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On the applicability of the Aristotelian principles to the definition of life

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Abstract: Despite numerous attempts, we still do not have a satisfactory definition of life. It is generally accepted that one of the essential features of life is the ability of an organism to reproduce. This implies that mules, workers ants, and other sterile individuals are not alive. To correct this apparent problem, we suggest that life should be defined in two ways. First, we define life as a phenomenon, for which the reproduction of some, but not all, individuals is essential. Second, we define life as a set of characteristics of an individual organism, among which reproduction is not essential. We explore Aristotle's classifications of things that exist, in which he placed individual living beings as primary substances, above their species and genera, which are considered secondary substances. The definition of life as a phenomenon needs to link life to its origins. Life presumably emerged from abiotic matter via chemical evolution. We have examined Aristotle's concept of change in which potentiality goes to actuality, and its variant, Kauffman's concept of 'adjacent possible', for their possible application in prebiotic chemical evolution. We have found that these principles are somewhat useful in the back-engineering process, but that they have very little predictive value. We have also considered whether viruses should be considered alive, and have pointed to the need for astrobiology to include viruses in its studies.

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Key words: Aristotle on life, definitions of life, potentiality to actuality change, reproduction as a criterion for life, the role of viruses in astrobiology.

Introduction

A preliminary version of this paper was published in a conference proceedings (Kolb 2006). This is an extended and revised form of the paper, in which a new section on viruses has been added. In this paper we first present selected definitions of life and notice that there is no universally accepted definition of life. Many of the definitions we cite successfully capture some of the life's essential characteristics. A combination of various definitions could be used for defining life on Earth and as a guide in the search for life elsewhere. Many definitions list reproduction as a key requirement for the system to be alive. This requirement causes controversy, since it does not recognize various sterile organisms as being alive. We explore this controversy and suggest a way of solving it by defining life in two ways: life as a phenomenon, and life as a set of characteristics of an individual organism. Next, we consider defining life by a minimal set of its characteristics. We note that such an approach may be useful in the search for the primitive, but not for highly developed extraterrestrial life. The resolution of this problem is that multiple definitions of life are needed to address different potential cases. We examine Aristotle's classification of things that exist, in which he placed individual living beings as primary substances above their species and genera, which are secondary substances. We utilize his ideas to argue that for understanding life sometimes more characteristics of life are better than less. Life as a phenomenon cannot be understood unless we understand its origins. We address this problem, and briefly summarize the most recent developments in the study of life's origins. One of the guiding principles for chemical evolution could be Aristotle's principle of potentiality to actuality change (Aristotle 1961, 1979) and the related principle of adjacent possible by Kauffman (Kauffman 2000). We explore this approach and find that it is not very useful for this particular application. We first provide the necessary background.

Background

On various definitions of life

The definition of life is very important for understanding life on Earth and also in the search for extraterrestrial life. The latter, if found, may not have the same biology or morphology as ours. We are thus in need of a definition of life which is not focused on geocentric details, but rather on the essential features of life, as we understand it. There is no universally accepted definition of life on Earth. Various researchers have given different definitions of life and each individual definition brought up some important features of life. We give here some examples from a recent comprehensive publication on the subject (Popa 2004) to illustrate the point and to provide the reader with the background on this subject:

