not to be strained or overturned by a statement which falls short of or overreaches its mark.

That the Professor should experience a sense of "relief" in hugging to himself this dwarfed idea of the Universe is not the least of the many curiosities we have been favoured with. Coming from one appreciative of the utility and beauty of science—from one who has often given it a helping hand, it does seem an anomalous thing that he should thus delight in a conception which narrows its field down from an infinite to a finite extent, so that he can avoid contemplating what he is pleased to style "the dreary infinities of homaloidal space."

Well, tastes differ, and mine accords with a belief which is diametrically opposite to this of Professor Clifford and his disciples, a belief that not only is the Universe infinitely extended, but that its constituents are infinite in kind, infinite in quantity, presenting aspects infinitely diverse to us, according to our standpoint, and in none of these aspects, whether in infinitesimal parts or as a whole, to be conceived of by any finite mind, however discriminating or comprehensive its grasp; a sealed book to all, except by scientific aids, but not wholly to be revealed even by these; an eternal enigma always resolving, yet never to be resolved—a Universe whose laws and phenomena are to be interpreted and discovered in so far as can be, rather by active research than by those mystical constructions which we have just considered, and the criticism of which has been the prime object of this paper.

For my part, I blame making so much in this way of the gap "in the chain of reasoning," by which the truths of geometry should be logically connected and represented; but more I blame this illegitimate fecundity of idea—this ill-directed creative power—which, out of the shortcomings of one of its definitions, and the axiom made to supply its deficiencies, would breed this monster to thus devour all that has preceded it. And I conceive that those who forsake geometry, as now defined and understood, to take up with the new, the transcendental philosophy, are really straining out a gnat to swallow a camel.

Art. VIII.—*On Life.* By W. I. Spencer.

[Read before the Hawke's Bay Philosophical Institute, 11th October, 1880.]

The paper which I propose reading this evening was not intended originally to be placed before the members of this Institute. As you are aware, a proposal was made some time ago that I should undertake the direction of a class of biology, in connection with the Athenæum. Owing to one cause and another, however, the opening of this class was delayed until the season was so far advanced that, for the present, it had to be abandoned. As I had prepared what was intended to be the introductory lecture, it occurred to me that it might not be unwelcome to the members of the Philosophical Institute, especially as it was upon a subject of the highest interest, but one which, at the same time, has not been treated at any of the meetings of the various branches of the New Zealand Institute, so far as I am aware. The subject, then, with which I purpose to occupy you for a short time this evening is *Life* and its correlation to physical force. The definition I have given of my proposed subject will be sufficient to show you that it does not include those higher processes of animal life, which include consciousness, sensation, and mental phenomena,—it does not refer to that breath of life which, we read in the book of Genesis, God breathed into the nostrils of man,—but to the physical life which the mould that grows in our jam-pots enjoys in common with man, and the mushroom and the oak equally with the elephant and the whale.

What then is this physical life? It is not a substance, it is not an existence, it is not an entity. We become cognizant of it through a series of phenomena inseparable from matter. But our only knowledge of matter depends upon the ways in which it affects our senses—in other words, we know nothing of matter, excepting through the physical phenomena it exhibits, which phenomena are capable of making such impression, through our nerves, upon our brains, that they, in their turn, are capable of calling into play the faculty of sensation or consciousness. In the first place, we have the power of recognizing matter in actual motion, that is to say, matter which has been set in motion by some external force, whatever that force force may be. Secondly, from this we gather that there are certain powers which are able to set inert matter in motion, and we term these the forces of nature. And in the third place, we recognize certain properties in matter itself —inherent in and essential to it; and these, for the most part, are the result of inertia.

As a brief illustration of the way in which matter in motion makes itself cognizable by our brains, I may mention firstly sound. If a piece of metal be struck, or a string in a state of tension be made to vibrate, or air be blown into a tube under certain conditions, the vibrations thus produced are communicated to the surrounding atmosphere, and these sonorous vibrations are of a peculiar nature. They are not waves in the sense of a progressive sideway movement, but a series of elastic attenuations and condensations which travel in lines coincident with their own movements. When the sound-waves strike the ear they are conveyed by a specially arranged apparatus to a portion of the brain where that peculiar sensation is aroused which we term sound. We *hear* the vibrations.

