Such movement of living matter may be seen in the amœba, in the mucus corpuscle, in pus corpuscles, and in white blood-corpuscles, and many other forms of bioplasm. The bioplasm (nucleus) of the frog's red blood-corpuscle often completely divides into several portions, some of which I have seen make their way through the surrounding

coloured material into the liquor sanguinis beyond. I have described the phenomenon under consideration as it occurs in the growth and multiplication of yeast, and also in the growth of the mycelium of fungi. What determines the precise spot upon the surface where the formation of the bud or outgrowth commences it is difficult to say. It may be that the first movement takes place where there happens to be least resistance, but certainly it does not necessarily begin at the lowest point or at the highest, or at that part which happens to be nearest to the light, or at that most distant from it. The outgrowth does not usually contain a visible new centre, but its growth soon becomes accelerated, and the rate of formation of new bioplasm in the bud greatly exceeds that of the rest of the mass.

4.—*Movement of a mass of Living Matter from place to place.*

This form of vital movement is also to be seen very distinctly, and so many instances of its occurrence have been recorded, that it must be considered an attribute of bioplasm generally. In many cases, though the movement may not be seen, there is conclusive evidence of its occurrence. Not only amœbæ and allied forms, destitute of locomotor organs, move actively, but many of the bioplasm particles of man and the higher animals may be seen to move from one situation to another under the microscope. The movement of entire mucus corpuscles, white blood-corpuscles, and pus-corpuscles, over a space equal to more than twice the diameter of the corpuscle has been seen by me many times, and I have described the phenomenon in more than one of my works.

In white fibrous tissue, in muscle, nerve, yellow elastic tissue, and some other textures, there is distinct evidence of the movement of the formative bioplasm during the formation of the tissue. In some instances I have satisfied myself that an elongated mass of bioplasm has divided longitudinally or obliquely into two parts, which have moved away from one another in opposite directions, one forming the upper and the other the lower part of the same fibre. The thickening of many fibres results from the formation of new matter from the oval mass of bioplasm as it moves backwards and forwards upon the surface. Before 1861 I demonstrated the bioplasm of yellow elastic tissue, which had not been previously observed, and showed that new tissue was formed from the bioplasm as it moved over the surface of the fibre.* In some cases the bioplasm is prevented from moving from place to place in consequence of being imprisoned in a cavity, but it may continue to move actively nevertheless. Thus, in many plant cells the bioplasm moves round and round the circumference just within the cell wall. In many cases the direction of rotation is that of a spiral, and formed matter, produced by transformation of the bioplasm, is deposited during the movement. The result is a spiral, or double spiral raised line of secondary deposit in the interior of the cell. Sometimes bundles of fibres are formed by the movement of the bioplasm in the interior of a cell after the "cell wall" has been formed. The fibres of the cells of the cartilage of the epiglottis are produced in this way, and I have seen the bioplasm gradually tapering so as to form a delicate

* "The Structure of the Simple Tissues," 1861, p. 118.

fibre, which seemed to have been spun off, as it were, from the bioplasm as it moved round and round the cell cavity.

Of the several primary vital movements I have described, none can be imitated. They are peculiar to living matter and not one of them has been explained by physical law. No mere physicial or chemical attractions, or repulsions, on the part of any material particle at all resemble vital movements. Neither can these be adequately accounted for by attributing them to changes in the environment, for no conceivable changes outside would cause such movements. Nor is there any *machinery* in bioplasm to explain the movement.

Of the several movements of living matter, I believe those which affect the ultimate living particles of bioplasm never cease. That moving of matter from centre which involves the movement of pabulum in the opposite direction, I believe to be an essential phenomenon of life. The movement of living particles amongst one another, the movements of a portion of a living mass from the rest, the movement of a living mass as a whole may entirely cease, but I cannot conceive the cessation of motion in a vital centre. The rate of movement certainly varies very much. At one time it may be very rapid, at another it may take place very slowly, but I cannot imagine a recurrence of movement in the direction indicated, and in the same centre, even for an instant, after absolute cessation.

I beg you to carefully consider the evidence upon which the views I have advanced are based. It has been affirmed that the phenomena occurring in the simplest living matter are not far removed from the phenomena of the non-living, and like these, are to be explained mechanically, but

only the assertion, not the explanation, is forthcoming. If but one class of these movements of living matter can be accounted for by any laws that are known, can you not insist that the laws be stated, and that it be shown precisely by what means the particles of a living mass that is alive are enabled to move in any direction with equal facility? The particles uppermost in a mass of bioplasm do not move downwards more easily than those at the lowest point move in the opposite direction, neither do the roots of the tree grow into the soil with greater force than its stem shoots upwards.

Of the Constitution of Living Matter.

The difficult problem which relates to the constitution of living matter has been very little considered, probably because the absolute distinction between the living and the non-living matter of a living body has not been generally recognised. Indeed, authorities who have written very recently, evidently do not admit that the distinction I have drawn between living matter and formed material exists in nature.

Feeling confident that ere long the remarkable characteristics of living matter, and its distinction from all formed matter, will be admitted, I shall venture to speculate upon the constitution of the bioplasm in the living state. In the first place I would remark that all bioplasm contains moisture. Water is necessary to its constitution, and is invariably present in every kind of living matter, and in every state in which living matter can exist. As I have before intimated, movement of particles from centres is involved in my idea of life. Such movement would be impossible in the absence of water. The moment a particle

of bioplasm is deprived of its water, it must therefore die. In cases of resuscitation after desiccation, the bioplasm has not been perfectly dead—has not been entirely deprived of its water.

Water must be very intimately associated with the particles of matter that live. These living particles cannot be regarded as dry solids, suspended in water and moving freely amongst one another in the fluid, for, as already intimated, every particle is composed of smaller particles which are likewise in constant motion.

Now let us, guided by observation, try to realise what must be going on in every centre of the most minute of the multitudes of living centres which constitute the most minute living particle. And in the first place it is necessary to bear in mind that each central point when magnified seems to have circumference as well as centre. We may follow on in our imagination, nevertheless keeping true to the line of observation, and pass into the region of speculation, and still we shall find it impossible to reach in conception a true centre. One may imagine excessively minute compound semi-fluid molecules of pabulum, moving in fluid and coming within the sphere of the operation of molecules of living matter. We may conceive the lifeless passing among the very minute living particles, but to conceive how the atoms of the particles of lifeless pabulum separate from one another, and then become re-arranged and acquire new living powers like the living particles which existed before them is not yet possible. There must be transference of power from the living to the non-living, the latter gaining power from particles which have imparted that power without having lost or created

anything. In fact a vast amount of non-living matter may acquire living property or power in a very short period from an extremely minute particle of matter already in a living state. There seems no limit to the capacity or power of making alive—no loss being occasioned by the repetition of the process—no failure or exhaustion.

Such then I believe to be the nature of the wonderful changes which occur in the minute particles of every form of bioplasm in nature, from that of the bacterium to that of man. Not only do they characterise the bioplasm of health, but that of every disease-carrying particle, which has resulted by descent from the normal bioplasm of man or the higher animals, as long as its vitality and active powers exist. Between living particles and globules of oil and fragments of albumen or any non-living matter whatever, there cannot, therefore, be the remotest analogy.

That new centres of living matter appear in pre-existing living matter is a fact that has been proved by observation. The so-called nuclei arise in pre-existing living matter, and nucleoli in the nuclei. In the new centres themselves a second series of new centres may appear, and in these a third series, and so on; and, what is still more remarkable is, that the properties or formative powers of these different series, and of the bioplasts resulting from their division and sub-division, may be different. The new power seems to be acquired by the matter at the time when, or just before, it comes into being as a new centre. The centres in question from which matter inherits vital properties and acquires the power of transmitting these onwards, must be extremely minute. Indeed, as to the real size of the most minute particles that are made to live, one hardly dares offer a sugges-

tion more definite than the following:—that on the one hand, they must be hundreds of times more minute than the smallest particle visible under an amplification equal to five thousand diameters; and, on the other hand, they must be larger, or at least heavier, than the individual atoms of the chemical elements which are grouped to form them. It is remarkable that those who have spoken of *living atoms* should have thought so little about the matter as to have permitted themselves to suggest an absolute impossibility,—for it is obvious that *no single atom can be thought of as alive.* The idea of a living atom of oxygen or hydrogen or carbon or nitrogen is clearly untenable. We might as well talk of a living atom of sulphur or iron or lead. And it is absurd to talk of *dead* carbon, oxygen, or hydrogen atoms, since a living state of the atoms of these and other bodies is thereby implied; but such living state is inconceivable. Every form of matter that is alive is composed of several elements, and it is probable that the most minute particle of matter that lives consists of multitudes of atoms of several different substances in a state of collocation that cannot be compared with any other state of combination that is known.

But it is not merely the power of moving from centres, of progressive movement, of transforming pabulum, of forming new and peculiar chemical compounds that is acquired, but powers far more wonderful than these, by virtue of which the living matter produces living particles, generation after generation, from which definite organisms and definite and very different tissues in each single organism result. These powers are peculiar to the living world, and there are no forces, no behaviour of non-living matter which can be said in any way to resemble them, or to exhibit the most distant

analogy to them. How these powers are acquired it is too soon to speculate, but I should, nevertheless, like to refer now to one or two points. First, I would remark that time exerts an important influence, in the transmission of powers from living matter to that which descends. The time required for the production of a given result, though constant within certain limits for forms of life of the same kind, varies greatly with respect to different kinds of living things. Precisely corresponding changes take place within very different periods of time, and the influence of temperature, food, and external conditions is uniform only in the case of the same species. One particle of living matter much less than the $\frac{1}{50000}$, may take weeks or months to acquire its full powers; another only a few days. We have not at present the data upon which to found general deductions, and we must withstand the temptation of framing laws and applying them to vital phenomena, until a good deal more shall be known than we have yet been able to discover, or assuredly the exceptions to the laws laid down will multiply faster than the examplars.

Powers and properties have been attributed to pabulum, and some have said that the organism is only what it feeds upon. But what the organism is, depends far more upon what the organism was that produced it than upon the particular material that constituted its food.

The pabulum of the tissues of complex animals is undoubtedly peculiar, and must be properly prepared before it can be taken up, but by what means is the preparation effected? The bioplasm of the tissues selects pabulum out of blood. But how is the blood itself formed? By bioplasm. Living matter takes up pabulum of the proper kind and

grows, at last becoming resolved into formed matters, which constitute the pabulum of other bioplasm, and this process occurs several times before our food becomes converted into our tissues. Whatever act of life we investigate we soon trace the phenomena back to bioplasm, and then we find ourselves face to face with the question of the nature and mode of working of vital power.

If the method by which non-living matter is converted into living matter is understood, by all means let it be explained. If conversion like that effected by living matter can be carried out in the laboratory, let it be done; but if the change can be effected by living matter alone, let this be openly admitted, and let it be clearly stated, and in the most public manner possible, that the phenomena in question are peculiar to living matter, and cannot be shown to be due to physical and chemical changes apart from life.

By admitting vital power I am able to explain results without attributing metabolic influences to cell walls, cell contents, intercellular substance, walls of vessels, and other textures, which, in reality, are passive. I need not assume hypothetical actions and differentiations, or attribute to some hypothetical force, said to be akin to aggregation and crystallization, phenomena which have not the faintest analogy with those processes, nor have I need to assume governing powers of which the mind cannot conceive, or matter-guiding forces acting in some unexplained way through all sorts of matter. *Vitality* acts in living centres upon matter only infinitely near the centre. This is all that is demanded by the terms of my hypothesis. I venture to think that few who consider the facts of the case will be indisposed to grant me thus much.

Origin of Life.

The far-fetched conjectures seriously advanced by some physical speculators concerning the origin of life, serve to show what extreme difficulty has been experienced by those who have attempted to construct a plausible hypothesis by which the conversion of the non-living into the living might be reasonably accounted for. One great authority, dissatisfied with every suggestion, and being evidently convinced that no physical explanation of the origin of life upon our globe would ever be discovered, despairingly submits to us the proposition that life did not begin here at all, and that our earth was first peopled by the offspring of germs brought to us upon a fragment broken off from some distant orb that teemed with life. Whether even the simplest living forms would have survived after such a ride through space, unfortunately had not been determined by experiment, so the idea of our fauna and flora being derived from those of another world found little favour, and probably all who have considered the subject would now agree that it is probable that life-forms originated upon our globe, though there might be great difference of opinion concerning the precise mode of their origin.

