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Article

On the Evolution of the Biological Framework for Insight

Claudio Neidhöfer, M.D.[1*]

[1] Heinrich-Blömer Weg 12, 53127 Bonn, Germany, claudio.neidhoefer@ukbonn.de
* Correspondence: claudio.neidhoefer@ukbonn.de

Abstract: The details of abiogenesis to date remain a matter of debate and constitute a key mystery in science and philosophy. The prevailing scientific hypothesis implies an evolutionary process of increasing complexity on earth starting from (self-) replicating polymers. Defining the cut-off point where life begins is another moot point beyond the scope of this article. We will instead walk through the known evolutionary steps that lead from these first exceptional polymers to the vast network of living bio matter that spans our world today, focusing in particular on perception, from simple biological feedback mechanisms to the complexity that allows for abstract thought. We then will project from the well-known to the unknown to gain a glimpse on what the universe aims to accomplish with living matter, just to find that if the universe had ever planned to be comprehended, evolution still has a long way to go.

Keywords: evolutionary biology; astrobiology; philosophy of biology; epistemology

1. Introduction

Our aim in this work is to approach the question of what the universe aims to accomplish with living matter from an evolutionary biology perspective and, hence, focus on the capacity of the human mind to handle the issue of the role of life in the universe. After addressing the question of the reducibility of biological phenomena, we will introduce some of the most important milestones in evolutionary history. We will examine the evolution of known life focusing in particular on early life, major evolutionary breakthroughs and finally the evolution of the biological framework that allows for perception and reflection. As a result we will have acquired the perspective that allows us to examine the limitations of our knowledge-building instruments and discuss the lead question.

2. Results & Discussion

2.1. *Reducibility of Biological Phenomena*

As physics is the study of how matter acts and reacts to various forces and aspects of the world and the universe it not only has massive implications for the biological sciences, it actually has growingly taken over the latter at increasing pace in the last decades and caused the science of life and living beings a reduction of large part of its autonomous theories to basic theories of a physical nature.

This has therefore lead to numerous debates in philosophy of biology on whether and which branches of biology can be reduced to molecular biology and physics. The main branches in biology are two: Functional biology and evolutionary biology. The former deals with the physiology of living beings and is believed to be based almost entirely on physics and chemistry, the latter on the other hand deals to a large extent with unique phenomena that occurred in a time frame.

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Physical laws explain us in increasing detail how atoms are constructed and behave. Molecular biology explains processes in an organism on the basis of biochemical reactions. Through deep understanding of physics and observation of celestial bodies and astronomical phenomena, significant insight on the history and functioning of the universe has been gained. Likewise, through growing knowledge of molecular biology and the study of living beings and fossils, deep insight in the evolution of life has been acquired.

Surely it can be argued that physics explains chemistry and thereby molecular biology, but a physicist will soon notice that the reductionism inherent to physics can prevent one from recognizing important relationships underlying seemingly chaotic events, from appreciating evolutionary origins, and from perceiving the heterogeneity of complex systems, which is at the very essence of the study of biology. The success of reductionism in physics is that the concept of classes whose members are identical, applies superbly to the inanimate world. In the study of the animate world we deal with populations in which, by contrast, each individual is unique. These populations' characteristics further change gradually from generation to generation and do not differ from each other by their nature, but only by statistical averages. In biological sciences we therefore often encounter a holism that can, on the contrary, complicate recognizing fundamental principles within complex systems.

So while physics and molecular biology explain us how the animate and inanimate worlds work, and astrophysics and evolutionary biology teach us the history of both, only together they provide the bigger picture. The living world conveys the concept of eternally variable objects of study, grading into each other from generation to generation, whereas the immutable laws of physics predispose to a typologist's view. These two fundamentally different approaches colliding show the importance to approach the fundamental questions on the future and purpose of life and the universe in an interdisciplinary and unifying way, since neither of them can accomplish it independently.