It is not at all necessary to the perception of sound that the vibration should be received by and traverse the ear. The ear itself is merely a mechanism for augmenting and transmitting the sound, just as a relay instrument is used in long telegraph lines to increase and pass on the almost exhausted current. Sonorous vibrations can traverse wood, water, metals —in fact any substance which possesses the requisite degree of elasticity, even the bones of the skull, for it is well known that in certain forms of deafness the ticking of a watch held between the teeth is distinctly audible, when its application to the ear produces no sensation. But the vibration of sound can, by appropriate means, be rendered visible; they can also be counted, and we know precisely how many vibrations per second are required to produce a note of any given pitch. But there are other modes of motion which we are capable of perceiving through the medium of our senses. If we take a piece of iron and hammer it on an anvil, after a time the percussion produces motion amongst the molecules of the iron, and this motion is perceptible to our senses—if we place a finger on the vibrating iron we *feel* the vibrations, and say it is hot. If the hammering of our supposed piece of iron be continued stronger and faster, or if it receive one tremendous blow as from a Nasmyth hammer, the molecular vibrations become so rapid that they are capable of setting in motion the particles of the hypothetical luminiferous æther by which they are conveyed to the eye, and we *see* them. This we term light. Together with the production of light electrical phenomena are called into play, and the relationship between heat light and electricity is so intimate that it too must be included amongst modes of motion. All these then,—sound, heat, light, and electricity,—are simply molecular vibrations which are perceptible by our senses.

As examples of the natural forces, I may mention gravitation, that force which draws masses of matter towards each other;—chemical affinity, that force by virtue of which bodies of dissimilar nature unite to form compounds of definite constitution;—and cohesion, the power which holds the particles of substances of a like nature in contact. The *properties* of matter may be considered as either general or special properties. The former include impenetrability, extension, divisibility, compressibility, and inertia; the latter, solidity, fluidity, tenacity, ductility, elasticity, hardness, transparency, and many more. The question for our consideration is, can we relegate that series of phenomena we term life to either of the foregoing categories? Before we attempt a solution, I will endeavour to explain to you a few of the processes of life, and also something about the matter which exhibits these processes. For life can by no means be dissociated from matter—without a peculiar form of matter we never find life, without life we never find this matter. Professor Huxley has aptly designated it, "The physical basis of life." In fact, it may be termed "life-stuff," to use a form of expression lately come into vogue. This "life-stuff" has received the name of protoplasm from the Greek πρῶτος and πλάσμα, meaning the first formation.

The simplest form in which this protoplasm has as yet been found, may sometimes be discovered if a drop of an infusion of some animal or vegetable substance which has been allowed to stand a few days, be placed under the microscope. There, if the magnifying power be sufficient, you may see a minute mass of jelly-like substance, looking very like a particle of white of egg escaped from its shell. Watch it, however, and you will quickly perceive that although it is to all appearance structureless, it is never for a single instant at rest. It is continually changing its shape—pushing out first at one side and then at another finger-like projections, which extend a certain distance and are then retracted, to be followed only by further extensions and retractions in other directions. Occasionally two of these little streams of semi-fluid stuff will meet and unite into one, or the end of it will apparently fix itself to the glass, and the main body will draw itself up to it, thus producing a tardy kind of locomotion. These jelly-like bodies are not always perfectly clear, often their substance is occupied by minute dots, or by a spot which has the appearance of an empty space, and which is in consequence termed a vacuole. If you find one of the dotted bodies, you will see the dots running through the interior of the body, racing up the protrusions as they are formed and again returning when they are withdrawn, showing thus that the matter within the cell is in a state of continual motion. If you are fortunate enough to see a minute animal or vegetable come within the grasp of the finger-like protrusions when this jelly-like being is hungry you will see that it is gradually drawn towards the central portion, which slowly changes its elastic shape so as to form a hollow in which the particle of food is enclosed, and in which it is digested. The digested portion becomes absorbed, and the bit of jelly, if there be any indigestible part left, quietly opens out either at the place where the food was admitted or some other place, and exudes it. This organism has received the name of Amœba, or Proteus Animalcula, from the perpetual variations taking place in its shape, and it is probably the simplest form in which we are able to recognize those phenomena of irritability and mobility which we designate life.

