ON THE FORMATION OF CRYSTALS, DENDRITES, AND SPIRAL STRUCTURES, IN RELATION TO GROWTH AND MOVEMENT, ESPECIALLY RHYTHMIC MOVEMENTS.

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The distribution and movements of atoms and molecules in the universe, especially that part of it forming the organic kingdom, is of the utmost importance in biology and physiology. No one, so far as I know, has succeeded in giving a satisfactory explanation of them.

Atoms and molecules, there can be little doubt, move and are moved, and arrange themselves under the operation of a First Cause, as represented by life and physical force—gravitation, attraction, repulsion, changes of temperature, condensation, rarefaction, osmose, etc.  

Atoms and molecules for the most part display a tendency to dispose themselves in straight lines or in curves, the curves forming circles and spirals, especially the latter. As a consequence, growth and development in the organic and inorganic kingdoms proceed in one or other of the directions indicated.

The straight-line formations produce bodies bounded by plane surfaces; the curve formations producing spheres and spiral structures and modifications thereof. The straight-line formations are represented by crystals of every form and variety, crystallites, and dendrites; the latter branching and assuming a characteristic tree

1 In the present communication, the operation of a First Cause, in everything that pertains to the inorganic and organic kingdoms, is taken for granted.

Newton and Swedenborg held strongly to a First Cause.

Newton, when speaking of the formation of the sun and fixed stars, says: "I do not think (this) explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary agent."

In like manner, Swedenborg remarks "that nothing can be truly known of the visible world without a knowledge of the invisible, for the visible is a world only of effects, while the invisible, or spiritual, is a world of causes."

Haeckel and Tyndall reject a First Cause. They attribute everything to a power inhering in matter as matter, in virtue of which it assumes shape and movement, as apart from a Creator and as apart from life.

Kant, Herschel, Laplace, and others endeavoured to explain the existence and movements of the heavenly bodies by what is known as the nebular hypothesis. Laplace was of opinion that the matter of the solar system "existed originally in the form of a vast, diffused, revolving nebula, which, gradually cooling and contracting, threw off, in obedience to mechanical and physical laws, successive rings of matter, from which subsequently, by the same laws, were produced the several planets, satellites, and other bodies of the system."

Descartes attempted to account for the formation of the universe, and the movements of the bodies composing it, by a theory of vortices.

It will be observed that all the philosophers referred to above assume the existence of matter. It is the distribution and movements of matter, not only in the physical universe, but also in the vegetable and animal kingdoms, which is still sub judice.
shape. Crystals are formed by aggregations of atoms and molecules, the additions, as a rule, being made in straight lines, and giving rise to plane surfaces. The curve formations are represented by spheres and modifications of spheres, where the atoms and molecules combine to form bodies having concentric arrangements; the additions being made in successive curved layers. Beautiful examples of straight-line formations are seen in the crystals of snow, and of the straight-line and curve formations in the crystals and conglomerations of hail. In the latter, the straight-line and concentric arrangements are both present. Perhaps no better illustrations of the extraordinary plasticity and power of nature to assume different shapes and conditions, under slightly altered circumstances, can be given than are afforded by the structure of snow and hail respectively. The spiral formations of the physical universe are seen in spiral nebular arrangements, in whirlwinds and spiral sandstorms, in whirlpools and spiral waterspouts, etc. In all these cases, the atoms, molecules, and bodies concerned are arranged spirally. The straight-line, curved, circular, and spiral formations obtain also in plants and animals. The globular, rod-like, and spiral structures are seen in the very beginnings of life, and in the very lowest living forms, e.g. cocci, bacilli, and spiralia, measuring from the $\frac{1}{10,000}$ to the $\frac{1}{2,000}$ of an inch in diameter. Examples of the straight-line arrangements are met with in the stems, roots, branches, and other parts of plants. Examples of curve formations are to be seen in the concentric arrangements (rings of growth) in the stems of plants and trees; and examples of spiral arrangements occur in the twisted stems of climbing plants. Twisted stems are not uncommon also in forest trees. Trees and plants split up and branch after the manner of dendrites. They thus combine, in their structure, the straight-line and curve formations to which reference has been made.

The same thing, within limits, happens in animals. Animals are symmetric and asymmetric. A good example of a symmetric animal is the five-rayed starfish. In general configuration it greatly resembles a crystal. The body, as a whole, displays the straight-line and curve formations in combination; the diverging rays affording an illustration of the former, and the curved surfaces of the rays, of the latter.

