THE ADDRESS OF THE PRESIDENT OF THE ROYAL MICROSCOPICAL SOCIETY.

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As it is usual on this occasion for the President to deliver an address, I venture to offer for your consideration this evening some suggestions in connection with a subject which in one or other of its aspects must needs be of great interest to every one who wishes to learn all he can about the wonderful changes which continually go on in all living things, some being within and some beyond the present limit of scientific investigation; and though I shall express some views with which perhaps many here will not agree, I trust my remarks may kindle interest and encourage discussion, rather than offend. Where wrong I shall be glad to be corrected, but I claim permission to speak freely what I think, and liberty to advance my conclusions, which, though not at present very popular, may yet be worthy of your consideration.

THE MICROSCOPIC LIMIT, AND BEYOND.

Increased skill and ever-extending knowledge may enable the scientific worker not only to reach the utmost limit of inquiry in his time, but possibly to gratify that constant desire to see into the limitless region which lies beyond the bounds of actual investigation. This is the hope which encourages the thoughtful observer; for who would not consent to spend years in patient research, if by so doing he could succeed, as it were, in projecting his intellect, were it ever so short a distance, beyond the circumscribed region in which the senses can alone operate? Failures and disappointments may be endured if only the observer's mind be buoyed up by the hope that ere his nerve-tissues grow too old, and begin to fail, the longing of his intellect will probably be gratified. To many, indeed, who are unable or unwilling to look into the secrets of nature, such hopes and desires will seem unintelligible or incredible. They will be regarded as the idle fancies of an idle mind; and the ardent scientific inquirer will be pitied or condemned as a weak, foolish person who, like a child, is unable to repress his morbid curiosity to peer into the unseen, and his craving to kno w the unknowable;—as one deserving to be classed with simpletons and madmen, on the ground that it is absurd to suppose that a really sensible person would spend his life in hard work without remuneration, in preference to doing that which would enable him to gain wealth, and to live at ease, if not in luxury and enjoyment. And certainly it must be confessed that in few departments of research is there less prospect of gaining by success such rewards as are generally sought for, than in the one to which we are attached.

The microscopist, like the astronomer, is ever longing to get a little beyond the point at which he has already arrived. Each new fact gained by research seems but to indicate the existence of more and more important things beyond. Limit is reached and then surmounted, but soon a new limit seems to rise from the mists in the distance, towards which the worker is impelled by new hopes and desires. It is this never halting progress which distinguishes scientific from every other kind of inquiry, and particularly microscopical investigation, for it can never be completed. It deals with the illimitable. The boundaries of to-day are found to have vanished to-morrow, and the eyes and understanding begin to penetrate into regions which but a short time before had been considered far beyond the range of possible investigation.

He only who was quite ignorant of the many and great improvements constantly being made in our methods of research, and in the instruments required in investigation, would think of fixing any limit to the advance of microscopical inquiry. The records of the work of this Society contain many examples of progress towards and advance beyond barriers regarded not very long before, and by considerable authorities, as insurmountable. I well remember the time when in many branches of inquiry, it might have been truly said that the optical instrument was in advance of the methods of examination; when our magnifying powers were higher than we could use without losing rather than gaining as regards the definition of delicate structure. As, however, time went on, this was changed. New and improved methods of examining tissues were discovered, and means adopted, by which excessively thin layers could be submitted to examination, and a power of five or six hundred diametres was no longer sufficient to enable the observer to see all that it was almost certain was to be seen. These remarks more particulary apply to a class of researches upon which I was engaged in 1856-60, concerning the structure and arrangement of the ultimate nerve-fibres in various tissues and organs. Indeed, I feel quite sure that at and before that time advance was actually retarded by the discouragement offered in some quarters, and the hypothetical objections raised to the use of very high powers, and more especially to the methods of preparation of the tissues that were necessary before they could with any advantage be submitted to examination.

Although at this time we can work easily with a twelfth and a twenty-fifth, the results of observation conducted with the aid of such powers are still regarded by some with doubt and incredulity; and if we draw attention to actual structure and arrangement discovered by the higher powers, which could not possibly be demonstrated with the aid of a more moderate lens, our statements may possibly be met with insinuations that what was advanced as the result of observation was, after all, discovered by the imagination only.

