Research, Society and Development, v. 9, n.1, e200911879, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i1.1879

O contexto astrobiológico como ferramenta estratégica para o Ensino de Biologia: uma perspectiva do currículo brasileiro

Astrobiological context as a strategic tool for the teaching of biology: a perspective from Brazilian curriculum

El contexto astrobiológico como herramienta estratégica para la enseñanza de la biología: una perspectiva del currículum brasileño

Recebido: 17/10/2019 | Revisado: 21/10/2019 | Aceito: 29/10/2019 | Publicado: 31/10/2019

Bruna Mayato
ORCID: https://orcid.org/0000-0002-8431-8299
Universidade Veiga de Almeida, Brasil
E-mail: bruna.astrobio@gmail.com
Maíra Moraes
ORCID: https://orcid.org/0000-0002-1766-2137
Universidade Veiga de Almeida, Brasil
E-mail: maira.pereira@uva.br
Bruno Leonardo do Nascimento-Dias
ORCID: https://orcid.org/0000-0002-3632-9073
Universidade Federal de Juiz de Fora, Brasil
E-mail: bruno.astrobio@gmail.com

Resumo

A Astrobiologia envolve a investigação da origem, evolução e distribuição da vida no universo. O objetivo deste estudo é investigar assuntos astrobiológicos que possam ser utilizados em sala de aula de maneira integrada ao currículo de biologia proposto nas escolas brasileiras. Em nossos resultados, foi identificado uma correlação entre a Astrobiologia e a Biologia utilizando como metodologia a análise de conteúdo de um documento curricular. Desta forma, foi possível sugerir que Astrobiologia possa ser utilizada como uma ferramenta interdisciplinar/multidisciplinar para o ensino de biologia, de forma a orientar os educadores e facilitar o processo de ensino-aprendizagem.

Palavras-chave: ensino médio; educação em astrobiologia; multidisciplinaridade.

Abstract

Astrobiology involves the investigation of the origin, evolution and distribution of life in the universe. The objective of this study is to investigate astrobiological subjects that can be used in the classroom in an integrated manner to the biology curriculum proposed in Brazilian schools. In our results, we identified a correlation between astrobiology and biology using the content analysis of an official curriculum as a methodology. In addition to this, we briefly discuss some critical topics reported in the literature. Thus, it was possible to suggest that Astrobiology can be used as an interdisciplinary / multidisciplinary tool for biology teaching, in order to guide educators and facilitate the teaching-learning process.
Keywords: high school; astrobiology education; multidisciplinarity.

Resumen

La astrobiología implica la investigación sobre el origen, la evolución y la distribución de la vida no universal. El objetivo de este estudio es investigar temas astrobiológicos que puedan usarse en el aula de manera integrada al plan de estudios de biología propuesto en las escuelas brasileñas. En nuestros resultados, identificamos una correlación entre astrobiología y biología utilizando el análisis de contenido de un plan de estudios oficial como metodología. Además, discutimos brevemente algunos temas críticos relacionados con la literatura. Por lo tanto, fue posible sugerir que la Astrobiología se puede utilizar como una herramienta interdisciplinaria / multidisciplinaria para la enseñanza de la biología, con el fin de guiar a los educadores y facilitar el proceso de enseñanza-aprendizaje.
Palabras clave: escuela secundaria; educación en astrobiologia; multidisciplinariedad.

1. Introduction

Astrobiology is a recent field of scientific research that investigates the origin, evolution and distribution of life in the universe (Blumberg, 2003; Domagal-Goldman SD et al., 2016). Astrobiology has attained popularity ever since NASA laid the foundation of its Astrobiology Institute (NAI) in the late 90s. At that time, NASA restructured and extended its space program, which was previously concerned only with the search for extraterrestrial life. Now NASA include research on various aspects of life on Earth (Staley, 2003; Rodrigues et al., 2012). Such reformulation occurred due to the recognition that it is essential to understand the mechanisms and conditions that enabled life to occur, particularly given that Earth is the only known planet where life has arisen and prospered.

In the Brazilian scenario, Astrobiology began to emerge in the early 2000s, shortly after its scientific recognition by NASA. However, in 2006 it was officially institutionalized at the First Brazilian Workshop on Astrobiology, an event that brought together several researchers from different fields and enabled the creation of the first collaborative research groups with an astrobiological approach (Paulino-Lima & Lage, 2010; Rodrigues et al., 2012). Since then, several individual and regional initiatives have been carried out to consolidate and develop the field in Brazil, such as the installation of the first Astrobiology Laboratory (AstroLab) in 2010 and the creation of the Astrobiology Research Center in 2011, both at University of São Paulo. Such initiatives have promoted great advances in the development of the Brazilian scientific community on this subject (Rodrigues et al., 2012).

Astrobiology as an integrating tool for teaching

The twenty-first century has become an epoch of many challenges for humanity. Global and complex questions, such as climate changes and its anthropogenic influences, must be faced with seriousness and commitment by humankind or we will continue to see mass extinctions and potentially endure consequences of our own actions as species on this planet (Saliceti, 2015).

Along with the challenge of environmental perturbations, we have come to a time of crisis in our education systems, which has the potential to disrupt our objects to nurture an informed and deliberative society. This could lead to a scenario in which future generations will be ill-prepared to resolve critical global issues with regard to life on this planet.