2.2. *The Origin and Provision of the Elements*

All known forms of life require a certain set of chemical elements for biochemical functioning. These core elements are the building blocks for carbohydrates, nucleic acids, proteins and lipids, the four categories of molecules that make up the structure and function of organic life. It is thought that quarks and electrons formed when the universe started to cool after the Big Bang. Quarks aggregated to form protons as well as neutrons which in turn combined to form nuclei. Upon further cooling electrons intertwined in orbits around these nuclei to form the first atoms, mainly hydrogen and helium, the by far most abundant elements in the universe (Allday 2016; Puy & Signore 2002; Weisskopf 1989). Gas clouds of these than formed the first generation of stars which includes the most massive ones. Since a star's lifetime is inversely proportional to its mass cubed, these stars would have been relatively short-lived. Within these stars hydrogen and helium were fused into heavier and heavier elements and expelled into the interstellar medium during their burst, enriching it with the remaining chemical elements required for life (Bromm 2013; Susa 2013; Iwamoto et al. 2005; Pei et al. 1999).

Stars that formed subsequently would not be exclusively composed of hydrogen and helium which would prevent them from growing as massive and thereby prolong their lifetime. In fact, some are still visible today. Others, instead, exploded and allowed later generations of stars, such as the Sun, to be richer still in heavier elements (Hartwig et al. 2018; Smith & Sigurdsson 2007).

Within our solar system planets are believed to have formed by collision and self-organization from the gas and dust that was left of the fraction of giant molecular cloud that formed the Sun. At greater distance from the Sun, where volatile molecules like water and methane remained icy and hence solid, respectively large planets could

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form. Closer to the Sun planets like Earth could only form from less prevalent compounds with high melting points, such as metals and rocky silicates, and therefore remained comparatively small (Montmerle et al. 2016; Lissauer 1993).

Due to frequent collisions with other bodies and extreme volcanism, the Earth was initially molten. With time the outer layer of the planet cooled and formed a solid crust (Yin et al. 2002; Wetherill 1990). When and how oceans of liquid water appeared on planet earth is not yet entirely resolved, but, as we will see, it is on the bottom of these that life on earth has its most likely origins.

2.3. *The Birth of Life*

A central unifying concept in biology, known as cell theory, recognizes the cell as the basic unit of life (Mazzarello 1999). Living beings, which are composed of one or more cells, are thermodynamically open systems that achieve homeostasis by reducing entropy by using energy. Also, according to cell theory, cells arise by division from pre-existing cells, which leaves the question of the origin of the first cell unanswered.

Abiogenesis defines the yet unknown process though which life has arisen from matter and is agreed upon to not be a single event but a process of increasing complexity that involves molecules capable of self-assembly and self-reproduction (Pross & Pascal 2013; Mulkidjanan & Galperin 2007; Orgel 1998; Küppers 1990; Gilbert 1986; Oparin 1957). Ribonucleic acid (RNA) macromolecules best match this profile, but the formation of such in the first place and the path from these polymers to the first membrane-enclosed cell would yet still need to be elucidated. The first step from matter to life is the formation of organic molecules; these can form from inorganic molecules in certain environments under certain conditions (Vastel 2014; Podlech 2001; Chyba & Sagan 1992). Early Earth's atmosphere provided the required ingredients and hydrothermal vents have been described as one potential source of organic compounds (Colín-Garcia et al. 2016; Konn et al. 2015; Martin et al. 2008; Van Dover 2000).

The theory of evolution is based on the idea that all species are related and gradually change over time due to genetic variation affecting an organism's phenotype and natural selection (Smith 1993) and, hence, postulates a last universal common ancestor for all currently living beings, LUCA. LUCA is hypothesized to have been a hyperthermophilic single-celled organism with a lipid bilayer membrane and a circular DNA chromosome. It encoded the standard machinery for replicating its chromosome and to translate genes. It is believed to have inhabited anaerobic hydrothermal vents in hydrogen-, carbon-dioxide- and iron-enriched atmosphere (Weiss 2016; Glansdorff et al. 2008; Koonin 2003; Penny & Poole 1999).

