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*LIFE AND CHEMISTRY.**

As I look into the eyes of those before me, I can not but have the feelings of Moleschott in his address at the reopening of the University of Rome when he found himself 'in the face of an audience whom he had nothing to teach, but from whom he had much to learn.'

An imposing knowledge of the distinctions attained by my two distinguished predecessors, perhaps should be depressing; for it is no longer an investment here to forge ahead, but an investment to keep up. On the contrary, their unseen presences stand not as spectres, but as gracious good guardians.

It becomes necessary in the outset to confess to an inner consciousness, that we know. *How* we need not consider for the present further than that the internal thought-centers, association or sense-centers take impressions from the external world and transform them into presentations, which automatically, as it were, frame themselves into concepts. The 'ultimate nature of reality' is not of immediate moment.

Doubtless, man from his earliest experience has speculated on the origin and perpetuation of life, that is, nature. This period is no exception. President Jordan has written, 'whatever else may be said of it, this is certainly the age of deliberate scrutiny of origins and destiny.'

Kant, among many things, wrote 'Only

* Inaugural lecture on the assumption of the head professorship of chemistry in the College of the City of New York, February 28, 1905.

in experience is there truth.' And Haeckel, in his persistent advocacy of the great monistic system, based upon the unity of nature and the unity of science, has asserted, 'All natural science is philosophy, and all true philosophy is natural science. All true science is natural philosophy.'

The great pile at a distance presents itself to the mental perspective in barest outline. As the imaginer draws nigh, the multitudinous variety of the structure is limned on the intellectual horizon. The enormity of the edifice is overmastering. "The larger grows the sphere of knowledge, the greater becomes its area of contact with the unknown." Various crafts must needs arise to disentangle its intricacies.

Numerous subdivisions of natural science have resulted. Each gives more and more to its specialty. At times, in the close scrutiny, the investigator is so near that he fails to grasp the whole and see their relationship. It is unfortunately a fact, as Pearson says, that 'no man whose nose is always on the details of observation is a safe fact-gatherer, while no one whose head is too high above such necessary drudgery is a safe generalizer.'

The complexity of nature seems boundless. "Boundless inward in the atom; boundless outward in the whole."

Biology is the science of life. Elsewhere I have asserted that biology is the application of physics and chemistry to living matter. It requires little knowledge to show that these divisions of science are purely arbitrary. After all, they are not so much divisions or parts of science, as they are simply different methods of looking at the same mystery. While Laplace in his mechanical conception of the world asserted that the progress of nature could be foretold for all eternity if the masses, their position and initial velocities were given, Mach has well said, "Physical science does not pretend to be a complete view of the world; it simply claims that it is working towards such a complete view in the future. The highest philosophy of the scientific investigator is precisely this toleration of an incomplete conception of the world and the preference for it rather than for an apparently perfect but inadequate conception." It is not, therefore, gross temerity which prompts the chemist to give thought to the relations of life and chemistry, for life is chemistry, chemistry applied. It may border on rashness, however, to give utterance to those thoughts, as masters have lost themselves in such contemplations.

Chemistry has taught man to know aright the requirements of mother earth, the conditions which must be fulfilled to ensure bountiful crops. No longer need virgins be sacrificed to the genius of maize, as was done by some tribes of American Indians, in order to plead for a generous yield of the life-sustaining cereal. (Wiechmann.)

While science appeals to us from a most practical point of view and especially is that true for chemistry, it is not to that phase of the subject that I desire to direct your attention.

Before Darwin there was more anticipation, but some interpretation, of nature. Although preceded by Heraclitus and Empedocles, Aristotle appears to have laid the foundations of biology. For fifteen centuries, with limited exceptions, they were unbuilt upon. Then there began the gradual growth of the scientific renascence, culminating in the Encyclopædists. Science, however, does 'not consist solely in the description of observed facts.'

Biological history for our purposes may be schematized as follows: organism, organ, tissue, cell protoplasm. Altmann's visible granules, Flemming's threads, Frommann's skeleton, Bütschli's honeycomb, according to Haeckel, are but secondary products of the differentiation of the plasma.

