Signatures of Life on Earth and in Cosmos

An important aspect of astrobiology is the ability to clearly distinguish signs of past or present life in extraterrestrial environments. A better understanding of how to distinguish signs of life from alternative inorganic processes has the potential to enrich the general understanding of how planetary systems evolve over geological and astronomical time-scales. For example, what does the presence of water and minerals such as hematite on the surface of Mars tell us in terms of its geological history, and what can the spectroscopic detection of gases such as carbon dioxide, methane, and oxygen in the atmosphere of an exoplanet indicate about its propensity to harbour life?

We do not at this point know enough about the biomarker signals for different species on the earth. Data both for extinct fossil forms and for now-living organisms are largely lacking. How can we interpret data from the Mars rovers when we do not have a full picture of the data we have from our own earth?

Signs of life can be in the form of chemical signatures, biogeology, or electromagnetic waves. To correctly interpret the signs it is necessary to have a deep understanding of the chemical, physical, geological, biological, and semiotic aspects involved. Of equal importance is a deep understanding of the linguistic, cognitive, and cultural aspects involved in producing and interpreting signs, and a conceptual understanding of 'life' as a phenomenon. In order to put these aspects into perspective, an understanding of the historical, philosophical, social, and cultural aspects is also important. In other words, to find, identify, and interpret signatures of life, an interdisciplinary approach is essential.

Research questions

1. The nature of life
At the moment there is no consensus regarding how to define life, and therefore it is not obvious which criteria should be used, and in turn what can be considered signatures of life. On the other hand there is an on-going and lively debate and no lack of suggestions. One of the challenges the group will take on is to handle this question with philosophical rigour and produce constructive and original submissions in the discussion.

2. Distinguishing between geological and biological structures
To handle this challenge it is imperative to utilize the analogues we can find on our own planet. The geological archive in the rocks of our planet documents the geochemical traces and cellular records of early life on the earth. The geological deposits of our planet preserve a remarkable and invaluable archive of life's history on the earth spanning at least 3.5 billion years. The earliest part of this biological record consists of geochemical traces, cryptic cellular records, and stable carbon, oxygen, and sulphur isotope ratios, whose partitioning is influenced by biological processes. These signatures are expected to be amongst the most immediately recognizable signatures of present or past life, on the earth as well as on other planets.

3. New possibilities for analysing the habitability of other planets
In the light of on-going development of high-precision telescopes and new space missions, the stage is set for a broad range of transformative discoveries in the near future addressing fundamental questions about habitable environments in space in general, and signs of past or present life in particular. However, the exact ramifications of many astronomical observations are often difficult to assess. One of the currently most challenging tasks in observational astronomy is the identification of signatures of possible life on exoplanets: To find "biomarkers" through high-resolution spectroscopy using large telescopes. However, the identification of signatures of life will not be achieved through astronomical competence alone but rather demands a multidisciplinary approach, including fields such as atmospheric chemistry, earth sciences, and others. Proper analysis of new data sets calls for a new and improved level of understanding of astronomical observations in terms of underlying geological, chemical, and biological processes.

The latter two questions also present a common challenge in the form of recognising an environment as habitable. Recent exploration of many seemingly inhospitable environments on the earth such as Yellowstone hot springs, the Atacama Desert, and hot springs emanating from deep ocean trenches, has demonstrated a remarkable ability of living organisms to thrive in harsh environments that include extreme temperatures, pressures, pH, salinity, and arid conditions. Such extremophiles have expanded our general understanding of what constitutes a habitable environment, and have revealed metabolic pathways and biochemistries not previously suspected. We want to analyse and compare a diverse set of extreme environments with biological signatures from fossil records. Understanding the terrestrial signatures of life through geologic time is essential for defining and interpreting astronomical observations of possible biosignatures on other planets, both within and outside our solar system.

4. Signal recognition
A particular kind of signature of life could be in the form of signals emitted by technical civilizations. If we manage to receive such signals from beyond the earth it presents interesting challenges in terms of interpreting the signals, and also in terms of distinguishing signals from "noise". A radio signal which stands out from the background noise could be coincidental or natural, e.g. the regular pulse of a pulsar, or it could be a sign of organization, i.e. of artificial origin. If a signal can be shown to have an artificial origin, it could either be the unintentional result of some kind of activity, or it could be a deliberate message. This could either be an instance of internal communication within a civilization, (cf. radio communication on the earth if intercepted by another species) or a message directed towards other worlds, e.g. us. How such signals should be interpreted depends of course on our perception of the intended receiver.

5. The historical perspective
In this part of the project dealing with contemporary history of astronomical biosignatures, the technological and scientific developments driving the field will be discussed, especially the role of instrumentation and big-science facilities in modern astronomy. The project will also be a unique opportunity for participant observation by our historians.

The Signatures of Life research team

Dag Ahrén, Ph.D., Biology – dag.ahren@mbioekol.lu.se

Anna Cabak Rédei, Ph.D., Semiotics – anna.cabak_redei@semiotik.lu.se

Dainis Dravins, Professor, Astronomy and Theoretical Physics – dainis@astro.lu.se

David Dunér, Associate Professor, History of science and ideas – david.duner@kultur.lu.se

Sofia Feltzing, Professor, Astronomy and Theoretical Physics – sofia@astro.lu.se

Gustav Holmberg, Associate Professor, Research policy – gustav.holmberg@fpi.lu.se

Arthur Holmer, Ph.D. Linguistics – arthur.holmer@ling.lu.se

Erik Persson, Ph.D. Philosophy – erik.persson@fil.lu.se

Petter Persson, Ph.D. Chemistry – petter.persson@teokem.lu.se

Vivi Vajda, Professor, Earth and Ecosystem Sciences – vivi.vajda@geol.lu.se