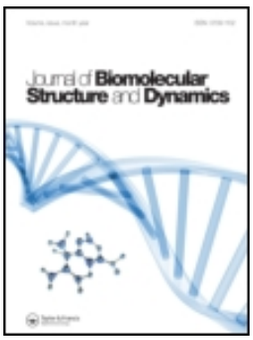

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Comment

Life = Self-Reproduction with Variations?

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Trifonov's paper (1) is a delightfully clever, objective and quantitative approach to defining life. Doing a linguistic analysis of 123 published definitions of life, Trifonov tabulates the words used in these definitions, to seek a consensus definition of life. This approach synthesizes some of the thinking and work of hundreds of scientists, and non-scientists as well.

Popa (2) contributes 90 of the definitions used by Trifonov. Popa's list of 90 definitions of life is an unusual one. Historically, it is impressive, running from 1855 to 2002. It is also very broad, including non-scientists such as Friedrich Engels ["No physiology is held to be scientific if it does not consider death an essential factor of life. . . . Life means dying." From *Dialectic of Nature* (3)] and unusual definitions, such as: "Life is a system which has subjectivity."

Popa himself says that his list of life's definitions serves only a general bibliographic purpose, and he cites four bibliographies and discussions of definitions of life that he says are more extensive than his own. Would any new insights be gained by doing a similar analysis of more rigorous bibliographies of the definitions of life, such as the four cited by Popa? Would it make sense to weight recent definitions of life more heavily than older definitions of life, given that we have learned much about life in recent decades? For example, in 1944, when Erwin Schroedinger wrote his book, *What is Life*? (4), he predicted that life will be found "working in a matter that cannot be reduced to the ordinary laws of physics."

"Life is Self-Reproduction with Variations." This consensus definition of life from Trifonov's paper (1) is reduced to only two concepts – Self-Reproduction and Variation. It contrasts with the often-used definition from a panel for NASA (National Aeronautics and Space Association): "Life is a chemical system capable of Darwinian evolution." (5) In a paper based on this definition, Benner (6) explains how 'reproduction with variation' is *not* an acceptable definition of life, because crystals grow, incorporating defects; and they reproduce when powdered and used to seed the growth of more crystals. What crystals lack is heritability, as in Darwinian evolution.

Perhaps a better definition of life would be, "Self-reproduction with *heritable* variations." In Popa's 90 definitions, I find only about 17 instances that might be related to heredity, by summing the following search results: heritable, heredity, hereditary, genetic, anagenetic, genome, mutation, and Darwinian. Perhaps there are other relevant search terms that I have not thought about, or perhaps 'heritability' is simply not a common concept for defining life.

What about viruses? There is good reason to argue that viruses are living parasites that are capable of reproduction but not self-reproduction. This classification

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of Viruses as Living is consistent with Trifonov's linguistic analysis, in which there are 25 instances of reproduce/reproduction/replication but only 5 instances of self-reproduction. Whether or not viruses are alive, they are clearly on a continuum between Living and Non-Living. The existence of such a continuum complicates the search for an all-purpose definition of life.

Do we need an all-purpose definition of life? On one hand, Dyson writes an entire book, *Origins of Life* (7), without explicitly defining life. Origins-of-life researchers do not necessarily need a definition of life. For example, when I write about the possible emergence of life between mica sheets (8), I am hypothesizing about a wide span of events from non-living to living. On the other hand, Hazen (9) says 'scientists crave an unambiguous definition of life.'

In response to the problem of defining life, another 2011 paper (10) uses quite a different approach. This paper rejects altogether attempts to *define* life, saying that the concept of life is 'impossible to define' and is thus a metaphysical concept instead of a scientific concept. The proposed solution is to use 'origin of evolution' instead of 'origin of life.' 'Evolution,' it says, 'may be defined by "as few as three conditions": [1] the emergence of "open non-equilibrium structural systems," [2] self-replication, and [3] the acquisition of "heritable structure/function properties." Self-replication is comparable to Trifonov's self-reproduction, though 'replication' is perhaps a worse term, because it is typically used to describe the copying of genetic material, which is only one element in the reproduction of an organism.

Origin of Evolution is especially problematic, given the use of 'evolution' in other contexts, such as cultural evolution, evolution of language, and evolution of the airplane. One is left with the question, Origin of Evolution of What? In fact, a new scientific subfield is the 'evolution of minerals'. (11) Life and minerals have co-evolved, according to Hazen, who states that the earth had ~1500 minerals before the origin of life, increasing to ~4300 minerals today, most of which may be the result of biochemical processes. The origin of evolution might thus be said to start when the biogeochemical processes started during the process of the origin of life.

One of the biggest needs for a definition of life is in the field of exobiology. What does one look for, when seeking evidence for life on Mars, for example? We know about life on earth, but what about life as we do *not* know it? Trifonov's paper is clearly useful for determining whether life has been created *in vitro*, as he describes in his paper, that cross-replicating ribozymes (12) evolve but do not replicate. Does Trifonov's paper help those who are searching for life on Mars? Probably not. Benner (6) addresses this problem by going beyond the definition of life and into a range of questions, such as, Does life require carbon? And, does life require water? Regarding the first question, the response is that carbon forms stronger bonds than silicon, but only about one-third stronger.

In summary, Trifonov's paper is not the final answer to the question of 'what is life'. It is, however, a brilliant approach to the problem of giving scientists and non-scientists an unambiguous definition of life.

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