Life Sciences in Space Research 17 (2018) 15–22

Contents lists available at ScienceDirect

Life Sciences in Space Research

journal homepage: www.elsevier.com/locate/lssr

Opinion/Position paper

If technological intelligent extraterrestrials exist, what biological traits are *de rigueur*☆

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ARTICLE INFO

Keywords:
Extraterrestrial
Intelligent
Life
Biological
Traits
Required

ABSTRACT

If extraterrestrials exist in the depths of cosmic space, and are capable of interstellar communications, even space flight, there is no requirement that they be humanoid in form. However, certain humanoid capabilities would be advantageous for tool fashioning and critical to operating space craft as well as functioning under the disparate extreme conditions under which they may be forced to operate. They would have to be "gas breathing". The reasonable assumption that life based upon the same elements as Earth life requiring water stems from the unique properties of water that no other similar low molecular weight nonmetal hydride offers. Only water offers the diversity of chemical properties and reactivity, including the existence of the three common physical states within a limited temperature range of service to life, avoiding the issues presented by any alternatives. They must, like us, possess a large, abstract-thinking brain, and probably possess at least all the fundamental senses that humankind possess. They would also be carbon-based life, using oxygen as the electron sink of their biochemistry for the reasons considered. They most likely are homeothermic as us, though they may not necessarily be mammalian as we are. Their biochemistry could differ some from ours, perhaps presenting contact hazards for both species as discussed.

1. Introduction

The subject of extraterrestrial intelligent, ETI, life is a captivating topic of scientific as well as popular interest. One study asserts that there may be 10^9 Earth-like planets in our galaxy alone; perhaps 10^{20} in the 10^{13} Mpc^3 Hubble Volume (Behroozi and Peeples, 2015). Several authors have considered Darwinian evolution, conditions of the Earth and its environment, and the anthropic principle in light of biological convergence in speculations on intelligent life arising (Henderson, 1913; Bylinsky, 1981; Russell and Sequin, 1982; Davies, 1995a; Morris, 2003; Denton, 1998).

Additionally critical, though intelligence and perhaps more so cognition are pre-requisites for technology development, it also requires a cultural development as well. There must be a means for amassing not only the knowledge, but to pass it on to future generations for further advancement in knowledge and technological development. A cultural development leads to specialization, which further enhances technological and knowledge advance.

The propensity for the emergence of life is suggested by the laws of physics as stated by Davies (1995b).

> "The laws of physics have the remarkable property that they encourage matter and energy to evolve spontaneously from simple initial states towards highly complex states (such as living or conscious systems). This general self-organizing tendency in nature suggests that the emergence of life is a universal phenomenon, rather than a miracle or a highly improbable accident."

However, despite this self-organizing property, if we take all the known ingredients in the relative concentrations and quantities of the best characterized cell system, mix them in a vessel, no such phenomenon as life springs forth. Is it something we are missing or doing wrong, or is it time, lots of time for this self-organizing property to take hold? Additionally, the traits of intelligence such as language, mathematical ability do not themselves seem to derive from any Darwinian basis. They are "a world away from survival 'in the jungle'. (Davies, 1995c)" However, they are critical to technological advance.

Henderson set the stage for environment's role in life's emergence and advance (Henderson, 1913). He argues for the "fitness" of the environment and he focused on several features of earth and other planetary bodies. Water and all of its unique physico-chemical properties, carbonic acid, and the physico-chemical properties of oceans were considered at length for the interplay of their physical and chemical properties necessary for the environmental conditions for supporting life on Earth.

Convergence in biology essentially concerns itself with common

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☆ No grant sources funded this research.
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https://doi.org/10.1016/j.lssr.2018.01.004
Received 7 November 2017; Received in revised form 8 January 2018; Accepted 20 January 2018
2214-5524/

motifs arising among different biological systems. This includes bipedalism, bilateral symmetry, similar helical arrangements in transport proteins, or the human eye versus the squid eye among other examples considered by Morris (2003). It suggests that in issues of intelligent life, similar characteristics of humans would not be unprecedented in an intelligent, cognitive being on some other far-flung planet. Interestingly, Russell and Sequin in 1982 published a monograph under the auspices of the National Museum of Natural Sciences, the National Museums of Canada that extrapolated the body structure of a Cretaceous theropod *Stenonychosaurus inequalis* to a theorized descendant, bipedal, dinosauroid (Russell and Sequin, 1982). What is interesting is that the humanoid body morphology is the center-piece of such a speculative evolution, had the dinosaurians not perished via extinction.

What ETIs may look like is not as speculative as it may seem. Technological prowess and space exploration abilities will require certain biological traits on the part of the ETI, and render certain other traits unworkable from both a biological and a technically operational standpoint. Searches for the telltale signs of such are perhaps hallmarked by the activities of the Search for Extraterrestrial Intelligence (SETI, 2015). If intelligent life other than us, exists in the cosmos, it must be multicellular beings with a brain capacity and ability for abstract thought, mathematics and the ability to fashion and use complex tools, and necessarily, language as well. These abilities, among others, are critical requirements as without them, there can be no intraspecies communications and virtually nothing else beyond subsistence existence. Additionally, they would have to be gaseous atmosphere dwelling creatures, rather than liquid media for very compelling reasons (below). What is of interest here is the biological nature of any ETIs that may exist out in the vast depths of the cosmos who have the biological and technological development to engage in electromagnetic communications.