Latterly, Osler has said, "Around the nature of cell-organization the battle wages most fiercely, and here again the knowledge of structure is sought eagerly as the basis of explanation of the vital phenomena. So radical have been the changes in this direction that a new and complicated terminology has sprung up, and the simple undifferentiated bit of protoplasm has now its cytostome, cytolymph, caryosome, chromosome, and with their somacules and biophores. These accurate studies in the vital units have led to material modifications in the theory of descent."

It is unnecessary for us to trace fully the history of the idea of 'spontaneous generation,' which has persisted for twenty centuries. The story has been recommended 'to the psychological historian as a labyrinth of error, with glimpses of truth at every turn.'

Leeuwenhoek, by using a crude microscope, showed 'spontaneous generation' to be only apparent, not real. A memorable scientific battle was fought over parasitic animals. "Adam was said to have contained all the human parasites from the first—a state hardly consistent with Edenic bliss." Now *Darwinismus* makes such assumptions useless.

Pasteur almost proved that all 'life comes from preexisting life.' But Tyndall and Dallinger learned that in many cases 'young and immature germs could survive the boiling temperature, growing and propagating themselves when the liquid subsequently cooled.'

Life was in every case traced to other life. Its origin remained a profound mystery. Man beat in every direction hoping a door might open. Kelvin suggested that germ life may have been a meteoric passenger from otherwhere. Allowing such arrival gave no answer to the question as to the origin of the life found on the meteorite. Helmholtz, in advocacy of this 'cosmozoic hypothesis,' said, 'Organic life either came into existence at a certain period, or it is eternal.'

Just a few years ago Professor Rücker in his address before the British Association said: "Perhaps the chief objection which can be brought against physical theories is that they deal only with the inanimate side of nature and largely ignore the phenomena of life. It is, therefore, in this direction, if any, that a change of type may be expected." Before then the Count de Gasparin wrote in the *Journal des Débats,* 'Take care; the representations of the exact sciences are on their way to become the inquisitors of our days.'

Projected as we are upon the stream of life, we endeavor to learn first how it continues and thus reach its source. This is not an altogether illogical method; quite the contrary, as it rests upon the great principle of true inductive reasoning from experience to cause.

There are two great principles upon which the philosophy of nature now rests. They are the doctrines of the conservation of matter and the conservation of energy. These are dependent upon our conception of length and time, measured by arbitrary standards. A metallic bar is the former unit. The revolution of the earth gives us a day, which may be shorter or longer according to tidal friction. Or the recurring seasons give us the year unit, depending upon the course described by our relation to the sun. We are aware of necessary calendar changes as a result. And yet Cavendish's idea of science was measurement!

These tenets have recently been brought into question as a result of the investigations pursued in the laboratory where Newton, Clerk-Maxwell, Stokes, J. J. Thomson and Rutherford worked. Before the intermolecular phenomena are understood, the marvels of the intra-atomic physics have amazed a decade accustomed to wonders.

One form of matter may be converted into another. Accepting for the sake of argument that this transformation may even take place among the elements, and it is by no means necessary that we do, we may abide a while longer with the idea of the discontinuity of matter. Our atomic base may be shifted, which is just as well, but with our conscious powers and experimental observations, we are not yet ready to say that something is made up of nothing. Matter occupies space and has weight.

We may, therefore, for the time being disregard the metaphysical energism of Ostwald, to revert to it again. Through the basic studies of thermo-dynamics by Willard Gibbs we arrive at the equilibrium in physical and chemical systems. Lord Kelvin, considering the dissipation of energy, reached the logical conclusion that permanent equilibrium occurs only when availability is a minimum. A point I desire to make, particularly, here is that the limiting brain of man finites the infinite in his experiments or actual experience.

We know life only in its association with matter. Yet it is not matter, it occupies no space, has no weight, as we know gravity. The dead cat is under the same gravitational influence as before the loss of the traditional nine lives. A copper wire weighs the same whether the current pass or not. A bar of iron neither gains nor loses in mass when it is magnetized.

These latter can do work; they have energy. The analogy—a dangerous thing not alone in science—is striking.

We know no matter without energy. Do we know any energy except through its manifestation on matter?