In the vegetable kingdom we find bodies of a very similar kind, minute, simple, single cells, either apparently empty or containing green or red colouring matter; and which sometimes are stationary, at others whirl and gyrate round the field of view in a manner which contrasts strongly with the slow motion of the amœba, but which are evidently and certainly only minute masses of living protoplasm enclosed within an outer coating—in fact, vegetable cells, just as the amœba is an animal cell.

The chemical composition of this protoplasm is very complex. It is a combination of C., H., O., and N., and often contains also S. and P. Its precise composition has not been determined, but it is probably nearly the same as that of the white of the egg—pure albumen, the formula of which is:—

$$C._{53\cdot5}\quad H._{7}\quad N._{15\cdot5}\quad O._{22}\quad S._{1\cdot6}\quad P._{0\cdot4}$$

Of these protoplasmic cells, which I have so far described merely as separate individualities, all living animal and vegetable structures are compounded. We can discover them in all the living tissues of the vegetable kingdom—in the roots, leaves, flowers, and seeds of herbs, shrubs, and trees; and in the tissues and blood of animals,—in that of man himself. If a drop of blood be drawn from one of our fingers and placed under the microscope, we see a multitude of reddish corpuscles, flattened on the two sides, and which show a tendency to arrange themselves in lines, like strings of beads. But amongst these is a much smaller number of larger sized colourless cells (the so-called white corpuscles), which, if kept at a proper temperature, and under appropriate conditions, exhibit the same phenomena as the amœba—move slowly from place to place, change their shapes, and project and withdraw those finger-like processes which have acquired the name of pseudopodia. In living vegetable cells we do not, under the microscope, see the same elastic movements as in animal cells, because the limiting membrane is generally formed of cellulose, which does not admit of the protrusions and retractions seen in the amœba and the white blood corpuscles; but we have abundant evidence that the protoplasmic contents are in a state of perpetual mechanical motion. In the sting of the common English stinging nettle, and in various fresh-water Algæ, under sufficient magnifying power, minute granules in the fluid cell-contents may be seen circling round and round the interior of the cell, showing that the structureless protoplasm is in a condition of unceasing movement. One of the most beautiful specimens of this cyclosis with which I am acquainted, is to be found in the *Closterium lunula.* This microscopic plant, which is very common in the ditches and pools in this vicinity, belongs to the Desmidiaceæ, a family of the confervoid or green Algæ. The whole plant consists of a single cell of an elongated form, somewhat lunate shape, broader in the centre, and tapering towards each end to a rounded extremity. The interior is occupied with chlorophyl, excepting at the extremities, where are clear transparent spaces, and a very narrow channel between the cell-wall and the green endochrome. In the clear space at each end is a black spot which, under sufficient magnifying power, is resolved into a number of excessively minute cells, each with a dark circumference and clear centre. These cells are in a state of continual motion, in and out amongst each other, changing their relative *position*, and circling round and round. Frequently cells leave the terminal group, pass down between the cell-wall and the endochrome-wall for a certain distance; then, altering their course, return in the opposite channel, and rejoin their friends at the extremity of the frond,—the whole diorama forming a scene of wonderful activity and exquisite beauty. So that we may fairly infer that the physical difference between the animal and vegetable living cell is only one of mechanism. But these living cells have other functions to perform than mere mechanical motion, whether that motion be external or internal. They have to perform certain vital acts—they have to grow, and they have to multiply; and their growth is carried on in a manner peculiar to the organic kingdom. It is not a mere increase in size, like the growth of a crystal which, as you know, may be suspended in a solution of the substance of which itself is composed, and, as evaporation takes place, becomes enlarged simply by the deposition of the matter, which can no longer remain in solution, on its exterior. Living beings, on the contrary, grow by the admission of matter (the chemical composition of which is often quite different from themselves) to their *interior*, where it first undergoes a process of chemical change by which it is assimilated to their own composition, and is then incorporated into the living bodies themselves.