> 'Life means dying.' (Engels)
>
> 'The three properties, mutability, self-duplication and heterocatalysis comprise a necessary and sufficient definition of living matter' and 'Life is synonymous with the possession of genetic properties. Any system with the capacity to mutate freely and to reproduce its mutation must almost inevitably evolve in direction that will ensure its preservation.' (Horowitz)
>
> Life has the 'ability to store and process the information necessary for its own reproduction.' (Gatlin)
>
> 'A living system is an open system that is self-replicating, self-regulating, and feeds on energy from the environment.' (Sattler)
>
> 'We regard as alive any population of entities which has the properties of multiplication, heredity and variation.' (Maynard-Smith)
>
> 'The sole distinguishing feature, and therefore the defining characteristic, of a living organism is that it is the transient material support of an organization with the property of survival.' (Mercer)
>
> 'Life is an expected, collectively self-organized property of catalytic polymers.' (Kauffman)
>
> 'Life is a self-sustained chemical system capable of undergoing Darwinian evolution.' (Joyce; accepted as NASA's working definition of life)
>
> '... consider the origin of life as a sequence of "emergent" events, each of which adds to molecular complexity and order.' (Hazen)
>
> 'A living system occupies a finite domain, has structure, performs according to an unknown purpose, and reproduces itself.' (Sertorio & Tinetti)
>
> 'Ignoring the misgivings of those few life-origin theorists with "mule" fixations, life is the "symphony" of dynamic and highly integrated algorithmic processes which yield homeostatic metabolism, development, growth, and reproduction.' (Abel)
>
> 'Life is the process of existence of open non-equilibrium complete systems, which are composed of carbon-based polymers and are able to self-reproduce and evolve on the basis of template synthesis of their polymer components.' (Altstein)
>
> 'Any living system must comprise four distinct functions: 1. Increase of complexity; 2. directing the trends of increased complexity; 3. preserving complexity; and 4. recruiting and extracting the free energy needed to drive the three preceding motions.' (Anbar)
>
> 'Life is defined as a system capable of 1. self-organization; 2. self-replication; 3. evolution through mutation; 4. metabolism and 5. concentrative encapsulation.' (Arrhenius)
>
> 'Life is a chemical system capable of transferring its molecular information independently (self-reproduction) and also making some accidental errors to allow the system to evolve (evolution).' (Brack)
>
> 'The functions, which are called life, are: metabolism, growth, and reproduction with stability through generations.' (Guimaraes)
>
> 'Life is metabolism and proliferation.' (Keszthelyi)
>
> 'Life is a new quality brought upon an organic chemical system by a dialectic change resulting from an increase in the quantity of complexity of the system. This new quality is characterized by the ability of temporal self-maintenance and self-preservation.' (Kolb)
>
> One of the characteristics of life is that 'it must be able to sense the environment and respond to it, i.e. it must be able to synthesize active molecules capable of utilizing materials it encounters in the environment.' (Lacey *et al.*)
>
> 'From a chemical point of view, life is a complex autocatalytic process. This means that the end products of the chemical reactions in a living cell (nucleic acids, polypeptides and proteins, oligo- and polysaccharides) catalyze their own formation. From a thermodynamic point of view, life is a mechanism which uses complex processes to decrease entropy.' (Marko)
>
> 'Life is continuous assimilation, transformation and rearrangement of molecules as per an in-built program in the living system so as to perpetuate the system.' (Nair)
>
> 'Any definition of life that is useful must be measurable. We must define life in terms that can be turned into measurables, and then turn these into a strategy that can be used to search for life. So what are these? a. structures, b. chemistry, c. replication with fidelity and d. evolution.' (Nealson)
>
> Living systems are those that are 'able to replicate structurally distinct copies of themselves from an instructional code perpetuated indefinitely through time despite the demise of the individual carriers through which it is transmitted.' (Schulze-Makuch *et al.*)

We can see that most of these definitions capture the life's essentials, and some are also practical. However, there is no broadly accepted definition of life at this time.

Statement of the problems with some current definitions of life

On the problems with the Darwinian definition of life

A recent influential paper on defining life (Cleland & Chyba 2002) states that many proposed definitions of life suffer problems, often in the form of counter examples. In some cases the proposed criteria for life are also valid for systems that are not alive, such as fire. One then needs to discount such counter-examples in order to save the validity of the proposed criteria. Such a process is not scientifically acceptable. The authors correctly state 'Claiming this or that counter-example to be an "unimportant" exception merely implicitly invokes further criteria beyond those ostensibly comprising the definition'. They discuss the chemical Darwinian definition of life, cited also above as NASA's definition 'Life is a self-sustained chemical system capable of undergoing chemical evolution' (Joyce, cited in Popa 2004), and note some of its problems. Thus, living sterile organisms such as mules cannot reproduce, so they are 'not capable of Darwinian evolution'. Although it is intuitively clear that living mules are alive, based on this Darwinian definition they are not. This is a clear discrepancy which needs to be resolved. The authors make the following statement: 'Trying to diffuse this dilemma by dividing our subject into two categories, "life" and "living entities" needs to be explained as more than an *ad hoc* effort to protect a particular definition'. The first objective of our paper is to show that such division into life and living entities is essential for defining life, and should not be looked at as a procedure for saving faulty definitions. Rather than considering the interest in the mule problem as a 'mule fixation' (see Abel's definition of life in the previous section), the mule case needs to be explained not as an exception but as a part of the definition of life. There are other sterile organisms, such as worker ants, for example. The problem of classifying sterile individuals as alive may be solved if we define life in two ways: life as a phenomenon, and life as a set of characteristics of an individual organism. We will consider this point in greater detail later in this paper.

