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DEFINING LIFE

Origin of Life and Definition of Life, from Buffon to Oparin

Stéphane Tirard

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Abstract Many theories on origin of life at the end of the XIXth century and the beginning of the XXth, generally use conceptions of life instead of explicit definitions of life. This paper presents ideas on the origin of life as studied by Buffon (1707–1788), Lamarck (1744–1829), Darwin (1809–1882), Huxley (1825–1895), Oparin (1894–1980) and Haldane (1892–1964). We show that their conceptions on the evolution of matter and life reveal their conceptions of life rather than their definitions of life.

Keywords Buffon · Darwin · Haldane · Huxley · Lamarck · Oparin

Introduction

One of the relevant characteristics of many theories on origin of life of the end of the XIXth century and the beginning of the XXth, is the fact that they generally use conceptions of life, instead of explicit definitions of life. In the works of Buffon, Lamarck, Darwin, Huxley, Oparin or Haldane, we can see how their thoughts about the origin of life are included in complete theories on the evolution of the Earth and the evolution of life and reveal their complex conceptions of life.

Buffon: Life as Organized Matter

In his *Histoire Naturelle* (1749), the French naturalist Buffon did not define life but gave a very complete theory of life based on important concepts. His concept of *organic molecules* is a central point of his theory. He claimed that these microscopic entities are alive and constitute all organisms in nature. Indeed, plants receive *organic molecules* in soil with

S. Tirard (✉)
Centre François Viète d'histoire des sciences et des techniques (EA 1161), Faculté des sciences et des techniques de Nantes, 2 rue de la Houssinière, BP 92 208, 44322 Nantes CEDEX 3, France
e-mail: stephane.tirard@univ-nantes.fr

their roots and animals receive *organic molecules* when eating plants and others animals. When they die, living organisms release their molecules in soil.

O*rganic molecules* are also central in the concept of species proposed by Buffon. He claims that during the generation of living organisms, *organic molecules* are responsible for the transmission of the *interior mold* that indicates the organization of each species, In this way, Buffon's species concept belongs to a very large view about life. According to him, species are not only collections of living beings at a specific moment, but also the perpetuation of these collections through time, generation after generation.

At the end of his career, in his *Epoques de la Nature*, Buffon introduced a new concept of time to describe the history of the Earth and thus abandoned cyclic time for sagittal time (Buffon 1778). In spite of this new historical view, he remained "fixist" and continued to claim that species do not change in other species, even if some reversible changes could occur in each species. In the first ages of the Earth, when temperature was sufficiently cold, organic molecules produced spontaneous generations and produced each species. Depending on his fixist conception, each new form belongs to a definitive *interior mold*.

Therefore in Buffon's view we can underline that life is a property of matter. Nature produces life and this production finds its place in sagittal history of the Earth.

Lamarck: Life as Transformable Organization (Adapted from Tirard 2006)

We have to distinguish two periods in Jean-Baptiste Lamarck's life. This French naturalist was indeed fixist until 1802. But from this date, he supported a new theory based on evolutionary processes retrospectively named transformism, which he defended all his life (Lamarck 1802). In the presentation of his theory, he gave a short definition of life: "Life is an order and a state of things in the parts of every body that possesses it. Life allows or makes possible the performance of organic movement, and, as long as it subsists, effectively counteracts death." (Lamarck 1802 p. 71). However, this is more in the mechanisms of the evolutionary process described by Lamarck that we can perceive his complete conception of life. Indeed, his definition makes sense when he continues saying that animalized matter is in a gelatinous state, between solid and liquid states, a state in which transformation of structure can occur. The first characteristic of living matter is the presence of "vital orgasm", a particular force that maintains molecules separated in spite of universal attraction. The causes of this "vital orgasm" are the uncontainable fluids: electricity and heat. The latter mainly maintains space between molecules.