The Aplysia, one of the molluscs, furnishes an example of an asymmetric animal.

The symmetric animals are in the ascendancy. In matters of symmetry they, in not a few cases, resemble crystals. They also resemble dendrites from the fact that, in a great many instances, they branch out in more or less straight lines, as witness the integumentary appendages, and the extremities and travelling organs of animals.

Animals reveal spiral formations in their bodies, as a whole, and in certain parts of their bodies. The animals inhabiting shells are almost all spiral, and quadrupeds and bipeds have spiral extremities, these being composed of spiral bones, spiral muscles,
etc. The quadrupeds have, in many cases, spiral horns. Both quadrupeds and bipeds have, as a rule, spiral hearts.

The general configuration of animals is rounded or convex, while the internal arrangements, in the majority of cases, are dendritic, i.e. they branch out in straight lines after the manner of trees. This holds true of the blood vessels, lymphatics, bronchial tubes, nerve cells, etc., in the higher animals. It also holds true of the respiratory, alimentary, and other systems in the lower animals.

Animals, like plants, are the products of straight-line, curve, and spiral formations. The movements in the organic and inorganic kingdoms are also in straight lines, curves, ellipses, circles, and spirals.

In the physical universe we have examples of straight-line movements when a body flies off at a tangent into space. We have examples of elliptical and rotatory movements in the earth travelling round the sun, and turning upon its own axis while so engaged. The spiral movements are seen to advantage in the whirlwind and the waterspout.

In plants and animals, the straight, circular, and spiral movements reappear. In plants, straight-line movements are seen in the upward and downward progress of branches and roots in the process of growth; in the bifurcation and growth of the stem, branches, leaves, etc. The circular movements are seen in the free ends of plants whose summits revolve; and the spiral movements in climbing plants which wind round supports, and which have for the most part twisted or spiral stems. In animals, straight-line movements are witnessed in Pseudopodia, which supply the most plastic and direct form of movement, also in the forward movements of worms, slugs, etc. The circular movements are seen in the 'Rotifera'; the curve movements in snakes; and the spiral ones in the walking, swimming, and flying of animals. In the higher animals, the travelling organs are spiral, both as regards form and function. The same remarks may be made of the viscera of several of them, namely, the ventricles of the heart, the stomach, bladder, uterus, etc.

As regards both form and movement, plants and animals find their analogues in the physical universe; the organic kingdom is not separated from the inorganic one, unless in the matter of life. Nor will this, on reflection, occasion surprise. All the elements entering into the formation of living plants and animals come directly or indirectly from the physical universe. They also return to it at death. There is in the universe a store of matter, and a store of force, which admits neither of increase nor diminution. The organic and inorganic kingdoms are inseparably united, and there are good grounds for believing that the life in building up plants and animals, not only appropriates all the materials employed in the constructive process from the physical universe, but also a considerable proportion of the force which inheres in those materials, and which, strictly speaking, cannot be separated from them.
If the views now put forth be adopted, most, if not all, the structures and movements with which we are familiar in the organic and inorganic kingdoms fall into line. They go far to explain how the heavenly bodies are built up, and how they move and wheel in space—in tangents, ellipses, circles, spirals, etc.: how the nebulae, in some instances, form vortices; how there are eddies and whirlpools in the water; cyclones or circular storms in the air; spiral waterspouts and spiral sand-storms on sea and land, etc. They also go far to show how crystals and dendrites are formed in the inorganic kingdom; how structures, bounded by plane and curved surfaces, are produced in the organic kingdom; and how straight, curve, circular, and spiral movements in plants and animals, and parts thereof, are produced.

Movement at once precedes and follows structure, and the direction of movement in living things is, in every instance, determined by the composition and configuration of the moving part.

There are good reasons why atoms and molecules should arrange themselves, and move in straight lines and in spirals. Straight lines and spirals do not return upon themselves and admit of indefinite extensions, i.e. matter can be added in straight lines and in spirals to any amount, and movement in either direction has practically no limit. Those peculiarities of straight-line and spiral formations and movements are of the utmost consequence in growth and progression, especially in the locomotion of animals.

The straight-line formations are crystalline and dendritic in character, i.e. they form structures bounded by straight lines and plane surfaces, as in crystals; the dendrites of minerals and metals; the frost pictures seen on window-panes and pavements in winter; the lightning flash, etc.