The multiplication of these cells occurs in at least three different ways. First, as may be seen in any fermenting solution, the yeast particles increase by gemmation or budding. A full-grown cell may be seen with a much smaller one sprouting as it were from it, and thus strings of several cells are sometimes formed. These secondary cells having attained a certain growth, detach themselves, and in their turn carry on the process. Second, by the process of cell division. A constriction appears in a cell, and gradually becomes deeper, until eventually it divides the cell into two, which become independent bodies. Third, by the division of the protoplasm of the parent cell into numerous secondary cells; the parent cell then bursting, the secondary cells become free, to go in their turn through the same process. By one or other of these methods all animal and vegetable growth takes place, and may be watched, not only in those living beings which consist of a single protoplasm cell, but also in the growing parts—the seeds, roots, and tender sprouts—of the higher plants, and in the eggs of animals.

So far you will perhaps have noticed that no distinction has been drawn between animal and vegetable life, and indeed it would appear that structurally, chemically, and physiologically, no distinction is at present demonstrable.

Not only are there numerous classes of living beings whose animality or vegetability is disputed, but there is a distinct class (the Protista) which is separated from both the animal and vegetable kingdom, and defined as "A kingdom of organic nature, which is intermediate between the animal and vegetable kingdoms, and which comprises the so-called lowest forms of life." And yet, again, other forms appear at one stage of their existence to be animals and at another vegetables. There is a fungus—the *Æthalium seplicum*—which sometimes infests the tan in hot-houses, and which at one period of its growth is undoubtedly a vegetable, but the mycelium of this mould exhibits amœboid movements, and characteristics which would place it in the dominion of the animal kingdom. Of this living being Professor Huxley asks the questions, "What is it? Is it an animal? Is it a plant? Is it both, or is it neither?" By certain biologists it is referred to the Protista as being neither, but Professor Huxley seems to consider this as only doubling a difficulty which at first was single.

It is therefore apparent that he considers that the same living being may be both an animal and a vegetable. An analogous phenomenon may be observed in the *Volvox globator*, a unicellular confervoid Alga, spherical in shape, and studded with minute cilia, by the aid of which it performs a continual rolling motion. In the interior of this plant are to be seen numerous bright green globules, which are, in fact, young *Volvoces* waiting to be liberated by the bursting of the parent cell. Occasionally, however, one of these globules will lose its green colour, become transparent, the contents escape, and at once assume the characteristic appearance and movements of the amœba.

The identity of animal and vegetable life is further confirmed by various facts in their physiological actions. Thus we know that certain plants belonging to the Droseraceæ, or sun-dew tribe, have the power not only of closing their leaves when stimulated by the contact of an insect so as to entrap their prey; but also, after having entrapped, to digest it—to assimilate the digestible portions and to exude the indigestible; and for this purpose the plant secretes a peplie fluid, not dissimilar to the gastric juice of animals. The actions of certain therapeutical agents also are so identical in their effects on animal or vegetable living matter that little doubt can remain as to the oneness of their composition and vitality. We all know that if animals are subjected to the vapour of chloroform or ether they quickly fall into a state of profound slumber, from which they cannot be awakened by any ordinary phpsical means, but which soon passes away when the anæsthetic is withdrawn. Exactly the same series of phenomena is exhibited by plants under favourable circumstances. On this point, in a lecture delivered before the British Association, in August, 1879, Professor Allman, at that time President, says:—"We owe to Claude Bernard a series of interesting and most instructive experiments on the action of ether and chloroform on plants. He exposed to the vapour of ether a healthy and vigourous sensitive plant by confining it under a bell-glass, into which he introduced a sponge filled with ether. At the end of half an hour the plant was in a state of anæsthesia; all its leaflets remained fully extended, but they showed no tendency to shrink when touched. It was then withdrawn from the influence of the ether, when it gradually recovered its irritability, and finally responded, as before, to the touch." It is not, however, the motor power of plants alone that is arrested by anæsthetics. "Claude Bernard has shown that germination is suspended by the action of ether or chloroform. Seeds of cress, a plant whose germination is very rapid, were placed in conditions favourable to a speedy germination, and while thus placed were exposed to the vapour of ether. The germination, which would otherwise have shown itself by the next day, was arrested. For five or six days the seeds were kept under the influence of the ether, and showed during this time no disposition to germinate. They were not killed, however, they only slept, for on the substitution of common air for the etherized air with which they had been surrounded, germination at once set in and proceeded with activity. * * * Experiments were also made on that function of plants by which they absorb carbonic acid and exhale oxygen. * * * Aquatic plants afford the most convenient subjects for such experiments. If one of these be placed in a jar of water holding ether or chloroform in solution, and a bell-glass be placed over the submerged plant, we shall find that the plant no longer absorbs carbonic acid, or emits oxygen. It remains, however, quite green and healthy. In order to awaken the plant it is only necessary to place it in non-etherized water, when it will begin once more to absorb carbonic acid and exhale oxygen under the influence of sunlight."

