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Invited Paper

A Journey to the Origins. The Astrobiology Paradigm in Education

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ABSTRACT

Astrobiology is a new multi-disciplinary field of knowledge concerned with the study of the origin, distribution, and destiny of life in the universe and, naturally, in our planet. For this goal we must introduce and develop the adequate tools for teaching this science in schools and universities. New curricula, with a more open mind, must be established for the formation of the present and future generations of students and also, in our point of view, of teachers. One example of this effort can be seen in the Portuguese project “A Journey to the Origins. Astrobiology in the Lab”, where secondary school students recreate experiments regarding the Origin of Life and Cellular Evolution. The work will be widened to the educational community through the carrying out of Open Laboratory Sessions, conferences and the drawing up of a digital portfolio compiling all of the material developed by students and teachers throughout the project. A proposal will be made to restructure the curriculum to include a new unit entitled "Astrobiology and Cellular Evolution". The repercussions of this innovative paradigm could be seen in the future, not only in the educational community, but also in the society in general.

Keywords: astrobiology, life detection, education, society, project, paradigm

1. INTRODUCTION

It is proper of Man to question himself on the issue of his origins and of that which surrounds him. Two questions have always been related to the human species: how did life appear? What is the role of Man on Earth and in the Universe? In order to answer this, man developed simple or sophisticated explanations involving the presence of philosophical and theological concepts. For those reasons, the development of astrobiology as a credible science had a hard route against the social status, including the scientific one. The public imaginary was also a barrier as it looked at this new science as the “temple” for the cutting edge of futuristic science and as a “search for little green men”[1].

Astrobiology is a new multi-disciplinary field of knowledge concerned with the study of the origin, distribution, and destiny of life in the universe and, naturally, in our planet. In a more detailed sense, astrobiology seeks to understand the origin of the building blocks of life, how these biogenic compounds combine to create life, how life affects - and is affected by the environment from which it arose, and finally, whether and how life expands beyond its planet of origin. None of these questions is by any means new - but for the first time since they were raised, these questions can now be answerable.

Astrobiology seeks to provide a philosophical and programmatic underpinning whereby life's place in the universe can be explored - at levels of inter-related complexity ranging from molecular to galactic[2].

2. ASTROBIOLOGY AND THE ORIGIN OF LIFE

The existence of extraterrestrial life is quite an old idea. Found for the first time in Ancient Greece, this concept suffered a series of modifications and changes throughout History. Several authors, namely Christian Huygens, Emmanuel Kant and Goethe, defended it. However, it was only with the works of Camille Flammarion, during the second half of the XIXth century, that the idea became more widespread. In the XXth century, during the 40's, appeared the term astrobiology associated with the Russian school. The term exobiology was introduced as an alternative to the word astrobiology in 1959 by Joshua Lederberg, an American geneticist who won the Nobel Prize for Medicine in 1958 and who was responsible for the biological area of the Apollo Program[1]. The initial meaning of these concepts, which was limited to the study of life outside our planet, soon evolved into a wider perspective, comprising the study of life on Earth and other planets. In that sense, this area of science is characterized for its multi-disciplinarity and its implication with various domains such as biology, chemistry, physics, astronomy, geology and its interfaces. The ambit of this science includes, namely, the study of the pre-biotic conditions that existed on our planet, as well as the nature of the chemical reactions, which led to the formation of life[2,3].

Several authors played, as it was previously referred, a fundamental role in the establishment and development of astrobiology as a science. For the contribution they made, we would like to point out the pioneer work of Oparin (1924), Haldane (1927), Urey and Miller (1953), who, in an unequivocal way, laid the scientific foundations for the understanding of organic compounds' formation in abiotic conditions. This first phase was essential to overcome the barrier of skepticism and doubt, resisting the possibility of a formation of organic compounds in the absence of living organisms. Among other methods, experimentation allowed this stage to be overcome, laying new challenges and raising new questions. Also, we must underline the role of NASA in the development of exobiology/astrobiology as a new science. This involvement was reinforced by the "Cold War" situation and the race for the control of space by Russia and the USA[1]. When spacecraft became a reality and NASA decided to implement Lederberg's idea of a discipline of exobiology, the research on the origin of life changed in a fundamental way[1]. The examination of life's origin on Earth immediately began to be combined with the search for life on other worlds. Thus, the two issues rapidly started to be considered at the same level and included in the same problem[1].