The brilliant metaphysical teachings of Ostwald demand our utmost consideration, whether we give allegiance or not. In abstract, his reasoning asserts that we are aware of matter only through energy. Matter is an assemblage of energy systems; there is no matter. All resolves itself into the mechanics of energy. Life, electricity, heat are elementary energy systems, having definite capacity and intensity, as chemical entities with their equivalents represent our atomic conceptions.

Is life energy? We know of no manifestation of life without evidence of energy. It does not necessarily follow that all energy is accompanied by life demonstrations. I am not sure but we shall yet see that energy manifestations include life.

A stone rolling from an elevated position has kinetic energy by virtue of its motion. If its progress be checked by an obstacle in its path the translational energy is converted into heat energy. One form is converted into another. There is no loss of energy. If the obstacle be removed the body continues its descent. An impulse was necessary. At rest it possessed potential energy by reason of its position. To acquire that position equal muscular or other form of energy was necessary. There was no gain of energy. That depended upon the combustion of the tissues, a chemical process, chemical energy. We are accustomed to the idea that all energy may be measured either as gram-centimeters or as foot-pounds, merely convenient units into which other terms are easily reducible. Considering life from the energy point of view Hibbert says, 'All other forms of energy can be measured in foot-pounds of work.' Therefore, life is not energy.

I am not altogether sure that we have measured the energy of the Röntgen rays. The charge on the cathode particle was the recent fundamental determination guiding J. J. Thomson. Rutherford has just succeeded in learning the positive charge on the alpha-particle from radium. These are forms of energy, the nature of which in part only has lately become known. Certainly it is suggestive that refinements may possibly in time give us measurements of a life-energy!

Energy activities are not seldom actuated, directed and facilitated by certain inorganic or lifeless things. These substances, which cause things to happen with acceleration, are known technically as catalytic agents. Sulphur dioxide and oxygen when mixed appear to remain so. The presence of platinum brings about a rapid union. Platinum and other finely divided metals convert alcohol into acetic acid, a process for a long time attributable only to the influence of living organisms.

In 1828 Wöhler bore down the barrier between inorganic or dead matter and organic substances, supposed to result solely through the activity of vital forces. It is now well known that certain complicated organic compounds of undetermined composition, as the enzymes, act as catalytic agents. Complex sugars are broken down into simpler sugars. Complex fats are built up from simpler constituents. Although the action may be attributed in part to chemical reactions, the details of the progressive and continuous action of these agents are as yet little understood and are demanding much attention at present.

When complex carbon compounds are burned with oxygen, heat is produced. The heat of this chemical action is simply the resultant of the energy absorbed and given out. We have so far secured no way of measuring absolutely chemical affinity, as we may measure heat in calories, for example. When certain organic bodies are mixed with oxygen without the presence of a living thing, or one of these exciters, no evidence of chemical energy, within reasonable time, has been noted. However, we are by no means sure that there are no energy manifestations. The exciter facilitates or accelerates its manifestation. The oxygen carried into the lungs reacts throughout the animal tissues. We are not yet ready to say how this is. It is not unfair to assert, however, that the energy binding the oxygen atoms together in the molecule is perhaps overcome in part through the organic catalytic agents present. We are aware of cases of suspended animation in which the organs returned to the performance of their functions.

The term catalyzer has been confined to substances and not used in reference to energy agencies alone. Grove considered the facts of catalysis dependent upon voltaic action, 'to generate which, three heterogeneous substances are always necessary.' We know that ultra-violet light will quicken the union of hydrogen and chlorine. By simply holding metallic tin at a definite temperature (20° C.) the whole crystalline structure is altered from tetragonal to rhombic. This does not occur at any other known temperature, requires no foreign substance, and we are unable to measure the actual energy involved. It is not unfair, therefore, to suggest that energy is converted under certain conditions into some transformation we have not yet learned to measure. Equally must it be true that under conditions this unmeasurable form of energy is transmuted into a measurable variety.

To the supporters of the doctrine of vital force, to quote Rücker again, "the principle of life was not a hidden directive power which could, perhaps, whisper an order that the floodgates of reservoirs of energy should now be opened and now closed, and could, at the most, work only under immutable conditions to which the living and the dead must alike submit. On the contrary, their vital force pervaded the organism in all its parts. It was an active and energetic opponent of the laws of physics and chemistry. It maintained its own existence, not by obeying, but by defying them; and though destined to be finally overcome in the separate campaigns of which each individual living creature is the scene, yet like some guerilla chieftain it was defeated here only to reappear there with unabated confidence and apparently undiminished force.''