At this stage during animalization, that is to say during spontaneous generation process, Lamarck considers that the gelatinous matter obtains capacity of contractility as simplest polyps. Following, transformations, induced by action of containable fluids, gases and water are the second step of the process. In the formation of polyps the second fluid is the most important. The continuous flow of water through the gelatinous matter induces the formation of a larger pore. That is the first expression of habit in the evolutionary process described by Lamarck. This pore, progressively enhanced, constitutes the first primitive digestive tube.

We claim that Lamarck's description of animalization of matter is a synthetic presentation of his entire evolutionist or transformist theory. This description indeed uses the fundamental concepts of his theory: fluids, habits and modification. With these concepts Lamarck can explain all transformations of organisms from animalcules to mammalians.

With Lamarck, we see that the definition of life depends on transformation processes that include spontaneous generation as well as species formation.

Darwin: Life as Historical Process

In *The Origin of Species* Darwin did not give any definition of life (Darwin 1859). His approach to life concerned proofs and causes of evolutionary processes of species, but he was not directly interested in any physical or chemical characterization of life. We will note that with Darwin, life becomes an historical process. However, he emphasized that no clues remain from the beginning of this process: there is no fossil of those very old times. In the last lines of his book, he asserts that "There is grandeur in this view of life, with its several powers, having been originally breathed into a new forms or into one; whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved." (Darwin 1859, in 1985 pp. 459–460). However, in this book, he gave no more details about the origin of life. It was only in his famous letter to Hooker that he described a hypothetic primordial phenomenon: "It is often said that all the conditions for the first production of a living organism are now present, which could have been present. But if (and oh what a big if) we could conceive in some warm little pond with all sort of ammonia and phosphoric salts,—light, heat, electricity &c, present, that a protein compound was chemically formed, ready to undergo still more complex changes, at the present day such matter would be instantly devoured, or absorbed, which would not have been the case before living creatures were formed." (Darwin 1871 in Calvin 1969 p. 4).

These sentences are very informative about his conception of life. It seems that concerning the chemical nature of life, Darwin agreed with a protoplasmic concept based on albuminoidal substances and admitted that they could emerge spontaneously in nature. The most interesting point in his analysis is the impossibility for these substances to subsist: present life prevents emergence of new life. This constraint is a pure consequence of the historical nature of life. Darwin's conception of life could perhaps be summarized as to the importance he gave to historicity: life is an irreversible process and an event that can't be repeated, because life itself changes the condition of each step of the process.

Life and Evolution of Matter

During his entire career, Louis Pasteur (1822–1885) defended the idea of a barrier between inert and living matter (Pasteur 1994). At the beginning of the 1860s, his experiments and his debate with Félix Pouchet (1800–1872) showed that spontaneous generations do not exist and comforted his own conviction about limits of life. For most of the scientific community, these results led to definitively giving up the spontaneous generation theory. However thinking about a very simple and unique primitive ancestor still remained of a great difficulty. Indeed, as suggested by Darwin, there was a necessity to imagine a process between inanimate and living matter with a kind of progressive evolution of matter.

In this way, during the second part of the XIXth century, studies of the chemical and physical properties of living matter produced several central concepts. For example, in his famous text, *On the Physical Basis of Life*, Thomas Huxley identified life with its constitutive matter, i.e. the protoplasm. He described the link between elementary chemical constituents and complex organic matter present in the cell and claimed that life lies in the properties of the protoplasm (Huxley 1868).

This conception of life permitted the development of theories of evolutionary abiogenesis (Tirard 2005). These theories conceived progressive evolution of matter, which represented the first step of a global evolution of living beings. At the end of the XIXth and

at the beginning of the XXth century, biologists or chemists (Haeckel 1879,1897, Chamberlin & Chamberlin 1908) formulated several short suggestions, but the most important hypotheses came in the 1920s.