"Evolution" is now supposed to solve the difficulty of life formation, but this term has had at least two meanings assigned to it. By some it has been restricted to the living world, while others have given to the term evolution a much wider signification, and have maintained that it should include not only the evolution of living forms from pre-existing living forms, but the formation of the living out of the non-living. There is, it is scarcely necessary to point out, the widest possible difference between these two doctrines;

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for while the one teaches that all living forms came direct from living matter, without accounting for the origin of life at all, the other is a tenet of the fiery-cloud philosophy which teaches as a cardinal point that the evolution of life is but one of that great series of changes in which the evolution of the Cosmos is comprised. But surely such an idea may, for the present, be regarded as a conjecture so extravagant as to be unworthy of serious consideration. Facts are wanting, and the arguments advanced in favour of the hypothesis are such as cannot have much weight, since it has been deemed necessary to bring forward, in their support, utterances of a prophetic character.

If, then, evolution is restricted to the living world, the origin of the first living thing will be still unaccounted for. The presence of a very simple living form seems to have been assumed; but whether that being came of itself from the non-living, or arose in consequence of some prior changes, or was formed by an act of creative interference, is not suggested by the terms of the particular form of the hypothesis under consideration. Neither is the precise nature of the first living substance indicated, and we are even left in doubt whether one or two or many forms of living matter came into existence at the first appearance of life.

Now with reference to the origin of the first living matter, several not improbable suggestions present themselves to the mind, in all of which, however, it is assumed that the change from the non-living to the living was sudden and abrupt, and not gradual.

First, we may conceive that one form of living matter was produced direct from the non-living, and that from this all future living was evolved.

Secondly, we may prefer to imagine that more than one form of life originated from the non-living at or about the same time.

Thirdly, we might think it more in accordance with facts to conceive that several different kinds of bioplasm originated in the beginning of an epoch, from which all life of that epoch was derived. New forms originating anew in the next epoch, the results of evolution from the first gradually dying out as those of the second epoch increased and became dominant. As life-epoch succeeded epoch, new forms of bioplasm may have appeared as old forms of life died out.

But the above by no means exhaust the list of what I would term the reasonable hypotheses concerning the origin of life that may at once be suggested. All of them involve in some form or other the admission of a remarkable change in capacity or power not to be accounted for by physics. In all, the communication to matter of powers or forces which it did not always possess, and which it is conceivable might never have been communicated at all, is suggested.

Whether this communication of new powers occurred once only or was repeated at many successive periods in the remote past,—whether it be reasonable to consider a recurrence of the process in the future as probable or improbable, I shall not now venture to discuss.

What I particularly wish we should keep before our minds is that facts and arguments render it much more probable that the passage from the non-living to the living is *sudden and abrupt, than that there is a gradual transition or scarcely perceptible gradation from one state to the other.* I should, however, clearly state that this inference is in opposition to

the views of many authorities, and in particular is opposed to the clearly expressed opinion of one of the greatest discoverers and most acute thinkers of our time, who maintains that the conversion of physical into vital modes of force is continually taking place. It is suggested that the change from non-living matter to living matter is a transition easily effected and continually occurring. Of the facts in support of so startling a proposition I confess I am ignorant, nor have I succeeded in my efforts to discover any facts in the writings of those who appear to have accepted the conclusion in question, which has never failed to enlist advocates in its support from the time when it was believed that highly complex living forms were produced from earth or dew, to the present day, when the advocates of the doctrine are so terribly restricted in the discovery of parentless living particles.

We have now reached the point where we are brought face to face with the modern developments of the old doctrine of spontaneous generation.

I cannot but remark that the more minutely investigation is carried out—the more thoroughly and intently facts bearing upon the matter are examined—the more improbable, in my judgment, does it appear that any living form should be derived direct from the non-living. Notwithstanding all that has been recently written upon this subject, I cannot but feel surprised that at this time many good reasoners should decide in favour of the *de novo* origin even of bacteria. Whether we consider the matter from the experimental side only, or study the evidence obtained in a general survey of nature, or carefully reflect upon the facts learnt from investigations concerning the properties of living and non-

living matter, with the aid of the most perfect instruments of minute research now at command, or from other standpoints, the conclusion seems to me irresistible that the verdict of a jury of well educated men would be against the direct origin of any form of living from any form of non-living.

Driven from one position to another, the advocates of spontaneous generation have entrenched themselves in the unassailable stronghold of experimental investigation. Here they may hold their own for any length of time, for no one can say what may not be demonstrated by new experiments in the time to come. Nay, although the conflicting results of different skilled experimenters, whose experiments have been conducted upon the same principles and professedly in the same way, even to the minutest details, may shake the confidence of some in the experimental method of enquiry, it is certain that the teachings of experiment will finally prevail over all other information.

Of the new supporters of the doctrine some do not put their trust in experiment only, and appear to deem it necessary to fortify their position by the introduction of a number of preliminary matters with the view of showing that there is nothing improbable, impossible, or unreasonable in the proposition they support. Their readers' minds are carefully prepared, as it were, for the reception of the experimental evidence, as if the latter were not quite strong enough to be allowed to stand by itself. Hundreds of pages have been devoted to the enunciation of general facts and preliminary enquiry, in order that a doctrine may be introduced which might have been fully and clearly expounded in a single chapter, and the experiments demonstrating its

truth described in their minutest details in half-a-dozen pages.

But the modern advocate of abiogenesis should be skilled not only in explaining facts, but in explaining facts away. The fact that bacteria germs exist in all parts of the higher organisms, in the most internal parts as well as upon the surface of man's body, is to be accounted for by their spontaneous origin! Although millions are to be found about the mouth and upon the surface, and it can be shown that it is easy enough for them to get from the outside amongst the tissues within, we are asked to believe that those inside originated there direct from the non-living, or, as an alternative proposition, that they were derived not from parental bacteria, but by transmutation from some of the constituents of the tissues, on the principle that a living fungus comes not from a fungus germ, but from a dying tree. The next suggestion will be that man, after all, is but an aggregation of lower forms, peculiarly conditioned for a time, but which assume their ordinary forms when their environment shall be modified, as it must be at death.

Nor are observations wanting by which authors profess to have proved that such changes do actually occur, and that tissues in their disintegration are actually resolved into bacteria. It has been stated that elementary fibrillæ of muscle have been seen to resolve themselves into bacteria just as an oil globule of milk, it is said, has been seen (?) to give origin to a fungus. I have recorded the formation of vibrating bacteroid bodies from the lifeless matter of the red-blood corpuscles, but because such particles are like living bacteria in many respects, it would be most unreasonable to attempt to force upon me the acceptance of

the ridiculous notion that the hæmoglobin of the red corpuscle is composed of bacteria, or is resolved, under certain circumstances, into bacteria.

Erroneous conclusions of many kinds have been employed as facts in support of abiogenesis. When one finds that it is believed that fungi may be developed from oil globules, and other living organisms of a much higher type produced without parents out of organic matter, one fails to see any limit to the support that may be gained to the cause. Volumes of facts and arguments hitherto advanced in favour of abiogenesis may be republished without in the slightest degree modifying the real state of the case. What is now required is well devised experiment, and that is all. No resuscitation of old arguments and doubtful facts, however ably the task is performed, will in the slightest degree increase the cogency of experimental proof, and in the absence of new experiment such facts and arguments will avail nothing.

I think we may be satisfied that before long the advocates of spontaneous generation will have to rely upon the production of the lowest organisms only. The only view in any way tenable at this time is, that such organisms as bacteria are the only ones that can, under any arrangement of conditions possible to an experimental enquirer, be formed anew, and that these alone, at any period of the world's history, sprang direct from the non-living. All are of extreme minuteness, many of the forms being so very small that they could not be identified with a magnifying power of less than eight hundred diameters. These are the smallest, simplest, and probably lowest forms of life known. That multitudes do now spring from pre-existing

forms is absolutely certain, for the process can be seen. Whether some spring direct from the non-living is the question. Those that are supposed to be formed anew are very like those that have had a progenitor, and from those supposed to have been produced anew, forms exactly like those derived from undoubtedly pre-existing forms result. It cannot be pretended that new forms of existence are produced anew. No matter how the conditions are varied, the living forms supposed to result resemble known living forms, and give rise to forms of the same kind.

Considering the minuteness of the germs, their universal distribution, in air, in water, in soil, in every climate of the globe, their presence, as already remarked, not only upon the surface, but in the very substance of the textures of nearly every known form of animal and vegetable organism, —particularly of the higher kinds,*—and the fact of their retaining life under very adverse circumstances for a length of time, is it not, I would ask, more in accordance with known facts to suppose, in the cases which are advanced as instances of *de novo* origin, that the bacteria came from germs that had somehow resisted the means relied upon for

* Of course it will be objected that, if bacteria germs were present in a quiescent state as I suppose, they would destroy the tissues. But in truth they could not do so, because as long as the normal state of things lasts there are currents of fluid passing to and from the bioplasm of tissues, which is not a suitable pabulum for these low forms of life. Bacteria cannot attack the healthy growing living bioplasm of man and the higher animals, for the higher living matter will, as long as it retains its healthy state, successfully resist the assaults of lower forms. As soon, however, as the higher bioplasm deteriorates or dies, the bacteria germs grow, and actual decomposition may have scarcely commenced before they increase and rapidly multiply, and are soon in the ascendant.

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their destruction, than to conclude that the particular ones discovered came direct from non-living matter?

But, as I have before remarked, the question of the origin of bacteria can be only determined by experiment. All irrelevant considerations in favour of abiogenesis ought now to be left in abeyance. The assumed *de novo* origin is contrary to what goes on throughout the whole kingdom of nature, and the only exception which there is the remotest possibility of establishing, is the spontaneous origin of some of these lower forms of life. While, therefore, it is allowable to permit ourselves to be influenced by general evidence against a new and exceptional doctrine, which a few observers are very anxious to establish, we may fairly insist that only evidence of the most convincing and demonstrative kind should be listened to in its support. As regards the validity and reliability of the most recent experiments for and against the doctrine, I offer no opinion. Time must be allowed for others to repeat the experiments; and, for my own part, I could express no opinion unless I had been present, and had carefully watched each experiment in every stage. As far as I can judge, the reports of recent results are not more convincing than were those that were adduced years ago, many of which have been discarded and proved to have been unreliable from want of care, or from defects in the method of procedure.

By some I may be considered bigoted and weak, but I must plead that my views are based upon facts and observations which have much impressed me. I have *seen* these low organisms growing and multiplying, and I cannot admit that the things I have seen over and over again ought not to be allowed to influence my understanding, and that con-

clusions are worthless and of no account if they do not rest upon discoveries of the physical imagination. However positively we may be assured that it is easy to conceive that molecules might coalesce under certain undiscovered conditions, and thus form a bacterium, I hold that we are justified upon thoroughly scientific grounds in regarding every form of the doctrine in question as inadmissible at this time.

The idea that these low organisms may arise in some mysterious manner, and neither from bacteria on the one hand, nor from ordinary non-living matter upon the other, has been apparently suggested as a sort of peaceful compromise. But the supposed matter out of which it is conceived they may spring, is some very mysterious substance, the nature of which is unknown. An observer finds that he cannot see and identify germs which he can actually prove to be, in many instances, far too small to be seen and identified even by the highest powers ; but, rather than admit this as a simple fact, resorts to the far-fetched exceptional hypothesis, that the bacteria *may* come from some organic matter which he knows nothing about, in some peculiar state of which he has no knowledge or experience. As I have already remarked there is no good reason for believing that there is any intermediate state of matter. Matter *is living* or it is *not living*, and it is unjustifiable on the part of any one to add confusion to this sufficiently complicated discussion by assuming, without a shadow of evidence, the existence of matter in a third state, which is neither living nor non-living. The half or imperfectly or incompletely living state of matter is not conceivable. It may appear plausible to suggest that certain forms of albumen, for instance, are nearer to the living condition of matter than ammonia or

carbonic acid ; but, then, we must bear in mind that no form of albumen can be converted into living matter any more than inorganic matter, unless already existing living matter be present to effect the change.

If the formation of a bacterium germ, direct from non-living matter, be possible, three very remarkable series of changes, as it seems to me, will have to be brought about. Whether any means will ever be discovered of effecting these changes is surely most doubtful.

First, the atoms of the non-living substances must be separated from their combination.

Secondly, the atoms will have to be re-arranged to constitute groups of which the organic matter is made up.