Straight-line formations are also witnessed in the arborescent arrangements of the roots, branches, leaves, and other parts of plants, and in the branching of nerve cells, blood vessels, lymphatics, bronchial tubes, and other parts of animals.

The spiral formations and movements everywhere abound in the vegetable and animal kingdoms; in spiral growth and development; in the spiral cells, hairs, and vessels of plants; in the spiral stems of climbing plants; in the revolving movements of plants; in the spiral distribution of branches, leaves, fruits, etc.; in the spiral configuration of shells and horns; in the spiral structure and distribution of the bones and joints of the vertebrate skeleton; in the spiral formation and movements of the soft parts, especially of the voluntary and involuntary muscles, as seen in the limbs, the ventricles of the heart, stomach, bladder, uterus, etc.

In suggesting possible explanations of the distribution and movements of atoms and molecules in living plants and animals, I recognise most fully the existence of a great First Cause, as regards the creation, disposal, and supervision of matter, both in the organic and inorganic kingdoms. A First Cause may operate in two different
ways:—(a) In creating matter (inorganic or organic) and in giving it a certain rôle to perform as apart from supervision. (b) In creating matter, and in supervising every change which occurs in it.

In the former case, creation is as it were a completed work; everything infallibly working out its own destiny, according to law and order. In the latter case, creation is only in part completed—in other words, is progressive, and requires constant supervision and guidance. The first view is that adopted by many evolutionists; the second, that favoured by those who believe in separate creations.

Nothing short of a First Cause can, it appears to me, explain many of the phenomena with which biologists and physiologists have to deal. Spiral structures and movements are in special demand in the organic and inorganic kingdoms.

Stereo-chemistry has shown that "optically active substances may be divided into two classes. Some, like quartz, sodium chlorate, and benzil, produce rotation only when in the crystalline states; the dissolved (or fused) substances are inactive. Others, like oil of turpentine, camphor, and sugar, are optically active when in the liquid state or in solution. In the former case the molecules of the substance have no twisted structure, but they unite to form crystals having such a structure. As Pasteur expressed it, we may build up a spiral staircase—an asymmetric figure—from symmetric bricks; when the staircase is again resolved into its component bricks, the asymmetry disappears. In the case of compounds which are optically active in the liquid state, the twisted structure must be predicated of the molecules themselves, i.e. there must be a twisted arrangement of the atoms which form these molecules."

Pasteur, in discussing the molecular constitution of tartaric acids, says: "That the molecular structures of the two tartaric acids are asymmetric, and, on the other hand, that they are rigorously the same, with the sole difference of showing asymmetry in opposite senses. Are the atoms of the right acid grouped on the spirals of a right-handed helix, or placed on the solid angles of an irregular tetrahedron, or disposed according to some particular asymmetric grouping or other? We cannot answer these questions. But it cannot be a subject of doubt that there exists an arrangement of the atoms in an asymmetric order having a non-superposable image. It is not less certain that the atoms of the left acid realise precisely the asymmetric grouping which is the inverse of this." . . . "Pasteur regarded the formation of asymmetric organic compounds as the special prerogative of the living organism. Most of the substances of which the animal and vegetable tissues are built up—the proteids, cellulose—are asymmetric organic compounds, displaying optical activity." . . . "Meso-tartaric acid contains two equal and opposite asymmetric groups of atoms within its molecule." . . . Pasteur was of opinion that compounds exhibiting optical activity were never obtained without the intervention of life. He also says:
"Artificial products have no molecular asymmetry; and I could not point out the existence of any more profound distinction between the products formed under the influence of life, and all others. And, again, he refers to the molecular asymmetry of natural organic products as the great characteristic which establishes, perhaps, the only well-marked line of demarcation that can at present be drawn between the chemistry of dead matter and the chemistry of living matter. . . . Non-living, symmetric forces, therefore, acting on symmetric atoms or molecules, cannot produce asymmetry, since the simultaneous production of two opposite asymmetric halves is equivalent to the production of a symmetric whole, whether the two asymmetric halves be actually united in the same molecule, as in the case of meso-tartaric acid, or whether they exist as separate molecules, as in the left and right constituents of racemic acid. In any case, the symmetry of the whole is proved by its optical inactivity." 1

The well-marked tendency to spiral formations and movements, everywhere observable in the organic kingdom, has its counterpart in the inorganic kingdom. In the latter there are spiral formations and movements on a grand scale, as witness the vortices of nebulae, of air, of water, etc. Examples of these are seen in the whirlwind, the whirlpool, the water-spout, and other natural phenomena.