Among the multiple factors that make the issue of education complex, two constitute the root of the problem. One is the influence of the Cartesian scientific thought, which separates the parts of the problem to obtain an understanding of the problem as a whole. When applied to education, this line of thought contributes to the fragmentation of knowledge and can lead to the disjunction of disciplines that do not communicate with one another. This can culminate in a reductionist form of education and foster meaninglessness and alienation from historical-social context (Morin, 1999).

The second factor of influence is the traditional teaching-learning method, which prioritizes the passive transmission of information and encourages the memorization of content. Such a method has become increasingly inefficient at a time of constant transformation such as the contemporary world, in which countless aspects of knowledge and new technologies are continuously produced (Saliceti, 2015).

Due to its multidisciplinary nature, Astrobiology has already contributed a great deal in terms of interrelated research. Given that the central guiding issue in Astrobiology is the understanding of life as a complex and universal phenomenon, this discipline involves knowledge acquired from three major scientific areas: astronomy, biology and geology (Staley, 2003; Domagal-Goldman, S.D. et al., 2016).

Thus, Astrobiology can become an ideal resource to promote an integrative teaching strategy, because, besides causing curiosity in people, it propitiates the collaboration between teachers from different disciplines, in order to work with open issues, of multiple approaches (Rodrigues & Carrapiço, 2005; Arino de la Rubia, 2012; Silva, L.M.A. et al., 2016).

When investigating life in the cosmic context, Astrobiology also brings up Environmental Education issues, as it promotes reflections on the identity and the connection of the human being with the planet itself. This reflection makes them aware of the urgent need to preserve the environment in which they live (Rodrigues and Carrapiço, 2005; Rodrigues, F. et al., 2012).

In the Brazilian educational system, guided by the Guidelines and Bases Law, the High School is the final stage of basic education, whose purpose is the development of intellectual autonomy and critical thinking of students and the understanding of the scientific-technological foundations (Brazil, 1996). When applied to biology teaching, astrobiology satisfies the guidelines proposed in the National Curricular Parameters of High School in Brazil, in which interdisciplinarity and the contextualization should guide the teaching-learning process (Silva, L.M.A. et al., 2016).

From this context, this paper aims to verify how the astrobiological context can be applied in the official curriculum of the discipline of Biology, in order to propose an opening in which Astrobiology can be used as an integrating tool of scientific knowledge.

2. Metodology

This work was developed by a qualitative approach, applying the methodological procedures of documentary and bibliographic research.

The qualitative approach the researcher is the main instrument of data collection. In this approach, the researcher's interpretation of the phenomenon under study stands out (Pereira et al., 2018).

According to Gil (2002), documentary research uses materials that have not been analyzed or that can still be reworked according to the research objects. Thus, the curriculum contents proposed for the Biology subject by the Complementary Educational Guidelines to the National High School Curricular Parameters (PCNEM +) are materials that can through analysis be used as a source of data to be investigated.

According to Fonseca (2002), bibliographic research occurs through the survey of theoretical references already analyzed and published, such as books, scientific articles, websites, in order to collect information about the problem to be studied.

Both procedures, documentary and bibliographic research, complement each other in the elaboration of this work.

Documentary Analysis

The document analyzed was the Complementary Educational Guidelines for National Curricular Parameters of High School in Brazil (PCNEM+, in Portuguese). It was selected due to its national scope and because it proposes some complementary curricular guidelines suggested by the Brazilian National Curricular Parameters of High School, in order to present a direct dialogue with teachers and other professionals of education. Thereby, it presents and discusses questions related to scholar curriculum and each discipline, allowing the docent team to analyze and select the points that merit deepening (Brazil, 2002).

The use of documentary analysis in this research served as a basis to identify the thematic subjects proposed for the biology curriculum that correlate with the areas of interest in Astrobiology research.

Bibliographic Research

After the identification of the themes, each thematic subject was commented through comparative bibliographic research with use of reference to books and scientific articles.

The purpose of this method was to promote a clarification on the main topics of Astrobiology and to present an integrative vision of the natural sciences in their multidisciplinary nature. Thus, it was possible to seek information that was in agreement with our subject of study and investigate the possibility of Astrobiology to be applied as an interdisciplinary didactic resource for Biology teaching.

3. Results

According to the information contained in the PCNEM+, Biology can be presented in six major structuring topics, in order to make a remarkable contribution to students' lives,

Research, Society and Development, v. 9, n.1, e200911879, 2020
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i1.1879

regardless of their professional choices, abilities or intellectual preferences (Brazil, 2002).

The six major topics are:

1) interaction between living beings
2) quality of life of human populations
3) identity of living beings
4) diversity of life
5) transmission of life, ethics and genetic manipulation
6) origin and evolution of life

For didactical purposes, these structuring topics are presented sequentially in two distinct ways: one that privileges the general functioning of living beings in their macroscopic manifestation and another that addresses the microscopic dimension of their phenomena (Brazil, 2002).

Hence, we have sequence 1, whose concepts and visions depart from the current scenario of life on our planet and goes, from the first to the last school year, from macroscopic dimension to microscopic dimension, as shown in Figure 1.