Thirdly, the groups of atoms must be made to live.

What facts known, I would ask, render it likely that air, rarefied or condensed, or pressure of any degree or of any special kind, or any degree of heat, or light, or any conceivable modification of physical or chemical conditions, would, at the same time, account for the pulling asunder and joining together of atoms, and for the conference of new and peculiar powers of growth, of movement, of division, and the formation of new substances? In short, it is not easy to conceive, in the imagination, the several steps which result in the formation of a living bacterium even from *organic matter*. But the first germ must have sprung direct from matter that never had lived nor manifested phenomena in any way like those of life. Let us try to imagine a living germ being produced out of non-living matter. Atoms of many substances must be conceived as separating from one another, and then recombining. Attractions and affinities must, in the first place, be overcome; then the

forces that effected the change must cease to operate; and these must, somehow, be exerted again. By what means the separation of atoms is effected cannot be suggested, neither can we conceive how the atoms are caused to recombine in a definite way. The supposed phenomena would be really more complicated than I have represented. For atoms are not related to one another—atom to atom, but group to group. How the atoms are grouped, and how the groups are related, how the groups act and react upon one another, and new groups are formed—what makes the atoms combine and begin a new course which may continue on and on for ever, cannot be conceived. Upon the whole the production from non-living matter of any living form, however simple, must be regarded as most improbable.

Absolute distinction between the Living and the Non-living.

The conclusion which is impressed upon my mind, with ever-increasing force, is, that the distinction between the living and the non-living is not of a gradational kind, but, on the contrary, that it is absolute. Whatever may be the difference between plant and animal, however deep and wide may be the gulf which intervenes between the lowest and the highest living, it will, as I believe, be shown to be as nothing compared with the chasm by which the lowest living is separated from every form of the non-living.

It has been contended that because the line, supposed by our predecessors to mark off the vegetable from the animal kingdom, has proved to be fallacious, the distinction held by some to exist between the living and the non-living will, some day, be broken down. But what analogy is there

between the two cases? It would be as logical to insist that, as it can be shown, that certain changes in a dog, in some particulars, somewhat resemble certain changes in an oak, it necessarily follows that at some future time it will be proved that dogs and oaks are not to be distinguished from crystals. It ought not to be necessary to point out that the proof that a distinction formerly believed to exist between different kinds of life could not be established, did not ensure the further demonstration, at some future time, of an alliance between any life and no life. We may be, in some respects, like plants, without men and plants being like stones.

In this lecture I have adverted to many facts and arguments which seem to me to justify the conclusion that there are certain phenomena characteristic of all living matter, and which are included under the terms *nutrition*, *growth*, *formation*, *multiplication*,—which are not physical, and which cannot be in any degree explained by physical law. I propose, therefore, to call these *purely vital actions*, and I consider that they ought to be placed by themselves in a class or category distinct from that of physical phenomena.

I have never been able to discover in any non-living bodies whatever any phenomena which can be fairly said to correspond to, or to be comparable with, the above. Nor can I discern the faintest analogy between the marvellous changes which affect every kind of living matter in nature, and any changes which have been proved to occur under any circumstances in matter which does not live. And if we believe with Grove that "man will never know the ultimate structure of matter or the minutiæ of molecular actions," must we not conclude, *à fortiori*, that man will never know

the ultimate structure and arrangement of the atoms of living matter, and the minutiæ of those marvellous phenomena which proceed in the centre of every living particle?

Until the ultimate structure of non-living matter and the minutiæ of molecular actions, and the ultimate arrangement of the atoms, and the minutiæ of the actions of living matter shall have been made known, there can be no valid objection to our being influenced by facts that are actually known at this time, which justify the arrangement of phenomena in two distinct classes :—

1. Vital phenomena.
2. Physical phenomena.

The vital actions of living beings are exclusively confined to the bioplasm or living matter. When this becomes converted into any kind of formed material, or when it suddenly dies, physical and chemical changes ensue which we are able to investigate. The purely vital phenomena of the bioplasm continue only as long as this remains in its living state. If we endeavour to investigate the nature of vital actions, and attempt, in the first place, to ascertain the constitution of living matter, the first thing we do is to destroy its life. The substances we submit to examination are not really the actual materials that were alive, but only chemical compounds that were formed at and after death.

There is yet another consideration to be advanced in favour of the doctrine of the absolute difference between living and non-living matter. In the non-living world every change is dependent upon, or is a consequence of, anterior change; and must, in its turn, lead to consequential changes. Each antecedent has its consequent. A real cause is not conceivable in the physical world, but I do not know upon

what data the same could be affirmed with respect to the living world.

Consider how the simplest vital action is to be accounted for. Such movement, for example, as may be seen to take place in the living matter of a common amœba. Let us enquire what was the condition of the moving matter at a given spot just before the visible movement occurred. Who shall prove the nature of the antecedent to which the movement of the particles is a consequent? And who will demonstrate that the movement immediately following was a direct consequence of that which had been observed? It will, I know, be again most confidently asserted by physical authority that the movement in question, as well as other phenomena which puzzle us at this time, will, to a certainty, be proved to be due to physical change in the time that is to come. "To-morrow, and to-morrow, and to-morrow," has always been the refuge of the philosophers who have faith in the dogma that matter alone is competent to develop every form of life. But the "to-morrow" of Lucretius has not yet dawned, and how many thousand years, I would ask, may be expected to pass away before the prophecies of those who would now go along with Lucretius shall be fulfilled?

Although it is well known that the physical region has been fully explored even to the inmost recesses of the imagination, and no adequate explanation of the simplest of vital phenomena discovered, I fear that my suggestion that the true cause of vital phenomena should be sought for in a region apart from the domain of physics, and beyond the empire of physical law, will meet with little favour and no support.

Let us now revert to the changes occurring during

the nutrition and growth of the simplest living organism such as the yeast corpuscle. May we not conceive physico-chemical forces to be at work there to any extent imaginable, and yet fail to gain anything approaching to an adequate explanation of the facts discerned? Let it be admitted that in nutrition electro-chemical changes play an important, if you please, an absolutely essential, part. The internal surface of the cell-wall, in contact with the bioplasm, and the external in contact with water will, no doubt, be in opposite electrical states, and electrical currents will be constantly manifested. But will these or any other physical conditions account for the formation of the matter of the "cell-wall," or the increase of the bioplasm within?

Physicists seem to think that if they can offer a plausible hypothesis to account for certain actions in living beings, they are justified in assuming not only that *all* the actions are physical, but that, in accounting for action, they have accounted for everything, whereas it is obvious that the true explanation of the action of every living thing will, of necessity, include an adequate explanation of much more than mere action. For any one who considers the matter with the least care, will see, at once, that the formation and construction of that which did not exist has to be accounted for, and in such a way that action is permitted while formation is proceeding. The living "machine" works while its evolution is carried on. Action commences from the very first moment of its existence. In truth, certain phenomena of living beings, which have been regarded by some as the essential causes of their actions, are but consequences of arrangements little recognised by the physical school.

As it were, behind all the physical and chemical actions

in living beings are prior changes which are as essential as is the arrangement of the metals and solutions of a voltaic cell to the establishment of the current. Behind the osmose and the currents in the living cell are the changes in the bioplasm, by which alone the physical actions are rendered possible, and the continuance of these provided for. The phenomena of the bioplasm is their antecedent or cause. These phenomena have already been briefly adverted to under another head, but it is desirable I should recur to them here.

Observation has accompanied us throughout a long line of investigation which has been passed by, almost without notice, by physical philosophers. Let us now, however, proceed beyond this point and stretch onwards in imagination, and see whether our notion concerning the absolute difference between the living and non-living is supported or contradicted, neither swerving to the right nor to the left from that straight path which was pointed out from the first. We must again try to conceive the changes proceeding in those minute centres of living matter to which I have already adverted. Within every centre of every one of the thousands of minute molecules of which I conceive every particle of living matter is constituted, is a more central centre in which the matter is a degree nearer the point where it began to live, and where new powers were first communicated to it. To bring the mind, as it were, face to face, with the actual change that occurs, seems, at this time, hardly possible. But surely one is justified in concluding that the *cause* must be, so to say, very central, and that in living matter the direction of the action of the forces is from, and not towards, centres. All that goes on in the environment is necessary

—essential if you please—but it is to the power acting from the centre within, and welling up, as it were, from a yet more central source of power which seems inexhaustible, that vital phenomena must be attributed. Having been carried so far, how am I to resist the conclusion that the power that influences must be more central than the matter that is influenced; and that, therefore, the central life-communicating power plays a far more important part in the phenomena of life than anything in the environment acting from without. That forces in the environment react upon the force or power acting from the centre may be fully admitted, but that these are the *cause* of central activity is clearly an untenable proposition. The central action is absolutely essential, and the difference between the matter in the centre, and the matter in the environment, is absolute. Neither can the conditions, under which action occurs, be regarded as the true cause of the action, since the conditions are conceivable without the action; and the action, in question, clearly must exist, ere it can be influenced by conditions. It would surely be as unreasonable to regard the *power* by which the atoms of a mass of living matter are arranged and their forces guided as the same in nature as the atoms and forces themselves, as it would be to suggest that the mind of the artist is but another form or mode of the properties of the matter of the paints he blends, and disposes as he may determine upon his canvas.

The phenomena which I have described as characteristic of every kind of living matter in nature, and which are known only in connection with living matter, I must ask you to regard as purely *vital actions* due to the operation of a force or power capable of controlling matter and its forces, but

neither originating in them, nor formed by or from them, nor capable of being converted into them—a power which we cannot isolate or physically examine, but the effects of the action of which we may study. Thus we may learn much—and even, I think, form some dim conception of this wonderful power which, stirring in every living particle, establishes between it and every non-living atom, or collection of atoms, a difference which is absolute.

The Construction of the Body by Bioplasm.

All development of structure, all the structural peculiarities of living beings, are due to changes which have taken place in bioplasm, all those characters upon which we depend for distinguishing one living form from another, are the result of changes occurring in bioplasm, changes which took place long before any differential characteristics had manifested themselves. In the formation of every tissue, in the construction of every organ, and of every form of mechanism existing in a living being, bioplasm is the sole essential and active agent. And if, as I have endeavoured to show, the ordinary phenomena, characteristic of all living matter, cannot be adequately explained except by the operation of an agency of an order or kind distinct from, and without direct dependence upon, or causal connection with any mode of physical force yet discovered, how is it likely that the yet more remarkable results of formative or constructive power should be accounted for, unless we admit the operation of such peculiar agency? Whether we examine the marvellous details of the most minute structures entering into the formation of the tissues, or study their chemical composition, whether we take note of the simplicity of the conditions

under which they are produced, or consider their wonderful, and in many instances, inexplicable properties, we shall be forced to conclude that no ordinary physical actions will, alone, account for the result. The more minutely the details are investigated, the more firmly, I feel sure, will the conviction become established, that the agency by which each one of a long series of successive, but not necessarily consequential changes cannot possibly be of the nature of ordinary force, seeing that no forces known, except those operating in living matter, have been found competent to effect special structural arrangements. But the case is still stronger than I have stated it, for many of the special arrangements in living animals, wonderful and elaborate as they are, serve only a temporary purpose. While these are in active function, more permanent, and perhaps still more highly endowed, organs are slowly undergoing formation.

Is there anything, I would ask, in the non-living world that can be compared with the series of phenomena which occur in the development of a tooth, and which succeed one another in pre-arranged order? The slow changes by which the growth of every tooth is prepared for, the gradual absorption of the fang of the temporary tooth, the development of the permanent one which is to replace it, commencing from a time long before the development of the tissues of the temporary tooth had proceeded far, the arrangements providing for gradual changes extending over many years of life by which the permanent tooth is led to its proper place, to say nothing of the contemporaneous changes proceeding in neighbouring tissues—all these, I say, involve numerous phenomena, no single one of which has been adequately accounted for.

Every attempt to explain the formation of any definite

organ by what is called evolution and the operation of physical causation, independently of intelligence, and of guiding governing power, has signally failed. Even with the aid of that wonderful "nature," with a capacity for differentiating herself, which the evolutionists have been obliged to call to their aid, we get only a very confused and inadequate notion of the formation of any single tissue of any one organ —the eye for example. Let it be fully explained, in full detail, according to evolutional law how the formation, not of the eye as a whole, but of one only of the tissues of the eye is carried out. Such an explanation would have far more weight than the assurance that the eye may be compared with a telescope, or that it exhibits an indelible stamp of its lowly origin. By vague suggestions of this sort, nothing whatever is proved, or even rendered probable. An interpretation of facts is authoritatively given, favourable to certain preconceived views, and that is all. Other interpretations might be given, but for the time all others are excluded, by authority which rules as if it were infallible.