Our present limit of observation in investigations on the structure and action of the tissues of man and the higher animals, in my opinion, includes the use of magnifying powers of upwards of 2000 diameters. Objects considerably less than the hundred-thousandth of an inch in diameter can be studied with success, but how much less than these dimensions cannot, I think, be determined with accuracy at this time; for so much depends upon the character of the object, and a number of small points of detail as regards the mode of examination. All who are accustomed to work with high magnifying powers are well aware of the great advantages gained by some very slight change in the degree of illuminating power, the direction and concentration of the rays of light, and very slight and happy alterations in the focus, which may momentarily reveal to the mind new facts of the greatest importance after, perhaps, many hours of careful but almost profitless study.

But in other departments of microscopical research, our present means of investigation enable those familiar with the requisite methods of inquiry to demonstrate characteristics of structure far more intricate and minute than the remarks just made would lead you to infer. Various modifications in immersion lenses and in immersion media have greatly contributed to advance our knowledge of structure and action in the lower forms of life; and there is every reason to think that, as time goes on, methods of observation will be still improved and new methods discovered, and that in consequence conclusions already arrived at will have to be greatly modified or entirely changed. Not only so, but by the aid of photography things dimly seen by the eye may be very distinctly and correctly delineated, and with a perfection of accurate detail which a few years ago we should not have supposed to be possible. In all probability, the application of photography to investigations opon minute structural details will be carried far beyond anything yet reached, although it is really wonderful how much has been achieved up to this time

As regards direct observation, with the aid of very high magnifying powers, upon animal tissues, a department of

microscopical work which has engaged much of my attention during many years, I would remark that many observations have been made upon the structure and arrangement of the most delicate nerve-fibres less than the hundred-thousandth of an inch in diameter, and other tissue-elements of very small insects. With due care, facts are ascertained which could not have been demonstrated with the aid of object-glasses magnifying less than from 2500 to 3000 diameters. Not only is the demonstration of structure and arrangement satisfactory, but in many cases a conception of the action and working of the textures during life has been formed, which would not otherwise have been obtained. The exact relation of certain delicate nerve-fibres to the living matter of the nerve in special organs has been determined, and many elementary facts necessary for the determination of the changes constituting nerve action have been ascertained.

To my mind, however, the study, with the aid of high powers and various improved means of examination, of the phenomena which occur in living matter during life, transcends in importance at this time all other inquiries in which the Microscope takes a leading part. For these changes characterize every form of living matter at every period of its being, and in every condition of health and disease. In every form of living matter which exists or has ever existed, the great mystery of life and death is enacted under our very eyes, but we have not yet been able to discover the exact nature of the change, though we can prove most conclusively that it is not merely mechanical or chemical, as some pertinaciously insist. No chemist or physicist has been able to explain the changes which do occur, or has succeeded in imitating them out of the living body. The most diverse structures and the most widely different chemical compounds are produced by changes occurring in particles of living matter which could not be distinguished from one another, and which are equally devoid of color and structure. Many of the current theories on the nature of vital phenomena are in advance of some that were propounded two thousand years ago; and yet men occupying high scientific positions are found to defend them, and to repeat again and again statements concerning the relation between the living and non-living, which are at variance, not only with facts familiar to every one, but are contradicted by the experience and knowledge every person possesses concerning certain vital phenomena of his own organism

When a particle of living matter is increasing in size —is growing by taking lifeless matter into its substance, and without itself losing anything, is communicating to certain of the elements of this non-living matter, or to combinations of these, the marvellous powers it possesses —movements take place, it may be in every part of the original mass. These movements are, however, always most observable, most active, and most extensive at some part of the circumference. Occurring now on one side, now on the opposite, it is very improbable that the movements in question are determined by any changes occurring in, or by force belonging to, any non-living matter in the vicinity of the living mass. These remarkable movements are universal in the world of life. They are more accelerated in some kinds of living matter than in others, but they are present in all, and in most are discernible at some time or other during the course of existence. Parts of the living matter continually tend to move away and separate from the rest, not in consequence of any attraction between these and surrounding matters outside, nor from any repelling influence exerted by parts of the mass itself upon other parts. There seems to be an active tendency on the part of different portions of a living mass to move away from the rest and so to detach themselves, and, having acquired vital power, to become independent, and to increase and then divide. This remarkable tendency on the part of every kind of living matter to divide and subdivide begins to operate as soon as the original mass has attained a certain size, and it seems to increase in intensity as the living matter approaches its proper dimensions. Invariably when a certain size has been reached, which, however, is different for different kinds of living matter, division occurs. The size is always, within certain very moderate limits, fixed and definite for the living matter of each particular species of living being. Among the lowest forms of existence, however, no definite limit of size has to be attained before division can occur. Particles smaller than the smallest particles that can be seen with the aid of the highest magnifying powers freely divide and subdivide, and there is reason to think that under certain conditions the division and infinite multiplication of the animate particles may continue for a considerable time, none of them attaining their fully developed form or dimensions. In higher forms of life, premature division of a living mass before it has grown for a proper time and reached a certain size, is very detrimental, and in many cases disastrous; for it is associated with degradation or even complete loss of formative, constructive, and developmental power. In some cases, by the rapid multiplication and division of the particles, the well being of the whole organism is jeopardized, and death may be occasioned by the changes brought about by great increase and rapid growth and multiplication of certain particles of living matter belonging to the blood or to some of the tissues.