Evolution had gone a long way from abiogenesis to LUCA and, even though, it is considered to be far less complex than any organism living today, tangibly envisioning the genesis of life from matter to reach even such vast complexity currently seems beyond reach.

The first living organism in an otherwise abiotic world by definition would be assumed to be an autotroph, capable of fixating carbon. Being the last universal common ancestor for all currently living beings is not the same as being the first living being on earth. Nevertheless, LUCA seemed capable of using hydrogen to reduce carbon dioxide to carbon monoxide and formic acid, which indicates a not too distant relationship to the first living being (Schönheit et al. 2016; Weiss et al. 2016; Lane & Martin 2012; Martin and Russell 2003).

The tree of life begins with LUCA and splits into the two main domains from there, the Bacteria domain and the Archaeae domain. The first bacteria are believed to be the clostridia, the first archaeae the methanogens, both sharing many properties with LUCA (Martin et al. 2016). Organisms living during this time, which is believed to be the early Precambrian where the earth's surface had just started to cool down and its atmosphere

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consisted in large part of nitrogen, hydrogen, carbon-dioxide and methane, relied on a strictly anaerobic biochemistry.

We summarize: Hydrogen formed in the big bang, most other elements later in the demise of stars and similar events. Organic compounds have several potential sources; deep hydrothermal vents on earth are one. All life forms known to date can be traced to one common single-celled ancestor that displays features that suggest such a habitat.

The sun is a star, of which there are countless many. Earth-like planets had been hypothesized and are now being described more and more often. Nevertheless, to date there is no evidence pointing to the fact that abiogenesis occurred more than once in the history of the universe, momentarily elevating the uniqueness of this event to that of the big-bang. Understanding how life formed could tremendously advance understanding of its nature and purpose. Unluckily, currently we still lack knowledge on the events that lead from complex organic compounds to LUCA. Nevertheless, based on the gathered evidence we apprehend that the oldest known cell is an already complex machinery that has its construction manual and work instructions written in form of complex organic molecules (DNA).

Key point here is that LUCA’s genetic code is purely non-functional (contrary to the genetic code of self-replicating RNA molecules) but contains all necessary information on how to build the tools (mostly enzymes) that ensure the tools are built and the code is copied. For this machinery to work the tools that read and build (called ribosomes) need to already be built and carried along. Ribosomes are largely composed of RNA and are hypothesized to have been fully composed of it during early life on Earth (Petrov et al. 2015; Fox 2010; Caetano-Anollés 2002). Since RNA also has DNA like properties it is believed that the instruction manual (DNA) and the tool that reads and builds according to it (ribosomes) have a common precursor molecule.

RNA molecules can fold to complex three-dimensional structures but are composed of a one-dimensional matrix that contains mostly no more than a few thousand characters that are furthermore limited to four variables. The molecule that gave birth to life could, hence, be experimentally determined and reproduced. It should be noted that environmental conditions could have influenced the folding pattern. Therefore, computer simulations might prove even more useful than laboratory experiments in regard to finding a candidate.

The current state of knowledge depicts life as unique system that started under highly particular circumstances and then grew in complexity which then allowed it to expand to other environments, like a spark that ignites a blaze. The discovery of mentioned hypothesized molecule, however, could really portray life as little but a complex physical system and abiogenesis as a consequence of the physical laws.

