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Comment

The Role of Logic and Insight in the Search for a Definition of Life

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Gerard A. J. M. Jagers op Akkerhuis

Center for Ecosystem Studies, Alterra,
Wageningen University,
6700 AA Wageningen, The Netherlands

In a recent paper Trifonov (1) has carried out a statistical analysis of the frequency of the vocabulary used in 123 existing definitions. The goal is to identify the most important words and to use these for phrasing a commonly acceptable definition of life. Trifonov arrives at the conclusion that "*(self-)reproduction and evolution form the minimal set for a concise and inclusive definition: Life is self-reproduction with variations*". Also a more lengthy definition is presented: "*Life is metabolizing material informational system with ability to self-reproduction with changes (evolution), which requires energy and suitable environment*". Trifonov's work is part of the important and long standing quest in science and philosophy for a commonly acceptable definition of life (2-7). While reading Trifonov's publication a few questions came to my mind.

The first question is why the author suggests using a vocabulary method instead of insight when defining life? I am worried that although the use of vocabularies may represent a proper tool for identifying keywords and the like, the methodology seems fundamentally inappropriate for suggesting definitions. Would any definition process not require the logical integration of scientific insights and thorough testing by confronting them with 'difficult cases'? It is not clear to me how vocabulary studies meet such criteria, because the ranking of words according to frequencies seems blind to the underlying logical relationships.

My second question involves some methodological aspects of using vocabulary analyses for creating definitions.

1. Can lists of definitions reflect recent developments? Innovative insights will in general require several years to become generally referenced in the literature. In addition, recent studies will generally relate to advanced scientific insights and may not use 'conventional' wording. Would this effect potentially bias lists of definitions towards past and potentially aged insights?

2. Has the list of definitions been checked for dependence of information? It is general practice to use 'old masters' as a basis when improving definitions. Such practices are likely to cause biases towards certain words in definitions inspired by the most influential examples.

3. How to extract meaningful results if vocabulary studies take words literally? Definitions frequently originate from different 'worldviews'. As a consequence, the meaning of the words may differ between definitions. For example, some people use life for indicating all ecosystems

Corresponding author:
Gerard A. J. M. Jagers op Akkerhuis
E-mail: gerard.jagers@wur.nl
www.hypercycle.nl

and organisms on earth ('life' on earth), while others think of the length of the period between birth and death (he had a long 'life') or of daily existence (my 'life' as a teenager). How has the study accounted for the summation of words with different meanings?

4. Would the vocabulary method recognize the confusion that presently exists with respect to the word 'life'? Many well-known definitions of 'life' actually refer to concepts related to 'living', for example metabolism, activity, reproduction, *etc*. As has been suggested by the author of this comment, it may be profitable to science when life would be used to describe organisation, while living is used in relation to the dynamics of those organisations representing life. This distinction was already recognized by the famous Société de Biologie in Paris (8). Examining frozen or dried bacteria, the Society concluded that the potential to revive an anabiotic stage is an inherent aspect of the organisation of the material of which the object consists and that it is equally persistent as the molecular state of the matter forming the system. The society concluded: "La vie, c'est l'organisation en action". In other words, living refers to the dynamics of organization(s) that represent life. How would vocabulary studies assist in identifying which organisation(s) represent life?

5. How do vocabulary studies distinguish between 'appropriate' and 'inappropriate' definitions? Without such distinction, the most popular concepts will always be partly associated with inappropriate definitions. How can statistics on vocabulary circumvent the problem of deciding about the 'correctness' of a given definition?

My third question involves the testing of definitions based on vocabulary analysis. Any commonly acceptable definition must be able to deal with 'difficult cases'. What happens if we undertake this exercise using the above definitions? How about a sterilized cat? If I understand the above definitions well, this cat would not be a living being because it cannot 'self-reproduce'. Even a normal fertile cat is a problem. It cannot 'self'-reproduce, because it needs the male's sperm. And a frozen bacterium? While being frozen, it is neither metabolically active nor can it reproduce. Not life according to the above definitions. But a frozen bacterium still possesses the structure of life, which can be demonstrated when it resumes living activity after being thawed. How to value the above definitions in the light of these results?

In relation to the above questions, I would like to invite the author to take an interest in a recently developed framework that uses the evolution of complexity as a basis for defining life. In order to analyse the organisation in nature in a stringent way, the author of this comment developed the Operator Hierarchy (9, 10). This hierarchy represents a 'ladder' ranking all types of physical particles and types of organisms, generically indicated as 'operators', according to discrete transitions in the complexity of their organisation. As has been advocated in a previous publication about the definition of life (11), this ladder offers a fundamental basis for defining life as a common property of all types of entities on the ladder (the operators) that are equally or more complex than the cellular operator (bacteria s.l.). From this point of view, talking about life implies a focus on the *presence* of the level-defining organisation in selected operators. As long as the level-defining organisation is present, the entity represents life. And when an entity that represents life is dynamically active, it is living. Consequently, death implies the *loss* of the level-defining organisation. Biologists generally consider all the operators with a minimum complexity of the (bacterial/prokaryotic) cell as organisms. The complexity ladder of the operator hierarchy thus offers an underlying logic connecting the concepts of life and the organism. The ladder therewith solves an old circularity problem that occurs when life is referred to as a property of organisms, while organisms are defined as living beings. As has been discussed in (11), the operator based definition of life deals without problems with a broad range of 'difficult cases'.

Assuming that defining life requires the logical integration of scientific insights and thorough testing of the results by confronting them with 'difficult cases' I was inspired to a range of questions about specific aspects of the use of vocabulary study for defining life. I find it worrisome that the method seems not to invoke insight and that the resulting definitions seem to have problems with simple test cases. I hope the author can take away my worries in his response.

References

1. E. N. Trifonov. *J Biomol Struct Dyn 29*, 259-266 (2011).
2. R. Popa. Between necessity and probability. Searching for the definition and the origin of life. Advances in Astrobiology and Biogeophysics. Springer (2003).
3. D. E. Koshland, Jr. *Science 295*, 2215-2216 (2002).
4. C. Emmeche. *Ultimate Reality and Meaning 20*, 244-264 (1997).
5. M. A. Bedau. What is life. In: Sarkar, S. and Plutynski, A. (Eds.), A companion to the philosophy of biology, pp. 455-603 (2007).
6. C. E. Cleland and C. F. Chyba. Does 'life' have a definition? In: Planets and Life: The Emerging Science of Astrobiology, Woodruff, T., Sullivan, I. I. I., and Baross, J. A. (Eds.), Cambridge University Press (2007).
7. J. M. Maynard Smith and E. Szathmáry. The origins of life. Oxford University Press, Oxford (1999).
8. P. Broca. *Mém Soc Biol 3me Série* II, 1-139 (1860).
9. G. A. J. M. Jagers op Akkerhuis and N. M. van Straalen. *World Futures, the Journal of General Evolution 53*, 329-345 (1999).
10. G. A. J. M. Jagers op Akkerhuis. The operator hierarchy, a chain of closures linking matter, life and artificial intelligence. PhD thesis, Raboud University, The Netherlands (2010).
11. G. A. J. M. Jagers op Akkerhuis. *Found Sci 15*, 245-262 (2010).