Sequency 1

	1st year	2nd year	3rd year
1st semester	1. Interaction between living beings	3. Identity of living beings	5. Transmission of life, genetic manipulation and ethics
2nd semester	2. Quality of life of human populations	4. The diversity of life	6. Origin and evolution of life

Figure 1: Approach made from macroscopic to microscopic view.

Source: modified from PCNEM+ (2012)

The second sequence deals with conceptual and abstract subjects in the first academic years, in which the microscopic dimension of living beings is discussed, followed by the macroscopic manifestation of the living systems, as shown in Figure 2.

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i1.1879

Sequency 2

	1st year	2nd year	3rd year
1st semester	6. Origin and evolution of life	4. The diversity of life	1. Interaction between living beings
2nd semester	3. Identity of living beings	5. Transmission of life, genetic manipulation and ethics	2. Quality of life of human populations

Figure 2: Approach from microscopic to macroscopic view

Source: modified from PCNEM+ (2012)

These six topics represent the gathering of conceptual fields of Biology and highlight the essentials aspects of human life and other living systems life.

4. Discussion

In this section, the discussion of structuring topics will be presented from the astrobiological approach and sequence 2 previously discussed.

Origin and evolution of life

In this first topic, the discussion is guided by instigating concepts, such as the origin of life in the universe. In this way, the curricular contents approaches in this topic have a great scientific and philosophical relevance, in which students will have the opportunity to perceive and discuss possible interpretations of their own origins and of everything that exists.

Currently, in the scientific community, the origin of life on Earth is discussed, basically, following two possible perspectives. One of them, known as Abiogenesis or Hypothesis of the Spontaneous Generation, suggests that life may have arisen through inert matter by a spontaneous process, extremely slow and gradually increasing of functional-molecular complexity. In counterpoint, there is the hypothesis known Panspermia, which suggests that life may have arisen from outside the Earth, by the biogenic process, such as the action of microorganisms that have the ability to survive interplanetary travels or even interstellar travel (Rodrigues & Carrapiço, 2005).

Historically, many philosophers and scientists have already proposed explanations for the origin of life. Some of them, as the Greek philosopher Aristotle, a pioneer in the defense of Abiogenesis, wrote that nature can be able to advance, little by little, from lifeless things to animal life, in way that would be impossible to draw a line between the living and non-living. In this way, it would be difficult to define the simplest living organism, considering that they may have arisen as early as the first 500 million years after the emergence and formation of the Earth (Impey, 2009).

According to Damineli and Damineli (2007), the English naturalist Charles Darwin, in a still conceptual way, imagined that life could have arisen from a puddle of nutritious broth, containing ammonia, phosphorus salts, light, heat, and electricity. Basically, these ingredients would be part of the chemical process that would originate the first proteins and that would have been transformed into more complex compounds until they gave rise to the first living organic beings.

However, according to Luisi (2013), the exclusion of any divine intervention in the historical course of the origin of life, theoretically, is due to the Russian chemist Alexander Ivanovich Oparin (1894-1980). According to the author, the extension of evolution to the molecular world, as the first chapter of life's evolution, has only made progress from Oparin's ideas. With this, Oparin sought to understand the origin of life as part of the evolution of biochemical reactions, through competition and Darwinian selection in the prebiotic Earth, that is, before the emergence of life. He argued that molecules would have the capacity for spontaneous grouping, forming functional structures in increasing degree of complexity.

Fundamentally, at some point, this hypothesis can be considered as a modern version of the spontaneous generation, as illustrated in Figure 3.

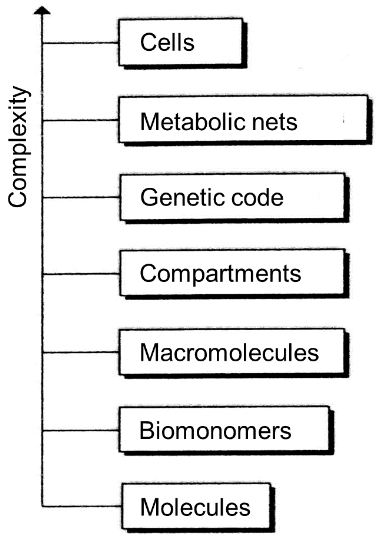

Figure 3: Arbitrary scale of complexity to the origin of life.

(Source: modified from Luisi, 2013).

The figure shows that there is an increase in the complexity of the biological system, starting from molecules to the formation of cells.

In general, the further we go back in the history of life, the more primitive are the living organisms that inhabited the Earth. Thus, according to Maia and Dias (2012), the first living beings may have been:

• Autotrophic beings, whose metabolism would occur by forms of energy other than sunlight, such as chemosynthetic;

• Heterotrophic beings, whose metabolism is generated in a process of biochemical evolution already greatly improved;

• Beings from outside of the Earth, characterized by the hypothesis of panspermia.

Regardless of whether any of the three assumptions cited are correct, Davies (2000) reports that the fossil record clearly shows that ancient life was very different from present-day life. According to the author, the oldest fossils of well-documented animals were found in Australia and are about 560 million years. Shortly after this time, about 545 million years ago, a real explosion of species would have initiated, culminating gradually in the colonization of the Earth by large plants and animals. At this point, it is important to note that 1 billion years ago, life was restricted to unicellular microorganisms.