No one has yet been able to account for the arrangement even of the nerve fibres of a nerve plexus of the eye or of any other organ. The little papillæ of the frog's tongue are, as I have remarked, organs admirably adapted for investigation, and I wonder that these have not been selected to illustrate the theory of evolution. They can be easily obtained for study, and are far less complex, and more easy of investigation, at every stage of development, than the eye.* A discussion concerning their formation, and the laws by which it is governed, would be extremely interesting. It is not very likely that evolutionists will accept this or any

* "Protoplasm," 3rd edition, p. 349.

other challenge for the purpose of testing the application of their doctrine to the details of anatomical structure. They prefer generalities; and as long as they are able to make people believe that their doctrines are true, and that their prophecies will be verified, they are wise. If they are encouraged to persist in calling attention to general characters, to the exclusion of details, and to select, out of nature's storehouse, just those facts which support their own theories, taking no account whatever of facts which cannot be explained by them, they will be able to hold their own, but whenever they are forced to go into detail, and study the minutiæ of the development of an individual organ, the difficulty of the application of the doctrine will be apparent enough to every one, and the farther the investigation is pushed, the more will the difficulties to be surmounted by the evolutionists increase, as regards degree and number.

Let me now consider, but only in the merest outline, the changes which occur when bioplasm, manifesting its wonderful developmental powers, at last gives rise to the formation of tissue.

The earliest state of matter, in every kind of development, is that of bioplasm, which was derived from pre-existing bioplasm. The masses of living matter absorb nutriment, and the whole increases in bulk. So far, the only indication of formed material is afforded by the presence of a little soft transparent mucus-like matter without any indications of any definite structure. This material is formed, and accumulates around each mass of bioplasm. During the development of tissue, bioplasm masses, embedded in their soft matter, continue to divide and subdivide. As development advances, there may be discerned, amongst the bioplasts

here and there, one which undergoes more active change than the rest. This, in fact, becomes a new centre, from which growth proceeds, while the neighbouring bioplasts remain passive for a time, and some gradually waste. Soon, by division and subdivision, a collection, composed of a new series of bioplasts, results. Many such collections are formed, being separated from one another by the altered bioplasm particles of the previous generation, and their imperfectly developed formed material. Thus results the first indications of the different structures and organs which appear in the embryo of man and the higher animals at a very early period of development. The process above indicated is repeated many times, probably ere the first traces of actual structure with capacity to act are to be detected. Nay, the tissue which is at last formed, and which acts, exhibits structure, but this first tissue only serves a temporary purpose, and differs in its characters from the permanent texture which is at length formed. Thus the first muscular tissue, for example, which is produced in the mammalian embryo, only lasts but for a short time, and it is entirely replaced by a form of contractile tissue which differs materially from it in structural arrangement and in mode of growth. The formation of cartilage, bone, nerve tissue, glandular, and other organs, illustrates the same fact.

But formed material—whether its structural character be simple or complex, its function be low or exalted, and exerted only temporarily or throughout life—results from changes in bioplasm. I propose, therefore, now to consider the actual change from bioplasm to formed matter, and then I shall advert to the powers and properties of the particles of the bioplasm which succeed one another, series

after series, or generation after generation, as long as the development of tissue continues.

The production of formed material may be studied in the early development of any of the tissues, and, in many of them, at any period of life. Epithelium, muscle, nerve, certain forms of fibrous tissue, are being produced from bioplasm at every period of life, and changes of the same order as those by which the first formation of tissue is provided for may be observed. In all cases the newest formed material is that which is nearest to the living matter. This formed material is pushed out, and a more recent formation occupies the space between it and the bioplasm. Gradually the formed material loses water, becomes firmer, and slowly undergoes other alterations, until it assumes its characteristic form and begins to fulfil its proper function. In some cases, as I have already remarked, the bioplasm actually moves onwards, leaving the formed material, which it has produced, behind it. I have described this phenomenon as it occurs in certain forms of yellow elastic tissue and muscle, in which tissues the thickening of the fibre can be clearly seen to be due to the formation of new material by the bioplasm as it moves over the surface of the fibre already formed. The new matter is soft and does not at first exhibit the peculiar characteristics of the tissue.

But however long a period may elapse before the formed matter assumes its characteristic peculiarities, and becomes functionally active, its characters, its properties, and its chemical composition mainly depend upon the changes which occurred just at the moment it ceased to be bioplasm. The elements entering into its composition must have been arranged in a definite way, while they were yet bioplasm, so

that they were certain to combine in the manner required at the time when they assumed the condition of formed material. If, then, we desire to discover the true cause of the formation of tissue, we must search for it in the bioplasm ere formation occurs. Some of the elements of the living matter combine to produce the formed material, while others combine to form gaseous or solid substances which escape or are carried away dissolved in fluid. That which determines the combination—that which causes the elements to unite so as to produce the definite matter or the tissue is the *cause* of its formation.

According to my idea, which however may be considered by some very unphilosophical, there is something operating in each kind of bioplasm which in fact determines the kind, by virtue of which the living matter *must* grow and *must* produce formed material of a certain character, if only it be supplied with pabulum, and be placed under certain conditions. This something is, I believe, a power or force which the bioplasm has derived from pre-existing bioplasm —a force or power which has been transmitted onward, perhaps for ages, with or without variation. Conditions may indeed modify the action of this power within certain limits, or may prevent its action altogether, but that the action results from the power, and ought not to be attributed to the conditions, is obvious from the fact that one form of bioplasm exposed to the conditions favourable to the developmental phenomena belonging to another kind, will not be so influenced as to exhibit those phenomena.

The characters of previous generations are indelibly stamped upon every individual belonging to each generation, and these inherited characters can be transmitted

by the bioplasm only. In fact, is not the "nature or constitution of the organism" the nature or constitution of the bioplasm out of which the organism is formed? It may still be asked, whether all generations were potentially included in the first, and whether the germs of all were included one within the other from the first creation, as Leibnitz thought—each being containing the germs of its successors one within the other, which were thrown off one after the other, as envelope might be removed from envelope? Such questions must now be regarded from a point of view different from that from which they have been considered hitherto. The study of the characters and properties of the bioplasm will open out new lines of enquiry, more particularly with reference to the powers by virtue of which all formation takes place.

Those peculiarities of external form, and of external and internal structure and action, in which one species differs from all others, must also be attributed to the vital phenomena of the bioplasm. In like manner the power of origination, and handing down of newly acquired properties and characters, is limited to bioplasm. Bioplasm is the agent concerned in the transmission of all hereditary structural peculiarities. Nay, this living matter alone can inherit, and whatever it inherits comes from bioplasm. There is nothing in the non-living world, it need scarcely be remarked, that presents any analogy with this marvellous power of inheriting from predecessors definite characters, and transmitting them to those that succeed. All will accept Mr. Darwin's conclusion, that whenever variation occurs, the cause of variation must be attributed to something in the "nature or constitution of the organism,"—or, as I venture to think, we

may say with still greater accuracy, to something in the nature or constitution of the bioplasm from which the organism is developed. This cause of variation must, as it seems to me, be very closely related to the cause of the formation of tissue by bioplasm, and is in its nature *vital*—not *physical.*

The *vital powers* to which the special constructive peculiarities of bioplasm ought to be attributed are, however, not admitted by all. It has been truly remarked that the embryo of the common fowl, for example, will not be formed unless the egg be exposed for a definite period to the influence of a temperature which may vary only within a very limited range. The necessity of this condition has led some to regard the heat as the efficient cause of development, and it has even been maintained that the physical *heat* undergoes conversion into the non-physical *life.* The matter in the peculiar living state out of which the embryo was formed has been regarded as ordinary matter which, possessing only ordinary material properties, underwent, as the saying is, certain peculiar "differentiations," or which "differentiated itself" into the tissues, and organs, and actions constituting the chicken. No such conclusion as to the forming or creating powers of any external physical agencies is however in the present state of knowledge to be justified.

The early changes in development require a considerable *time* for their completion, but the laws by which varying rates of growth in different living forms are governed or determined have not been discovered. Although wonderfully little pabulum is taken up, and but a small quantity of matter undergoes change, phenomena of paramount importance

proceed, and time is very necessary for the completion of these early changes in all organisms, and especially of course in those that are complex. In vegetable organisms the time that must elapse between the completion of the formation of the seed and its germination varies very much, as also the periods of time during which the seeds of different plants will retain their vitality, and this must depend upon inherent properties of the bioplasm. So also with respect to the periodical rests from growth, the greatest individual differences are noticed. Inherent vital peculiarities also manifest themselves in cases in which a moderate rise of temperature is far more damaging to the vital phenomena of the normal bioplasm than a corresponding fall. If the average temperature be a little above or below that which is adapted for the growth and development of certain creatures, the organism soon begins to suffer, and many tissues, although they may be formed, never attain the most perfect construction possible, or their highest functional activity; and probably they begin to deteriorate long before those of similar organisms developed under the particular conditions suited to their special vital phenomena. But is there not something very remarkable in the fact of the existence of powers or properties in the several kinds of bioplasm, by virtue of which each seems to grow and flourish only within its own particular range of temperature? A fall of a few degrees in the average temperature will ensure the destruction of some organisms—a slight rise maintained for a time that of others. We cannot even lay it down as a law that a low temperature is necessarily destructive of vital action, for there are organisms which flourish at or below the freezing point of water. In short, the various forms of bioplasm have

their individual peculiarities and characteristics, which they inherit, and may transmit, and which are not to be accounted for by physics, and which seem in truth to belong to their constitution. Conditions which are life to some forms of bioplasm are death to others. We may speculate as to the origin of these individual peculiarities which characterise the different forms of living beings, but we cannot at present expect to determine how they have arisen, or whence they have been derived in the first instance.

Some are content to be assured and have faith enough to believe that peculiarities from time to time originate, and that their fortunate possessors gain thereby great advantage, so that they are enabled to overcome their less fortunate brethren, and even to utterly exterminate them. A never-ending scramble for mastery seems to be regarded by philosophical naturalists as an essential factor in the origin of species. Success in the perpetual life-struggle falls to the lot of the strongest, or the most cunning, or to those blessed with some other fighting or out-lasting quality, the origin of which is to be traced, it is said, to some slight deviation from the ordinary upon the part of one of a vast number of organisms of the same kind, which gives to that one the advantage of an offspring certain to survive the offspring of the less fortunate multitude. Being the fittest to live the few soon predominate. Bioplasm, with the newly acquired properties, transmits the peculiarities to that which descends, until bioplasm, capable of producing an organism still more fit, somehow results. The organisms derived from this then prevail, and enjoy the advantage of living and continuing the race. So the experiment is supposed to proceed. Whether or not new constructive power is thus acquired by

bioplasm, the existence of wonderful powers in relation with the bioplasm is proved by the fact of the formation of tissues in the new organism having the individual characteristics of those of its progenitor, at a time long after the bioplasm mass was produced and detached from the organism that formed it.

One of the most remarkable examples of inherited constructive power, and one which, as it seems to me, is especially worthy of our consideration with reference to many abstruse questions relating to the transmission of vast power through the agency of infinitesimal particles, is the bioplasm of the spermatic particle. The powers derived from the organism which produced it, are by this tiny speck of living matter transferred to bioplasm through which its influence is brought to bear upon vast quantities of living matter.

The bioplasm of a human spermatozoon, which, perhaps, hardly weighs as much as the one-hundredth part of a single red blood-corpuscle, may stamp with unmistakable individual characteristics several tissues and organs which, in their fully developed state, weigh many pounds. Moreover, the influence of the power thus conveyed extends over many years, and is as distinctly manifest in the action as in the structure of tissues. This influence may not be clearly evident until many years have passed since the minute particle of bioplasm left the organism that produced it. But how are we to explain the association of such far-reaching constructive power with molecules of such minute size? With what properties of ordinary matter can these powers be placed in comparison?