Fleischaker (1990) brought up more problems with the Darwinian definition of life. A weakness of the definition of the living that includes 'the capacity to evolve' is 'doubly problematic because such a definition requires not only the future state of a single system but other systems as well. Individual living systems do not evolve.' There is also a problem with using implied future states, such as 'capacity to grow', 'capability to reproduce', etc. This becomes even more important in the search for life elsewhere. How long should we wait for the results of growth or reproduction? (Fleischaker 1990).

On the problems with the definitions of life that are too basic

The above selection of the definitions of life (Popa 2004), which is comprehensive and representative of various views, shows that most definitions try to capture life's essentials that are applicable to *all* living organisms. Such an approach, by necessity, considers only *the lowest common denominator of life*. It thus does not consider intelligence as one of life's characteristics, since it is not common to all organisms. This definitely creates problems in the search for extraterrestrial intelligent life. For the latter search we do need to include intelligence as one of life's characteristics. However, if we search for very primitive life, this inclusion is not necessary. It appears that we need different working definitions of life's characteristics, depending on what our objectives are.

Two ways of defining life: life as a phenomenon, and life as a set of characteristics of an individual

There are two different ways of defining life: life as a phenomenon, and life as a property of a living individual.

Life as a phenomenon

Life is a continuous phenomenon, which is carried on by a series of individual living organisms which themselves perish within a time period that is much shorter than that of the phenomenon of life. Life presumably emerged from inorganic matter over 3.5 billion years ago (Bennet *et al.* 2003). Life has continued to exist from that time on. For life as a phenomenon to continue, reproduction of the individual organisms is essential, although not every single individual has to reproduce. Reproduction is indeed a key feature of life as a phenomenon. This view is also addressed in some definitions from Popa (2004), given above, and repeated here: life is able to perpetuate 'indefinitely through time despite the demise of the individual carriers through which it is transmitted' (Schulze-Makuch *et al.*, cited in Popa 2004), and 'We regard as alive any population of entities which has the properties of multiplication, heredity and variation' (Maynard-Smith, cited in Popa 2004). In the latter definition, life is associated with the population of the entities, and not an individual. Fleischaker also states that life is 'a single collective phenomenon that exists over time' (Fleischaker 1990).

Definition of life as a phenomenon has to include its beginnings

One of the problems in defining life as a phenomenon is that we do not fully understand how it evolved from the abiotic matter to the RNA world and further to the Last Common Universal Ancestor (LUCA) (Forterre 2006). Cleland and Chyba have already pointed out that a complete, theoretical definition of life is not possible at this time because of this problem (Cleland & Chyba 2002). However, there has been recent progress in this field, and such a definition may become possible in the near future. Progress has been made in elucidating possible pathways from the abiotic matter to the LUCA. These include the emergence of RNA as an early genetic material and catalyst, in a so-called RNA world (Orgel 2004), and the emergence of hypercycles as cooperative entities (Eigen 1981; Eigen & Schuster 1982). The transition from an RNA world to LUCA involved the RNA to DNA transition and may have been facilitated by viruses (Forterre 2006; Whitfield 2006; Zimmer 2006). Viruses may have had a profound role in the chemical and biological evolution, a role that has only recently been recognized (Suhre *et al.* 2005; Forterre 2006; Siebert 2006; Whitfield 2006; Zimmer 2006). Life as we know it started from LUCA (Forterre 2006). Various analyses of genetic materials and enzymes of living species support this hypothesis. The hypothesis of common ancestry has also been tested theoretically (Sober & Steel 2002).

Life as a set of characteristics of an individual

When we consider the life of an individual organism, we quickly realize that reproduction is not the key feature that makes it alive. The cases of sterile organisms were discussed earlier in this paper. In addition to the arguments presented, even among the organisms that have the potential for reproduction, reproduction may not happen. This would be the case if a female does not find a male, or if the organism is not in a fertile stage of its life, such as babies or old people, among other examples. To consider such cases as alive, we need to apply a criterion for life other than reproduction. Margulis and Sagan stated that autopoiesis should be such a criterion:

> 'Reproduction is not nearly as fundamental a characteristic of life, as is autopoiesis. Consider: the mule, offspring of a donkey and a horse, cannot 'replicate'. It is sterile, but it metabolizes with as much vigor as either of its parents; autopoietic, it is alive. Closer to home, humans who no longer, never could, or simply choose not to reproduce cannot be relegated by the strained tidiness of biological definition, to the realm of the nonliving. They too are alive.' (Margulis & Sagan 1995)

However, the autopoiesis has its own problems as a sole criterion for life, when it comes to viruses.