In addition, another relevant point for this discussion is that all the life on earth descends from a common ancestor. According to Davies (2000), this argument is valid through a regressive analysis of the process of complexification and diversification explained by Darwin's theory of evolution, where, in the past, all the lineages that now diversify, would converge to a single common point of ancestry, called the Last Universal Common Ancestor (LUCA), shown in Figure 4.

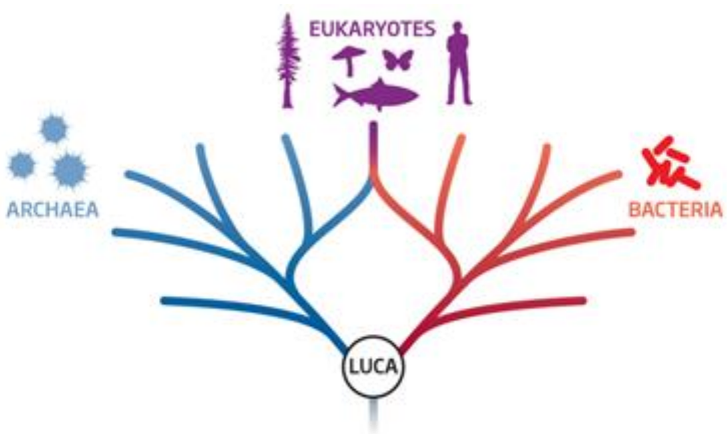

Figure 4: Last Universal Common Ancestor (LUCA).

(Source: Weiss et al., 2016)

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v9i1.1879

This figure shows the schematic phylogeny of LUCA, so that eukaryotes originate from prokaryotes and LUCA represents the ancestor of archaea and bacteria.

However, there is controversy regarding the fact that life on Earth could not have arisen from non-living matter, that is, in an abiogenic way. Thus, if we assume the hypothesis that the origin of life on earth necessarily occurred in a biogenic way, then we would have to resort to the argument of panspermia.

Basically, this hypothesis about the origin of life by biogenesis argues that life may have arisen somewhere in the universe and been transported to our planet. It regards life as an intrinsic property of the universe, which permeates the cosmos (Luisi, 2013).

Thus, Astrobiology is shown to be important in the search for answers that satisfy the questions still open about the origins of life.

Diversity of life

This second theme falls on issues related to how life has diversified from a common origin. In this way, students can acquire knowledge and scale the problems related to biodiversity, relating the physiological processes used by living beings with their adaptive strategy.

According to Maia & Dias (2012), the first evolutionist ideas were called transformers. They established that life has a long and continuous history during which the animal and vegetable organisms were transforming and thus populating the Earth. The earliest historical records related to these ideas come from the time of the ancient Greeks, such as the pre-Socratic Anaximander, Heraclitus, Empedocles and Xenophanes, and later with Aristotle. In a somewhat more recent period, shortly after 1600, a movement of intellectuals called naturalists arose, which sought to provide explanations that would support the development of a theory of the evolution of living beings.

According to Maia and Dias (2012), the Danish priest Nicolaus Steno, around 1685, sought to explain the existence of fossils with the hypothesis that species could change over time. In the following year, the English naturalist John Ray published, in his book *History Plantarum*, the definition of species based on the concept of the common ancestor Then Carolus Linnaeus (1707-1778) published in his work called *Systema Naturae* the description of the method of classification of all organisms, which is still used today.

Following this chronological line, in France, Pierre-Louis Moreau de Maupertuis (1698-1759) and George Louis Leclerc (1707-1788) respectively published the works *Essai* *de Cosmologie* and *Historie Naturelle*. The first brought the hypothesis that stronger animals produced more children while the second suggested that living things could evolve.

Finally, the naturalists Charles Bonnet (1720-1793) and Erasmus Darwin (1731-1802) were the last to leave their contributions before the development of ideas by Jean-Baptiste Lamarck (1744-1829) and Charles Darwin (1809-1882) on the evolution of species.

According to Pantoja (2016), Lamarck published, in 1809, his work Zoological Philosophy, oriented and grounded in two laws:

• Law of use and disuse

• Law of transmission of acquired characters

The first law follows the principle that any part of the body that was widely used would develop and those that were not used would atrophy. The second law is based on the argument that the morphological changes acquired by the principle of use and disuse would be transmitted to the next generations. However, the great problem of the Lamarckist theory, according to this author, is that it considers that the phenotypic issues could somehow alter the genotypic ones, which is not true.

In contrast, Charles Darwin published the book The Origin of Species, in 1859. In this book, he asserted that the better-adapted individuals survive the environmental obstacles, and the less adapted have lower chances, thus leaving fewer descendants. We now call this phenomenon Natural Selection of Species, which serves as the basis for the Synthetic Theory of Evolution (Darwin, 2014).

Charles Darwin, just like Lamarck, lived in a fixist period and also did not know genetics, which only appeared years later through the experiments of the monk and botanist Gregor Mendel. With the advent of genetics and the use of the theory of natural selection, the Synthetic Theory of Evolution was created.

According to the author Sonia Pantoja (2016), in addition to the Darwinian precepts, are also added to the Synthetic Theory of Evolution the phenomena chromosomal mutation, recombination, migration and genetic oscillation as factors that increase the genetic variability of a population. Thus, it is necessary to consider that in a population, there is genotypic and phenotypic variability of the individuals and that these small differences, when associated to geographic isolation, can lead to the formation of new species over time.