When a portion of a mass of living matter moves away from the rest, the moving portion invariably presents a convex surface, of which the portion in the exact centre is of course in advance of the rest and is the point towards which the movement of adjacent portions tends. It almost seems as if one minute portion had moved away from the rest and had dragged with it neighboring portions, the power of the particles constituting which was not strong enough to act in opposition to it or to resist its influence. These seem to yield and follow the one or few particles in which the movement is strongest, and which seem to act the part of leader. It may be that certain particles here and there, having attained a larger size, or from being more active than the rest, move forward and determine the direction which is to be taken by those near. As far as can be seen, multitudes of living particles stream in one direction, the greater number being either carried along by the very few or irresistibly drawn onwards by them. The direction taken by flocks of birds and clouds of insects in still air or upon the surface of smooth ground, and shoals of fishes in water, is evidently determined and often very quickly changed in obedience to impulses affecting a very few of the great multitude of individuals of which the whole body is composed. These movements cannot, however, correctly be compared with those of a mass of living matter, inasmuch as there is no reason whatever for supposing that, in the latter, one particle has the power of choosing and determining, much less of conveying to its neighbors the results of its decision or choice and the request to follow.

It will, of course, be said by some that the remarkable phenomena we are considering are comparable with the movements occurring among iron filings under the influence of the magnet, or with the Brush discharge of electricity, the movements of the streams of highly attenuated moving matter in vacuum tubes, and other changes in place affecting particles of non-living matter. Surely it must be obvious to any one who thinks over the facts of the case that no true analogy has been shown to exist between the movements of living particles and those of any form of non-living matter. Nevertheless, the existence of such analogy is still maintained by a few, although the fallacy of the arguments upon which it is supposed to rest has been many times pointed out.

I dare say that for some time to come it will be most difficult to get a hearing for any views not in accord with the

materialist tendencies of what is miscalled the *science* of our time. Thought is to be crushed, and any speculations are to be condemned which do not happen to favor the arbitrary dogmas of the purely physical school. But no doubt these attempts, like preceding ones of the same order made at different periods of history—although they may succeed for a time, and by them people may be driven away from the truth—will ere long be given up. They may be safely left to the gradual process of disintegration and ultimate dissipation by which these and such-like fancies of physical ingenuity will be disposed of.

As I have shown elsewhere, whenever tissue and other matters peculiar to living beings are to be formed, living matter undergoes change. In fact, the act of forming these things corresponds with the cessation of life in the particles.

Let us now consider the probable nature of the marvellous forces or powers which operate upon the material of the living matter, and determine the relations to one another of the elements or collections of elements of which it consists. By the relations established between the elements shortly before living matter dies, will depend the properties and composition of the resulting formed substances. The changes in each particular kind of living matter are somewhat different, but peculiar to and characteristic of that particular kind, and as regards it, constant and uniform. But no differences in the chemical composition or in any physical characters to be shown in different kinds of living matter, will in any way account for or explain the differences so remarkable in the formed material which is produced by or results from the death of the living matter. Nor do any properties of the particles yet discovered enable us to suggest a plausible physical hypothesis to account for the facts.

All those peculiarities in form, structure, and properties of tissue, which characterize the multitudinous forms of life around us, and which enable us to distinguish them from one another, are imposed upon the matter of the moment when it passes from the living to the formed state, or succeed as the result of a long series of changes then initiated. These peculiarities are not found in any ordinary matter, and can only be accounted for on the supposition that some force, property, or power exists which is peculiar and belongs to the matter only while its life lasts. This exerts but a temporary influence on the material particles, which are by it constrained to take up such prearranged positions with respect to one another as must necessarily result in the formation of definite compounds. To this prearranged disposition of the atoms of matter must every character of formed material and every distinctive property of tissue be traced back. This is, indeed, the cause of the varying form, structure, and property of every tissue and every living form in nature. The instant the influence of vital power in restraining the combination of atoms, ceases to be exerted, definite compounds are formed, but these are not living. The matter of which they consist has ceased to live. There are no phenomena occurring in non-living matter in any way comparable with these vital phenomena. Scientific opinion on these matters has lately been unduly influenced by a materialist party, which, like a political caucus, has assumed the right to direct thought and to promulgate the particular dogma which alone is to be accepted by the faithful.

