About Life

by

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**1 - An overview of definitions for life**

Defining life is a hard deed. First of all, it is hard to have all people around you accept your definition as the one. Our definition picks everything that we consider alive to be alive and exclude what we think that isn’t alive.

As presumptuous as it may be, in this paper we are trying to gather as many definitions of life that we can find and order them from the least to the most embracing in order to produce a meta-analysis of the definitions. Based on that, we will extract the best one to maybe find other life forms. [3]

It was common in the early human civilization for people to confuse life with consciousness. So, our first and most strict definition of life is by the early humans, which thought that they were the only truly living beings, and all the other things that seemed alive were just some kind of “automata” (a machine that has no will).

As time goes by, humans typically have the tendency to expand their vision of what is alive. They believe that things that have some kind of movement or growth are alive. This definition is broad, and its purpose is to encompass a wide range of definitions: since the ones that find living beings that are similar to us like mammals, to those that are widely different from us but still have this property. This definition can yet be separated in two classes of definitions, the one before the discovery of microscope and the one after. That’s because before the microscope we couldn’t see the micro-world, so humans couldn't tell that micro-organism existed or yet that they were alive.

Another property that is widely used is that the living being needs to be able to reproduce. In this list we haven’t found anything yet that doesn't cease to exist at some point so, it is normal that reproduction is somewhere to be found in the definitions.

And yet complementary to the last rule we have the one that says that the living being needs to be able of Darwinian evolution[5], this combo of properties is used for national space agencies to define life. The line between definitions starts to get a little blur, that is because most properties aren't necessarily excluded, or they even don't necessarily have some chronological order of adoption or discovery. This definition is pretty broad even for biological sciences standards. That is because, even for biology, the theme of viruses is widely open for discussion on whereas it is a living being or not. A question that pops up from discussion is that since viruses can’t sustain life on its own, maybe it shouldn't be considered life. On the other hand, a counter argument for that is that we have other niche forms of life that are obligatory parasites too.

Now, for the last “grade” of definition of life, there are those who define it by energy. It suggests that what unites all the definitions above is that living beings need the system where they are to have unevenly spread-out energy. Based on that, why shouldn’t we consider any system with uneven energy distribution alive? Since it needs to evolve in time from a highly uneven distributed to an evenly distributed energy system, every moment that it is trying to achieve equilibrium it’s alive, and it ceases to be alive when it reaches its equilibrium. From that, we can assume that every part of the ecosystem is part of a bigger living being. As an example, it’s known that the human being is alive, but he can’t reproduce by itself neither evolve in a Darwinian way, so the logical conclusion is that the ecosystem in which he is part of, is part of himself.

As a conclusion of this brief rundown of a gradient of definitions of life, we as searchers

of other life forms need to funnel down on what may be practical for searching life with the technologies that we have at our disposal. The technologies that we have are limiting in some sense, which is that we don’t have unlimited computing power to scan every single piece of the sky, and more than the universe that we live in, there are some pretty uncool physics that limit our capabilities of searching. As an example, we are trapped in a bubble of space caused by the increased acceleration of space-time probably caused by dark energy, limiting even further where we can search.

Given all those obstacles, the definition that we chose to “elect” as the most useful to use for searching life is from aerospace agencies, and that comes from the fact that it is embracing enough to pick up life forms that we don’t have here on Earth, buy yet not so embracing that it almost picks up anything that has mass and has energy unevenly distributed.

* **Question asked by our colleagues:**

**Is it necessary for life to have the capacity to reproduce itself and to perpetuate itself? Is life objective by definition?**

As any definition is up to us to pick what suits us the most, as discussed in the conclusion, we will stick to the aerospace agencies definitions for practical purposes. In most cases, as we observe in our daily lives, we don't have anything that is truly perpetual. So, in order for things to exist for long periods of time it needs to be deconstructed and reconstructed as a cycle and the way it happens is reproduction. An added benefit to this, which is the Darwinian evolution, is to keep the living being adapted to its surroundings.

**What are the fundamental pillars to define life?**

As we have previously discussed in our text, the very definition of life may vary a lot, and it depends on what your objective is. The only pillar that is found throughout our discussion is that it needs to have some unevenness of energy.

But if we pick the practical definition of the aerospace agencies, they blatantly sustain the pillars of how life needs to be self-sustaining and capable of Darwinian evolution.

**Is NASA's(aerospace agencies) definition of life, which is widely used, limiting or geocentric?**

We think that the aerospace agencies definition is limiting in a good way. We need a north to look up as the space is vast and our technology is limiting. So, when we look at it, we want to filter places and things that have a good chance of finding at least good signs that life could be formed in this place.