In addition, with the development of new knowledge and technological advances, the study of evolutionary processes and the study of life in the astronomical context become more and more instigating.

According to Damineli & Damineli (2007), the most fundamental point is that we would never be able to describe a general theory of life while knowing only the terrestrial exemplary. Basically, if we have the knowledge of multiple occurrences of life in the universe, this would allow us to make predictions, exposing the theory to empirical testing.

Another point to consider is that the information about the physical and chemical conditions of the primitive Earth is almost completely lost. Hence, astronomical knowledge becomes essential, through the observation of other stars that allow us to see the past, since, as we look at the celestial bodies in the night sky, we are actually receiving information from events that happened a long time ago.

An analogy that we can use at this point is that light propagates through the universe in a manner that is similar to the rock that goes through time. While the latter brings us information about the past of terrestrial life through fossil records, other planets and moons can bring us information about their several stages of formation, thus allowing us to be able to review the evolutionary stages through which Earth may have passed.

Another good reason to look at the sky is simply the fact that we can test the philosophical assumption of evolutionism, which holds that life arises as part of the processes of matter transformation and energy dissipation. Thus, any other planet in the same environmental conditions as Earth could have the same chance of generating life, as we know it here on our planet (Damineli & Damineli, 2007).

According to Santos & Alabi (2013), the search for a link between the origin of life on Earth and the origin of life in other habitable places in the universe could be the beginning of a General Theory of Biology. Fundamentally, the framework of this idea would be linked to a structure of concepts that would sustain the necessary processes related to how the development of life occurred. Therefore, this cosmic connection could help explain fundamental questions of terrestrial biology, thus revealing whether other organisms in the universe share the same biochemical basis as ourselves or not.

The fact that known complex biological systems are able to organize themselves based on the intrinsic characteristics of their molecules, along with the realization that physical properties of matter are the same everywhere, could indicate that life in the universe would follow at least part of the evolutionary paths observed on Earth (Santos and Alabi, 2013).

Currently, it is not possible to say whether there is the possibility of a panorama in which we could describe evolutionary processes throughout the cosmos, that is, we can test the universality of Darwinian theory. However, understanding our planet in all its aspects may possibly enable Astrobiology to create methods and techniques to seek information about the existence of life forms detectable by our species, whether they are similar to ours or not.

According to the authors, there are limitations to the recognition of life forms that may exist outside the Earth, since the very biodiversity on our planet is still little known. However, the attempt to extrapolate biological knowledge into the cosmic context is important for the formulation of a general theory of life.

Identity of living beings

In this third theme, the discussion is basically oriented through cytology, genetics and biochemistry, contents in which students may realize that all life forms are recognized by their cellular organization, suggesting evidence of their unique origin.

The discussion of this theme is extremely pertinent, because, until much of the twentieth century, it seemed appropriate to bring organisms together in only two general kingdoms: vegetables and animals. Thus, vegetables were seen as organisms that were most capable of producing their own food, being called autotrophic beings. In addition, vegetables were also seen as sessile, that is, as fixed beings. On the other hand, animals were characterized mainly as moving and heterotrophic beings (Cockell, 2011).

As new scientific techniques arose, especially with the advent of optical microscopy, it was possible to realize that bacteria, which were previously traditionally grouped with plants, are distinct in terms of the structure from all other organisms. At this point, the division between prokaryotes and eukaryotes arose.

However, still according to Cockell (2011), many eukaryotes continued to present problems regarding the old vegetable and animal division. Fungi contradict their plant classification, for example, because they are heterotrophic. Other examples include heterotrophic unicellular eukaryotes that display flagella and also others that are autotrophic and present chloroplasts for photosynthesis.

Thus, only with detailed studies on cell structure and differences in DNA sequences could it be possible to classify organisms more precisely. Although there is currently no universally accepted definition, it is possible to adopt a pragmatic division of eukaryotes (Table 1).

Table 1: Divisions of eukaryotes in different kingdoms, with their descriptions.

Kingdom	**Description**
Animalia	Multicellular, heterotrophic forms that ingest their food.
Fungi	Mostly multicellular (despite having incomplete partition walls), heterotrophic forms that feed on organic molecules, which are absorbed directly or externally broken with enzymes and then absorbed.
Plantae	Mostly multicellular, autotrophic forms, which include terrestrial plants (all multicellular) and algae (both algae that are multicellular, as unicellular forms related.
Protista	Other unicellular forms, which may be autotrophic or heterotrophic. This grouping is still a heterogeneous set of several groups only remotely related, some of which have relatively more recent ancestors in common with some of the other kingdoms.

Source: adapted from Cockell (2011)

It is also important to note that the understanding of the formation of the cellular structure of living beings is relevant to the search for signatures of life outside the Earth, since the cell is the fundamental unit for the identification of a living being.

Transmission of life

In this fourth theme, the foundations of heredity are treated with emphasis on the transmission of human characters. Understanding these fundamentals is essential so that the students can know and evaluate the meaning of the applications that have been made of genetic knowledge on the diagnosis and treatment of diseases and also on criminal investigations.