But although it appears that the protoplasm of animals and vegetables is, in its chemical composition, microscopic characters, and physiological manifestations, identical; yet that there are variations, probably due to difference of molecular arrangement, is equally manifest,—for we know that every plant and animal in the Universe produces protoplasm, which can only reproduce its own kind. We know that a man or an elephant could never be developed from the protoplasm of a plant; nor could the egg of a fowl or a fish ever produce anything but another fowl or another fish. But we may go further, and show that the difference does not end here.

Animals and plants derive their nourishment from different sources. The pabulum of the vegetable kingdom is derived from the inorganic world in the form of water, carbonic acid, and ammonia. Animals, on the other hand, are unable to assimilate these simple compounds, and can only live on protoplasm already prepared for them, either by vegetables or by other animals, which have, in their turn, absorbed previous vegetable protoplasm into their own bodies. Again animal and vegetable chemistry are, as it were, essentially antagonistic. The chemistry of vegetable life is synthetic, it takes simple compounds and, after rejecting those portions it does not require, builds of the remainder compound substances of great complexity. Animal chemical processes are analytic; they consist in seizing these highly complex matters, and reducing them to the simple compounds in which they originally existed.

From this we learn that the essential element of life consists in the eternal and incessant circulation of matter. The vegetable kingdom takes water, carbonic acid, and ammonia, separates and discharges the oxygen it does not require, for the use of the animal kingdom, forms complex compounds of the remainder—protoplasm, vegetable albumen, gluten, starches, oils, fats, sugars for food, those volatile oils to which the scent of flowers is due, resins, camphors, guttapercha, turpentines, india-rubber, alkaloids as quinine, morphine, strychnine, and many others; indeed, the number of these vegetable products is infinite. Again, animals seize upon the oxygen exhaled by plants, and convert it into carbonic acid. They feed upon the protoplasm provided for them by the vegetable kingdom, and after utilizing it for the higher functions of animal life—locomotion, consciousness, sensation, thought, reason—they return it to the inorganic kingdom as water, carbonic acid, and ammonia, to be again taken up by vegetables, and recommence the never ending cycle of physical and chemical change. Letourneau remarks, "In living beings, in effect, matter is in a state of extreme mobility; it is subject to a perpetual movement of combination and decombination, without repose, without truce; its elements go and come, have reciprocities of action, aggregate themselves, disaggregate themselves; there is a whirl of atoms amongst unstable compounds, capable of forming, disaggregating, metamorphosing themselves, of renewing the woof of the living tissues." And Professor Huxley tells us that, "the wonderful noon-day silence of the tropical forests is, after all, only due to the dullness of our hearing; and could our ears catch the murmur of the molecules as they whirl in the innumerable myriads of living cells which constitute each tree, we should be deafened as with the roar of a mighty city."