The special particles of matter endowed with the powers

under consideration, are produced in one particular organ which does not attain its power of production until many years have passed since its development commenced. Surely no one would consider it reasonable to attribute the powers manifested by the spermatozoon to the properties of the elements of which its minute speck of bioplasm is composed. No properties of any elements that have been discovered, are, in any way, comparable with those manifested by this wonderful particle. Mr. Darwin has therefore endeavoured to explain the marvellous properties in another way. But let us consider what insuperable objections immediately present themselves to the acceptance of his hypothesis of pangenesis.

Here is one of the very smallest living particles, carrying the most extensive powers—powers which may reach to every tissue in the being that is to be formed. It is nevertheless suggested that the spermatozoon may be composed of millions of particles, one or more having been detached from every component element of the tissues of the parental organism. But this is not all, for every one of millions of spermatozoa must be considered as having been formed in the same way.

Now concerning the manner in which the supposed particles meet together to form the spermatazoon :—We are asked to conceive that particles are being continually detached from each anatomical element of each tissue, and that they pass from every part of the body where they were formed, and move with unerring precision towards the gland tubes, where they collect together in sets without confusion, thus to form the spermatic particle. If several particles from the same locality come together, they must separate again,

and find their way to the collections which were deficient in these particular particles. By what means all these millions of particles find their way to the precise spot which is their proper destination—how they sort themselves, or by what means they are sorted, how at last they arrange themselves in proper order in the minute particle of bioplasm which they are supposed to constitute, has not even been suggested. But this is not all. The hypothesis assumes that particles are detached from each anatomical element. But from what *part* of the cells they are supposed to come, is not stated. Now these anatomical elements are complex in structure, and many are composed of several kinds of matter. Many are growing, and the matter of which they consist, is in very different states in different parts at different periods. As I have shown, the outer parts of the cells and certain of their contents are, in many cases, non-living. Now, if non-living particles were to collect in the manner assumed, the resulting collection would not be anything like a spermatozoon, and it is not conceivable that such a collection of non-living particles could, in any way, have vital powers communicated to them after they had collected together. On the other hand, if we assume that the minute particles from the different anatomical elements are detached from the bioplasm, our difficulties will still be found to be insuperable, for the bioplasm is surrounded by the formed material, and we should have to assume that minute particles of bioplasm passed through even the thickest and hardest formed material in a direction the opposite of that in which nutrient fluid was flowing. We must further conceive such living particles as making their way into the intercellular spaces, and directing themselves, or being drawn, into the blood-

vessels or lymphatics, or working their way through the tissues in the most direct course towards the seat of their development. By what means they find their way, why they do not take up nutrient material and grow so large as to be stopped in their course, how it is that many are not lost and impacted in growing parts, it is impossible to conjecture. Upon the whole, I think it will be difficult for any one to accept this doctrine if he tries to realise the occurrence of the phenomena implied by the terms of the hypothesis.

Lastly, I have to consider whether it is probable that in living things, especially in those having an organism of complex structure, there is any agency which exerts *a directive influence* over the whole, as some have supposed. It has been suggested that a general directing agency might be influential in regulating and governing the phenomena contemporaneously proceeding in all parts of a living body, which result in the formation of very different structures, somewhat as a number of workmen are controlled and directed by a central authority placed over them. And, certainly, the facts of the case do seem to demand some such postulate; for, as each part grows and undergoes development, changes occur in other parts not anatomically connected with the first, but otherwise related, though separated, perhaps, by a considerable distance. But the more carefully we consider the question the less shall we feel inclined to accept any hypothesis which involves the idea of supervision on the part of any central power acting in the organism. There is, in fact, no centre from which such power could act, and there are no means by which it could be conceived to operate upon tissues at a distance. I cannot even admit that any facts known to us justify the belief that one cell is

capable of acting upon adjacent cells. I do not believe that any particle of living matter is capable of influencing the phenomena of any other particle except, perhaps, by taking up more than its own share of pabulum, in consequence of an unequal distribution. I have, elsewhere, adduced reasons for rejecting Virchow's views upon this matter. It is difficult to conceive how one living particle can "excite" increased or diminished action upon the part of adjacent living particles; and I cannot think that under any circumstances do particles of living matter act in sympathy or in antagonism with neighbouring particles. Once detached from a living mass, the particle of bioplasm acts, I believe, for and by itself—influenced as to the rate of its growth, and the production of formed matter, by the distribution of nutriment, by temperature, and by surrounding conditions, but neither exerting governing power nor being subjected to the influence of any power that acts beyond the sphere of the particles of each mass of bioplasm. Particles near to it being as independent of its influence as those very distant from it. I cannot think that any directing agency, seated in the bioplasm, can influence particles situated at a distance so slight as the five thousandth of an inch.

The well-known phenomena of the nervous system, it may be thought, can be adduced in opposition to the above conclusions; but, upon examination, it will be found that there are two quite distinct questions. By nervous action the distribution of nutriment is regulated and equalised, and many actions are governed and controlled, as it were, by a central power and authority, but this need not complicate the question of the growth and formation of structure, and the orderly arrangement and growth of the several tissues of the

organism,—for do not the latter, in certain cases, unquestionably occur independently of any nervous system whatever? In plants very complex structures are formed, temporary structures appear to prepare the way for others that are to follow, cells are arranged with wonderful regularity, and complex organs exhibit marvellous evidence of adaptation, and yet there is no regulating centre, no tissue through which the mandates of any hypothetical central authority or influence could be carried to distant parts. In the higher animals and man, the development and arrangement of all the tissues take place at a time before the nervous system is developed. The whole organism is, as it were, planned, and the basis of the tissues laid down before the nervous system attains any definite structure, and long before it begins to act. Nay, nerve is the last of all the tissues to reach its full development, and at least a part of the nervous system continues to improve for many years after birth, and indeed does not always attain its highest state of structural perfection and functional activity until after some of the tissues have already begun to deteriorate. It may, therefore, be laid down as certain that highly elaborate structure, manifesting a complex and perfectly orderly arrangement and adaptation to one another of its several parts, may be formed without any harmonizing or controlling influence on the part of the nervous system.

It will be asked how, then, are the facts to be explained? If the development of any particular tissue be carefully studied, as may be done by comparing specimens taken at different stages of growth, the observer will be able to form a conception of the phenomena which succeed one another in an orderly manner, until, in place of the bioplasm-particles of

the embryo, he finds a highly elaborate arrangement of parts performing a definite office; but I fear I shall fail in my attempt adequately to represent the series of pictures which would be formed and combined into a moving panorama in the mind of one who had thus studied.

At first, all that is to be seen is a number of masses of bioplasm which divide and subdivide. Each bioplast, by virtue of its inherent vitality, continues to produce successors in regular series, and, at a certain rate,—a limited range of change in external circumstances, being, as it were, allowed for, does not affect the result.

After the process of multiplication has continued for a certain period of time, each portion of bioplasm undergoes change upon the surface, and produces formed material. The arrangement and shape, assumed by each particle, will, in some measure, be determined by the growth of neighbouring masses, and the pressure that may be exerted, as well as by a number of other circumstances. Indeed, the general form of the organ or tissue is determined chiefly by the inherent vital powers of each individual portion of bioplasm out of which it is formed, but, in part, by the growth of contiguous organs or structures. Whether the elementary part shall be drawn out like tendon, muscle, or nerve, flattened, many sided or oval, like certain forms of epithelium, will depend upon its connections which were determined at a very early period, and whether it be subjected to stretching or pressure. If free to grow equally in all directions, as in fluid, the mass will certainly be spherical.

Many questions that might be asked with reference to many of the matters to which I have very briefly adverted cannot, in the present state of our knowledge, be answered,

and are likely to remain unanswered for a long period of time. But I venture to think that if scientific men substitute conjectures for answers, and confidently recommend to the public their own speculations as if they were scientific conclusions based upon evidence, it is the duty of other scientific men to examine the propositions, and to carefully criticise them. From what has lately fallen from some of those attached to the doctrine of evolution, it would almost seem as if they considered that their views were to be accepted by us without even the slightest examination. Against this idea one cannot too strongly protest, and especially when one finds the most far-fetched hypotheses advanced and pressed upon the people as worthy of being accepted, and believed as actual truths. No objection ought to be made to the free discussion of whether, for instance, certain instincts constitute the foundation of the moral faculties, but it would be monstrous to assert that such had actually been proved to be the case. In the same way, attempts might be made to force people who have not the knowledge to enable them to form a judgment upon such a question, to believe in the truth of the hypothesis that man has resulted by direct descent from lower forms. Now one can conceive that if but one clear case could be made out in which it had been clearly proved that two distinct species of any kind of animals had descended from a common progenitor, the evolution hypothesis would be received almost without opposition, but at present no evidence advanced is perfectly conclusive, and people ought to be allowed to discuss the matter freely without condemnation. "Aut Darwin aut nullus," is a method of argument that seems to me by no means more convincing than

the assurance on the part of a philosopher that he would prefer to have descended from an amiable beast than from a savage man.

It may be reasonable to prefer to regard oneself as having descended from the "heroic little monkey who braved his dreaded enemy, in order to save the life of his keeper," or from some other humble creature, rather than from merciless naked men whose "mouths frothed with excitement, and whose expression was wild, startled, and distrustful," but individual preferences, it need scarcely be said, prove nothing concerning our origin. A few old baboons have, no doubt, displayed what might pass as virtues, and very many savages, as well as men not so called, have unquestionably exhibited most of the vices and crimes that can be named, but it is difficult to see how such facts can influence the question whether the baboons and ourselves came from a common bioplasm. It is possible that the resemblance between certain structures in our bodies, and corresponding structures in some lower animals, may be due to our lowly origin, but that explanation is certainly far from proved, and the whole question is still open to discussion. And the same may be said of the evidence supposed by some to be conclusive in favour of the doctrine that we are descended "from a hairy quadruped, furnished with a tail and pointed ears, probably arboreal in its habits." But I will not further offend than by suggesting that as the general likeness of species to species has been pointed out and accounted for, it might be well if evolutionists would study the points in which the corresponding organs and tissues of any closely allied species differ from one another in minute structure and arrangment, and ascertain, further, whether

the points of difference can be accounted for by the hypothesis considered to satisfactorily explain the likenesses and points of resemblance.

Bioplasm in Disease, and the Degradation of Bioplasm.

Having considered the changes taking place in simple living matter, and those wonderful phenomena which succeed one another with perfect regularity and in perfect order, until the formation of the organism, with its complex tissues and organs, is accomplished, let me ask your attention to vital phenomena of a different kind, which result in degradation as regards formative power, although there is *increase*, not diminution of those changes to which I would restrict the term *vital*. We can trace the formation of the living disease particle from normal living matter, and may see exactly how it results from an alteration of the conditions under which the life of normal bioplasm is carried on. Not only so, but if I have interpreted the observations aright, I shall be able to show how the disease-carrying germ is produced in the living body as a consequence of abnormal changes going on in successive generations of bioplasm particles; these morbid living particles having invariably originated, as I believe, in normal bioplasm.

If the bioplasm of man or one of the higher animals grows more rapidly than in the normal state, its power of forming tissue and of developing structure is impaired. If any structure whatever is produced it is soft, incapable of discharging its function properly, it is weak, and it does not last. It has been produced too quickly to attain power of resistance. But if the rapidity of the growth

of bioplasm is very considerably increased, no tissue at all results. Bioplasm produced by descent from that which grows and multiplies quickly, does not regain formative power. Rapid increase is associated with loss in constructive power, but, as I have remarked, *vital activity* is increased, if by the phrase we mean to imply that more pabulum undergoes conversion into bioplasm, within a given time, than in the normal state; and I know no other meaning applicable to the words.

If the bioplasm of any tissue in a state of inflammation or fever, be compared with that of the same tissue in health, it will be found that the bioplasm masses have considerably increased in size. In every kind of inflammation and in all ordinary fever, bioplasm grows. It is, in fact, the increase of the bioplasm that constitutes the malady and gives rise to the characteristic phenomena of the disease. I shall not describe the changes as they may be observed in the tissues, for I have already considered this part of the subject in my Report on the Cattle Plague, published in 1866, in "Disease Germs," and a brief account has been given in one or two other works. The essential change, both in inflammation and fever, seems to be *increased nutrition of bioplasm.* An inflammation, as I have remarked, may be regarded as a local or circumscribed fever, and a fever as a general inflammation. The growth of the bioplasm in ordinary fevers does not proceed far enough to end in pus-formation, because the general changes in the blood, in the nervous system and in other parts of the body, cut short life long before the whole organism could pass into a state of general suppuration; but how often do we find a sufficiently marked tendency to such a state in the extensive and too often

wide-spread suppurations occurring in tissues and organs of persons who just escape death from severe attacks.

