Chemical Origins of Life – its Engagement with Society

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Abstract

Comprehending the origin of life on Earth is intriguing and its scientific endeavors have engaged society while guiding the search for life elsewhere. However, some persistently question the science and support for such endeavors. This Science & Society article attempts to put this in context and contemplates how engagement could prevent misunderstandings.

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Nothing is more mysterious and riveting than the question of how life arose on earth. It engages everyone, irrespective of their background, and results in a vigorous debate with ideas ranging from God's creation to intelligent design to panspermia to scientific reductionist reasoning and experimental evidence – and yet it remains an "unanswerable question" at least from a historical perspective [1]. With the invention of the microscope which revealed a whole new world of microorganisms that set off the inquiry into the nature of the molecules that constituted living things and their basic building block, the cell, the then prevailing views of life and its origins were challenged. The scientific (and spectacular) demonstrations of the transition of inorganic molecules into organic- and biogenic-molecules (Wöhler synthesis of urea from ammonium cyanate, Kolbe's synthesis of acetic acid from inorganic carbon, and the Urey-Miller spark-discharge experiment transforming primordial gases into a suite of organic chemicals, including amino acids) changed the scene forever, setting the stage for a systematic scientific-proof-based hypotheses and experiments to understand the chemical origins of life [2]. Coupled with the rapid progress in the field of molecular biology (the discovery of the structure of DNA and RNA, and their interrelationship with proteins and translation machineries), the time was ripe for understanding the machinations of life's process at a molecular level [3]. The field prospered with the discovery of many natural and unnatural variants of nucleic acids, proteins and cell components – which provided inspiration for discoveries in synthetic biology and applications in medicine, all of which have had positive impacts on, and benefited, society at large [2].

As with any field, competing theories on the chemical origins of life (e.g., the protein, lipid, metabolism, and RNA worlds) emerged [4], as a consequence of the extrapolation and simplification of existing biological paradigms to the early earth, ca. 4 billion years ago [2]. As the field advanced and discoveries were made [2, 3, 4], it began to engage society more by attracting the attention of the public at large to life and its potential for existence in the universe,

and of some highly vocal parts of society that invoke the concept of creator/intelligent design to explain the origins of life [5]. Every time a high-profile scientific work was (is) published claiming to have "addressed" a significant problem in the chemical origins of life, there was (and is) an immediate reaction from an opposing scientific faction and/or the believers in creation/intelligent design, pointing out the weaknesses and/or why this cannot be so. The higher the profile of the work or the scientist, the greater the push back! The scientific objectors would lay out rational reasons for why the claim is insufficient; the others, not only borrow(ed) these same arguments, but also level(ed) the common "biology is too complicated to create itself out of inanimate chemicals" criticism, and that there must be a "watch-maker" behind the watch [6].

There has been a lengthy scientific, religious and philosophical back-and-forth with little common ground or understanding of what the "other side" sees or believes in [5]. There have been attempts to reconcile this "unanswerable question" [5] - for example, by stating that the creator uses the laws of chemistry and physics to fashion life from atoms and molecules - but that retains a purposeful and knowing creator. As Carl Sagan famously stated when discussing the origins of the universe "*In many cultures, the customary answer is that a god or gods created the universe out of nothing. But if we wish to pursue this question courageously, we must, of course, ask the next question: Where did God come from? If we decide that this is an unanswerable question why not save a step and conclude that the origin of the universe is an unanswerable question? Or if we say that God always existed why not save a step and conclude that the universe always existed? There's no need for a creation. It was always here*" [7]. Such an argument points out the weakness in invoking a creator, which/who cannot be tested (nor comprehended). However, we cannot make an equivalent statement that "life was always here" to get out of this conundrum, since it is fairly sure that earth was formed about 4.5 billion years ago and that life must have appeared on the early earth anywhere between 4.1 and 3.8 billion years ago based on scientific evidence that has held up to intense and continuing scrutiny [8].

It is obvious that experimental demonstration of the chemical origins of life is not an easy task and has to be a methodical and investigative process based on reasonable hypotheses. Therefore, it is only natural that one must expect that each scientific outcome and claim is met with a healthy dose of skepticism, which is the stepping-stone for what must be done next and how shortcomings can

be addressed. However, criticizing every scientific work under the guise of creation, nor summarily dismissing genuine concerns about the scientific claims, helps neither side in the long run and only widens the gap and mistrust between the various segments of society. Can anything be done to rectify this short of conversion? A good beginning would be to admit the obvious – neither side knows with certainty how life appeared on the early earth (and may never know the historic pathway). What scientists are trying to comprehend is how chemicals *can* (and not *did* or *could*) transform themselves to a functioning collection of molecular systems that can exhibit biological behavior (Box 1) [9].

