THE VIRGINIA TEACHER

VOLUME XII JANUARY, 1931 NUMBER 1

WHENCE PROTOPLASM?

IN THE VIRGINIA TEACHER for November, 1929, the author sketched in bold outlines the progress of animal life on the earth. The present article deals with the nature and origin of protoplasm. It is impossible to give the sources for much of what follows. They have been too long part and parcel of a teaching equipment. However, it may be said that the treatment of the subject as found in Osborn's *Origin and Evolution of Life* has furnished a particular inspiration for much of what follows.

Ever since Purkinje first used the term "protoplasm," as a name for living substance, its nature has been a subject of absorbing interest. It is not strange that its unique properties fostered the idea that it must have had a supernatural origin, that it must be a thing apart, utterly mysterious. Yet, to the most casual observer, living beings, plant or animal, have substance. They are definitely material objects. Since this is so, they must be subject to physical and chemical analysis like any other substance. However, when we come to apply the methods of the chemist to matter in the living state; when we attempt to determine its chemical structure, we upset that subtle interplay of forces within the protoplasm which we term life. In spite of the difficulties met with in all attempts to analyze protoplasm, some progress has been made. This has been done indirectly by studying the properties of non-living colloidal systems, and directly through microdissection of the living cell.

Assuming that the reader is familiar with the elements which are found in protoplasm, and with the fact of its colloidal nature, we will consider for a little the possible ways in which these particular elements may have come to be associated together as living systems.

The greatest contribution of science has been to establish that all phenomena of nature proceed in an orderly fashion, following certain fixed laws. The behavior of protoplasm is no exception to this principle. We are accustomed to thinking of the universe as being comprised of two things, matter and energy. The work of the last decade or so on the nature and structure of the atom seems to indicate that after all there is but one thing in nature, and that this thing is energy. Matter, viewed in this light, is but an expression of various energy relationships. However this may be, we usually think of energy as being of two kinds, potential or stored energy, and kinetic or active energy. Protoplasm has the unique power of automatically storing potential and releasing kinetic energy in the performance of its work. It is this property which, together with its power of self-perpetuation, that distinguishes matter in the living state from that which is not alive.

How did this peculiar state of energy relations which we term living substance come to be? It is impossible to know exactly how life came to exist upon the earth. None of us were delegated as official observers. It is not strange that much of mystery attaches itself to the synthesis of protoplasm, one of the most dramatic events in the earth's history. Does it, as many believe, represent something new in the universe, or does it as Osborn so well states, mean "the continuation and evolution of forms of matter and energy already found in the earth, the sun, and in the other stars?" Our analysis of protoplasm has shown it to be a colloidal substance. Colloidal chemistry and colloidal physics are relatively new fields of investigation. There is much to learn about colloids, and particularly about those in the living state. That which is unknown is always mysterious, hence living matter has seemed to be something so different from matter in the non-living state that it is still regarded by many as being something apart from the rest of the universe, a thing of mystery called into being by a special creative act. As the knowledge of colloidal substances increases, the mystery concerning the nature of protoplasm decreases, and we are less and less prone to regard it as being a substance distinct from the rest of the universe. Still our added knowledge, though it has marvelously increased our insight into the activities of protoplasm, has shed but little light upon its origin.

There are three possible methods by which life may have come to exist on the earth. Some incline to the belief that it has come to us from outer space, borne on meteors or planitesimals. Many believe that living organisms have arisen as the result of special creation. Still others believe that life has resulted from the action of natural forces similar to those operating in the rest of the universe, at a time when the primitive earth had assumed a form essentially like that of the present, but when conditions on its surface were possibly more favorable to the gradual changes necessary for the extensive synthesis of living matter from relatively simple inorganic substances.

To assume an extra-terrestrial origin for protoplasm is but begging the question. It is true that certain forms of living substance can endure extreme cold, possibly temperatures of the degree believed to obtain in interstellar space. Those who hold to this theory forget that meteors are heated to white heat by friction as they pass through the earth's atmosphere, so that any life they might have upon their surfaces would be destroyed by heat even were it able to withstand interstellar cold. Moreover, this theory does not account for the ultimate origin of life. It had to begin somewhere, why not on the earth? The physical and chemical structure of protoplasm point to its having arisen as the result of natural forces which may very well have been particularly active in the early days of the world's history. Because living matter has seemed to be a mysterious substance, it has been given a supernatural or miraculous origin by many. Such a belief tends to deny the very fact of the orderly progress of the universe. It is far more reasonable, far more reverent, to consider as most biologists believe, that living matter has arisen through the gradual establishment of those peculiar energy relations of colloidal substance which we recognize as attributes of matter in the living state. Osborn has well stated that "without being a materialist or a mechanist, one may hold that life is a continuation of the evolutionary process rather than an exception to the rest of the cosmos, because both mechanism and materialism are words borrowed from other sources which do not in the least convey the impression which the cosmos makes upon us. This impression is that of limitless and ordered energy." Nor does such an idea deny the existence of that creative force which we call God. Rather, it adds greatly to the dignity of our conceptions, giving them a force and majesty, a true reverence lacking in more primitive ideas.

