The Smith of the Gods

27 - «The Origin of Life is Intimately Linked to the Origin of Our Planet Itself, Linked to the Origin of the World»

270- To approach this question serenely, we can refer to the considerations of Alexander Oparin. According to him, to understand a problem well, one must trace its genealogy. Thus Oparin, as a biologist as much as a biogeochemist, leads us to an intimate history of the living on Earth. «Now, wrote Schrödinger by way of introduction to the origin of life, I think one can formulate in a few words the resemblance between a clockwork mechanism and a living organism. It comes down, quite simply and solely, to the fact that the latter, just like the clock, is built around a periodic crystal; that of a living organism is built around a metastable aperiodic crystal which constitutes the hereditary substance not subject, in essence, to the influence of disordered thermal agitation.» Let us return to our three fairies of the Sublime, those who presided over the advent of life here below. One may say that in the primordial conditions, the fairy Chance had free rein, while the fairy determinate was already pondering various eventualities, and the fairy relative simply knew nothing of the project, being fully occupied with the great works of the cosmos. In “The Origin and Evolution of Life”, Alexander Ivanovich Oparin sets out the foundations of the living process. «It becomes more and more evident today that knowledge of the nature of life is possible only through knowledge of its origin. This origin no longer seems enigmatic now, as it still did until recently. The real paths of the appearance of life on Earth are becoming more and more comprehensible to us. This appearance of life could only occur as an integral part of the general historical evolution of our planet. The facts at our disposal show that the appearance of life was a slow, one-way process, toward an increased complexity of organic substances and of the whole systems they formed, systems in constant interaction with the external environment. We must give a special place to the evolution of carbon compounds, for terrestrial life is the result of their progressive transformation into more and more complex compounds, with the elaboration of organic substances and, from these, of multimolecular systems.» Organic substances constitute the essential, indispensable part of life. The simplest of them are hydrocarbons. Hence organic chemistry is currently defined as the study of hydrocarbons and their derivatives. For our part, we may also consider hydrocarbons as the starting point of the chain of transformations which, from carbon compounds, leads to the appearance of life. However, hydrocarbons are not peculiar to the living world alone. These compounds are very widely distributed across all the celestial bodies one can observe. Their presence is found at the surface of stars, in the interstellar substance of gas and dust, in comets and in meteorites.

271- One may thus explore the process of the abiogenic formation of hydrocarbons and the initial stages of their transformation, in the light of the study of the evolution of various celestial bodies, in particular the formation and evolution of our planet. The interstellar gas consists chiefly of hydrogen and a certain quantity of helium and other inert gases. Very simple hydrocarbons, notably methane (CH4), have also been successfully detected there. At

the temperatures prevailing in the cluster of interstellar substances, methane can still partly be found in the gaseous state. As for the other elements and their compounds, they belong for the most part to the interstellar dust, in which one can distinguish: the group of «ices», comprising ammonia, methane and water (in the form of ice or hydrates), and the so-called «terrestrial» group (compounds of silica, magnesium, iron and other heavy elements). The initial material of our planetary system was a cloud of gas and dust forming part of a gigantic cluster of rarefied interstellar substance. This cloud, with dimensions comparable to those of the present solar system and at a temperature on the order of 220 °C below zero, contained about 1000 hydrogen atoms per cubic centimetre, together with a notable quantity of dust. Gravitational instability brought about its general disintegration. This disintegration was triggered by the explosion, in this region of the Galaxy, of a supernova accompanied by shock waves. Propagating through the surrounding medium of gas and dust, these shock waves caused a local compression which broke its unstable gravitational equilibrium. Consequently, some 5 billion years ago, at the centre of the cloud that gave birth to our planetary system, a central body appeared whose mass rapidly increased. Along with a rapid increase in its density, this body underwent heating due first to gravitational energy, then, as a result of the nuclear reaction of which it became the seat, and then to the transformation of hydrogen into helium (as occurs in the explosion of an H bomb); this central body was transformed into a star (our Sun). The remaining gases and dust would form a cloud in the shape of an accretion disk that would serve as the starting point for the formation of the «protoplanets». Meteorites are generally classified into two groups: iron and stony. Iron meteorites are composed mainly of ferronickel. They are apparently debris coming from the central part of asteroids. As for the stony meteorites, whose fall to Earth is more frequent, they break away from the peripheral parts; their iron content is much lower and they are composed mainly of silicates and oxides of metals such as magnesium, aluminium, calcium, sodium, etc.