Life in Evolution of the Earth

Alexander I. Oparin and John B. S. Haldane developed independently the first complete scenarios on the evolutionary abiogenesis in their texts respectively published in 1924 and 1929 (Oparin 1924, Haldane 1929). Oparin described the evolution of the Earth and the evolution of matter leading from mineral to organic matter and then to a form of primitive life. He claimed that in the primitive atmosphere and primitive oceans, organic matter became more and more complex. Oparin gave an interesting description of this evolution and said that appropriate conditions would arise "by chance" and "lead to the formation of a gel in a colloidal solution." His description of the process was as follows:

> "The moment when the gel was precipitated or the first coagulum formed, marked an extremely important stage in the process of spontaneous generation of life. At this moment material, which had formerly been structureless, first acquired a structure and the transformation of organic compounds into an organic body took place. Not only this, but at the same time the body became an individual. […] With certain reservations we can even consider the first piece of organic slime, which came into being on the Earth, as being the first organism. In fact, it must have had many of those features, which we now consider characteristic of life. It was composed of organic substances, it had a definite and complicated structure which was completely characteristic of it. It had a considerable store of chemical energy enabling it to undergo further transformations. Finally, even if it could metabolize in the full sense of the word, it must certainly have had the ability to nourish itself, to absorb and assimilate substances to form its environment, for this is present in every organic gel." (Oparin 1924 in Bernal 1967, p. 233).

Afterwards, some bits of gel progressively isolated themselves and the biggest incorporated the smaller.

Five years later, in 1929, Haldane proposed a very similar scenario concerning the primitive conditions on Earth, but with some particularities about primitive life. He used modern notions of biology, like "genes", and invented the term "prebiotic soup" to designate the primitive ocean. Regarding his conception of life, the important fact is that he claimed that primitive chemical reactions can produce some "half living molecules":

> "The first living or half-living things were probably large molecules synthesized under the influence of the Sun's radiation, and only capable of reproduction in the particularly favorable medium in which they originated. Each presumably required a variety of highly specialized molecules before it could reproduce itself, and it depended on chance for a supply of them."(Haldane 1929, in 1991 p.108)

In 1936, Oparin wrote a book about his theory, enriched with a lot of details and complements (Oparin 1936). He used the notion of coacervate experimentally described by Burgenberg de Jong (1932), which suggested a model of living entities. We could also present Alexandre Dauvillier's photochemical conception of life or John D. Bernal's hypothesis, which suggests that primitive chemical reactions happened on clays as support and catalyst.

All these scenarios include life in a large evolutionary process and explore some ways of chemical complexification leading to primitive living forms comparable to the present ones. Theses scenarios are in fact concepts of life, which depend on characteristics observed in present life and on hypothetic primitive conditions too.

Conclusion: Reconstructing the Past or Defining Life?

Undoubtedly, the puzzle of the origin of life results in a problem about the past of our planet, which contains an important historical dimension. This historical status of the problem of the origin of life was emphasized by Haldane in 1929: "The question at issue is 'How did the first such system on this planet originate?'. This is a historical problem to which I have given a very tentative answer on the not unreasonable hypothesis that a thousand million years ago matter obeyed the same laws that it does today."

In the same way, Bernal in 1951 wrote that the problem of the origin of life was "at the same time historical and physiological."

Is the definition of life an absolute necessity for scientist working on origin of life? It seems that it is possible to explore past and hypothetical processes of the emergence of life with the help of theoretical and experimental ways without any circumscribed definition of life. However, a lot of approaches of the origin of life seem included in wide conceptions of life, which depend on the historicity of life.

In 1924, Oparin concluded his famous work with these words:

> "What we do not know today we shall know tomorrow. A whole army of biologists is studying the structure and organization of living matter, while a no less number of physicist and chemists are daily revealing to us new properties of dead things. Like two parties of workers boring from the two opposite ends of a tunnel, they are working towards the same goals. The work has already gone a long way and very, very soon the last barriers between the living and the dead will crumble under the attack of patient work and powerful scientific thought."

Therefore, Oparin described in this quotation the gap in which the problem of the origin of life remains. Necessity of experiments is obvious, but because of complexity and historicity, the experimental exploration of this gap needs an accurate point of departure, precise primitive conditions, and an orientation, i.e. the present life. Scientists can perhaps hope to find a definition of life somewhere in this tunnel.

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