Now, what is the cause of the increased nutrition and growth of the bioplasm? In fevers and in every form of inflammation the normal phenomena in the bioplasm undergo a striking change. The bioplasm of healthy tissues, which is living very slowly, taking up little nutrient matter, and slowly being converted into formed material, perhaps gradually diminishing, but never increasing in size—suddenly, quickly, that is perhaps within a few hours, increases greatly in amount. It may divide and subdivide into several masses, all of which grow rapidly and take up a large quantity of nutrient matter. So far from the production of formed material of tissues going on under these circumstances, not only is this change for the time suspended, but much of the formed material last produced, and still in a soft and imperfectly developed condition, is taken up by the bioplasm which produced it, and the latter, in fact, grows at the expense of the structure of the body. Much tissue may in this way be destroyed, and portions of organs completely removed, never to be replaced. The body is thus permanently damaged, for the parts destroyed could not be re-formed, unless they were developed anew, and this in man and the higher organisms is impossible. The power of new formation, however, does exist, and to a wonderful extent, in many of the lower animals, the fully formed lobster being able to develop a new claw, the salamander and axolotl, new limbs, and the lizard a new tail. The muscles, nerve fibres, vessels, and all the complex tissues entering into the formation of these organs, be it observed, are developed from formless bioplasm, in the same manner as they are formed during the embryonic

period of existence. Man cannot develop a new finger—not even a nail or a tooth—if these structures, with the matrix from which they grow, be removed after their development is completed. Not even a bone will be replaced if, with the bone itself, all the soft tissue which takes part in bone formation be removed. But new vessels, new nerves, new epithelium, new fibrous and some other tissues may be developed even in man long after he has reached maturity. Vessels and nerve fibres are, however, formed in continuity with and from the bioplasm of already existing tissues of the same kind. A low form of epithelium and connective tissue, with the exception of certain textures found occasionally in the ovary, are probably the only tissues which are formed in the adult from bioplasm, which we can be sure has not been derived from that belonging to the tissues. The above may be, I believe, developed from bioplasm which has been produced by the white corpuscles of the blood.

I must, however, leave this interesting question, and revert to the consideration of the cause of the enlargement of the masses of bioplasm in fever and inflammation, but we may first enquire what would happen if the living matter did *not* increase—if pus were *not formed*, and perhaps much tissue destroyed? Although the inflammatory process in question is undoubtedly destructive, the tissue destroyed is as nothing compared with the amount of texture that would be totally destroyed by decomposition if the phenomena of inflammation did not occur. The bioplasm particles would die, and that regular flow of fluid to and fro in the very substance of all the tissues, being deranged, the bioplasts near the part affected would also die, and the organic matter of these, with that of the tissue, and

organic matter present would undergo decomposition. The resulting products would diffuse into the neighbourhood, and extensive mortification would ensue. The blood would stagnate in the neighbouring vessels, its bioplasm would die and undergo decomposition. In such cases it too often happens that the death of the organism very soon follows. If, however, a part of the body mortifies, and inflammation occurs around the dead tissue, life may be saved and the dead mass detached. But in this case there must be rapid growth and multiplication of bioplasm between the part that is dead and the healthy tissues.

If the bioplasm of any tissue be supplied with more nutrient material than it receives in the normal condition, it will grow more rapidly than usual. This increased growth, owing to an increased access of nutrient pabulum is the *first change that occurs in inflammation, and it is essential to the inflammatory process.*

The more ready access of nutriment may be due to an opening in the formed material and exposure of the bioplasm at one point, as may occur in mechanical injury; or it may depend upon a softened state of the formed material which is thereby rendered more permeable to the fluids, or lastly, the character of the nutrient fluid may be so altered as to permeate the formed material much more readily than the nutrient fluid which transudes through the walls of the vessels from healthy blood,—a condition which is met with in some forms of inflammation, and in all the more severe forms of fever. In the latter state changes in the blood often proceed to such an extent as to materially modify its chemical composition.*

* "Disease Germs," p. 340.

The bioplasm of epithelium and that of connective tissue undergoes the change referred to more readily than that of other tissues, and is the first to increase in inflammation and fever; but there is no bioplasm in the organism that may not alter in the manner indicated, and thus gradually pass from a state of physiological into one of pathological action. From every form of bioplasm in the body pus may, in all probability, be produced by descent, but in some forms of bioplasm the change occurs much more readily than in others. The pus-corpuscle then is bioplasm which has, in all cases, been produced by descent from some form of normal bioplasm of the body. When growing and multiplying rapidly the pus-corpuscle, as I have stated, is not spherical, but little projections are seen over every part of it, every one of which may increase. From time to time some of these particles are detached. In this way the corpuscles increase rapidly in number. When quiescent in the fluid of the pus, the pus-corpuscle, like the colourless blood-corpuscle, is spherical, and new centres may appear in its central part. It may be well to consider here how the fact, that a mass of bioplasm, which has been produced by direct descent from one of an oval or other form assumes that of a sphere, may be explained. The spherical is the form any mass of bioplasm will assume if it be free in fluid. Other forms depend not upon peculiar properties of the bioplasm itself, but are due to the circumstances under which the living matter has grown. The position of the new centre or nucleus varies according to the form the bioplasm is made to take, and the situation of the part of the mass which may be nearest to the nutrient matter.*

If we are to ascertain the true cause of the enlargement of

* When the mass of bioplasm is oval and elongated owing to the

masses of bioplasm in inflammation and fever, it is clear we must carry our enquiry beyond the fact of the increased access of pabulum, for it is obvious that the access of pabulum could not determine increased growth unless there was an active tendency on the part of the bioplasm itself to appropriate the pabulum and to grow—in fact a tendency on the part of the bioplasm to move towards the pabulum, take it into itself, and convert it into living matter. Bioplasm *always tends to grow.* It *must* in fact grow if it be supplied with nutriment.

Bioplasm has within itself no power of regulating or controlling the rate of its growth. As already stated the condi-

influence of traction or pressure of surrounding tissues, the new centre of growth or nucleus may be in the centre or nearer to one end, according to the source of nutrient supply and the influence of external circumstances. If to any given mass of bioplasm nutrient matter be supplied upon one side while the conditions favourable to the production of formed material are present upon the opposite side, the result will be a cell or elementary part generally of an oval form, with its new centre (nucleus) towards its lower extremity, and the new centre of the latter (nucleolus) in corresponding position. It would, therefore, appear that the growth of bioplasm and the development of new centres in bioplasm already existing takes place in a direction towards the pabulum, while the formed material accumulates in a contrary direction. The bioplasm and its centres, regarded as a whole, tend to move towards the pabulum. But if the bioplasm be surrounded upon all sides by nutrient matter it will be spherical, and a new centre will appear in its central part. We see, therefore, not only how it is that a spherical corpuscle may result from an oval, or very elongated, or stellate mass of bioplasm, but we are able to form an idea how the multitudinous forms which the mass of bioplasm assumes in the different tissues are brought about by pressure or traction exerted in certain directions by the growth of structures in the neighbourhood, and why the pus corpuscle, which may result from a mass of bioplasm of any form, is spherical, instead of resembling in form the mass from which it originated.

tions under which it grows exert an important influence in the results of growth and development of bioplasm, and these "conditions" vary as regards every kind of bioplasm, and not only so, but different forms of bioplasm differ greatly in their power of bearing a change in the conditions without suffering deterioration. Some forms will live under external circumstances of the most varied kind, and are, therefore, found over a very wide area. Others suffer or are destroyed if the external conditions are altered only so slightly as to be imperceptible to many living creatures, and in this case the distribution of the life-forms, resulting from the development of the bioplasm, will be confined to a very limited area. The same observations may be made with respect to the several different forms of bioplasm in one living organism. Some, like that of epithelium, bearing very great changes in temperature, &c., without being much affected, while other forms like those of some glands, and those of some parts of the nervous system, suffer under comparatively slight alterations of the ordinary conditions under which they live.* There is no cogent reason for supposing that all forms of bioplasm might be made to bear without suffering similar great alterations in external conditions, than for believing that we might domesticate the wolf and the lion, as we have domesticated the dog and the cat, or make the swallow flourish in our little home prisons like the canary bird.

As it were between the two extremes, are forms of bioplasm that grow and deteriorate, but still live for years under

* The "conditions" under which bioplasm grows in the higher animals are, it must be borne in mind, very complex, and are determined partly by the results of growth of pre-existing bioplasm and in part only by external conditions. The same remark applies to the "environment" of any cell or elementary part of the body.

adverse circumstances, the structures formed never attaining a state of vigour, but still being formed and acting in an imperfect way, and perhaps for a long period of time. The weak succulent too quickly developed vegetation of our fern cases is an example; and the soft ricketty tissues of some of our weak, flabby, over-fed, town-bred, highly-precocious children, supply a very painful instance of too quick formation and growth. In such cases the bioplasm has grown too fast, and tissue has been formed too quickly. Time has not been allowed for its condensation and strength, and for the acquisition of resisting and lasting properties. But is it not a mistake to point to such cases as examples of diminished *vital action?* It seems to me that life has been carried on too fast and not too slowly. Too much pabulum has been taken up—not too little. Too much heat, too much food, favour a quick rank succulent spongy sort of development, inducing the formation of soft bones and weak imperfectly acting tissues which are likely soon to deteriorate.

In inflammation and fever the bioplasm of fully formed tissues grows too actively, and such intensity of the process may be acquired that, as I have said, the bioplasm feeds upon the very tissue that has been formed. These changes are not however due to "excitation." There is no calling forth of new power by "stimulation" from without. In the healthy condition the changes occur slowly, and the access of the pabulum to the bioplasm of the tissues generally is moderated. If too much food be taken, the excess is taken up, changed, and eliminated without ever contributing to the nutrition of the bioplasm of the tissues in any way. In inflammation, the *restrictions under which the normal changes go on are to some extent removed,* and the

bioplasm lives faster than in the healthy state. We cannot say that the bioplasm is in any case "excited" to grow, any more than we can maintain that a ball is "excited" to roll if obstacles which prevent it from rolling are removed.

In connection with the question of the nature of *vital* actions, the loss of formative power as the rate of growth and multiplication of the bioplasm increases, must be regarded as a fact of great interest. Bioplasm may form tissue and give origin to multitudes of bioplasts, from which tissue may also be developed. But the very particle of bioplasm which might have taken part in tissue-formation will, if it grows and multiplies too fast, not only lose its power of forming tissue, but the particles that may be produced from it by descent will never regain the wonderful capacity that has been lost. No pus-corpuscle or any of its decendants, then, ever take part in tissue formation. It has deteriorated, and the deterioration in formative power remains a characteristic of all its descendants. But although formative power is lost, new powers or properties may be nevertheless acquired. These are, however, remarkable for destruction—for pulling down and destroying that which has been formed—never for construction. Some forms of pus acquire during their production the most wonderful capacity for rapidly growing and multiplying, as well as for living, and resisting the influence of external conditions. The little offsets or particles that are detached from them may rise in the air, live for a time in water or milk, or other fluids containing organic matter, adhere to a sponge or a probe or other substance, or be carried in a living state on the foot of a fly or some other insect, and thus transported to an organism at a distance from the one which was the seat of their production. The

minute germs being in contact with material adapted for their nourishment, rapidly grow and multiply in their new situation. As we know but too well such forms of *virus* have been produced *ab initio*, fostered, and propagated to the destruction of hundreds of human beings.

In some cases we are almost able to watch the series of phenomena which result in the development of a contagious animal poison. I have shown that the active agent is a minute particle of living bioplasm, which I have good reason to believe may have been produced by descent from the normal bioplasm of the body. This particle of deteriorated bioplasm, which in some cases may be *seen*, is a "disease-germ," and of these "contagium" consists. The word *contagion* was used by Hippocrates, by whom, as well as by Harvey, and indeed by authors who lived since Harvey's day, it was employed to signify something immaterial—something intangible, that was supposed to emanate somehow from the affected organism. Now, however, we use this word in a very different sense, for by it we mean actual matter of some kind. This matter, as far as I have been able to ascertain, is composed of minute particles of bioplasm, which resemble in their general characters bioplasm which exists in some situations in the healthy body. The contagious bioplasm results from normal bioplasm, the life of which has been carried on for some time under unusual conditions. It has been already shown that an ordinary form of morbid bioplasm, pus, often originates in the bioplasm of epithelium and in that of connective tissue, and that certain forms of pus have specific virulent properties, and are in fact animal poisons, which may be inoculated.