Box 1. Can *versus* Did or Could in the Chemical Origins of Life.

"The natural genesis of life on Earth is a hypothesis of evolutionary science; it is the task of synthetic organic chemistry to test this hypothesis experimentally. The aim of an experimental aetiological chemistry is not primarily to delineate the pathways along which our ('natural') life on Earth *could* have originated, but to provide decisive experimental evidence, through the realization of model systems ('artificial chemical life'), that life *can* arise as a result of the organization of organic matter" [9].

While we are not there yet, recent research provides promising clues –by focusing not on biological processes, but on what prebiotic clutter and experimental simulation can teach us, for example: (a) the natural emergence of peptide bonds from a mixture of α-amino- and α-hydroxy-acids (paralleling the mechanism found in ribosomes) [10]; (b) the spontaneous formation of higher order supramolecular structures by a simple phosphorylation process (imitating what transpires in biology) [11]; and (c) the emergence of homogeneous RNA and DNA starting from a mixture of chimeric nucleic acids by replication [12]. These show that the biological processes that we observe today *can* be the outcome of natural chemical evolution [10].

In this endeavor, it should also be acknowledged that simply extrapolating biological complexity backwards in time (to ca. 4 billion years ago) may be misleading [10] and, therefore, one should refrain from making (and tamp down) over-reaching claims to *have solved the problem* (although the popular media may still twist them into sensational headlines). To paraphrase a famous saying, "*the (chemical) origins of life must be reinvented"* [13], with this, one must realize that these sensational headlines are not what the scientists claim in their original work, and the invocation of a designer (intelligent or otherwise) is another way of expressing "we *also* do not know" ! Such a simple (but difficult) step may force a look in the mirror, and allow reflection on how to proceed further, when both sides are trying to grasp the ungraspable (at least historically). Another simple step would be to know the difference between "purpose" and "reason". *While there is a reason for everything (that may not be evident), there is not a purpose for everything*, since purpose implies

a desired end result. A great deal of misunderstanding stems from the mixing-up and misuse of these two terms in the context of 'why and how' in chemical- versus biological-evolution versus creation (Box 2).

A question that naturally arises for either side is why does (should) it matter as to what the other side thinks and does?. While not immediately obvious, it becomes painfully apparent when one considers the current situation in a democratic society where one side or the other controls the decision-making process. There are a growing number of cases where decisions are made by people who have been appointed based on the policies of government officials who have been elected to power, and who do not believe in what the scientific evidence shows or how it has been presented. A stark example of this is the ongoing debate over climate change, and how it has been influenced by who is in charge. Whether this is right or wrong is a point for a different debate, but the result of the distrust between the different sides – how they perceive each other has been treated has real and practical consequences depending on which side controls the purse when in power. While this is not so severe (currently) for research on the chemical origins of life, it has been more acute for the teaching of evolution and how and where (or whether) it can be presented in certain parts of the world.

Box 2. Reason versus Purpose.

Let us consider fire, a primordial source of energy. Fire can accomplish many things: one could read a book, keep warm or cook a nice meal. But with the same fire, one could burn the book (or the meal!). While there are reasons for every incident mentioned above (light or heat emitted from the fire), one cannot attribute the purpose of what happened, to the fire. The purpose of the fire is neither to read a book nor burn a book. Fire exists naturally, and light and heat are a natural consequence of its very chemical and physical existence – there is no need to invoke a purpose for the fire's existence.

Similarly, life's processes are a natural consequence of the existence of chemical interactions in a given physical environment. We can try to understand the reasons of 'why and how' for each of the processes, but not ascribe a purpose to them. To do so confuses reason with purpose and leads to the need for the existence of a desired end result and, therefore, a 'knower'. The statement "evolution is a tinkerer, not an engineer" [14] is true also for the chemical-origins and -evolution of life.

Depriving one side or the other of resources, or dismissing them entirely because of their beliefs, is not a healthy way to shape a productive debate and understanding in a democratic society, as

this leads only to recrimination by the others when they return to power. To avoid such societal consequences and to benefit from the positive impacts on society at large, both sides must understand what the other brings to the table in the endeavor to understand our origins on this earth. Scientists should continue their dialog by constructive engagement and by being frank about the current limitations of our scientific understanding of the chemical origins of life. By the same token, one must admit that the stance of dismissing every scientific fact is the equivalent of not wanting to know the reasons (*and not the purpose*) of the wonders of how life's chemistry originated on earth [15].

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