According to Damineli and Damineli (2007), among the most complex themes in Astrobiology to understand the origin of life is the emergence of a universal genetic code. Understanding how it was able to store the sequences necessary for the development of living organic beings is possibly one of the main and vitally important issues not only in what concerns questions related to the origin of life, but also in the search itself for understanding a little more about ourselves.

In biology, the discovery of rules governing inheritance in pea by Mendel (Brock, 1997) began the study of genetic inheritance, which revolutionized our understanding of genetically inherited diseases and improved our ability to detect and treat such diseases.

The exploration of hot springs in Yellowstone Park (USA), commonly used in Astrobiology research in studies with extremophile organisms, led to the discovery of Taq DNA polymerase from *Thermus aquaticus* (Freeze and Brock, 1970; Brock, 1997), which was subsequently used to develop the Polymerase Chain Reaction (PCR) (Mullis *et al.*, 1986).

Furthermore, PCR is a laboratory method used to amplify the number of fragments of a DNA model for different applications, including molecular identification, disease diagnosis, paternity test and forensic science. It has completely revolutionized the entire field of molecular biology, directly impacting medical research and was an essential part of the process used to sequence the human genome.

Therefore, it is possible to note that the genetic issues involved in the areas of knowledge related to Astrobiology allow students to be introduced to discussions with numerous philosophical, political and economic implications on the use of genetic manipulation.

Interaction between living beings

With the support of the environmental sciences, this theme will provide insight into the workings of living systems and deepen discussions on global climate challenges. (Brazil, 2002).

In an approach in the astrobiological context, this theme also rescues the connection of the human being with his own planet, making him aware of his role in the preservation and conservation of the environment in which he lives.

According to Morin (2003), the human condition does not depend only on the perspective of the human sciences, as well as should not depend only on philosophical reflection or literary descriptions. In fact, everything should be linked to the renewed natural sciences, gathered in Cosmology, Earth Sciences and Ecology.

Fundamentally, this thought is related to the knowledge that we have within us a physical, chemical, and biological world. Thus, Cosmology, Earth Sciences and Ecology would allow us to situate our human condition on Earth and in the cosmos presenting a type of information that organizes knowledge that was dispersed and compartmentalized.

To know humanity, one should not separate it from the universe, but include it within it. After all, all knowledge, to be meaningful, must contextualize its object. The "Who are we?" Is inseparable from "Where are we?", "Where do we come from?" and "Where are we going?" (Morin, 2003).

According to Gleiser (2010), the entire Universe may have arisen from a quantum fluctuation, so that the cosmos would be a product of an accident that carries the seeds of life. Initially, this process would have formed the lighter chemical elements that would then form the clouds of hydrogen and helium. Such clouds, due to gravitational action, would collapse to form the first generation of stars and galaxies. Thus, billions of years later, a planet bathed by vast oceans orbiting an ordinary star began to collect necessary ingredients for life. Hence, this whole cosmic process would have given rise to our first ancestors.

From the beginning, when humans became aware of their existence, they began to question and seek answers in the stars about what would be the reason for their origin and their place in the Universe. According to Gleiser (2010), the lack of detection of life elsewhere in the universe should be the wake-up call for humanity to reflect on our relationship with the Earth and the way we are taking care of it.

The progressive technological advance seems to have left us indifferent to the damage we are causing to our planet. The climate is changing and more than 30,000 species are dying every year. In this scenario, it is important that humanity, as a species on this planet, becomes aware of its responsibility to preserve life and the environment in which it lives. (Gleiser, 2010).

Although we have learned a lot about our position in the Universe and what we are made of, we still know very little about everything that exists. Science tells us, for example, how nature works and not how we want it to work (Gleiser, 2010). So when we come to have a defragmented thought of our cosmic origins, it is possible, at last, to notice a character not only human, in which the situation of the human being in the world is a tiny part of the whole, but we must also add ourselves as part of this terrestrial environment, which is present in the whole of this tiny part of the immensity of the cosmos (Morin, 2003).

Quality of life of human populations

In this theme, the central question is about the quality of life of human beings. In the common-sense imaginary, a pure scientific area like Astrobiology does not produce direct application. However, contrary to what they imagine, the knowledge produced by pure science research contributes to the development of technologies.

Among several examples of how the pure scientific investigation can lead to practical applications, we could begin from the practical use of astronomic knowledge such as the orientation in the geographic space that allows the maritime navigation, the management and monitoring of satellites, and the observation of regular climate patterns that make possible the development of agriculture.

Another example is the understanding of the dynamics of Earth's atmosphere obtained through the method of comparative planetology made from the observations of the planet Venus. Fundamentally, some research has demonstrated a critical role of certain chemicals substances in the Venus´s atmosphere (Prinn, 1971; McElroy et al., 1973). Afterward, the Montreal Protocol was created, whose objective is to substantially reduce the emission of gases and harmful substances into the environment.

In addition, Astrobiology and Astronautics can instigate human curiosity in knowing and exploring space. This motivation has made it possible to construct artificial satellites that monitor the Earth's climate and allow the understanding of the direct influence of climate change on the quality of life of populations (Jaxa, 2008; NASA Science, 2014).