If you have followed me hitherto you will see that all the physical and chemical phenomena of life which I have endeavoured to describe are purely modes of molecular motion—first, the locomotion and cyclosis of animal and vegetable cells, and, second, the chemical motion of combination and dissociation of elements. For chemical combination is merely a molecular motion of the combining elements. When hydrogen and oxygen are mixed in a vessel, they may remain in contact for an indefinite time—but if an electric spark or a lighted taper is applied, they immediately rush together and form water. But the force which produces this sudden activity is merely matter in motion, which imparts its own vibrations to the hydrogen and oxygen, and thus produces their union. The application of electricity in the form of a galvanic current, by producing a different form of motion, separates the elements again, shakes them asunder as it were, into hydrogen and oxygen, which may be collected in separate vessels. Thus the latent life of a seed or an egg is analogous to the chemical affinity of hydrogen and oxygen—the tendency to active vitality is there, but requires an appropriate stimulus to call it into action. This stimulus is heat in due proportion, which is, like the burning taper or the electric spark, only matter in motion, and in such form of motion that it is capable of communicating it to the hitherto inert protoplasm.

A most interesting series of experiments has been made by Dr. Siemens, the result of which he communicated to the Royal Society in March last. You all know that plants only form that green colouring matter termed chlorophyl under the influence of sun-light, and that chlorophyl performs its special function, that of decomposing carbonic acid, in the day-time. Plants kept in darkness are blanched, and during the night the evolution of oxygen by them ceases. Dr. Siemens has, however, shown that the electric lamp can take the place of the sun, and that under its light plants will develope chlorophyl, dissociate the elements of carbonic acid, and evolve oxygen, the same as when exposed to direct solar influence. Here, then, we have the cycle of the vital physical forces complete. Heat is converted into light and electricity—light is converted into heat and electricity—electricity is converted into heat and light. For not only does the chlorophyllian action continue under the influence of the electric lamp, but seeds will germinate, and plants grow, and produce those starches and sugars which are in reality the great deposits from which animals derive their heat.

Again, many animals possess the power of emitting light, and this faculty appears to exist in some cases in connection with muscular action, in others with nervous influence; in others again a special apparatus of photogenic cells exists, and these cells seem invariably to be in intimate relation with the nervous system. Whilst in one class, which is not endowed with a nervous system, the luminosity appears to be the result of some unknown property of the protoplasm of the phosphorescent being.

In this round of organic life there is no loss or destruction of material. Plants take their C. H. O. N. from the inorganic world, and having utilized the elements restore them again to the source whence they were originally obtained, either through the processes of decay, or through the processes of animal life. So in like manner it is demonstrable that in the round of life there is no loss of energy. The heat, the light, the electric force, which plants, as it were, absorb to carry on their life, are not lost—they are, like the material elements, transmuted into other forms—into mechanical motion and chemical motion; but the very compounds in the manufacture of which the chemical action is expended—sugar, starch, fats, and oils—are the main sources of the heat of animals, the very compounds by the absorption and reduction of which animals are enabled to maintain a temperature above that of the circumambient atmosphere. So, also, animals which possess a nervous system evolve electricity. Our brain is a galvanic battery; our nerves are telegraph wires, conveying messages to and fro between the external world and our consciousness, which, as it were, sits behind the operating machine—the brain—receiving and sending messages, manipulating the machinery, just as a telegraphist does with the ordinary telegraphic apparatus.

In this outline sketch, which I have endeavoured to lay before you, of life and its physical correlatives, you will perceive that we have had to deal with nothing but ordinary chemical elements, and ordinary physical forces. As I said before, life is not an energy, it is not a force, it is not an entity. When we analyse its processes we see nothing more than a series of actions and re-actions produced by heat, light, and electricity, within a mutable, unstable combination of carbon, hydrogen, oxygen, and nitrogen.

ART. IX.—*Watershed Districts. County or other Division of the Country to be determined by the Area of the Watershed.* By. J. REES GEORGE.

[*Read before the Wellington Philosophical Society, 10th October*, 1880.]

THE subdivision of the country for representation and local government purposes is a question that with politicians is generally decided in some haphazard manner, and chiefly by taking the nearest river-bed as a boundary, but is one that should receive more scientific treatment, and is therefore fairly open for discussion at the meetings of the Wellington Philosophical Society; and I propose, as shortly as possible, to show that the area of the watershed of any district is the boundary that should determine such divisions both for local government and representation purposes.