Examples of crystals are met with both in the organic and inorganic kingdoms. Crystals are characterised by the most exquisite symmetry, and are typical, straight-line, and plane surface formations. They are endless as regards form, and have for the most part an unvarying chemical composition. They occur in the soft snow and in the hardest rocks and metals. They are deposited in the solids of certain plants, and in the fluids of plants and animals, as witness the crystals of sugar, blood, bile, urine, etc.

Examples of dendrites occur in plants as a whole; in roots and branches; in the venation of leaves; in the branching of blood vessels, lymphatics, nerve cells, bronchial tubes, the shaggy chorion, placenta, etc. The symmetry observable in crystals is not wanting in dendrites and in plants and animals. Plants for the most part are strikingly symmetrical; and the bodies of animals are, as a rule, composed of two halves, with a tendency to right or left spiral overlapping, the overlapping half being the larger and stronger, and giving rise to what is known as right or left-handedness in ourselves.

Examples of spirals (single and double) are found in large numbers in plants and in animals—spiral cells, hairs, stems, branches, leaves; shells, horns, bones, muscles, nerves, etc. Spiral formations are symmetrical when two or four opposite spirals are employed. They are non-symmetrical or lop-sided when only one spiral is employed. Complementary spirals are by no means infrequent.

1 "Stereo-Chemistry and Vitalism," by Professor F. R. Japp, as given in the "Report of the British Association for the Advancement of Science," 1898.
The unaccountable thing is that crystalline, dendritic, and spiral formations and movements occur both in inorganic dead matter and in organic living matter.

A hasty generalisation would naturally lead to the conclusion that there is in the universe only one kind of matter and only one kind of force. It might even be inferred that the living or organic kingdom is an outgrowth or product of the inorganic kingdom, and that vital force is a mere variety and product of physical force.

As, however, it has been satisfactorily proved that there is no such thing as spontaneous generation, a line of demarcation must be drawn as between dead and living matter, and between physical and vital force.

The question—and it is an exceedingly difficult one to answer—has still to be put: How comes it that living matter assumes crystalline, dendritic, and spiral shapes and movements? The following, it appears to me, is the only answer that can be given. Plants and animals, at the outset and during their lives, are composed of inorganic matter. All the substances which enter into their composition are taken from the inorganic kingdom. In building themselves up they appropriate not only the materials of that kingdom, but also a considerable proportion of the force which inheres in those materials. If, however, plants and animals are wholly composed of inorganic matter (plus life), and if they transfer to their bodies a considerable portion of the force which inheres in the matter of that kingdom, it need occasion no surprise if the structure and movements of plants and animals, and parts thereof, in many cases resemble the structure and movements of natural objects which never have lived or ever will live.

The universe forms a harmonious whole, and the inorganic and organic kingdoms are in no sense opposed to each other. Each plays its own important rôle, but the rôles are co-extensive, co-ordinated, and correlated.

The atoms and molecules which enter into the formation of the inorganic and organic kingdoms, as stated, naturally run in specific directions, in straight lines, curves, circles, and spirals, and the task of life is rendered comparatively easy by a preconcerted and prearranged distribution and movement of matter, whether this be solid, liquid, or gaseous.

It is the same First Cause which works in the inorganic and organic kingdoms; and the two kingdoms are, in the fullest and widest sense, complementary. They are in no degree antagonistic or opposed to each other. The earth, air, and water provide the food for the plant; and the plant, air, and water for the animal. In the Carnivora, animal food, prepared by the plant, is substituted; the Omnivora consuming plant and animal alike. Dead decaying animal matter, as is well known, enriches the soil and produces additional pabulum for plants.

The organic and inorganic kingdoms are interdependent, and
in order to realise the position of plants and animals in the universe, it is necessary to consider, very briefly, the properties of the earth, the water, and the air, and some of those physical arrangements and movements which purify the atmosphere, which enrich the soil, which supply and diffuse moisture, which provide and regulate heat, etc.