272- Among stony meteorites, particular interest is granted today to carbonaceous chondrites. These are fairly friable blocks, comprising an opaque black mass in which chondrules and grains of olivine and pyroxene are embedded. A characteristic of these chondrites is their high carbon content (up to 4.8 %) as well as the presence of combined water in minerals (hydrosilicates and aluminosilicates). The carbon is represented there by an amorphous carbonaceous substance and by graphite. It also enters into the composition of organic substances, low molecular weight hydrocarbons or polymerized compounds, chiefly of the aliphatic series. By similarity, these compounds sometimes resemble residues from the decomposition of micro-organisms (abiogenic compounds). Current data prove with certainty that the Earth constantly received in the past, and continues to receive, «food» in the form of various organic substances of abiogenic origin coming from meteorites and comet debris reaching us from the cosmos (thousands of tonnes per year). However, it has been calculated that this contribution represents only a relatively small fraction of all the organic substances on the Earth’s surface. The mass of organic substances that served as the basis for the appearance of life on Earth is therefore not directly of cosmic origin, but it was constituted at the surface of our globe from carbon compounds that were released into the primitive atmosphere during the formation of the Earth’s crust. According to the most widespread

opinion, our planet was formed at a relatively low temperature by the accumulation of cold solid bodies of heterogeneous constitution. These bodies had a variable content of iron and silicates, but were practically devoid of chemically free and volatile combinations; their chemical composition must have been very close to that of present-day meteorites. The difference in constitution and density of the solid matter from which the Earth was formed determined its heterogeneity, which manifested itself during the subsequent evolution, corresponding essentially to a progressive local warming of our planet, due mainly to the heat of disintegration of radioactive elements. When, as a result of this warming, the temperature of the Earth's depths rose sufficiently and exceeded 1000 °C, a partial melting of the solid rocks began. Subjected to the high pressures inside the Earth, the materials shifted, the heavier blocks, rich in iron, sinking toward the centre, the light silicates rising.

273- The formation of the Earth's crust, the lithosphere, took place at the surface of the globe through the melting of the most fusible combinations of the Earth's superficial layers. This process continued throughout the entire geological existence of our planet and one cannot believe it completed in our day. The Earth's crust consists of the granite and basalt layers covered by a layer of sedimentary rocks. Beneath the crust lies what is called the mantle, characterized by ultra-basic rocks, poor in silica (dunites). The granite layer covers nearly half the Earth's surface; it is very thick beneath the continents, but does not exist at the bottom of the Pacific; the underlying basaltic envelope covers the whole globe, but it is likewise thinner at the bottom of the oceans. The dunites of the mantle derive from the melting of the Earth's primitive matter, whose constitution is analogous to that of chondrites. The melting of the light basaltic rocks of the mantle, under the effect of radiogenic heat, must have been accompanied by the release of various gases and vapours forming with the rise in temperature, or else constituting themselves in the solid terrestrial envelopes during radioactive, radiochemical and chemical processes. That is why, from the very beginning of our planet, the formation of the Earth's liquid and gaseous envelopes (hydrosphere and atmosphere) was closely linked to the processes of the lithosphere. At that time, the mass of water at the Earth's surface must have been much smaller than it is today; on the primitive Earth there was only about a tenth of the water of the present seas and oceans. The remainder of the water appeared later, during the formation of the lithosphere, from hydrosilicates or from the combined water of the deep layers. Although the forming Earth lost a large part of its protoplanetary hydrogen, its abundance among the initial materials had an essential influence on the later constitution of our planet and especially of its atmosphere. Even after the loss of free hydrogen, the Earth must have retained a large quantity of it in the form of various combinations, several of which, during the formation of the Earth's crust, were emitted into the terrestrial atmosphere which was thus constituted, being conferred a clearly expressed reducing character. Conversely, we know that the Earth's present atmosphere is very rich in free oxygen, which makes it clearly oxidizing. But the abundance of gaseous oxygen could only occur long after the appearance of life on Earth. At the first stage of our planet's existence, free oxygen could be present in its atmosphere only in very small quantity, if indeed it was present at all. Free oxygen can form in the Earth's crust by the abiogenic route thanks to radiochemical reactions and in particular to the decomposition of rock water by gamma rays. But, given its great chemical activity, free oxygen oxidizes various