If now I permit myself to pass beyond the point to which I have been led by actual observation,—if I try to advance beyond the present microscopic limit, travelling as it were upon the same lines as when observing within it, and try to realize the phenomena which occur during the early period of development of some comparatively simple vegetable tissue, a leaf for example,—I think the following description will not be far from the truth: A mass of living matter, endowed with special powers working under certain definite conditions, takes up certain materials and increases in size thereby. Imparting to the new matter its powers, unweakened in force, as it grows, it soon divides into several portions, each of which in like manner grows and divides. The arrangement of the several masses, though fixed within certain limits, is determined not by any forces, powers, attractions, or repulsions acting upon all of them, but simply by the rate of growth of each, and division of the several masses under then existing external conditions; the dimensions each was to attain, as well as its properties, composition, color and the like being due to the life, force, or power each separate mass derived from the parental one which gave it origin, and from which it had been detached. But while the above phenomena are proceeding, changes are also occurring on the surface of each mass. The living matter in this situation, whether from the particles first formed, and being therefore the oldest, reaching the surface, and coming to the end of their living existence, or from some other cause I cannot say—passes out of the living state, and the component particles or certain of them combine, assume a certain form, and acquire physical properties they never possessed before. The formed material thus produced owes its colour, chemical composition, physical characters, internal structure, and the like, to the vital force or property in obedience to which the elements of the matter were made to occupy such positions and assume such relations with respect to one another just before death as must ensure the formation of the particular substances which result.

From the moment when the formation of the formed material occurred, the relative position of the several masses probably altered little. Growth may no doubt take place in certain directions by outgrowths, but none of the elementary parts with its surrounding formed non-living material cannot move from its place and get before or above any of its neighbors, as must at least be held to have been possible up to the time when its movements were restricted by the formed substances on its surface.

I would here remark generally, that if very little non-living matter is associated with the living matter, the latter may move in any direction with equal facility, and one part of a mass may place itself above or in advance of another portion just as easily as it could descend below it. But when a layer of formed material has been produced on the surface of the living matter, the entire elementary part becomes subject to gravitation in consequence of the quantity of non-living matter that is formed.

There is not, I think, any good reason for accepting the conclusion that one of a collection of elementary parts, at any period of development, can sympathize or otherwise influence the actions of others, as Virchow seems to think. The suggestion that any force or power acting, as it were, from a centre, governs, regulates, and determines the changes taking place in surrounding and more or less distant particles, is, in my opinion, inadmissible. We might, with as much show of reason, refer the harmonious action of the several parts of the adult organism to some controlling or governing power situated we know not where, influencing, we know not how, actions of many different kinds occurring at considerable distances from the seat of its existence. Although very high authorities have given their sanction to views of the kind, and have advocated the existence in connection with each individual organism of some power or force capable of operating through material of even considerable thickness and of controlling matter at a distance, I venture to assert that the conclusions are not supported by the results of observation and experiment. The idea of one particle of living matter influencing other particles at a distance from it, much less sympathizing with or being affected by vital changes occurring in them, cannot, I think, be entertained by any one who has studied the phenomena as they occur in living beings.

One can indeed conceive tissues of the most elaborate character, and new matter of the most wonderful properties and most complex composition, being developed in the most regular and orderly manner without supposing that any governing or controlling power acts upon them at all, as it were, from a centre. That the most wonderful order is manifest in the arrangement of the component elementary parts, say, of a growing leaf, must be obvious to every one who has ever examined it; but I feel confident that as soon as each living particle has been detached from the mass which preceded, it is no longer influenced by the latter, and does not influence neighboring masses. Each may be pressed upon by its neighbors, and press upon them in turn during growth, but there is no reason to suppose that any one determines the composition, governs the motion, or regulates the action of others. The nutrient matter is distributed to all by vessels or channels running amongst the several collections. Those elementary parts farthest from the nutrient supply will grow more slowly than those nearest to it, but no formative or constructive of synthetic or analytic influence is exerted by the nutrient fluid upon the living matter, nor by the several elementary parts upon one another. Each is under the influence of the vital power associated with the matter of which it in part consists; and whether each can exist independently if separated from its neighbors, or dies soon after it is detached, depends not upon any influence exerted upon it by those neighbors, but simply upon the inherent capabilities of its own vital power, transmitted to it from the living matter which existed before it, and of which it once formed a part.