We have arrived at the point where we may say that catalysators direct energy or facilitate its activity. So does life. There is much in common.

Going back to Ostwald, matter is an energy grouping. Catalytic agents then must be energy. Life is an agent of catalysis. In frankness, I am unable to conceive matter practically devoid of space occupation any more than I can comprehend energy except in the manner it is presented through its influence on matter. With or without the energetics of the distinguished German scholar, we may hold to the thesis, namely, life is energy or a manifestation thereof.

The experiments of Loeb and Matthews on parthenogenesis through the agency of dilute saline solutions strike at the root of the problem. According to the modern ideas of dilute solutions from the investigations of Faraday, Hittorf, Kohlrausch, Van't Hoff and Arrhenius the ions have electrical charges. Energy is involved, available. Böhn has recently effected similar reproduction through the influence of the rays of radium. These are forms of energy not yet measured.

One were devoid of judgment did he not let it be clearly understood that he appreciates the objections that may be raised, with reason, in opposition to the mechanical, physical, chemical or energy explanation of life. As yet we do not know the constitution of the highly complicated structures of the carbon, hydrogen, oxygen, nitrogen and sulphur compounds of the nucleus; 'chemical matter,' as Neumeister says. The same could have been truly said of the sugars before Fischer's masterly work beginning about a score of years ago. Can we say, having learned the structure, synthesized the nucleus, we shall not be able in the laboratory to give it that impulse which launches it upon a career of reproduction?

Powerful arguments favoring the vitalistic theory, consequently opposed to the energistic, are retention of form through years, reproduction of species and atavistic inheritance of character.

Considering these three in order, it becomes us to show satisfactorily their accordance.

1. Crystals beget like crystals in saturated solutions of the substance. Crystalline growth is by apposition. This is a most familiar phenomenon. Seed, one of the means of nature's reproduction, may remain years, centuries, in vaults, as within the Egyptian pyramids. When subjected to the proper conditions, they sprout and reproduce. Does it not appeal to reason to assume that the sprouting is just as well due to the renewal of the conditions favorable to sprouting, like moisture and proper temperature, as to some germ of life which may have remained dormant for all those years? All knowledge requires hypotheses. If the seed does not sprout then some factor is deficient. A fundamental law of chemistry, based on multitudinous experiments, is that like begets like. Monera, Haeckel's simplest protozoans, either the naked (gymnomers) or those with cell-walls (lepomera), grow by intussusception, or taking of new matter within their interior.

2. Substances to be absolutely the same must not fail in the least resemblance. No two acorns, no two oak trees, no two horses are ever exactly alike, although they may

have many similarities. The structure of the seed, cell or nucleus is complicated, else we should already have learned it. A simple concrete example will serve to illustrate our point. An equimolecular mixture of aluminum and potassium sulphates in water will crystallize in a definite form with a fixed proportion of water. By substituting ammonium for the potassium, we obtain crystals of the same form, with the same molecular proportion of water, yet they are different.

3. It is not difficult, in fact it is a common laboratory practice, to change several factors, either singly, alternately or simultaneously, so that the body first obtained resembles the parent in one or more ways or even not at all; yet on changing back one factor, the grandson resembles the grandfather.

The nucleus is made up of chemical molecules which are dissimilar. We know this much of the albumen molecule, namely, it is very large and complicated, containing from six hundred to a thousand or more of the nineteenth century atoms. They are combined in groups of variable sizes. We have to deal, therefore, with a system of several complicated components. There, doubtless, is a point at which such a system of definite composition may be held in perfect equilibrium through any length of time. If we add energy or take it away, as, for example, heat, the speed of the chemical reaction is altered. The reaction velocity is often reduced one half by a range of five degrees. One hundred degrees may cause it to fall to one millionth. The slightest change in medium, as adding or subtracting water, produces a marked acceleration or retardation in the speed as well as direction of the reaction.