Aristotle on life and some astrobiological applications of his ideas

Aristotle's list of characteristic life-functions

According to Aristotle scholar Gareth Matthews, Aristotle seems to have been the first thinker to consider a living thing by reference to a list of characteristic 'life-functions' (Matthews 1996). The list varies in his texts, but it is usually a selection from the following: self-nutrition, growth, decay, reproduction, appetite, sensation or perception, self-motion, and thinking (Matthews 1996). For example, in 'De Anima', Aristotle states:

> 'Some natural bodies are alive and some are not – by "life" I mean self-nourishment, growth, and decay' (Cohen *et al.* 2000). Aristotle says that it is sufficient that a living being is able to perform one of these life-functions (Matthews 1996).

Matthews points to the contrast with the modern approaches, which are much more restrictive. The modern approaches use the following criteria: (a) anything that can perform all of the specified life-functions is alive; (b) anything that cannot perform any of them is not alive; (c) anything that can perform some, but not all, may be alive or not (Matthews 1996). Matthews considers reproduction as one of the characteristic 'life-functions' that Aristotle described and states:

> 'Obviously some individual organisms, though certainly alive, are too immature to reproduce; others are too old. Still others are sterile throughout their full lives, either because of an individual defect, or because, as is the case with mules, their very kind is sterile. So being able to reproduce is necessary neither for an individual organism to be a living thing, nor even for a kind of organism to be a kind of living thing.' (Matthews 1996).

We came up pretty much with the same conclusion, as described previously.

Verification of life via some of its selected characteristics

For a definition of life to be practical, especially in terms of NASA's goal of searching for extraterrestrial life, an operational definition is desired (Fleischaker 1990). We need to select several of life's properties against which we can check to verify the presence of life. Metabolic properties were used to design the Viking missions' life-detection experiments (gas exchange, pyrolytic release, and the labelled release experiments) (DiGregorio *et al.* 1997; Goldsmith 1997). However, interpretation of the Viking experiments has created controversy (DiGregorio *et al.* 1997). An alternative list of life's properties has not been agreed upon.

When considering applications of Aristotle's, or a more contemporary, list of the characteristic life functions to the search for extraterrestrial life, our mind has to be open and free from geocentric contamination. Life elsewhere may include the systems that are living on the surfaces. Such systems may not have membranes and may not show a distinct morphology. The metabolism and/or reproduction of these extraterrestrial organisms may be extremely slow and not observable during the experiments that we design to verify life. We may have to define life via a single characteristic, just as Aristotle thought was possible, rather than via an extensive list of characteristics, as we are trying to do at this time. We need to look at every single property that we can observe and not commit ourselves to an extensive list of life's characteristics on Earth.

On Aristotle's definition of primary substance

In his 'Categories' Aristotle developed a theory of classification of existing things (Aristotle 1963). He introduced the notion of a substance, which is a fundamental ingredient of reality. He proposed ten categories: substance, quantity, quality, relation, place, time, position, state, action, and affection. Substances may be primary or secondary. His examples of primary substances are an individual man or a horse. He terms the species such as 'men' and the genus such as 'animal' as secondary substances. It is fascinating that Aristotle placed an individual living organism higher in the classification than its species or genera. He stated that the individual substance does not lose its qualities as it becomes part of a species and genera. However, this is a one-way road, since the converse is not true. The species and genera are, in today's language, information poor as compared with the individual. Aristotle concluded that manhood, which would be a generic description of the properties of all men in the species, is not contained in the primary substance, which is an individual man. General is not present in specific; abstract is not present in the real. This approach places the individual above its species and points to the uniqueness of the individual. More on Aristotle's views on substances are found in his 'Metaphysics', Book Z, and also Book H (Aristotle 1979). While Aristotle's concept of substances changed somewhat, for our purposes his original view, from 'Categories', is most applicable. Aristotle's view of the primary substance acknowledges that an individual is unique. In 'Categories' he also stated that the individual substances cannot be ranked. We believe that this principle is still valid. Each individual living organism has its unique place in the Universe. This view assigns the utmost importance to an individual living organism, in contrast with some contemporary reductionist views such that an individual organism is just a carrier of the selfish genes (Dawkins 1989).