substances while crossing the thick Earth's crust and can only reach the surface in negligible quantity. That is why, during radiochemical decomposition of water, the gas emitted into the atmosphere is rich in hydrogen and not in oxygen. Free oxygen could also form in an abiogenic manner in the upper layers of the atmosphere thanks to the photochemical decomposition of water vapour by ultraviolet rays. In this case, the gaseous hydrogen escaped into interplanetary space, since terrestrial attraction cannot retain it, while the free oxygen remained in the atmosphere. But its concentration must have been low, for it was fairly quickly absorbed by the water of the oceans. The oxygen then oxidized the ferrous iron salts, thus forming ferric oxide which, as it settled, gradually constituted the voluminous deposits of the most ancient iron ores. It is now beyond doubt that the main mass of the molecular oxygen of the present terrestrial atmosphere was formed by the biogenic route after the appearance of life on Earth. But when the reserves of free oxygen of the atmosphere are reconstituted directly by green plants, only the most superficial layer of the crust is fully oxidized. The deeper rocks remain strongly reducing and avidly absorb oxygen, which is verified by the well-known fact that the colour of lavas and basalts is black, green and grey, proving the presence of ferrous oxide. On the contrary, sedimentary rocks, clay, sand, etc., are red and yellow in colour; the iron is found there in the form of ferric oxide.

274- Thus there is a progressive absorption of the free oxygen of the atmosphere during the transformation of igneous rocks into sedimentary rocks, and only the continuous process of photosynthesis ensures the permanent reconstitution of this gas in the Earth's atmosphere. If all vegetation perished on Earth, the free oxygen of the atmosphere would disappear within a few millennia, that is, in a very short time on the geological scale, for it would be absorbed by the unsaturated rocks. Another essential gas of the present atmosphere, nitrogen, must have appeared at the Earth's surface in its reduced form: ammonia, a combination of nitrogen and hydrogen. There is every reason to think that, in the solid materials from which the Earth was formed, nitrogen was preserved above all in the form of its combinations with metals, nitrides, or in that of ammoniacal salts. Geological discoveries confirm the presence of nitrides in the Earth's crust; the nitrides must have entered into interaction with the hydration water of the deep layers, giving ammonia, which passed from the Earth's surface into the atmosphere. Carbides (combinations of carbon with metals) and graphite constituted the most stable form of the preservation of carbon in the solid bodies from which the envelope of our planet was formed. Cohenites of terrestrial origin constitute one of the deepest formations of the Earth's crust. During the constitution of the latter, the cohenites must doubtless have interacted with the water of the deep layers, giving rise to methane and other hydrocarbons which accumulated in the Earth's primitive atmosphere; indeed, after the formation of our planet, they were retained by the force of gravity and could not disperse into interplanetary space. Before the appearance of life, these processes were the only possible routes for the formation of the initial organic combinations; extremely perfected means of the synthesis of organic substances (photosynthesis in particular) use the inexhaustible sources of solar light energy to develop. Thus the greater part of the carbon at the Earth's surface was integrated into the biological process, while the former abiogenic mode of the constitution of hydrocarbons passed into the background. In the past, it was the sole agent responsible for the constitution of organic substances. Hydrocarbons and their close derivatives contain

astonishing, unique chemical possibilities. Doubtless, during the billions of years that elapsed from the formation of the Earth to the appearance of life, the hydrocarbons existing at the surface of our planet must have made wide use of these possibilities. They could not remain unchanged for long but necessarily entered into chemical interaction among themselves and with neighbouring substances, forming innumerable complex combinations, which is foreign to inorganic nature. This explains their exceptional role in the appearance of life. Life on Earth could only appear through a regular process making organic substances more complex, and that is why there is not, and cannot be, any life without these substances.

