The universality of biology, SETI, and our cosmic perspective

Martin Dominik

Our minds find it hard to cope with not only with imagining the vastness of the Universe, but also its emptiness. Planet Earth provides an oasis that we reside in. How peculiar can it be, orbiting a star that is one of hundreds of billions in the Milky Way, which itself is one of hundreds of billions of galaxies in the Universe?

If the laws of nature are universal, how can it be the case that there is only one instance of life; and exactly *one*, – or do we simply not know better, and the Universe is teeming with life all over…

While the laws of thermodynamics govern physical and chemical processes, and in particular the entropy increases, we suddenly see life coming up and evolving, with entropy locally decreasing. This is not forbidden, but *why* should it happen, and under what conditions should it happen? Rather than just trying to trace life on Earth back to some origin, marking a singularity, we would like to understand why it occurred, that is how life emerged. What are the foundations of biology, – and what are the universal characteristics of life? For addressing such questions, we have set up a research network exploring directions that cut across disciplinary confines: the Network of Researchers on the Chemical Emergence of Life (NoRCEL), and you can find us on the web.

Carbon chemistry not only has the feature of forming long hydrocarbon chains as well as rings, but more importantly, together with a few other elements, can create molecules of huge diversity, with characteristic functional groups fuelling reactions. This diversity provides resilience, and if carbon chemistry is possible, it will outperform any other chemical system. The chemistry of terrestrial life simply is a subset of organic chemistry, it does *not* use the most common elements. The Earth's crust is mostly silicates, and while they can build large structures, they are chemically as boring as hydrocarbons. However, in an environment in which carbon chemistry not possible, there might be other winners, e.g. potentially sulphur chemistry.

We need to be humble with respect to where we sit in the Earth's ecosystem: The average life-time of a mammal species is about 1 million years, and our ancestors living about 400 million years ago were some fish. We will get to a future that isn't about humans, and the real question might be what we will evolve into, or whether we sit on a branch of the tree of life that will go extinct.

The historic record of science shows that Earth-centric views or anthropocentric views have repeatedly been proven untenable. How many Copernican revolutions do we still need? Much talk around astrobiology is about "life as we know it", but neither do we actually know what makes the life we pretend to know "life", nor should we adopt yet another Earth-centric position. Just 30 years ago, it was widely thought that if there are stars other than the Sun with planetary systems, those will look pretty much like the Solar system, with its small rocky inner planets and outer gas giants.

Now we know about 5000 planets orbiting stars other than the Sun, which are quite different from the Solar system planets. These include massive gas giants in orbits much smaller than that of Mercury, as well as planets of a few Earth masses very far from their host star. Diversity is the most striking demographic feature, and the Solar system is not the generic prototype.

Life on Earth co-evolves with its environment. The Earth's crust, oceans, and atmosphere are linked through biogeochemical cycles. Life fits in with the geological evolution, and planetary science provides its context. If we are interested in potential habitats beyond Earth, the grounds of evolution are in the evolutionary history of the planets themselves. While the exact meanings as well as our understanding have changed, in searching for the key to astrobiology and the emergence of life, we are still pondering about the interplay between the classical Greek elements: earth, air, water, and fire.

One thing that connects all life on Earth is a universal language, namely the genetic code, which determines which amino acids to combine to form proteins, where the RNA holds the historic record of evolution.

I would like to argue that the defining universal characteristic of life is language. Biology builds on a historical record of prior information that needs to be communicated, so that there cannot be any biological process without language. Conversely, any language must have originated from a biological process. Language is a distinctive feature that sets apart biological from geological processes. This simple and general concept is neither Earth-centric, nor does it require any specific chemistry; in fact, it does not require life to be based on chemical reactions at all.

Language also provides a connection between microbiology and intelligent beings, – who communicate with each other beyond just transferring genetic information. The complexity of language can be assessed in terms of information entropy, and humans do not really stand out. We find language as a means of communication widely across the animal kingdom, where it is further evolved in sea mammals than in chimpanzees, i.e. our own branch of the tree of life also does not appear to be singled out.

Frank Drake, as well as Giuseppe Cocconi and Philip Morison, were true visionaries in realising that radio waves allow communication even over interstellar distances, and that we could in principle search for extra-terrestrial intelligence. While being highly speculative, this is up to this day the most straightforward way to potentially obtain evidence of life beyond the Solar system. It is by no means guaranteed that we will find something, and life beyond Earth might not exist. We however need to appreciate the value of explorative science, beautifully expressed by Cocconi & Morrison by stating: "The probability of success is difficult to estimate; but if we never search the chance of success is zero." Moreover, regardless of outcome, the cosmic perspective on our existence is something we should keep in mind.

In fact, the search for life beyond Earth is a search for ourselves: "What does it mean to be human?" This question cuts across all three classical pillars of philosophy: natural philosophy, metaphysics, and ethics, and was central to an exhibit titled "A message from a afar"showcasing the Search for Extra-Terrestrial Intelligence at the 2019 Royal Society Summer Science Exhibition, which I designed and led for the UK SETI Research Network. "What does it mean to be human?" is the deeper question behind the popular "Are we alone?", which is a question of natural philosophy alone. To convey one of our key messages, I definitely wanted a mirror, and we also placed the famous Earthrise image, taken from lunar orbit by Apollo 8 astronaut William Anders, on it as a background, in order to encourage thinking about a change in perspective.

What does humanity do when we discover we are not alone in the Cosmos? With the newly established SETI Post-Detection Hub in St Andrews, open to affiliates from around the world, we will do foundational research that could assist with best practices and informed strategies for managing such an event. This involves important questions about how we function as a global society (or rather not), how we adopt and communicate new knowledge, and how we respond to new challenges. As we have seen during the COVID pandemic, finding life beyond Earth is not the only future scenario we are poorly prepared for. We will need to dig deep into the scientific research process and its sociology, the popular reception to future discoveries, as well as science communication and risk communication strategies, in particular dealing with misinformation and disinformation, to properly address ethical and policy questions.

The SETI Post-Detection Hub is a long-term follow up on a Royal Society Scientific Discussion Meeting on "The Detection of extra-terrestrial life and the consequences for science and society" held in 2010, and we are organising a Kavli-IAU symposium "(Toward) Discovery of Life Beyond Earth and its Impact" in Durham in April 2024.

Earth's history and the evolution of terrestrial life might be part of a wider and more universal history. Who owns history, and whose history are we looking at? How does a cosmic perspective influence how humanity views itself?