2.4. *Heterotrophy*

While autotrophic organisms are capable of converting inorganic carbon dioxide to organic carbon compounds, heterotrophs cannot, and instead derive their energy from organic carbon compounds fabricated by others. High hydrogen environments such as hydrothermal vents thermodynamically favour the synthesis of organic compound synthesis whereas lower concentrations of hydrogen make fermentation of these more favourable (Preiner et al. 2019; Lane et al. 2010). The first heterotrophic organisms seem to have evolved at sufficient distance from hydrothermal vents or in no longer active ones living on cell sediments of autotrophs. Most of the machinery for fermentation of the organic compounds was already in place in autotrophs. Hence, heterotrophy was a conceivably suggestive evolutionary development of living cells and an opportunity for life to prosper in these environments.

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2.5. *Photosynthesis: The Implications of Innovation*

The next big leap was the evolution of pigments that were capable of being excited by light at certain wavelengths and thereby to convert and store light energy as chemical energy. This early form of photosynthesis was presumably Anoxygenic (Blankenship 2010; Blankenship 1992; Garlick et al. 1977). It reduced agents other than water and therefore did not produce oxygen. These organisms were descendants of the first bacteria and must presumably had already left the vicinity of the hydrothermal vents to inhabit light-accessible ocean layers.

Over hundreds of millions of years their descendants in turn evolved on the one hand a photosynthetic apparatus that reduced water and produced oxygen and on the other hand systems of protection against the destructive effect of this very product (Fischer et al. 2016; Ward et al. 2016). The ability to use water for reduction, an almost unlimited resource, led to the explosive proliferation of these organisms. These inconspicuous, minute, new tools allowed these organisms that were ancestors of today's known cyanobacteria, to bloom and shape this planet we know as earth in an unparalleled and unprecedented way. The growing abundance of thereby produced oxygen first reacted with minerals and once these were saturated accumulated in the atmosphere and depleted it of methane. Results were manifold, from further planetary cooling due to a markedly weakened greenhouse effect to a mass extinction of anaerobic organisms that were exposed to but not suited to this new environment and probably constituted the larger part of life to date (Och et al. 2012; Shields-Zhou & Och 2011; Kopp et al. 2005).

Anoxygenic photosynthesis provided an alternative energy source, but oxygenic photosynthesis provided a novel way of life. Independence from the limited resources of geochemically derived reductants enabled these cells to conquer completely new habitats and displaced differently evolved contemporaries into niches. An organism that is not appropriately geared to keep cellular functions running in the environment it is located has to change environment, gear up or survive until the environment is more favourable. Anything else likely results in the living organism irreversibly disintegrating to more- and less-complex organic molecules. The mass-proliferation of cyanobacterial precursors and mass-extinction of anaerobes suggests that the ultimate agenda of these unicellular organisms was to thrive and reproduce, if possible, no ifs and buts, as a consequence of the fact that the biochemical processes of these machineries did not amount to anything else.

2.6. *Eukaryotes: Symbiosis and Predation*

Approximately halfway through the Precambrian, the first highly complex unicellular organisms appear: Eukaryotes (Zimmer 2009; Roger & Hug 2006). These cells were significantly larger than their ancestors and had a highly organized internal organization. The high energy demand was satisfied by an entirely new evolutionary accomplishment: a cellular organelle completely dedicated to generate energy at peak efficiency through oxygen combustion.

The organelle is hypothesized to have been a small single-celled organism by itself that ended up in another larger single-celled organism; a relationship that turned out to have mutual benefit and resulted in the larger cell not only hosting the smaller but with time even encoding its genome. Two organisms had merged to form one (Cox et al. 2008; De Duve 2007; Cavalier-Smith 2002; Sogin 1991).

Predation is assumed to have had a large role in shaping evolution, to have arisen relatively early and is even thought of as one possible mechanism by which mitochondrial precursors entered their host (Davidov & Jurkevitch 2009; Langerhans 2007). Key point is the fact that although predation might have shaped evolution again and again, as we will later see the winning strategy here is cooperation. And we can term it "winning" given

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the subsequent evolutionary success of eukaryotic organisms, defining success as compromising a significant number of organisms and amount of biomass to this very date.