275- The evolution, at the surface of the Earth, of the organic substances that thus appeared in an abiogenic manner, an evolution prior to the appearance of life, dates from an epoch when conditions differed profoundly from those existing today. The absence of free oxygen in the primitive atmosphere excluded any possibility of direct and deep oxidation of hydrocarbons such as is now observed when they burn in air. The absence of free oxygen in the primitive atmosphere opposed the constitution of what is called an «ozone screen», impermeable to short-wave ultraviolet rays. The presence of such a screen in the present atmosphere prevents these rays from reaching the surface of our planet. As for the primitive atmosphere, on the contrary, it was entirely traversed by an intense ultraviolet radiation, far more favourable to the various photochemical processes than the longer wavelength rays received at present. The fact that its atmosphere was essentially constituted of hydrogen, and the absence, on the primordial Earth, of living organisms with an extremely perfected metabolism, **present** likewise a significant importance. During the process tending to make organic molecules more and more complex, these acquired, at a certain stage, a new property: dissymmetry. Thus methane, for example, and its close derivatives (methyl alcohol, formaldehyde, methylamine) do not have this property, and even the simplest amino acid, glycine, does not possess it. But all the other complex amino acids are endowed with it. This capacity manifests itself as follows: an organic substance possessing dissymmetry exists in two similar forms. Their molecules contain the same atoms and groups of atoms, but these are differently arranged in space. The radical of one form is to the left and vice versa. Our two hands offer a simple model of these dissymmetric molecules. If we place them before us, we shall see that, despite all their resemblance, the right hand and the left hand are distinguished by the arrangement of their parts. Each hand is thus like the reflection of the other in a mirror. The polymerizations that took place in the presence of other polymers, of polypeptides, of polynucleotides, which occurred in the primitive broth, these polynucleotides thus engendered form, with the other polymers, multimolecular complexes that separate from the ambient solution in the form of individual systems in «coacervate» droplets. A coacervate is constituted by a tensioactive process (effect of the weak force) producing persistent microscopic bubbles through the permanent agitation of the primitive broth. It is indeed these complex systems, and not the isolated molecules found in the solution, that must have constituted the starting formations which subsequently engendered the primary organisms. Only systems of this kind could evolve on the basis of natural selection and of interaction with the ambient environment. At first, they comprised only primitive polypeptides and polynucleotides of disordered structure. But subsequently, the intramolecular structure of the latter became more and more rational, ever better adapted to

the functions devolved upon them within the complete evolving systems. Given the internal structure and the determined organization of the interface of the droplets and the equilibrium liquid, coacervates possess the very clear property of absorbing the different substances of the surrounding solution through the properties of water molecules said to be in the «interfacial» state, having the property and acting as a filter. Metabolism is but the ensemble of a great number of relatively simple reactions of oxidation, reduction, aldolization, hydrolysis, transamination, phosphorylation, cyclization, etc. Each of them can be reproduced outside the organism, for they have nothing specifically vital about them. Life is an open system capable of self-reproduction, of conjugated organic reactions, catalysed in a staggered and isothermal manner by complex and specific organic catalysts which are produced by the system. The organism forms a whole as a system only when united with the conditions of life necessary to it. Living beings are «albuminoid» bodies, which contain proteins, nucleic acids, lipoids, specific carbohydrates and various other organic substances.

276- The static structures determining life are referred back to the domain of colloido-chemical formations and to that of intramolecular structure. The material support of life is a molecule of hereditary substance endowed with an invariable static structure and entering into the composition of the chromosomes of the nucleus. It is so static that it has preserved its determining internal structure throughout the whole evolution of life on Earth; adenosine triphosphoric acid forms part of it. Resorting to polyphosphates and to short-wave ultraviolet light, the abiogenic synthesis of adenosine triphosphoric acid, rich in energy, has been achieved. This synthesis is very important, given that this acid is the principal direct source of energy in all current living beings. The protoplasm is a complex multiple coacervate. The coacervate structure proper to living protoplasm exists only so long as the numerous chemical processes composing the metabolism take place there constantly and with great speed. As soon as these processes cease or are essentially modified, the protoplasmic system is destroyed. Its prolonged existence and the constancy of its form are therefore linked not to invariability, nor to rest, but to the permanence of movement.