2. ETI chemistry

2.1. Elements of life

If ETI life exists elsewhere, it would have tracked the Universe's carbon production and likely began its rise within the past three billions years (Livio, 1999). On Earth, life is constructed around the six critically important and biologically common elements of carbon, hydrogen [H-1], nitrogen [N–14], oxygen [O-16], sulfur [S-32] and phosphorus [P-31], and a smattering of various A- and B-group metals. On Earth, phosphorus is the critical element in bio-energy transfer and activation processes in the form of phosphate [PO_4^{3-}] such as ATP or creatine phosphate among others (Berg et al., 2015a). In a 2010 paper, researchers reportedly find a bacterium that utilizes arsenic, another group VA element like phosphorus, forming a phosphate analog, arsenate [AsO_4^{3-}] (Wolfe-Simon et al., 2010). The usual phosphorylation processes common to organisms on Earth are prevented if arsenate and arsenite are present (Devlin, 1986). ETI biochemistry may tract similar to us, but on the other hand, could anything replace carbon, yet retain the depth and breadth of carbon's bonding diversity and stability with other nonmetal elements?

2.2. Another polymerizing structural element–silicon?

Silicon is another Group IVA element as carbon, and the major component of terrestrial materials such as silicates and sand. Though silicon exhibits chemical properties similar to carbon, its carbon-analogous compounds are generally very different in behavior with water and oxygen. Silicon–silicon bonded structures with hydrogen (hydrides) are known and called silanes, analogous to some carbon alkanes. Only monosilane and disilane are stable at RT, while the higher analogs decompose to the two simpler homologs (Cotton and Wilkinson, 1980a; Housecroft and Sharpe, 2012). Silanes are spontaneously flammable in air yielding SiO_2 and water, though they are stable in water and dilute mineral acids. They also are strong reducing agents. The poly-silicon chain isn't a poly-silicon chain at all, but rather an alternation of silicon and oxygen atoms which is the basis of what are called siloxanes. At low concentrations some D4 (four Si-O units) siloxanes exhibit toxicity to some aquatic organisms (Wang et al., 2013). Longer or polymeric siloxanes are referred to as silicones.

Silicon appears important to plants as a vital constituent for their growth, mechanical strength, and resistance to fungal disease (Epstein, 1994). But silicon as a “structural element” of the interconvertible life molecules as is the case with carbon is not seen. A silicone backbone super structure would be the closest ETI life may come to being based upon silicon. But such a backbone structure with only two ligand sites employing classical hydrocarbon substituents would seriously alter what we currently see as protein, nucleic acid, carbohydrate, and lipid biochemistry. The diverse complexity of carbon compounds most likely could not be supported in silicon analogs. However, a silicon analog of cyclobutadiene with only Si—Si bonding of its backbone is reported (Suzuki et al., 2010) as well as a water soluble polysilylamide (Sohail et al., 2013). Finally, while carbon is tetra-coordinate in its bonding, silicon can be hexa-coordinate as well as tetracoordinate (Cotton and Wilkinson, 1980b) further complicating the fundamental biochemistry.

Respiration of silicon analogues in a fashion similar to carbon biomolecules would seemingly lead to SiO_2 which is solid and much more stable than CO_2 owing to the greater energy of the Si—O bond (Properties of Atoms, Radicals, and Bonds, 2017). Any silicon based organism certainly would not exhale “sand” as a waste product, though it could be excreted as a solid. The problem though is that in carbon biochemistry, CO_2 as a substrate or end product of metabolism (except in blood as bicarbonate) is cellularly bound to biotin (carboxybiotin) so it never exists as a gaseous component as for example in the case of pyruvate carboxylase (Berg et al., 2015b). Cellular creation of SiO_2 would result in cell packing of “sand” and no soluble medium way to utilize or remove it.

Then there is the issue of conformational traits of long, complex silicon molecules. Some studies reveal that silicone polymers can and do adopt helical conformations (Dubchak et al., 1985; Mehta and Somasundaran, 2007). Helical conformation is a well recognized secondary structure of both proteins and DNA (Berg, 2015c). But the intervening oxygen atoms of silicones would disrupt the spacial (secondary structure) physicochemical properties so inherently important in multi-carbon chains found in many terrestrial biopolymers (Berg et al., 2015d).

2.3. Another electron sink?

On Earth all multicellular aerobic animal life use gaseous oxygen as the electron sink in the electron transport chain of the mitochondria of cells (Berg et al., 2015e). Could another element serve as an electron sink? Any electron sink must at least be as chemically effective and versatile as oxygen or better. It must provide the chemical bonding diversity that oxygen offers with carbon. Fluorine, though a better electron sink and a gas, is also poisonous to carbon life. The fluorine product of a reputed alternate electron transport system for disposing of electrons and hydronium ions would be HF as the water analog. HF is also poisonous, and its fluoride is an inhibitor of some enzymes such as enolase of glycolysis (Niknahad et al., 1994). HF also is a weak acid (in aqueous solutions), though with a pK_a of 3.19, it is a much stronger acid than water [pK_a of 14]. HF would render aqueous solutions distinctly acidic while water is neutral. Water is a much more versatile solvent for life being an amphoteric substance. Pure HF is liquid between –83.55 °C and 19.5 °C, thus rendering liquid systems of it as a solvent indeed very cold over the bulk of its liquid temperature range, affecting reactions rates as a result [see below (Merck Index, 1976a)].

Methane as a solvent environment for life offers the same temperature dependent, reaction impeding issues, but worse. Methane is