The idea that an organism is actually composed of two organisms can be troubling to a human mind. In science and philosophy this key issue has hence been addressed in several ways (Booth 2014; Clarke 2010; Lane 2006).

The acquisitions of highly organized internal organization and a mitochondrial powerhouse enabled unique new thriving opportunities, among which preying on much smaller prokaryotic contemporaries was just one. The real breakthrough for eukaryotic cells, however, was the evolution to multicellularity. Thereby their actual potential was tapped.

2.7. *Multicellularity: Challenging Concepts*

The main disadvantage of being a large eukaryotic cell as compared to a small bacterial or archaeal one is the lower surface-to-volume ratio and the resulting difficulty absorbing and transporting nutrients through the cell. Multicellularity, as we will see, remedies this problem while preserving the competitive advantage of increased cell size.

Precursors of multicellularity are thought to be multicellular colonies (Herron et al. 2019; Libby & Rainey 2013). In these, increasing cell specialization then led to the transition from colonial aggregates to truly multicellular organisms. Unlike abiogenesis and the evolution of eukaryotes, the step to multicellularity seems not to have been a one-time event, but to have occurred independently several times in various species (Niklas 2014; Ruiz-Trillo et al. 2007; Bonner 1998). The main mechanism that allowed for multicellularity was adhesion. These organisms didn't have to reinvent the wheel. Mechanisms that were used to adhere to surfaces just had to be used to instead adhere to other cells. These organisms multicellularity was, however, limited to two-dimensional structures in which every participating cell was exposed to the environment, their main source of nutrient supply.

Somewhat more singular was the step to complex multicellularity that was not only based on cells of an organism sticking together but them to additionally exchange nutrients and signal molecules; necessary for their novel three-dimensional organization in which only some of the cells remained in direct contact with the environment (Nagy 2017; Knoll 2011). Interpreting this evolutionary step as a success, would not be based on metazoan bias but on the realization that complex multicellularity significantly better harnesses the potential of eukaryotic cells, over bacterial and archaeal ones. In the end it always is the biological framework to dictate the winning strategy.

The emergence of complex multicellularity was an important transition in evolution and is generally thought to be associated with increased genomic complexity (Nagy 2017; Niklas et al. 2017; Lynch & Conery 2003). Unicellular life is relatively simple because there is little division of labor, resulting in the genetic information content of single-celled organisms to be comparatively low. Multicellular life, on the other hand, requires more genetic information because significantly more cellular functions must be accomplished and cells differentiate into different cell types, tissues, and organs, but each cell contains the blueprint of the organism as a whole. Additionally multicellular organisms need a master developmental program, a way to direct specific cells to take on specialized jobs in different parts of the body. This master developmental program is a so called "Hox gene cluster" and responsible for the diversification of body plans ensuring that the correct structures form in the correct places of the body (Lemons & McGinnis 2006; Ruddle et al. 1994).

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The key to success of the symbiosis between mitochondrial precursors and their host cell was that both had different characteristics that complemented each other in a fruitful way. Today we think of a good team as one in which each member can rely on each other member to deal with the respective task allotted to them. And as teamwork has proven itself a successful strategy in the history of society, it has in history of evolution. Complex multicellularity follows the same principle, that of teamwork and labor division. Different cells take up different functions in the organism. Later in evolution this organization would further escalate to a whole new level by producing tissues and organs within organisms.

Complex multicellularity led to what appears to be a relatively explosive development and differentiation of organisms, many of which were fossilized and therefore allow us some clarity today. The degree of explosiveness of the event is debated but not relevant to our purpose. Relevant to our purpose instead is another concept: Even though up to now we could think of an organism as something enclosed within and limited by a cell-wall, the concept of organism can go beyond that. We now have to start thinking of an organism as something that can also be composed of many individual cells. We could abandon the thought that an organism's outermost borders are necessarily cell walls and rather try to think of an organism as the macromolecular complex that self-replicates, which includes its DNA and machinery both. Such a definition as well expands the status of an organism to hypothetical self-replicating RNA-molecules without a membrane.