Aristotle's potentiality to actuality transition as related to Kauffman's adjacent possible

What is the mechanism by which chemical evolution builds diverse and complex structures that eventually lead to life? As a part of the answer to this question Kauffman postulated the concept of 'adjacent possible', in which the chemical system explores the environment at its boundary (Kauffman 2000). Some reactions become possible as the boundary moves into the environment, where these possibilities become actualized. This concept is related to Aristotle's potentiality to actuality transition, explained in his 'Metaphysics', Book H (Aristotle 1979), and 'Physics', Book III.1 (Aristotle 1961). Aristotle defines change by his concepts of actuality and potentiality. A common interpretation of these concepts is that an object undergoing change actualizes a potentiality that it already has even before it changes. Aristotle gives an example of building a house from bricks and boards. As the house is built the potentiality of the bricks and boards eventually transforms to the actuality of the completed home. It is interesting that the organizational factor is critical here. The bricks and boards can be arranged in many ways, but only a specific arrangement will lead to the actuality of the house. This concept of change, as well as Kauffman's variant, works well in a back-engineering manner. If we know the structure of a system, we can back-engineer the steps by which the system was put together from its parts. In Kauffman's case, we initially look at a set of molecules that currently exist. We look at the chemical system as a specific arrangement of atoms and molecules. We can then try to trace back the steps by which the system was formed by the synthesis from some chemical precursors. The synthesis is a process in which the chemical elements and molecules become arranged in a specific manner. If we do not have enough data on those steps, we can propose some hypothetical alternatives. In prebiotic chemistry, for example, we can back-engineer the chemical steps that would produce the RNA from nucleosides and phosphate. Such back-engineering appears quite useful and gives us the impression that we understand the process of building chemical complexity. This, however, may be too optimistic. The back-engineering of prebiotic reactions may become too speculative, since we do not have much historic data on the chemical evolution steps. We fill in the gaps with the reactions and pathways that we think may have happened, but the early systems may have undergone different reaction sequences and may have utilized different chemical intermediates. We should note that the problem of back-engineering also exists in biological evolution (Levins & Lewontin 1985), but is less pronounced owing to the availability of historical records for biological evolution (e.g. fossils).

There is also a problem in predicting the pathways in chemical evolution. Let us suppose that the RNA was synthesized in the prebiotic system. What then? Can we look at the RNA and predict what will become of it? If we did not know in advance that RNA evolved to DNA, we would not be able to predict this outcome just by looking at the structure of RNA. There are numerous possibilities, and various pathways from RNA to DNA, and from RNA to many other substances. There are no specific laws to point us to any particular outcome other than the general laws of chemistry, which may favour some possibilities over others or exclude certain possibilities altogether, and some general behaviour of complex systems, such as Kauffman's emergence of order at the edge of the chaos (Kauffman 2000). Adding to this problem is our limited knowledge of the chemical composition, energy content, and other characteristics of the primordial environment (Bennett *et al.* 2003). Such factors also influence the prediction of the outcome of the chemical transformation. Therefore, the principle of potentiality to actuality transformation and Kauffman's variant of it has very little, if any, predictive value at the current level of knowledge.

Stretching the boundaries of life: are viruses alive?

According to NASA's definition of life, viruses would not be considered alive, since they are not capable of self-reproduction. Viruses can reproduce only in host cells, by utilizing the host cell's metabolic apparatus. It was proposed that viruses are in the twilight of the life zone (Villarreal 2004, 2005), reminiscent of the transition zone for life that we have proposed (Perry & Kolb 2004). The latest research on viruses reveals that they are ancient and have a prominent role in the evolution of life (Suhre *et al.* 2005; Forterre 2006; Siebert 2006; Whitfield 2006; Zimmer 2006).