I do not, however, entertain the opinion that all contagious disease germs spring from the bioplasm of epithelium or connective tissue. Some may come from white blood-corpuscles, or from lymph-corpuscles. But I do consider that many facts favour the doctrine that the contagious particles concerned in propagating many of our most serious specific fevers have been derived from the living matter of man's body, and that they are not germs of fungi, or bacteria of any kind whatever. Indeed, in certain instances, they may be seen in far greater multitudes in the tissues of the diseased organism than bacteria, which latter, as is well known, are found often enough in countless multitudes in cases in which there is no specific disease of any kind.

When I was studying the changes in the tissues of animals destroyed by Cattle Plague, 1865, I found a quantity of rapidly growing bioplasm in almost all the tissues, but in the skin the manner in which the contagious particles grew and spread could be very satisfactorily demonstrated. The minute particles having gained access to the interstices between the bundles of fibrous tissues of the corium, divided and subdivided, spreading amongst the bundles and separating them from one another. In some places the particles had made their way into the interstices of the epithelial cells of the cuticle, where they formed little collections, and had invaded the tissue itself of the cuticle cell. Similar bioplasm particles were found in the obstructed capillary vessels, and in not a few instances could the course pursued by these be traced from the interior of the capillary to the surrounding tissue by a narrow line of well defined bioplasm particles. Although it is true

bacteria were to be seen in some situations, no difficulty was experienced in finding collections of the bioplasm quite free from bacteroid bodies or their germs—a fact which I think conclusively proves that there is no necessary connection between the specific bioplasm particles and bacteria.

I have for years past, in fact ever since 1861, directed attention to what I cannot but characterise as the many insuperable objections to the acceptance of the bacterium and fungus germ hypothesis of contagious fevers. In these days there is nothing more striking than the pertinacity displayed in forcing upon our attention extravagant conjectures which seem to be almost unsupported by facts. One great scientific authority tries to persuade us to go along with Lucretius, another seems to think that it is our bounden duty to believe and confess that we are machines. We are expected to acknowledge that there are forms of life the physical actions of which are not far removed from those of an oil globule—that between a piece of lifeless white of egg and living bioplasm there is only a slight difference —and that omnipresent bacteria, which it is gravely asserted may be made out of non-living matter in a glass flask, or allied forms, are the active agents, or at least the essential concomitants, of almost every form of contagious disease which can be imparted by an infected to an uninfected organism. Indeed there is no end to the suggestions advanced to gratify our love of the improbable which are made to appear plausible by the selection and ingenious application of a few arguments, while the numerous facts opposed to them are altogether ignored. Does it not almost appear as if some of the foremost minds of

our day had joined in a crusade, having for its object that of persuading the most intelligent and the most highly trained intellects to accept, without question, scientific and philosophic statements which rest neither upon observation nor upon experiment, and which have nothing to support them but authority? But if some of the many scientific guesses which are being continually advanced be proved to be untenable, what happens? So far from any blow being given to scientific guess-work this accomplishment flourishes all the more in some quarters. At the worst a very extravagant hypothesis, may have to be dropped or quietly shorn of its meaning, or put forward in a new dress. Or by changing the terms of the hypothesis or judiciously shifting the ground, its fall may be so broken as not to seem a fall at all. It is not difficult to hide the badness of a very bad case in this way:—if, it may be argued, man is not a machine he is in many respects like, or not unlike a machine, or at least some of his actions are mechanical; and then it might be suggested that the machine and the man may be smashed by the same forces, and must therefore be closely related!

Some writers have committed themselves to the fungus germ theory of disease, and have so clearly stated their views that it is scarcely possible to misinterpret their meaning. Others have expressed themselves against this doctrine with equal clearness and equal force. But there is a third class of persons who seem to think that fungi may or may not be the active *materies morbi*. If, say they, contagium does not consist of actual bacteria it is caused by bacteria, or bacteria constitute an essential condition of propagation, or they prepare the body for the reception of the contagium, or they make the pabulum upon which the contagium lives, or they

are a stage in the development of contagium, or they are constant and necessary accompaniments of contagious particles. All this in spite of the broad fact staring us in the face that at the time when certain contagious matter is most virulent, no bacteria, or few or doubtful bacteria, are to be discerned, while as the bacteria multiply the specific properties of the poison become weaker, and when the bacteria are growing rapidly and freely multiplying its specific properties have diappeared. Again it is assumed that there is a necessary connection between the development of bacteria and the formation of pus, although anyone can satisfy himself by observation that the living moving pus-corpuscle is destitute of bacteria germs, while the dead inactive pus-corpuscle, or more strictly, the matter resulting from the death of the pus-corpuscle, is being devoured by them. Is it not astonishing that people do not think a little for themselves upon these matters, instead of believing what they are told to believe, and accepting as true fallacies of the most transparent character?

I do not think that the evidence adduced in favour of the doctrine that the contagious material of specific contagious diseases consists of bacteria, is stronger or more reliable than that which has been adduced in favour of the revival of the doctrines of Lucretius, or of the view that animals are machines. On the other hand, it seems to me that the conclusion is irresistible that at least pus-corpuscles and certain particles having specific contagious properties have nothing whatever to do with fungi, bacteria, or any other living things in nature, but come direct from the bioplasm of man's body. Multitudes of the lower forms of life, like bacteria and microscopic fungi, multiply whenever

organic matter, healthy or morbid, tends to pass into decay. As soon as the continual flow of fluid to and from the bioplasm through the formed material stops, as it must do if the bioplasm dies, many kinds of formed material, vegetable as well as animal, begin to undergo rapid chemical change, substances being formed which are quickly appropriated by these low forms of life. Millions of growing particles are to be found upon, and in the structure of, every dying leaf in autumn. Any tissue or any form of bioplasm in which fluid stagnates at a temperature between 60° and 100°, soon becomes the seat of the growth of multitudes of bacteria. No wonder, then, that the easily changing substances, which accumulate in the blood and tissues in inflammation and fevers, should be pervaded and appropriated by these organisms. It is exactly what anyone would be led to expect if the facts of the case were carefully considered by him. The very last conclusion, it seems to me, that would be adopted by anyone who thoroughly thought over the matter would be, that these low organisms were the *cause* of the changes in the fluids by which their growth was favoured, much less that they were the cause of the diseases which had existed for some time before they began to multiply. One might, I think, with as much show of reason, advocate the doctrine that bacteria were invariably the cause of death, since after every form of death they grow and multiply in the tissues and fluids of the human body.

We have now examined a somewhat extensive range of vital phenomena, and nowhere have we discovered a change or an action peculiar to living matter that could be adequately accounted for by any known facts and laws. The formation

of every tissue or organ seems to have been anticipated and prepared for, as it were, beforehand; and, in many cases, changes occur which it is difficult to persuade oneself were not in some sense foreseen, because provision is made for their occurrence long before the changes happen, and the preparation is such that it could only be accounted for upon such an assumption. But, in fact, this is characteristic of every kind of vital action, although it is much more apparent in some instances than in others. It need scarcely be said that physicists have failed to adduce any explanation of the phenomenon which, like many other facts to which I have adverted, is peculiar to life.

The acceptance of some dogmatic assertions concerning the nature of many of the actions of living beings proves only that numbers of intelligent persons must be so indolent that they prefer to accept a dictum, however groundless it may be, to the trouble of dissenting from propositions, the fallacies of which would be detected if only a little thought were brought to bear upon them. In these days intelligent persons are content to consider themselves molecular organisms or crystals, or automata, or anything rather than raise objections to statements which seem to be in fashion. We boast of the spread of education, we train our children in science, we devise all sorts of tests for ascertaining whether the mental faculties have been properly trained and exercised, and real knowledge communicated; and the rising intelligence seems content to believe in faith that man is an automaton—a mere machine. And yet how obvious it is that man, whatever he may be, is not an automaton. Where is the moving automaton that perceives an obstacle to its progress and avoids it. The maker of such an instrument

would have the proud satisfaction of feeling that he had made a machine which performed, by a very complex and beautifully wrought mechanism, what a little bit of the meanest living matter in nature effected without any machinery whatever. But the simple colourless structureless matter has the advantage over the most perfect mechanism, inasmuch as it is able to grow and produce other particles like itself, possessing those marvellous powers which nothing but the living can claim.

Never was there a time, like the present, in which mere assertion had so excellent a chance of being accepted without real criticism. It is not, in my opinion, too much to say that the manner in which some statements, falsely regarded as scientific, have been received and extolled is almost a disgrace. The circumstance proves either that, for some reason, people are determined to be taught dogmas which they know rest upon no foundation in fact, or that they desire to be amused by information called scientific, and the more extravagant the terms in which this is conveyed, the more satisfactory to the hearers. It is hard to have to speak thus of any doctrines or views taught in England, but I am confident ample evidence is at hand to justify the remarks I have considered it right to make, and I am very much mistaken if there are not many who thoroughly agree with me, though not inclined to take the responsibility of publicly expressing an opinion upon the matter.

I must apologise for troubling you with so many remarks against any form of physical doctrine of life, but I shall trespass very little more upon your patience. If by physics and chemistry, the phenomena common to all living—even in the case of the very lowest, simplest living—cannot

be adequately accounted for, it seems to me it would be an idle waste of time to recount the numberless facts and arguments against the acceptance of a physical doctrine as applied to thought. Nor shall I be greatly moved by the hardest words that may be used, or the intensity of the scorn that may be displayed by those who regard the brain as a machine, and thought as a result of chemical change. They may be well supported in their views, but until they can give a rational account of the changes which occur in a simple living organism, no one who uses his reason aright will believe that they really discern the nature of the difference in the state of the nervous matter of man's brain when the organ is active and when it is in a state of rest.

Have the supporters of physical doctrines been able to tell us what goes on when a nerve grows, what occurs when it acts, or the difference between the nerve matter of the nerve centres and nerve fibres when they are in a state of the highest activity and most complete rest? Have they shown us how a single nerve fibre is formed in its position, much less accounted for the manner in which that inextricable interlacement of fibres characteristic of all nerve texture is brought about? Have they proved how an odorous or a sapid particle influences the nerve, or the differences between the vibrations of the molecules of the nerves concerned in sight and hearing, or what happens when a nerve centre receives an impression from the periphery, or transmits an impulse outwards—nay, have they advanced a plausible theory to explain how we are able to bring about a definite degree of shortening in muscular fibres, maintain it for a time, and vary it as we will? And yet we are expected

to accept the dicta concerning the nature of the highest and most complex actions of man's organism, of authorities who are professedly unable to enlighten us as to the changes which occur when an amœba or a bacterium moves, or takes up nutrient matter, grows, or divides and multiplies.

The Highest form of Vital Action—Bioplasm of Nerve.

I venture to think, therefore, that we may entirely dismiss from our minds every vestige of the notion that the action of any nervous apparatus is mechanical, or that any part of it can be formed by physics or chemistry. I beg you to utterly refuse to accept the notion that mental action is a form of physico-chemical change, on the ground that neither the structure, nor the mode of growth, nor the mode of development, nor the action of the very simplest nerve apparatus in nature can be adequately explained at this time, and because the simplest changes in the simplest living forms in existence cannot be accounted for by physics.

Let us then pass on to the consideration of the action of the nervous system, particularly with reference to the part played by the bioplasm in the construction and action of that most wonderful apparatus.

As far as I am able to learn there is, in every nervous action, something behind that part of the process which is plausibly considered to be physical. Before the simplest reflex act can be completed there must be a nerve current, and the latter cannot be set free unless some chemical change occur. The matter undergoing this chemical change must be *formed*, and its particles must have been so arranged that the changes ending in the development of the

nerve current may occur,—but here we arrive at the bioplasm and its active forces and powers.