Cell theory, recognizes the cell as the basic unit of life among others because for a human mind thinking of a unit as something whose ends are unmistakeably demarcated and spatially separated from another unit or its outside is eminently conceivable. We see, however, how drastically this oversimplification can distort our understanding of what life might actually be.

The fact that complex multicellular organisms are composed of differently differentiated cells that have different fates and that some of these lose their ability of self-replication implies a tremendously complex concept of what the basic unit of life is and even challenges our very capability to define it. It is even more intricate due to the fact that these self-replicating complexes are designed to suffer alterations every few replications and thereby cannot really be termed "self-replicating" either.

Latest here we understand the complexity of matters discussed in philosophy of biology and leave addressing these for now, for our purpose in this work is limited to lighten the path that has empowered us to do so.

2.8. *Room for Sensation*

Being part of an organism in which one group of cells takes care of nutrient supply for all and another group manages remaining life-saving tasks gave all other cells the possibility to find utterly novel purposes that might prove valuable. In fact this point in time, known as the "Cambrian explosion" is characterized by tremendous evolutionary inventiveness (Lee et al. 2013; Marshall 2006).

While limbs and shells certainly seem resourceful inventions we will focus on the novelty, which has turned out to be the most significant in our context and perhaps as a whole: The neural network. Neurons are electrically excitable cells with the ability and purpose of transmitting signals from one end to another. Taken by itself this is no great accomplishment, in fact it is when many neurons are connected to form a network or

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neuronal circuit that their full potential is attained. Nervous systems enable organisms to receive sensory information from their external and internal environment, process this information, and regulate neurosecretory and motor systems. To operate such tasks at least three types of neurons are required.

Afferent or sensory neurons are those receptive for stimuli. These stimuli can be internal or external. A sensory neuron is the first link in the signal chain of a sensory organ. In most cases, it is designed for specific types of stimuli. The evolutionary earliest receptor cells were probably designed for chemical, thermal, mechanical or electrical stimuli (Milijkovic-Licina et al. 2004). In these sensory cells, these stimuli alter a receptive cellular receptive structure in a particular way and a neuronal signal is generated and transmitted.

Efferent neurons are just such that are stimulated by other neurons and eventually carry a signal to a target effector.

Interneurons, instead, the third type of neurons, are the most interesting ones. These compose neural circuits, conducting flow of signals between a sensory neuron and a motor neuron. Interneurons can be arranged in functional chains and perform complex functions through interactions with each other. In more complex multicellular organisms the network of interneurons can be sufficiently complex to allow processing and interpretation of the signal. Even different sensory information can be integrated.

Single-celled organisms were already capable to respond sensibly to stimuli in their environment by sensing food sources or toxins through special receptor molecules in the cell wall (Hooshangi & Bentley 2008; Bourret & Stock 2002). When these simple receptor structures are stimulated, they cause the prokaryote to move in a more favorable direction, such as toward food or away from danger. Even electrical signaling between cells started well before neurons (Catterall et al. 2017), but it was neurons that made signaling efficient in complex multicellular organisms.

The first neurons are believed to have had sensory and effector functions, hence interneurons have evolutionarily followed only subsequently. In the course of evolution and with the higher development of individual divisions of the animal kingdom, a clear tendency toward concentration and concomitant specialization of parts of the nervous system can be observed. While seemingly diffuse networks of interneurons were the rule at first, in some more complex organisms organized groups of neurons began to appear, forming what can best be defined as a central nervous system. This made it possible to process information, rather than to just transmit it, and enabled these organisms to move and respond to their environment in increasingly sophisticated ways (Arendt et al. 2019; Kristan Jr 2016; Moroz 2009).