The viruses undergo what we term 'an assisted reproduction'. The viral genetic material utilizes the host cell's metabolic engine to reproduce itself. We believe that the assisted reproduction model needs to be considered by astrobiologists, especially when we are looking for life elsewhere in the Universe. In some extraterrestrial environments there may be metabolic sacs available which would assist the reproduction of viruses or virus-like materials. Such an arrangement could have evolved as being advantageous in particular environments. The viruses on Earth can reproduce in 'metabolic sacs', namely the cytoplasm of the cells that are 'dead' by virtue of having their nuclear DNA destroyed (Villarreal 2004, 2005).

We suggest that the role of viruses in the possible interplanetary transport of bacteria needs to be explored. A relevant example involves cyanobacteria, which are often considered capable of colonizing Mars, and cyanophages, the viruses that infect them. When cyanobacteria are treated with a large dose of the UV light, their enzyme that functions at the photosynthetic centre may be destroyed. The cyanobacteria without the functional photosynthesis would die. However, the cyanophages encode their own version of the cyanobacterial photosynthesis enzymes, which is much more resistant to the UV radiation, and which can substitute for the destroyed enzyme of the host (Villarreal 2004, 2005). Based on this we suggest that the cyanophage-infected cyanobacteria may be more likely to survive the interplanetary transport than the cyanobacteria alone. We suggest that another feature of viruses, their ability to reassemble from parts, is also relevant to astrobiology (McLain & Spendlove 1966; Villarreal 2004, 2005). When cyanophages are destroyed by UV light they can sometimes regain form and function, via the so-called multiplicity reactivation (McLain & Spendlove 1966). There may be some disassembly during the interplanetary transport, but it may be followed by an assembly upon arrival to a less hostile environmental niche.

Based on the behaviour and importance of viruses for astrobiology, we believe that they should be included in the search for extraterrestrial life. On what ground, however, would we consider them alive?

Villarreal (2004, 2005) introduced an interesting argument in considering whether viruses are alive. He stated that viruses fail to reach a critical complexity that we usually associate with life, but that they still are more than an inert matter, and thus they are on the verge of life. We could thus focus on critical complexity as one of the criteria for the transition to life. This was also expressed in the definition of life by Kolb (Kolb 2002, 2005; Popa 2004). Villarreal also offered a view that 'a living entity is in a state bounded by birth and death' (Villarreal 2004). This criterion could also be added to the criteria for life. We believe that the reassembly of viruses after their initial destruction, as in the example of the cyanophages, may extend the definition of life beyond the boundaries of birth and death, should viruses be considered alive. The reactivation of viruses upon the assembly of their parts also represents an experimental model for the emergence of complex systems by the quantity-to-quality transition (Kolb 2005).

Villarreal drew a comparison between the seed and the virus:

> 'A seed may not be considered alive. Yet it has a potential for life, and it may be destroyed. In this regard, viruses resemble seeds more than they do live cells. They have a certain potential, which can be snuffed out, but they do not attain the more autonomous state of life.' (Villarreal 2004).

Based on this, the potentiality itself is not a sufficient condition for life.

Are viruses alive or not? We believe that they are indeed in the twilight zone of life, in the transition zone, when the pre-LUCA was just starting to form.

Summary and conclusions

Despite numerous attempts, we still do not have a satisfactory definition of life. It is generally accepted that one of the essential features of life is the ability of an organism to reproduce. This implies that mules, workers ants, and other sterile individuals are not alive. To correct this apparent problem, we have suggested that life should be defined in two ways. In the first way life is defined as a phenomenon, for which the reproduction of some, but not all individuals, is essential. In the second way, life is defined as a set of characteristics of an individual organism, among which the reproduction is not essential. We have explored Aristotle's classifications of things that exist, in which he placed individual living beings as primary substances, above their species and genera which are secondary substances. The definition of life as a phenomenon needs to link life to its origins. Life presumably emerged from abiotic matter via chemical evolution. We have examined Aristotle's concept of change in which potentiality goes to actuality, and its variant, Kauffman's concept of adjacent possible, for their possible application to prebiotic chemical evolution. We have found that these principles are somewhat useful in the back-engineering process, but that they have very little predictive value. We also considered whether viruses should be considered alive and have pointed to the need for astrobiology to include viruses in future studies.

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Dedication

I like to think about the old Greek's ideas which have persisted throughout the centuries. Here I am, going back to Aristotle for the wisdom, like many generations of humans before me. This paper is dedicated to the memory of my maternal grandmother, Maria Lopičić, neé Salambros, who was part Greek. Her intellectual brilliance was like the sun of Plato.

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