One of the most well-known branches of astrobiology is the search for extraterrestrial life, whose research investments include the possibility of finding life extinct or alive on another planet, such as Mars. As a result, these studies have increasingly forced technology developers to promote miniaturization of equipment, especially spectroscopes to be coupled to the robotic probes that are sent in interplanetary missions (Holland et al., 2003).

All of this is extremely important and has direct implications for the development of technologies that can improve biomedical analysis or advances in industrial processes.

Raman spectroscopy, for example, is a laboratory technique used to observe vibrations, rotations and other low-frequency changes in molecules in a system and has been applied for the detection *in vivo* of cancerous tumors (Quian et al., 2008).

Another example is how understanding about microbial processes in carbonate precipitation can contribute to preventing deterioration in buildings (Gadd, 2010). The communication technology is also included in this scenario, being developed in space missions due to the need of transferring a large amount of data in a small bandwidth, exposed to many environmental interferences.

More recently, according to Paulino-Lima & Lage (2010), the discovery of microorganisms living in environments that are extremely inhospitable to humans has significantly amplified the habitable zone pattern in space, increasing the chances of finding some form of extraterrestrial life. Furthermore, this new data has promoted advances in

Molecular and Evolutionary Biology, due to the research with these microorganisms. With the development of these technologies, society has been benefited in several areas, such as agronomy, industry of synthetic compounds, bioremediation, molecular diagnostics and criminalistics.

Thus, it is possible to observe how the knowledge produced by research in pure science, such as Astrobiology, can promote many applications for a better quality of human life.

5. Final Considerations

In this work, it was proposed a possible insertion of Astrobiology through structural themes identified in the Complementary Educational Guidelines for National Curricular Parameters of High School from Brazil, with the objective of providing an interdisciplinary and motivating environment for students, and facilitating the process of teaching-learning. Thus, educators can also favor the development of skills necessary for the development of students.

Furthermore, it was possible to evidence the relevance of Astrobiology as a multidisciplinary teaching tool due to the fact that its main object of study is the phenomenon of life in the cosmic context. This new scientific field has great potential for Biology teaching, as it provides students with an integrated view of the natural sciences.

Finally, it is expected that this work will serve of motivation for future research, in order to contribute for the dissemination of Astrobiology as a promising scientific field and to emphasize its importance for an integrative scientific education.

References

Arino de la Rubia, L. S. (2012) The astrobiology in secondary classrooms (ASC) curriculum: focusing upon diverse students and teachers. *Astrobiology* 12, 892–899. doi:10.1089/ast.2012.0841

Blumberg, B. S. (2003) The Nasa astrobiology institute: early history and organization. *Astrobiology*, 3(3), 463-470. doi:10.1089/153110703322610573

Brasil (1996). Senado Federal. *Lei de Diretrizes e Bases da Educação Nacional: nº 9.394.* Retrieved from: https://www2.senado.leg.br/bdsf/bitstream/handle/id/70320/65.pdf.

Brasil (2002). Ministério da Educação. Secretaria de Educação Média e Tecnológica. *PCN+ ensino médio: orientações educacionais complementares aos parâmetros curriculares nacionais: ciências da natureza, matemática e suas tecnologias*. Brasília. Retrieved from: http://portal.mec.gov.br/seb/arquivos/pdf/CienciasNatureza.pdf.

Brock, T. D. (1997). The value of basic research: discovery of Thermus aquaticus and other extreme thermophiles. *Genetics*, 146, 1207–1210. Retrieved from: https://www.genetics.org/content/genetics/146/4/1207.full.pdf

Cockell, C. (2008) (org.). *An Introduction to the Earth-Life System*. Cambridge University Press, 2008.

Damineli, A. & Damineli, D. (2007). Origens da Vida. *Estudos Avançados.* 21 (59), 263-285.

Darwin, C. (1999). *The Origin of Species*. Bantam Classics.

Davies, P. (2000). *The Fifth Miracle: the search for the origin and meaning of life*. Simon & Schuster.

Domagal-Goldman, S. D., Wright, K. E., Adamala, K., Arina de la Rubia, L., Bond, J., Dartnell, L. R., Goldman, A. D., Lynch, K., Naud, M-E., Paulino-Lima, I. G., Singer, K., Walter-Antonio, M., Abrevaya, X. C., Anderson, R., Arney, G., Atri, D., Azúa-Bustos, A., Bowman, J. S., Brazelton, W. J., Brennecka, G. A., Carns, R., Chopra, A., Colangelo-Lillis, J., Crockett, C. J., DeMarines, J., Frank, E. A., Frantz, C., de la Fuente, E., Galante, D., Glass, J., Gleesonm D., Glein, C. R., Goldblatt, C., Horak, R., Horodyskyj, L., Kaçar, B., Kereszturi, A., Knowles, E., Mayeur, P., McGlynn, S., Miguel, Y., Montgomery, M., Neish, C., Noack, L., Rugheimer, S., Stüeken, E. E., Tamez-Hidalgo, P., Walker, S. I. & Wong, T. (2016) The astrobiology primer v2.0. *Astrobiology* 16, 561–653. doi:10.1089/ast.2015.1460

Fonseca, J. J. S. (2002). Metodologia da pesquisa científica. Fortaleza: UEC. Apostila.