Yes, it is geocentric, and that comes with the fact that we have a statistical sample size of 1 for what life could be, and this comes with a bias. But even with that bias, we will discuss further in this text possible other life forms that differ from us molecularly, and yet we don't discard them even if we have never seen something like that.

**2 - Different possibilities for other life forms:**

Now that we find ourselves under a solid definition about what life is to guide our discussion, we can start asking ourselves: is there any possibility for life other than the one we know, based on water and carbon? This crucial question is broadly discussed when we ask ourselves about the possibility of extraterrestrial life. And before we start discussing possible alternative chemical compounds and elements for those theoretical lifeforms to bloom out of, we must understand a few factors that play a big role in the existence of life.

The first one is the chemical complexity of life itself, which is based in polymeric molecular compounds, formed with covalent bonds. That is one of carbon’s main features, as it is capable of forming a countless number of molecular compounds with stable bonds due to its high bonding energy and to the fact that it’s able to form four covalent bonds. Lots of those carbon-based compounds are easily found throughout our known universe, but we can’t bring ourselves to the idea that because of that, carbon is the one and only chemical element that can be a base for lifeforms. That’s an earth centric idea that we are trying to avoid in this discussion. There are plenty of other tetravalent atoms with similar properties with carbon that are currently discussed as potential bases for hypothetical life forms. And among them, silicon stands out as our best candidate.

Silicon stays right under carbon in the periodic table, which means that it’s the element that has the most similar properties to carbon. It’s also capable of forming four stable covalent bonds with other silicon atoms or with other elements, what allows an infinite number of possible chemical compounds. It’s also important to note that, when compared to carbon, silicon stands as a less reactive element, bringing him some good advantages as the main building block of life in colder environments, which are quite common in the universe.

Titan, one of Saturn’s moons, is one of the best possible places in our solar system where we can try to detect this possible silicon lifeform. The moon’s temperature can go as low as -179ºC, which might favor silicon’s low reactivity. The lower concentration of oxygen in its atmosphere that can prevent silicon-based compounds from oxidizing, and the absence of water, an incompatible solvent with silicon compounds, are also favorable conditions for silicon to come out as a possible building block for life in Titan. However, this possibility of silicon-based life in Titan is often doubted due to the fact that carbon, which is capable of forming stronger bonds, theoretically, is still present in the moon’s surface, with silicon being the dominant element in the undergrounds. Although we can’t assert the existence of silicon-based life in Titan, we do believe that simply negating it by using our earthly experience as the base of the argument is once again a geocentric idea to be avoided.

As for the other tetravalent chemical elements, due to the fact that most of them aren’t non-metals and they keep growing heavier and heavier, the molecular bonds that they form are quite less stable, and therefore, less sustainable in the conditions we know here on earth. But that doesn’t mean that the existence of lifeform based in those atoms would be impossible. They would only be impossible on our planet’s known conditions.

Proceeding with the discussion, we also need an energy source for life to be able to sustain itself and to keep up the chemical complexity. We have our Sun here on earth as an almost infinite energy source, but there could be living beings able to use other forms of disponible energy, such as the pressure in planets with dense atmospheres, the kinetic energy from the seas, or the convection winds, or even strong magnetic fields, or means of radiation.

As the last point to discuss when we come to think of the important factors for life to be able to sustain itself, we need a liquid solvent mean where the chemical interactions are able to occur. When we think about Earth, the only stable liquid that stands as a place for these reactions to happen is water, although some recent studies are coming out with the possibility that other liquid solvent means may ensure that the necessary chemical reactions keep on going. Among them, ammonia comes out as a great possible candidate. Ammonia is capable of dissolving a substantial number of organic compounds, which is why it’s used as a solvent in laboratorial organic reactions and sustains itself in liquid state in colder temperatures.

To be able to bloom, ammonia-based life also needs an oxygen absent atmosphere, as the oxygen molecules dissociates and oxidizes the ammonia molecules. Any hypothetical ammonia-based life form would probably be anaerobic, as some bacteria on our planet.

There is evidence that shows that Titan’s internal ocean contains significant amounts of ammonia, which once again, combined with the absence of oxygen in its atmosphere, may give ammonia-based life a shot for breaking out. Due to the fact that ammonia is a far more aggressive solvent, any lifeform based on it would be a lot different from any of the ones we know on earth, but, since it’s a pretty common solvent throughout the universe, we feel that we must acknowledge its potential.

**3 - Searching for extraterrestrial life**

As we have defined that life can probably be found in other planets, even and most for sure a bit different than the one on earth, our challenge is to communicate with them.

The observable universe is a big place that’s been around for more than 13 billion years. Up to 2 trillion galaxies made up of something like 20 thousand billion billion stars surround our home galaxy. In the milk way alone, scientists assume there are some 40 billion earth-like planets in the habitable zone in their stars [8].