I am not one of those who regard the nerve force as some mysterious and very peculiar form of energy, and am quite ready to accept the view that the current that passes along the nerve fibre is electricity, or something very closely allied or related to it. I can conceive that many of the phenomena of the nervous system are a consequence of nutritive acts, and that the latter are, in their turn, controlled and regulated by nerve action. I was, in fact, the first to describe the distribution of nerves to capillaries, and to point out that these form the afferent part of a self-regulating nerve apparatus connected with the distribution of blood. I showed how, when nutrition was too active, or when the capillaries were unduly distended with blood, an impression might be produced upon the *afferent* nerve fibres of the capillaries, and by these and the fibres with which they were continuous, transmitted to the nerve centre. The immediate consequence would be a disturbance of the nerve current traversing the *efferent* nerve fibres which are distributed to the circular muscular fibres of the artery. These immediately become shortened to a certain definite extent, mainly determined by the intensity of the impression upon the afferent fibres. Thus the diameter of the vessel is temporarily lessened, and the flow of blood to the capillary vessels being reduced, the supply of nutrient material distributed to the tissues, is, for a time, lowered. As the nutritive balance is restored by the agency of the same apparatus, the constriction of the arteries is relaxed to a certain extent, and the blood supply becomes equalised. This is only a part of those wonderful and extensive arrangements existing in

connection with man and the higher animals for the purpose of regulating the supply of nutrient material, equalising temperature, and generally preserving the balance with reference to the results of many conflicting actions, notwithstanding great irregularity in the supply of nutrient matter, and of substances concerned in necessary chemical change, and the most striking and rapid alterations in temperature, moisture, and other external circumstances. There is, one may say, always a tendency to the derangement of the complex phenomena of the higher organisms, but this tendency is compensated by the most elaborate and beautiful arrangements of which the self-regulating nerve "mechanism," in connection with the distribution of the blood in the capillaries, is one of the most remarkable.

We must not forget that all the nerves and nerve centres, and other tissues of which this so-called "mechanism" is constituted, were gradually formed by living matter, and that the action of this apparatus is due to the action of the bioplasm in connection with it; for when the latter is deranged the action of the "mechanism" is disturbed; if it ceases for a time the action is suspended, and if the bioplasm dies the "mechanism" is destroyed. *Vitality*, therefore, comes into play in the construction of the apparatus out of bioplasm, and in the preparation of the substances, by chemical change in which the nerve current is established. The nerve current, whatever may be its exact nature, results from changes in matter formed by bioplasm. But the actual nature of the nerve current is only a very small part, and by no means the most important part of the great question of the general nature of nerve action. The nerve current may be the same form or mode of force in all creatures, the different results

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effected by it in different animals, being due rather to differences in the construction and arrangement of the nerve apparatus of the organism, than to differences in the current which the nerves transmit. But the development and arrangement of the nerves is entirely dependent upon bioplasm. It has been shown that whenever nerve fibres are being formed bioplasm exists in large quantity, just as in the case of other textures undergoing development. There is no reason to suppose that the part of the fibre which transmits the nerve current is a very exceptional form of tissue, or that the active part of the nerves of one of the lower animals is very different in chemical composition from that of man. It is even conceivable that some human nerves might be replaced by those of animals, and action proceed as before.

Whether the bioplasm which takes part in the development of nerve fibres, and which is found in connection with the active part of all nerve fibres, at every period of life, is concerned in receiving impressions, or whether this office is performed by the fine nerve fibre only, is a question of great interest and well worth the most careful consideration.

I have shown that in all sensitive organs, and among the peripheral ramifications of all nerves, bioplasm particles are very numerous. In the retina, more than one layer consists almost entirely of bioplasm particles and the delicate nerve fibres connected with them. In connection with the nerves of the sensitive part of the cochlea they are very numerous. Many more are found upon the peripheral ramifications of the nerves of the gustatory, than upon those of the tactile papillæ of the tongue. In the tactile corpuscles, in the

tactile papillæ connnected with mucous membrane which are very numerous and well developed about the lips of serpents and many fishes, these masses of bioplasm exist in immense number. In short, in connection with all nerves forming the terminal expansions which constitute the essential part of sensitive nerve organs, these masses of bioplasm are numerous, and it is a fact of not less importance with reference to the question of the function of these particles, to bear in mind that numbers are found in connection with the ultimate ramifications of motor nerves distributed to some muscular fibres which are highly active, like those of the diaphragm and tongue. In the case of some muscles, the terminal nerve fibre is, at certain points, highly convoluted; and here we find the masses of bioplasm very numerous, and situated very near to one another. All these facts support the inference that these masses of bioplasm are intimately connected with the action of the nerve fibre as well as being concerned in its formation.

But, on the other hand, there are very few upon the finest ramifications of nerve fibres in the serous membranes which become extremely sensitive in disease. It might, therefore, be argued that the pain results rather from pressure upon, or stretching of the finest nerve fibres in the intervals between the bioplasts, than from any direct pressure or other influence upon the bioplasts themselves. Again, in the imago state of many insects the finest ramifications of the nerve fibres exhibit very few bioplasts in their course. I have traced excessively fine fibres and networks of fibres in the intervals between the layer of cells which forms the inner surface of the skin of the blow-fly; in connection with which I could discover minute bioplasts only at consider-

able intervals. The same remark holds good to a less extent with regard to the distribution of nerves to the involuntary muscles.

At the same time it must, however, be borne in mind that nowhere are the peripheral ramifications of nerve fibres *destitute of bioplasm*. If this were so, they would probably deteriorate, and no new ones could be formed. Probably one-hundredth of an inch is the greatest length of peripheral nerve fibre in the higher animals which intervenes between two bioplasts.

Upon the whole, then, I conclude that although the bioplasm is necessary to the peripheral expansion of nerves, it is not the material which is in all cases absolutely essential for the reception of impressions and their conveyance to distant parts. I think, however, there is little doubt that the bioplasm of peripheral nerves develops nerve currents, feeble perhaps as compared with those set free by central nerve cells, but yet of sufficient intensity to influence the nerve centre. This view is supported by the fact that small central nerve cells found in many of the ganglia are, as regards size, shape, and general characters, very like the masses of bioplasm attached to the peripheral ramification of nerves—indeed, in many of the lower animals no difference whatever can be detected between the peripheral and central part of the nerve apparatus.

Besides developing feeble nerve currents, the peripheral nerve-bioplasm is concerned, as has been already remarked, in the formation and renovation of the nerve fibres. This change is constantly proceeding in all nerve organs. New nerve fibres of extreme delicacy are being continually formed. Old ones as continually waste, leaving behind a

small proportion of connective tissue, which we find in all nerve organs, and which increases as age advances, even to such an extent as to render it a matter of great difficulty to demonstrate the excessively delicate and almost structureless nerve-fibres embedded in the mass of fibrous material.

There is yet another important change in which these bioplasm particles, so numerous in connection with the peripheral expansion of nerves, probably take part, and this is the development of heat. I have elsewhere adduced many arguments which seem to me to render it almost certain that the growth of bioplasm generally is associated with a rise in the temperature of the body. Is it not possible that, under certain circumstances, the mode of force developed in the matter of the nerve-bioplasm may be changed, heat being rapidly produced instead of nerve force? The suggestion at once occurs, whether the explanation of such exceptional cases of high temperature as that brought by Mr. John Teale before the Clinical Society a short time since, will not probably be found to have something to do with the phenomena of nerve-bioplasm. In this case a temperature of 122° was reached, on several occasions, and one above 112°, was maintained for several days, without any of the symptoms usually associated with febrile disorders in which the body heat rises.

Bioplasm of the Brain.

Let me now pass on to the last part of my theme, and endeavour to ascertain whether the most wonderful phenomena in nature, namely, those connected with the operation of mind, have their origin in bioplasm. The only

instrument concerned in thought attains its highest state of development in man. Not only is man's brain, as compared with that of a lower animal, actually very large in proportion to the body, but the difference will be found to be really much greater than it appears to be. The size of a nerve centre is, as is well known, by no means determined by the size of the animal. Varied combinations of rapidly executed movements will necessitate a brain of a size very large in proportion to that of the animal, and hence, as a rule, the brains of very small animals are enormous. The smaller the species the greater will be the weight of brain in proportion to body weight. Now man's muscular movements are by no means so varied or so powerful in proportion to the amount of muscular tissue, or so rapidly executed as those of many of the lower animals, which easily beat us as to the rapidity with which they execute complex movements. We are also behind many animals as regards the sense of touch, as well as regards the great power and precision with which the voluntary muscles of many annimals act in running, leaping, climbing, and other movements. The size of man's brain, therefore, is not due to those circumstances which determine the large size in proportion to the body, of the brain of the mouse or of the tom-tit, for example. Man indeed can only be placed at the summit of the scale of being in certain particulars, but in these he stands alone; no lower creature approaches him, or can be compared with him. In man, the action of every tissue and organ seems subordinate to that of the higher parts of his nervous system, which constitute an instrument remarkable not less for the complexity and subtlety of its delicate actions than for the capacity

exhibited by it alone for improvement after its development as an organ may be regarded as complete; and not only so, but the degree of perfection it may attain as an instrument is determined to a great extent by the will of him to whom it belongs. In the formation and action of this organ bioplasm is all important, and exists in greatest amount in that part which, upon other grounds, we know is concerned in mental action.

The very highest form of bioplasm or living matter in the world is that which, as I believe, is concerned in mind, and this attains its highest state of activity not until the age when that part of the nervous apparatus concerned in mental operations has attained a high degree of elaboration. This period cannot be assigned with precision, for it differs in different races and in different individuals, but it is never reached until some time after growth has ceased, and every tissue and organ is fully developed. But it is certainly very remarkable that, as far as I am aware, those parts of man's brain concerned in the manifestation of his highest mental faculties constitute the only structures in nature which continue to improve for many years after the rest of the organism has attained its highest state of development. So also these, above all structures, are remarkable for continuing to improve although many tissues of the body may have been, for some time, undergoing deterioration and decay.

The anatomical elements which constitute the gray matter of man's brain are well known. Large angular cells, with fibres radiating from them, the longest fibre passing upwards towards the surface near which it divides and subdivides into multitudes of the finest and most delicate threads, which

form with fibres from other cells and other parts, an inextricable interlacement. In this situation, no doubt, all the operations of the mind are performed. But to explain what happens in connection with the structures demonstrated, when the instrument is in active work, is no easy task. From a knowledge of the arrangement and action of the structure, we ought to be able to form some conception, however rough, of what happens when an idea is formed and when it is expressed so as to be rendered evident to others. The facts of the case seem to demand a means by which the mind may act upon the elaborate system of nerve fibres already referred to. We seem to require an instrument, and the means of acting upon different parts of the instrument, as we may will.

It is not easy to conceive by what means the angular cells, which form such prominent objects in the gray matter, could will. That these are concerned in the formation of the fibres is certain, and it is possible that in them nerve currents may originate, but it is very doubtful whether the bioplasm of these cells is the bioplasm concerned in thought. There are other bioplasm particles, and in enormous numbers, though they do not constitute such prominent objects as the angular or caudate cells. These are little spherical particles of bioplasm, many of which are smaller than a red blood corpuscle, and are probably connected by communicating fibres of great delicacy. These bodies are situated near the surface of the gray matter among the ultimate subdivisions of the excessively delicate nerve fibres. It is to be remarked that in this situation the supply of arterial blood is more abundant than in any other part of the nervous system, and the particles of bioplasm in

question being naked and unenclosed in any cell-wall at any period of life, are just such as we should expect would undergo rapid change. These are, I believe, the active agents which, by their movements, may act upon the delicate nerve threads which ramify on all sides in very close proximity to them. When we examine these particles of bioplasm after death, they are spherical, but are we not justified in assuming that during life they may change in form, at least, as much as a mucus corpuscle or an amœba? The slightest alteration in form would influence the current traversing the nerve fibres that were close to them. These delicate bioplasts are, I believe, during the waking state continually undergoing changes in form. That in some situations they increase in number cannot be doubted, and it seems likely that collections might increase in extent even long after the formation of the brain had been completed. What is very remarkable is, that these bioplasts retain their primitive characters throughout life.

I dare say few persons will be persuaded to believe that the bioplasts concerned in the highest mental acts of man are bodies not more complex than the lymph corpuscle or the white blood-corpuscle; but, as I have before remarked, all evidence is in favour of the view, that exalted function is not dependent either upon complexity of constitution or upon quantity of material. There are no differential characters to be demonstrated between different forms of living matter having widely different endowments, by which the peculiarities may be accounted for. There may be difference in power not dependent upon differences as regards matter and its forces. May we venture to conclude that *mind* is the form of *vital*

power which, stirring in these particles of bioplasm, causes the movement of the matter of which they consist, and that thus the elaborate mechanism slowly constructed and gradually brought to perfection is influenced? If this be so, mind is the highest form of vital power which exists in nature, by which particles of matter are caused to move in a definite manner for a definite purpose.

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