Freeze, H. & Brock, T.D. (1970). Thermostable aldolase from Thermus aquaticus. *Journal of Bacteriology*, 101, 541–550. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC284939/pdf/jbacter00581-0233.pdf

Gadd, G. M. (2010). Metals, minerals and microbes: geomicrobiology and bioremediation. *Microbiology*, 156, 609–643.

Galante, D., Silva, E. P., Rodrigues, F., Horvath, J. E. & Avellar, M. G. B. (org) (2016). *Astrobiologia: uma ciência emergente*. São Paulo: Tiknet.

Gil, A. C. *Como elaborar projetos de pesquisa*. 4. ed. São Paulo: Atlas, 2002.

Gleiser, M. (2010). *Imperfect Creation: Cosmos, life and nature´s hidden code*. Black inc.

Holland, W., Verplanken, B. & Van Knippenberg, A. (2003). From repetition to conviction: Attitude accessibility as a determinant of attitude certainty. *Journal of experimental social psychology*, 39(6), 594-601. doi:10.1016/S0022-1031(03)00038-6

Impey, C. (2011). *The living Cosmos: the search for life in the universe*. Cambridge University Press.

Jaxa (2008*). Earth Observation Research Center*. Tokyo.

Luisi, P. L. (2011). *The emergence of life: from chemical origins to synthetic biology*. Cambridge University Press.

Maia, H. L. S. & Dias, I. V. R. (2012). Origem da Vida: recentes contribuições para um modelo científico. São Paulo: Livraria da Física, 2012.

McElroy, M. B., Dak Sze, N. & Ling Yung, Y. (1973). Photochemistry of the Venus atmosphere. *Journal of the Atmospheric Sciences*, 30, 1437–1447. doi:10.1016/0019-1035(82)90080-X

Morin, E. (1999). *Seven complex lessons in education for the future*. UNESCO.

Nasa (2014). *NASA Earth Science*. Washington, DC, 2014.

Pantoja, S. (2016). *Filogenética: primeiros passos.* Rio de Janeiro: Technical Books, 2016.

Paulino-Lima, I. G. & Lage, C. A. S. (2010). Astrobiologia: definição, aplicações, perspectivas e panorama brasileiro. *Boletim da Sociedade Astronômica Brasileira*, 29(1), 14-21. Retrieved from: https://sab-astro.org.br/wp-content/uploads/2018/10/Paper2.pdf

Pereira, A. S. et al. (2018). *Metodologia da pesquisa científica*. [*e-book*]. Santa Maria. Ed. UAB/NTE/UFSM. Retrieved from: https://repositorio.ufsm.br/bitstream/handle/1/15824/Lic_Computacao_Metodologia-Pesquisa-Cientifica.pdf?sequence=1.

Prinn, R. G. (1971). Photochemistry of HCl and other minor constituents in the atmosphere of Venus. *Journal of the Atmospheric Sciences*, 28, 1058–1068. doi:10.1175/1520-0469(1971)028%3C1058:POHAOM%3E2.0.CO;2

Qian, X., Peng, X.-H., Ansari, D. O., Yin-Goen, Q., Chen, G. Z., Shin, D. M., Yang, L., Young, A. N., Wang, M. D. & Nie, S. (2008). In vivo tumor targeting and spectroscopic detection with surface-enhanced Raman nanoparticle tags. *Nature Biotechnology*, 26, 83–90. doi:10.1038/nbt1377

Rodrigues, F., Galante, D., Paulino-Lima, I., Duarte, R., Friaça, A., Lage, C. & Horvath, J. (2012). Astrobiology in Brazil: Early history and perspectives. *International Journal of Astrobiology, 11*(4), 189-202. doi:10.1017/S1473550412000250

Rodrigues, T. & Carrapiço, F. (2005) Teaching Astrobiology. A Scientific and a Cultural Imperative. *Proceedings of SPIE*, 5906:59060F-1–59060F-4. doi:10.1117/12.617594

Saliceti, F. (2015). Educate For Creativity: New Educational Strategies. *Procedia - Social and Behavioral Sciences* 197, 1174 – 1178.

Santos, C. M. D. & Alabi, L. P. (2013). Todo biólogo é um pouco astrobiólogo. *Ciência Hoje*, 301(51), 56-57.

Silva, L. M. A., Oliveira, G. S. R. O., Crispino, L. C. B. & Friaça, A. C. S. (2016). Astrobiologia no Ensino de Ciências: Uma abordagem interdisciplinar e transdisciplinar para professores do Ensino Fundamental. *Caderno de Resumos do IV Simpósio Nacional de Educação em Astronomia*, 48-48.

Staley, J. T. (2003) Astrobiology, the transcendent science: the promise of astrobiology as an integrative approach for science and engineering education and research. *Curr Opin Biotech*, 14, 347–354. doi:10.1016/S0958-1669(03)00073-9

Weiss, M. C., Sousa, F. L., Mrnjavac, N., Neukirchen, S., Roettger, M., Nelson-Sathi, S. & Martin, W. F. (2016). The physiology and habitat of the last universal common ancestor. *Nature Microbiology*, 1(116). doi:10.1038/nmicrobiol.2016.116.

Porcentagem de contribuição de cada autor no manuscrito

Bruna Mayato – 50%

Maíra Moraes – 25%

Bruno Leonardo do Nascimento-Dias – 25%