When we look at these numbers, it is hard to imagine that there is nobody else out there. It would change our perception of ourselves forever if we found others. Just knowing that this vast place is not dead would shift our perspective outward and could help us get over our irrelevant quarrels. But before looking for our new best friends, or worst enemies, we have a problem to solve: what are we actually looking for?

In a universe that big and old, we have to assume that civilizations start millions of years apart from each other and develop in different directions and speeds. So not only are we looking over distances of dozens to hundreds of thousands of light years, we are looking for a civilization ranging from cavemen to super advanced. So, we need a conceptual framework to enable us to think better thoughts that make us able to search better. Are there universal rules that intelligent species follow?

Currently our civilization sample size is only one, so we may make incorrect assumptions based solely on ourselves. Still, better than nothing. We know that humans started out with nothing but minds and hands that could build tools. We know that humans are curious, competitive, greedy for resources and expansionist. The more of these qualities our ancestors had, the more successful they were in the civilization building game. Being one with nature is nice, but it is not the path to irrigation systems, or gunpowder, or cities.

So, it is reasonable to assume that aliens able to take over their home planet also have these qualities. And, if aliens have to follow the same laws of physics, then there is a measurable metric for progress: Energy use.

Human progress can be measured very precisely by how much energy we extracted from our environment, and how we made it usable to do things. We started with muscles, until we learned to control fire. Then we made machines that used kinetic energy form water and wind. As our machines got better and our knowledge of materials expanded, we began to harness the concentrated energy from dead plants we dug up from the ground. As our energy consumption grew exponentially, so did the abilities of our civilization. Between 1800 and 2015, population size had increased sevenfold, while humanity was consuming 25 times more energy. It’s likely that this process will continue into the far future.

Based on these facts, scientist Nikolai Kardashev developed a method of categorizing civilizations, from cave dwellers to gods ruling over galaxies: The Kardashev Scale; a method of ranking civilizations by their energy use. The scale has been refined and expanded on over the decades, but in general it puts civilizations into four different categories.

A type 1 civilization is able to use the available energy of their home planet. A type 2 civilization is able to use the available energy of their star and planetary system. A type 3 civilization is able to use the available energy of their galaxy. A type 4 civilization is able to use the available energy of multiple galaxies.

These levels differ by orders of magnitude. It’s like comparing an ant colony to a human metropolitan area. To ants we are so complex and powerful, we might as well be gods. So, to make the scale more useful, we need subcategories.

On the lower end of the spectrum, there are Type 0 to Type 1 civilizations: Anything from hunter-gatherers, to something we could achieve in the next few hundred years. These might actually be abundant in the Milky Way. But a civilization that is not actively transmitting radio signals into space might be as close as our nearest stellar neighbor, the Alpha Centauri system, and we would have no way of realizing they exist. But even if they transmitted radio signals like we do, it might not be very helpful. On an interstellar scale, humanity is practically invisible. Our signals may extend over an impressive 200 light years, but this is only a tiny fraction of the Milky Way. And even if someone were listening, after a few light years our signals decay into noise, impossible to identify as the source of an intelligent species.

Today, humanity ranks at about level 0.75. We have altered our planet: we’ve created huge structures, mined and stripped mountains, removed rainforests, and drained swamps. We’ve created rivers and lakes, and changed the composition and temperature of the atmosphere. If progress continues, and we don’t make Earth uninhabitable, we will become a full Type 1 civilization in the next few hundred years. Any civilization that becomes a Type 1 is bound to look outside, because it’s likely that it’s still curious, competitive, greedy and expansionist.

The next reasonable step towards transitioning to Type 2 is trying to alter and mine other planets and bodies. This might start with outposts in space, transition to infrastructure and industries near the home planet, move on to colonies, and end with terraforming other planets, by changing their atmosphere, their rotation, or position.

As a civilization expands and uses more and more stuff and space, its energy consumption scales with them, so at some point, they may embark on the largest project a lower Type 2 civilization can take on: harnessing the energy of their star by building a Dyson Swarm. Once this megastructure is finished, energy has become practically unlimited for molding the home system however they see fit. If they are still curious, competitive, greedy and expansionist, and now have complete control over their home system, stellar infrastructure in place, and the energy output of a star, the next frontier moves to other stars light years away. For a Type 2 civilization, the distance to other stars might feel like the distance between Earth and Pluto does to us today: Technically within reach, but only with immense investments in terms of time, ingenuity, and resources.

This begins their transition towards Type 3. This step is so far beyond us that it becomes hard to imagine what exactly these challenges will look like, and how they’ll be solved. Will they be able to find a solution to the vast distances and travel times of hundreds of thousands of years? Will they be able to communicate and keep a shared culture and biology between colonies light years apart? Or will they split into separate Type 2 civilizations? Maybe even different species? Are there deadly challenges between the stars?