During this initial period, NASA's funds enabled American labs to be devoted, for the first time, almost exclusively to research on exobiology[1]. It was the case of the Ames Research Center in California and the Florida State University. In the latter, Sidney Fox established, in 1963, an Institute for Space Biosciences[1]. A year later this researcher, as a faculty member of the University of Miami, created the Institute of Molecular Evolution with the same goals[1]. After the Miller-Urey experiment, Fox described that mixtures of amino acids react to form under hot, dry conditions a substance he called "proteinoid"[1]. In 1959, Fox's group published an article in *Science* referring that when hot water was added to proteinoid, it spontaneously formed tiny spheres of 1-5 mm in diameter, about the size of small bacteria, which they called microspheres. These membrane-bounded structures showed some lifelike characteristics[1]. Another important contribution from NASA, was related with the research of Lynn Margulis, which work on cell endosymbiosis was funded by the exobiology program since the 1970's[1].

In Europe, the collaborative space programme began in the late 1950s, followed by the creation of a space agency in the early 1970s. Nowadays, it is possible to observe a series of new developments such as the establishment of a new European Exo/Astrobiology Network. The latter will hold regular meetings between astrobiology researchers, establish a database of expertise on the different aspects of exo/astrobiology, attract young scientists into the field, stimulate research funding from national and international bodies, promote the field to the public and forge links with its counterpart in the United States[14].

On the other hand, the discovery of organic molecules, namely amino acids and hydrocarbons, in some meteorites found on our planet and the existence of organic compounds in comets and in multiple regions of the interstellar space, have profoundly altered our vision of the world and of the universe, where the origin of life is concerned[15]. Likewise, and perhaps in an even more pressing way, the recent discoveries, even still controversial, of what seem to be microfossils associated with the meteorites ALH84001 (Allan Hills, Antarctic, 1984), Nakhla (Egypt, 1911) and Shergotty (India, 1865) originating in Mars[4,5], and the Allende (Mexico, 1969), the Orgueil (France, 1864) and the Murchison (Australia, 1969) meteorites[6], whose origin is located outside that planet, as well as the development of the research and space technology, allow us to foresee the study of environmental conditions in other planets. They would also serve as a kind of real experimental laboratories of what eventually happened or is still to come on Earth. In the same way, the existence of terrestrial microorganisms that live in extreme environmental conditions might help us build a model of life in some of those non-terrestrial ecosystems[7,8].

At the same time, space missions that were, are or will be carried out to different planets of our solar system allow us to gather new data, obtain answers and raise new questions. These studies include the knowledge of the planets' and their satellites' environmental conditions, the eventual discovery of new life forms and an attempt to understand their evolution or extinction within the ecosystems. The bigger technological and scientifical challenge, in the short run, will probably be located on the planet Mars, which could possibly have had conditions similar to those on Earth, such as liquid water and, eventually, the existence of life[9,10]. Besides, the data originating in the Viking Mission, which, in 1976, managed to land two probes on Martian ground, were never clearly refuted. The data pointed towards a detection of biological activity[9,10,11]. Since then, the coordinator of the experiment, Gilbert Levin, has insistently defended the veracity of this information, based on the data obtained during the tests carried out by the 1976 Viking Labeled Release (LR) experiment and also in new data[11].

3. ASTROBIOLOGY IN EDUCATION AND SOCIETY

The formulation of a problem determines the methods, the instruments, and the assembled data, defining the paradigm in which we live. We have passed from the question "How did life appear on Earth?" to the question "How did life appear?” just as, in the past, we evolved from geocentricism to heliocentrism. This way arose a different form of observing both Man and Nature - the ecological perspective of Astrobiology. In this sense, the problems, which are being formulated, reveal the evolution of mentalities.

Through the introduction of Astrobiology in the educational context, a change in students and teachers' mentalities can be observed. To perpetuate this change, individuals need to identify themselves with the new paradigm and, in order for that to happen, they have to know it; this kind of information can be reached through pioneer programs such as the one described in the following chapter. The latter will serve as a catalysis agent and propel others of the same kind, which, in the long run, will foster the consolidation of the new paradigm. Education is a context which paves the way for the introduction of conceptual changes in how life and the universe are apprehended.

Astrobiology is a new field of knowledge and in order for its information to be passed on, it is urgent and necessary for it to be integrated in the curricular domain, contributing to the dynamic of the transformation, as well as to the communication of scientific knowledge. This way, students and teachers are face to face with a problem whose solution is not definitive (how did life appear?), which allows them to create moments of reflection, questioning and creativity. Dealing with a problem such as this, that can have several approaches (some even being outside the scientific field), can lead to an adequate space of reflection on the nature of science and its inter-relations with other areas of knowledge, such as philosophy and theology[12,13]. For this goal we must introduce and develop the adequate tools for teaching this science in schools and universities. New curricula[3], with a more open mind, must be established for the formation of the present, new generations of students and also, in our point of view, of teachers. It allows the integration of disciplines, which are traditionally kept apart. This aspect enables the development of more holistic learning, also contributing to the flexibility of the mental

structure. The repercussions of this innovative paradigm would be seen on the future, not only in the educational community, but also in the society in general.