Nevertheless, each individual elementary part, say, of a leaf, or other organ or tissue, must not in any case be regarded as an individual, independent, or self-dependent organism, for it constitutes but a part of a highly complex whole which has been gradually formed in accordance with a definite structural plan and arrangement, foreseen and prepared for as it were from the very first.

It is only by attributing the observed phenomena to the operation of a special force or power, having no analogy whatever with any known inorganic forces or powers, that a reasonable explanation of the facts can be framed. The phenomena which have been referred to cannot correctly be compared to any processes or actions which occur independently of life, neither can any true analogy be pointed out between these and any physical or chemical changes or actions of which we have at this time any knowledge or experience. That the formation of all tissues and organs is governed by "law" is no doubt true, but the "law" is unknown, and whatever may be its terms, the mode of its operation upon matter is as different from that of any laws that are known to operate in the non-living, as are the known and observed facts of life from those of the inorganic matter of the world.

Now as regards the nature of the actual phenomena of living matter which are at present beyond the range of observation, at least two diametrically opposite ideas are entertained.

1. There is the commonplace notion that structure exists which will account for the actions which take place, but that the details of this supposed structure are too minute or too delicate to be demonstrated by any magnifying powers which have yet been constructed. For this idea there is no sufficient justification. It is one of those assumptions in elaborating which the modern materialist is so ingenious. In this way he struggles, and with some success, to postpone for a time the inevitable fall of the system he has endeavored to make popular in spite of the overwhelming evidence of facts against it. Here I must remark that the word "structure" as employed by physicists is used in a sense utterly distinct from that in which we use the word. This is evident enough if we consider what is understood by the "structure" of a crystal and the "structure" of an organ or tissue. The first "structure" at once disappears when the crystal is dissolved and reappears whenever it is formed. The other structure results, or, as some say, is evolved, only after many series of changes of a very complex character have been completed. Once destroyed, the structure of an organism can only be restored by a long course of similar developmental processes. In fact, there is not the faintest analogy between the structure of an organism and the structure of a stone—the structure due to the operation of living forces and the structure which is inherent with other properties in non-living matter.

2. There is the view supported by myself, and in favor of which I have adduced evidence which I believe to be perfectly convincing, that living matter has no definite structure whatever—that, in fact, its particles, and very probably their constituent atoms, are in a state of very active movement, which renders structure and fixity of arrangement impossible—this active movement being an essential condition of the living state, which latter ceases when the movement comes to a standstill. According to this view the idea of structure as belonging to living matter is inconceivable.

Now we know of no state in which non-living matter exhibits any analogy with matter in the living state, so that the cause of the state under consideration must have reference to the living state, and to that only; and to reassert, as many continue to do, that the phenomena manifested by living matter are to be accounted for by the properties of the material particles, is silly and perverse; and though the view of the peculiar nature of the vital power here put forward and based upon a consideration of the phenomena of living matter, may be ridiculed by materialists, every one who thinks over the matter will see at once why this course is taken by them.

Professor Huxley, in his article "Biology," in the "Encylopædia Britannica"—without defining what he means by the words "molecular" and "machine"—assures his readers that "a mass of living protoplasm is simply a molecular machine of great complexity, the total results of the working of which, or its vital phenomena, depend, on the one hand, upon its construction, and, on the other, upon the energy supplied to it; and to speak of vitality as anything but the name of a series of operations, is as if one should talk of the 'horology' of a clock."* This is the sort of teaching that has long retarded the progress of thought, and affords an example of the puerile objections palmed off on the public as scientific criticism, and supposed to be sufficient to controvert evidence founded upon observation, and arguments based on facts which any one may demonstrate. Is it not most wonderful that Professor Huxley can persuade himself that a single reader of intelligence will fail to see the absurdity of the comparison he institutes between the invisible, undemonstrable, undiscovered "machinery" of his supposititious "molecular machine" and the actual visible works of the actual clock, which any one can see and handle, and stop and cause to go on again?

Magnify living matter as we may, nothing can be demonstrated but an extremely delicate, transparent, apparently semi-fluid substance. But observations on some specimens under certain advantages of illumination, and with the aid of the very highest magnifying power that can be brought to bear, favor the conclusion that living matter should be regarded as consisting of infinite numbers of infinitely minute particles, varying much in size, and possibly capable of coalescing, free to move amongst one another, as they exist surrounded by a fluid medium which contains the materials in solution for their nutrition, and other substances. †

[To be concluded in our next issue.]

* Huxley, Article "Biology," Encyc. Brit.

† From the Journal of the R. M. S.