The organic substances are, so to speak, manufactured from the inorganic by plants and animals. A plant to live must be supplied with soil, with water, and air. The soil contains saline matters, to which are generally added decomposing substances, which furnish carbonic acid and ammonia. The water furnishes oxygen and hydrogen in chemical combination; and the air oxygen and nitrogen, and small but important quantities of carbonic acid and ammonia. The plant is thus supplied with water, salts, carbonic acid, and ammonia. But the plant can disintegrate the carbonic acid, and appropriate its carbon, which it can subsequently build up with oxygen and hydrogen into sugar, oil, and starch; or it can combine carbon, hydrogen, oxygen, and nitrogen to form those peculiar nitrogenous substances recently known as protoplasm. The sun lends its aid to the plant in these transformations; in fact, the heat of the sun enables the plant to separate the oxygen from the carbon and the nitrogen from the hydrogen in the formation of sugar, oil, and starch. The heat of the sun is, marvellous to relate, not lost in the process. It is stored up in the newly-formed sugar, oil, and starch; and may be reconverted into heat either by burning in the animal body or in an open fire. The heat thus obtained can, when collected, be made to perform a definite amount of mechanical work. The physical and vital forces are correlated and interact.1 Sugar, oil, and starch are manufactured by a vital chemistry, and, when once produced, are appropriated, with other substances, as food by the Herbivora, and subsequently by the Carnivora and Omnivora. By vital, chemical, physical, and other forces the inorganic material of the outer world is incorporated in the organic or inner world of plants and animals.

The animal, built up, as it were, indirectly from the inorganic and directly from the organic kingdoms by means of the plant, reverses the operations of the latter. It returns to the inorganic world the substances abstracted from it by the plant. Thus the animal takes the complex bodies produced by the plant, and oxidises or burns them. It restores the carbon of these bodies to the atmosphere chiefly in the form of carbonic acid, the hydrogen as water, and the nitrogen, with the remainder of the carbon, as urea, to the soil.

While these transformations are going on in the animal body,

1 "The life of men, animals, and plants could not continue if the sun had lost its high temperature, and with it its light.”
the tissues are being built up and conserved, secretions formed, and work done. This work may be either mechanical or mental, or both. The animate and inanimate kingdoms plainly interact. The plant lays the inorganic world under contribution, and the animal lays the vegetable world under contribution; but the animal in due time restores to the inorganic or mineral kingdom, in undiminished quantity, the substances abstracted from it by the plant. In like manner, the energy displayed by the animal is to be regarded as the sum of the potential energy stored up in chemical compounds; and this in turn is restored to the outer world as heat, which, like the matter, is undiminished in quantity. There is therefore a cycle of force and a cycle of matter in living beings. "Animals, like machines, can only move and accomplish work by being continuously supplied with fuel (that is to say, food) and air containing oxygen; both give off, again, this material in a burnt state, and at the same time produce heat and work. All investigation, thus far, respecting the amount of heat which an animal produces when at rest is in no way at variance with the assumption that this heat exactly corresponds to the equivalent, expressed as work, of the forces of chemical affinity then in action. As regards the work done by plants, a source of power in every way sufficient exists in the solar rays which they require for the increase of the organic matter of their structures." "A certain portion of force disappears from the sunlight, while combustible substances are generated and accumulated in plants, and we can assume it as very probable that the former is the cause of the latter. . . . The immense wealth of ever-changing meteorological, climatic, geological, and organic processes of our earth are almost wholly preserved in action by the light and heat-giving rays of the sun. . . . In the series of natural processes there is no circuit to be found by which mechanical force can be gained without a corresponding consumption."

It is necessary to say a word here regarding the great physical law of the conservation of energy. This law resolves itself into three parts, namely, the conservation of energy, the transformation of energy, and the dissipation of energy. We have examples of the conservation of energy in physiology, wherever we have mechanical or physical adaptations which produce a maximum of work with a minimum of power.1 We have examples of the transformation of energy in the muscles moving the bones, or the heart the blood; and we have examples of the dissipation of energy in the friction accompanying the movements of both bones and blood. In all the vital, physical,

1 "There is hardly a natural process to be found which is not accompanied by mechanical actions, or from which mechanical work may not be derived—heat, electricity, magnetism, light, chemical forces, all stand in manifold relation to mechanical processes. . . . While the steam-engine develops for us mechanical work out of heat, we can conversely generate heat by mechanical forces."—Popular Scientific Lectures by Helmholtz, 1872.
and chemical actions and reactions the law plays a prominent part.

