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Prebiotic chemistry

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Abstract. The session that I have had the pleasure to chair dealt with prebiotic chemistry at both the initial and the intermediate level of complexity.

The session that I have had the pleasure to chair dealt with prebiotic chemistry at both the initial and the intermediate level of complexity. The contributions are 5, here ordered according to the increasing complexity of the topic treated:

1. Plasma kinetics and prebiotic chemistry: a new way to look at the Miller-Urey experience, by V. Laporta et al.;
2. Modelling of the atmospheric entry and chemical decomposition of micrometeoroids in the context of organic matter delivery, by G. Micca Longo and S. Longo ;
3. Anomalous fluctuations and selective extinction in primordial replicators: a struggle for life at the origin of biological homochirality, by S. Longo and G. Micca Longo ;
4. Implication of poly-glycosylated nucleoside species in the prebiotic transglycosylation, by L. Botta et al.;
5. Sustainability and chaos in the abiotic polymerization of 3',5' cyclic guanosine monophosphate, by G. Costanzo et al.

As immediately perceived, the five topics deal with key problems of prebiotic chemistry. In order to appreciate the relevance of these topics and to put them in context, a little perspective is needed.

The focus of the reasoning here is the word *prebiotic*. Being at the initial and the intermediate level of complexity simply means that one is not dealing with what happened or characterized the pre-organismic or organismic level. That is: we are not dealing here with LUCA-related problems, even though LUCA always stays in the foreground of our models because, if we have a single hope to reconstruct a reasonable prebiotic scenario, this hope relies in a top-down approach. Only by starting from the properties of extant living entities, and by confronting them with the properties of possible abiotic-but-biogenic chemical systems we can evaluate the worth of our prebiotic search.

This takes us to the following considerations. The first consideration is very general in its nature and is summarized in the words by Martin Heidegger: *In order to find something, shouldn't we in general already know that it exists?* (Heidegger 1929) In our case (the search of the roots of life) even the object of our search is uncertain. The second consideration is strictly related to the purport of these words, and can by formulated as a question: *What are we actually looking for?* Or, more explicitly: *What is life?* The question has been asked frequently, and the answer most often relies in the definition formulated in 1992, credited to Gerald Joyce of the Scripps Research

Institute: *Life is a self-sustaining system capable of Darwinian evolution*. A more thorough analysis of the problem was carried out by Trifonov (2011), who compiled a list of the 123 existing definitions of life and, through their examination performed with the rules of structuralism, has extracted the consensus definition: *Life is reproduction with variations*. This definition does not establish what life is, but provides the formulation of what contemporary science deems to be life. Replication of what?

The answer is necessarily: replication of information. A living entity is the ensemble of a phenotype (what appears and can be seen, its physical structure and its metabolism) and of a genotype. Genotypes are the large world of genetics. On planet earth information is DNA. DNA derives from the simpler and more reactive polymeric molecule RNA. The organization of the information of genetic materials is similar to that of a computer that proceeds by successive binary choices of information provided by sequences of 0-0-1-0-1-1 entries. DNA is organized in the same way: its basic entries are two distinct chemical structures (purine and pyrimidine nucleic bases), aligned along a polymeric thread. In order to increase its information content, the binary code of DNA has duplicated itself into two purines (guanine G and adenine A) and two pyrimidines (cytosine C e thymine T). The sequence of the As, Gs, Cs and Ts aligned along a repetitive structure built on a repetitive sequence made of sugar-phosphate moieties, repeating themselves in succession and held by phosphodiester bonds, constitutes the variable and informational part of the genetic material. This is how things are in the biological world that we know, in our world, where information and DNA coincide. What about in the prebiotic world? Here is where the third question acquires its meaning. The third question is methodological, and has been formulated by A. Eschenmoser : *Origin of Life cannot be discovered; it has to be reinvented* (Eschenmoser 2007).

The prebiotic world can be imagined only accepting the point of view expressed by the physicist Victor Stenger : *Something came from nothing because it was more stable than nothing* (Stenger 2006). which at the same time re-establishes the fact that everything had to follow the laws of thermodynamics, and that evolution was the key. Of course. evolution at the molecular level, because organisms were yet to come. But evolution works at every level. At this point, we have sketched a reference frame : we are looking for something that is difficult to define precisely, that works inside the laws of thermodynamics, that consists on accumulation and replication of chemical information. We are thus able to frame in a general context the 5 presentations that have been given, whose reports are in the following pages:

1. The endless worth of the seminal Miller experiment : how to pass from 1-Carbon atom compounds to more complex prebiotic molecules? The revisitation of this experiment continues to spring surprises. Miller's flask contained much more than he was able to appreciate.
2. The distribution of organic matter, and its intrinsic evolution. Matter moves in the universe, in the form of atoms, of small molecules, of cosmic dusts, of aggregated structures. And of celestial bodies of varying dimensions. Given that life is chemistry with a history, micrometeroids, that keep track of their history, are not the last place where to look for traces of pre-life structures.
3. The unresolved problem of chirality, which translates in the aphorism: How to transform unknown properties of the microscopic level into universal rules ? Will the amino-acids of the forms of life that will be found on Mars have the same chirality of our proteins ? And, if so, what shall we conclude?
4. Implication of poly-glycosylated nucleoside species in the prebiotic transglycosylation process. Here the process of generation of complexity has almost reached its highest possible level. Nucleosides are spontaneously generated from 1-Carbon atom compounds as formamide, which also condenses into sugars

of various types. Do the ensuing molecules react among them and afford polymers of mixed nature ? The question is at the basis of complex chemistry, of mixed systems, of generation of new properties.

5. Sustainability and chaos in the abiotic polymerization of 3', 5' cyclic guanosine monophosphate. The core of the problem of generation of pre-genetic chemical information is how nucleic bases (and their descendants along the complexity path: nucleosides and nucleotides) polymerize and form defined molecules in the absence of a pre-formed template. The possible solution is in their self-reaction and aggregation properties, which borders with the laws of chaos.

From all this, it is clear that the frontier of prebiotic chemistry is its ability to explain the emergence of new properties (Sartenaer 2018). In this instance, the new emergent property is particularly relevant: life.

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