What was the nature of the earth when life first arose? What conditions were necessary for the evolution of the living from the non-living? No exact answers can be given. One must arrive at the nature of the primitive earth from indirect evidence. Among the earliest rocks we know, sedimentaries are to be found. Since they were deposited in layers, we are sure that the same agencies of water, ice, and wind now at work in rock-making were then operative. Vulcanism has always been a force instrumental in modifying the surface of the earth. We have direct proof of this written in the rocks throughout all stages of the earth's history. Volcanic emanations contain gases such as free hydrogen, carbon dioxide, volatile hydrocarbons, sulphur, and compounds of ammonia which are substances entering into the composition of protoplasm, and which may have played a part in its synthesis. Volcanic waters and those of hot springs contain similar substances in solution. These facts are true for volcanic gases and waters of the present, and there is no reason for supposing that they were essentially different earlier in the history of the earth. Even though the earliest rocks which overlie the primordial granite are sedimentaries, it is obvious that they were less abundant than now. The primitive world must have been richer in igneous rocks, which are usually alkaline in reaction. Water coming into contact with such rocks would accordingly have been richer in alkaline compounds than the soil waters of the present, and so would have contained more of the substances necessary for the synthesis of protoplasm which is alkaline in nature.

The atmosphere of the primitive earth is believed to have been more heavily charged with water vapor than is now the case. It must have been more cloudy, and the surface of the earth must have received less sunshine and more rain. In that case, the heat which reached the earth would have been retained by the blanket of cloud, so that there is no reason for supposing that there was any essential difference in mean temperature then and now. In fact, the temperature was in all probability more equable, subject to fewer extremes. It is probable, too, that volcanic activity was greater then than now, and if so, the atmosphere may well have been richer in carbon dioxide, at least in the vicinity of volcanoes and hot springs. Free oxygen was probably present, but in less amount than in the atmosphere as we know it, for there were no green plants to continually release it from combination.

The ocean owes its salinity to minerals brought to it by surface waters which have dissolved salts from the soil through which they have percolated. It is believed that the primitive ocean was very nearly if not entirely fresh. If this was the case, the conditions necessary for the synthesis of portoplasm would not have obtained in the sea. However, water is the main constituent of living matter if we consider bulk alone, and there can be little doubt that life had its origin in the water. Since the waters of the primitive ocean were not suitable for the origin of life, one has to look to the land for bodies of water in which protoplasm could have had its beginning. It is altogether possible that pools in the neighborhood of hot springs furnished favorable conditions of temperature, and an abundance of the substances necessary for the formation of protoplasm. The steps in the organization of such materials into colloidal substances we do not know. Nor can we understand how the store of carbon dioxide in the air was rendered available for the manufacture of protoplasm. It is doubtful if primitive protoplasm contained chlorophyll. The process of photosynthesis seems to have been a later development. We have no way of knowing if the primitive life stuff utilized free oxygen, was aerobic, or whether it depended upon chemically combined oxygen, was anaerobic in habit. Both systems for obtaining the necessary oxygen may have existed from the very beginning. The nucleus of every cell contains chromatin, that substance necessary to the life of cells as we know them, and different from the protoplasm outside of the nucleus. The question of the origin of chromatin may never be answered. We do not know whether it arose separately, independently, and later became associated with the cytoplasmic colloids, or whether the two were associated intimately from the very beginning as now. However, they may have arisen, it is certain that they are now inseparable, and that their association in the form of living cells is one of the most important facts made known through biology.

We have no way of telling how long it took to establish life. The rocks leave no record of this, the most important episode of terrestrial history. We may be sure that the time was exceedingly long, and that many combinations of colloids were formed which could not function as living systems, unsuccessful attempts as it were at making the living from the non-living. Once established, however, protoplasm by its very nature became self-perpetuating and self-varying so that life has continued from that early time to the present in ever increasing complexity, in ever increasing amount, in ever increasing variety of form, until the earth has come to so teem with it that a balance has become established among living things without which the world would speedily revert to its original lifeless form.

Ruth L. Phillips

A BOTANIST-EYE VIEW OF EUROPE

KNOWING that the International Plant Congress was meeting in England last summer, another botanist and I decided to attend, and since a European trip was more or less of an event in our lives, we decided to make the most of it and see some other interesting places and people before the congress. After landing at Cherbourg and staying over night in Paris, we went directly to Switzerland, which might rightly be called a "country on edge." Geologically, the Alps are mere infants among mountains, being probably not more than six million years old—hence the steep slopes and narrow valleys. One of the occupations of the Swiss people is wine-making, so we expected to see vineyards, and plenty of them. But they did not look like the vineyards with which we are familiar—at first sight they reminded us of fields of pole beans. Each grapevine had its own individual trellis—an upright pole with no cross bars. The Swiss people do not take kindly to mass production; the cultivated slopes are all divided into small plots, each planted with a different crop. Even the meadow slopes are divided. Of course, sometimes these divisions are natural ones—terraces or irrigation ditches. Mention of irrigation ditches seem queer in a land associated with rushing streams, but actually, the un-irrigated slopes are too dry to be good meadows or pastures. The mountain roads are masterpieces of engineering, though they are so narrow and winding that a driver traveling on them with safety must be a very good driver indeed. In many places the road is too narrow for two cars to pass, and on many curves the edge is guarded by scattered concrete posts above a sheer drop.

The alpine laboratory of the Botanical Institute of the University of Geneva was our first stop. It is located at a tiny village eight miles below the pass of Grand St. Bernard. It is a small building on top of a knoll, with no heat except two small electric grills. The "Cours des Vacances" was given this past summer by Professor Chodat and his son, and consisted of morning lectures —mostly in French—and afternoon excursions or research. Some of the morning lectures lasted from nine in the morning till the big cow bell was rung at our hotel down the hill to let us know that the noon meal was ready. On rainy days it was very cold—so cold that our hands became almost too numb to write notes. It was always cold in the morning, and we rarely stripped down to the bottom sweater at any time of the day unless we were climbing. But when