The interaction of the physical, chemical, and vital forces is thus expressed by Helmholtz: "If a certain quantity of mechanical work is lost, there is obtained an equivalent quantity of heat, or, instead of this, of chemical force; and, conversely, when heat is lost, we gain an equivalent quantity of chemical or mechanical force; and again, when chemical force disappears, an equivalent of heat or work; so that in all these interchanges between various inorganic forces, working force may indeed disappear in one form, but then it reappears in exactly equivalent quantity in some other form. . . . The universe possesses, once for all, a store of force which is not altered by any change of phenomena, can neither be increased nor diminished, and which maintains any change which takes place on it. . . . The force of falling water can only flow down from the hills when rain and snow bring it to them. To furnish these we must have aqueous vapour in the atmosphere, which can only be effected by the aid of heat, and this heat comes from the sun. The steam-engine needs the fuel which the vegetable life yields, whether it be the still life of the surrounding vegetation, or the extinct life which has produced the immense coal deposits in the depths of the earth. The forces of man and animals must be restored by nourishment; all nourishment comes ultimately from the vegetable kingdom, and leads us back to the same source. . . . We are thrown back upon the meteorological processes in the earth's atmosphere, on the life of plants in general, and on the sun." It would appear from this that living force can generate the same amount of work as that expended in its production.

The link which binds the organic to the inorganic, and the living to the non-living, is protoplasm in one form or other. This mysterious life stuff apparently provides the bridge which connects the inorganic and organic kingdoms. The approaches to this bridge are numerous, but, unfortunately, not altogether satisfactory or safe. Haeckel says: "The homogeneous, viscid, plasma substance which singly and alone formed the bodies of the first organisms, and even at this day quite alone forms them in the case of the moneres, or simplest amoebic forms, is analogous to the tenacious and viscid planetary substance which contains the elements and substance of the young earth, as well as of the other glowing world bodies." Herbert Spencer, one of the most advanced thinkers of the present day, avers "that the chasm between the inorganic and organic is being filled up, and that organisms are highly differentiated portions of the matter forming the earth's crust and its gaseous envelope." In like manner, Huxley, also in the vanguard of science, states "that protoplasm can originate only in that into which it dies—the elements—the carbon, hydrogen, oxygen, and nitrogen of which it is found to
consist. Hydrogen, with oxygen, forms water; carbon, with oxygen, carbonic acid; and hydrogen, with nitrogen, ammonia. Similarly, water, carbonic acid, and ammonia form, in union, protoplasm. . . . Protoplasm, then, is but an aggregate of physical materials, exhibiting in combination—only as was to be expected—new properties. . . . All vital action whatever, intellectual included, is but the result of the molecular forces of the protoplasm which displays it.”  

Protoplasm, according to Huxley, is the formal basis of life. “It is the clay of the potter, which, bake and paint it as he will, remains clay, separated by artifice, and not by nature, from the commonest brick or sun-dried clod. Thus it becomes clear that all living powers are cognate, and that all living forms are fundamentally of one character.” Huxley regards protoplasm as identical in composition and uniformly diffused in plants and animals; i.e. not contained in cells. In this he differs from the German histologists, who still regard the cell as the precursor and parent of protoplasm. With them “there is as yet no matter of life; there are still cells of life.” Huxley claims for protoplasm a threefold unity—a unity of faculty, a unity of form, and a unity of substance. Each of these positions has been disputed, and properly; for how, say Huxley’s opponents, can there be unity of substance if the elements, carbon, oxygen, hydrogen, and nitrogen, which constitute the protoplasm, are combined in varying quantity in different kinds of protoplasm? If there is not unity of substance there cannot be unity of form, and if there is neither unity of substance nor of form there cannot possibly be unity of function. The unity of substance of protoplasm depends for its proof mainly upon ultimate organic analysis. Ultimate organic analysis, however, teaches next to nothing in such cases. “Ozone is not antózone, nor is oxygen either, though in chemical constitution all are alike.” Further, some protoplasm, in addition to carbon, oxygen, hydrogen, and nitrogen, contains a certain proportion of sulphur; and the Germans have shown that the cells which produce protoplasm contain in some cases glycogen, in others cholesterine, in others protagon, and in others myosin. According to Stricker, protoplasm varies almost indefinitely in consistence, in shape, in structure, and in function. In some cases it is fluid, in others semi-fluid, in others firm and resisting. Occasionally it is club-shaped, bottle-shaped, spindle-shaped, branched, prismatic, polyhedral, etc. One kind produces fat, another pepsine, another pigment. There is a protoplasm for each of the tissues—nerve, brain, bone, muscle, etc. There is, further, a protoplasm for the several kinds of plants and animals, each producing its own kind.

1 Huxley, as epitomised by J. Hutchison Stirling, LL.D., to whose able critique on “Protoplasm” the reader is referred.

(To be continued.)