4. THE PROJECT

An example of what we have been saying can be found in the Portuguese project “A Journey to the Origins. Astrobiology in the Lab”. This project (P-IV-172) is developed in co-operation with the Centre for Environmental Biology/Department of Plant Biology and the Centre for Educational Research/Department of Education of the Faculty of Sciences, University of Lisbon and the Emídio Navarro’s Secondary School. The project is sponsored by the Program Ciência Viva - Ministry of Science and Technology (MCT) and jointed by a multidisciplinary team involving teachers and researchers on Biology, Geology, Informatics, Science Education and a class of 10th grade students of Biology and Geology. In the framework of this project, the students have developed practical activities, namely experiments about the Origin of Life and Cellular Evolution, field trips and the use of Internet as a searching tool for the Astrobiology knowledge. These activities were presented to the community in an Open Laboratory Day, Emídio Navarro's homepage, conferences and the presentation of a digital portfolio with all the materials developed by the teachers and students during the project.

• The main goals of the project are synthesized in the following points:

- To develop cooperative-learning approach for teaching Astrobiology
- To promote experimental work at school
- To develop attitudes of environmental responsibility, as a result of the understanding of the Origin of Life and the Universe
- To motivate the community towards scientific knowledge
- To promote the use of new information and communication technologies

• Activities and expected results:

• New curricular unit - Astrobiology and Cellular Evolution - envolving main goals, key ideas, activities and respective resources and assessment activities. Some of the proposed activities consisted on:

- recreating Redi, Spallanzani and Oparin experiments
- laboratory activities on experimentation with halophiles microorganisms under diverse environmental conditions
- Internet research on recent data related with this field
- inquiry-based activities - images and data analysis
- role-play activities - for instance, the debate “Abiogenesis or Biogenesis”
- School trips - for example, visits to saltpans to study environmental conditions and collect biological material
- establishing an on-line network of contacts with scientific institutions and researchers
- the game “Astrotrivial” whose objective was to synthesize the main ideas developed throughout every curricular unit

Parallelly, other activities were developed in order to divulge the project:

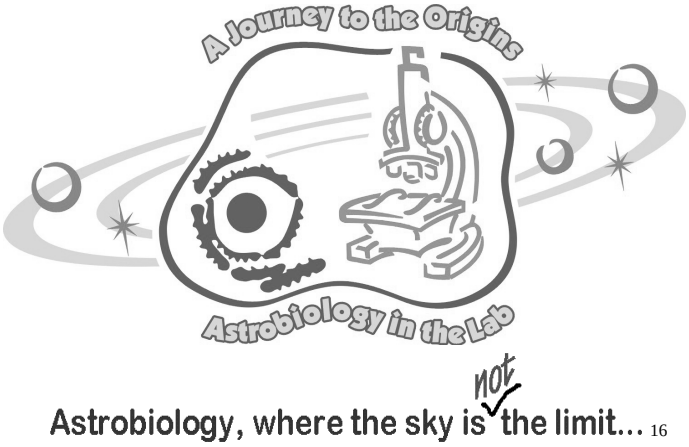
• Astrobiology Conference
• Workshop on Educational Technologies - in this activity, both students and teachers learned how to use new information and communication technologies as an astrobiology teaching/learning tool

• Open Laboratory Day - this activity consisted in an interactive exhibition of the main experiences and materials produced. It was organized and animated by the students and teachers involved in the project.
• Digital portfolio with all the materials developed by the teachers and students during the project (in progress).

• Difficulties felt by the team in the development of the project:

- To select the most adequate experiments regarding the Origin of Life and Cellular Evolution
- To integrate the context of research and the school context
  - different language
  - temporal gap
  - select key ideas for teaching

• The project logo



Project e-mail: astrobiolab@hotmail.com

5. FINAL REMARKS

As a conclusion, the introduction of Astrobiology in the educational context will be an important and positive factor for the development of mentalities. For this goal we must develop the adequate tools for teaching this science in schools and universities and also to the public in general. In this sense, it is possible to assert that the studies developed and the results obtained in the domain of Astrobiology should be considered as regulating elements of our own dimension in the Universe, with inevitable consequences on the way Man situates himself in the complex cosmological system and on the relationship he has with our planet. The repercussions of this innovative paradigm could be seen on the future, not only in the educational community, but also in the society in general.

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