So, the closer a species gets to Type 3, the harder it becomes to fathom what it might actually look like. They might discover new physics, may understand and control dark matter and energy, or be able to travel faster than light. We might be unable to grasp their motives, technology, and actions.

Humans are the ants, trying to understand the galactic metropolitan area. A high Type 2 civilization might already consider humanity too primitive to even talk to. A Type 3 civilization might feel about as like we feel about the bacteria living on the anthill. Maybe they wouldn’t even consider us conscious, or our survival relevant. We could only pray that they’re nice gods.

But the scale doesn’t necessarily end here. Some scientists suggest there might be Type 4 and Type 5 civilizations, whose influence stretches over galaxy clusters or superclusters, structures comprising thousands of galaxies and trillions of stars. Ultimately, there might be a Type Omega civilization, able to manipulate the entire universe, and possibly others. Type Omega civilizations might be the actual creators of our universe, for reasons beyond our comprehension. Maybe they were just bored.

As flawed as this classification may be, this thought experiment is already telling us interesting things. If our ideas about the nature of species that form interstellar civilizations is sort of correct, then we can be pretty sure that there are no civilizations of Type 3 and beyond near the Milky Way. Their influence would in all likelihood be so all-encompassing, and their technology so far above our own, that we couldn’t miss them. The galaxy should flash with their activity in thousands of star systems. We should be able to see or detect their artifacts or movements between different parts of their empire.

Even if a Type 3 civilization did exist in the past, and died a mysterious death, we should be able to detect some of the remnants of their empire. But when scientists looked, they didn’t find remnants of harvested stars, decaying megastructures or scars of great interstellar wars. So, they’re very likely not out there and never were. In a sense, this is very sad, but also very reassuring. It leaves the galaxy to us and others similar to us.

So, the most promising civilizations to look for may be somewhere in the spectrum form Type 1.5 to Type 2.5. They wouldn’t be too advanced to understand them and their motives. They may have finished their first megastructures, and they might be in the process of moving staff between stars, transmitting enormous amounts of information into space, by accident or on purpose. They would probably also look to the stars and look for others. Then again, maybe we’ve got it all wrong. Maybe progress to Type 2 does not mean expanding outwards, and humanity is still too immature to imagine otherwise.

For now, all we really know is that we haven’t seen anybody yet. But we’ve only just started looking. Until we finally find friendly super aliens and can ask them to explain the rules of the universe to us, most of us have to make do with learning stuff ourselves.

* **Question asked by our colleagues:**

**How hard is it to find other life forms on Earth (e.g., In long term isolated areas)?**

The most accurate estimate presented to date on the number of species existing on Earth indicates that humans share the planet with 8.7 million other different beings. In the world, as around 1.2 million species have been catalogued so far, this means that more than 7 million remain unknown to science. According to the study, 86% of species that live on land or inland waters and 89% of marine species have yet to be discovered. That fact itself shows we are far away from knowing the majority of life forms in our own planet, so as an answer we would say that there is a lot of hard work in this quest.

**Which life definitions should we use to find other life forms (is it possible to find life and not acknowledge it due to that)?**

There are **over 100 definitions** for 'life' and probably all of them are wrong. Most of us probably do not need to think too hard to distinguish living things from the "non-living" ones. Simplistically one can say a human is alive; a rock is not, right? Wrong!

It is not so linear, as it was previously discussed. In order to put our search in a realistic perspective, our suggestion is to accept NASA’s concept of being "a self-sustaining chemical system capable of Darwinian evolution". Always open to new ideas!

**How does the fact of not knowing other life forms makes it harder to find it?**

One can not recognize something that one don’t know what it is, so that is the main problem of this search. The answer is to have Extremely open minded guidelines for the definition what a “form of life” means.

**Can the idea of looking for water to find life interfere in our search for other life forms?**

Definitely yes, as we have already stated that water is fundamental for our physiology. Then, when we look for signs of life we naturally tend to look for water as a predictive indicator for that life!

This concept is changing lately with the idea of non-water-soluble environment being capable of working as a base for different forms of life.

**Conclusion:**

In this text, we have analyzed important facts that bring us to the conclusion that it is logic and statistic to think that there are different forms of life we don’t know. And It’s out of our knowledge to characterize them. One thing we’re sure of is that there is life beyond our capacity of finding it.

The main goal of this paper is to instigate our readers to embrace the cause which evolves searching and recognizing life different from the way we know it. So, we can learn from each other and cohabitate in the Universe.

That’s the main reason why we have had a deep dive in such a big human question: Are we alone in the Universe?

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