It may be urged that when the nuclei containing these systems are subjected to certain influences, as heat or poisonous substances, they no longer germinate. The vital force was killed. We may also poison the dead catalyzing platinum and it is no longer active. These things are no more than we should expect. When a single factor of a complicated system has been changed, as readily happens through the agencies mentioned, we have no right to ask the same variation in the systems until exactly the same components become concerned in the former way. Ostwald puts it thus: 'As disturbances accumulate, the dissipative actions outweigh the accumulative ones, and the organism goes out of commission.'

With or without the energetics of Ostwald, the reasoning appeals to me. It offers a logical explanation of nature, which is growth. By adding, taking away or varying the components in any system, we may change from a simpler to a more complex system, or *vice versa.*

Bunge, discussing vitalism in physiologic processes, has most eloquently said, "Many centuries may pass over the human race, many a thinker's brow be furrowed, and many a giant worker be worn out, ere even the first step be taken towards the solution of this problem. And yet it is conceivable that a sudden flash of light may illumine the darkness." Science has no impossible boundaries. "Science will continue to ask and to answer even bolder questions. Nothing can stop its victorious career, not even the limitations of our intellect. This, too, is capable of being made more perfect. There is no rational ground for thinking that the continuous progression, development and ennoblement of type which has been going on for centuries on this planet, should come to an end with us. There was a time when the only living creatures were the infusoria floating in the primeval sea, and the time may come when a race may dominate the globe as superior to ourselves in intellectual faculties as we are to the infusoria."

Professor E. B. Wilson, the retiring president of the New York Academy of Sciences, has recently addressed that body upon 'The Problem of Development.' The paper reached me just three days ago. It contains most interesting information on the question of vitalism and mechanism. "In so far as development may be conceived as the outcome of an original material configuration in the nucleus, and a secondary configuration in the protoplasm, it may be conceived as a mechanical process."

This leaves unsolved, however, certain fundamental elements of the problem, for example, 'the manner and order in which the protoplasmic stuffs are formed and assume their characteristic configuration,' or 'how the wonderful phenomena of the regeneration of lost parts in the organism can be explained.' Advances have been made in the solution of the problem on the mechanical basis, hence Dr. Wilson asks, 'by what right does the vitalist demand that we shall adopt his hypothesis for the portions still unsolved?'

I am fully aware that sufficient experimental data have not been obtained to reduce the complicated phenomena to our familiar physico-chemical terms. But as a result of his work on the amphioxus and the dentalium, Professor Wilson remarks, 'It is possible, probable, that living bodies may be the arena of specific energies that exist nowhere else in nature.'

Our survey of the development of natural philosophy has forced upon us one fact, which we can not avoid. It is that man's knowledge of nature has been a growth, an evolution. Just as Francis Bacon thought, truth in science can only be obtained by progressive generalizations. This is true whether we accept the teaching of Darwin or the opposing atavism of de Vries. The means whereby we have gained that extended knowledge are too numerous even for enumeration here. I doubt not the ancient Greek philosophers would have had some merriment in their pity for him who might have suggested the existence of such a substance as the torch of Satan (phosphorus), which was exhibited at the continental courts of Europe.

I am almost overcome with the thought of what I may see, when I consider the immensity of the panorama presented to my venerable predecessors, who happily survive this day. Their half century of greater experience than mine brought them to the light of radium, the penetrating energy of Röntgen, and the phenomena of parthenogenesis. Nations whisper their wonders thousands of miles through the pulsations of energy, which gives life.

Acceptance of this philosophy does not preclude man's reaching a higher state of perfection; nor does it obviate man, as he is, being the highest type this world may ever know. It will depend entirely upon the factors in the systems. When equilibrium of energy has come about, none will be available and life, all life, inorganic as well as organic, will cease. Our world will have come to an end. The degradation will be as imperceptible as the growth. That which is and was returns to that which has been forever—the quiescent ocean of energy in equilibrium, the source and recipient of all life, which we are pleased to name as God. Creation's chorus is stopped, 'hid in death's dateless night.'

"Gone—all gone—like the light on the clouds at the close of day."

Charles Baskerville.
College of the City of New York.

INTERPRETATION OF A WATER EXAMINATION.

Interpretation of a water examination may be considered from two quite different points of view. It may mean the private