2.9. *The Human Brain*

In the same way in which not all prokaryotes switched to photosynthesis and not all single-celled organisms took the path of symbiosis and or multicellularity, not all multicellular organisms invested in neuronal development, and even those who did developed quite differing nervous systems. Evolutionary conserved regions common to most, if not all brains, however, are those in charge of sustaining fundamental homeostatic functions (Grillner & Robertson 2015). Guided by our anthropocentric perspective we will focus on the development of the human brain.

The central nervous system started as a tube-like structure given its origin in worm-shaped complex multicellular organisms (Sarnat & Netsky 2002). Its evolutionary path on becoming a human brain, which just represented one of many, started with an expansion of the central nervous system at the foremost end of the body, called the forebrain. Two other centers, originated from expansion alike, just behind the former; the midbrain and hindbrain. From the hindbrain, to which the spinal cord connects, the cerebellum developed. The forebrain was originally in charge of smelling, the midbrain of processing the information it received from the eyes, and the hindbrain controlled movement and spatial orientation (Jerison 2012; Roth & Dicke 2005; Striedter 2005).

While more posterior parts of the brain were in charge of life-support functions, evolutionary changes occurred primarily in the forebrain, which is used to make decisions and evaluate information. Higher performance, the ability to perform complex actions and the willingness to learn, are owed to the enlargement of the outer layer of the forebrain, the cerebral cortex. In order for the ever-increasing surface area of the outer layer of nerves to still fit into the vertebrate skull, there was a continuous surface-increasing unfolding of the cortex (Passingham & Wise 2012). The evolutionary youngest part of the cerebral cortex is the neocortex, which is only found in mammals. It is particularly pronounced in humans and is the site of higher functions and cognitive abilities. It consists of sensory areas, areas which control voluntary movements and such that link sensory impressions with corresponding emotions and behavioral patterns (Florio & Huttner 2014; Rakic 2009; Northcutt et al. 1995).

The highly valued ability to think for example is not exclusive to humans, with certainty (Weil 2012; Povinelli & Vonk 2003); however, humans are a stone's throw ahead of their contemporaries in this respect. Which influences underlie the biological changes that caused the human brain to evolve the way it has, are highly debated issues. Nevertheless, it is not difficult to understand that complex reasoning, inventiveness and advanced comprehension have been highly valuable tools that allowed humans to survive, prosper and dominate.

2.10. *Implications for Knowledge Emergence*

The only ways through which information conventionally reaches the human brain are the sensory nerve cells. Artificial direct stimulation of interneurons with complex tools available today, bypassing afferent cells is imaginable, but by no means conventional. Our knowledge of the world within us and around us has thus always relied on mentioned cells. We refer to knowledge here as the totality of information and convictions we hold. Conversely, it has been proven that our brain acts on the selectivity of our perception (Lewis et al. 2015; Nuñez & Malmierca 2007; Kerr et a. 1999; Harter & Aine 1984), which leaves us with a fundamental issue: The only channel through which we receive information has a permeability that is modulated by the interpretation of the brain of the very same information. Hence, further incoming information to be interpreted is probably already selected, eventually modified and, hence, probably not absolute.

2.11. *Evolution: Patterns and the Question of Directionality*

Evolution resembles a probabilistic system (Gigerenzer et al. 1990; Simberloff 1980). Traits that give an organism a better chance to reproduce or survive and that can be passed on to offspring, become more dominant over time. Traits that do the opposite dwindle over time as unsuited organisms die out or are displaced by better adapted ones. However, there are parameters that influence the character of evolution (Birch 2016; Demetrius 1997). The question of directionality in the biological history of the Earth

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therefore depends very much on the nature of the evolutionary scenario in which we actually find ourselves, which may vary in time. In a low populated and newly claimed environment organisms my not yet be at their optimum fitness and evolution might appear to have directionality, selecting for more optimal fitness in time.

Species are constantly dying out as the environment changes, as organisms compete for environmental niches, and as genetic mutations cause older species to give rise to new ones. Occasionally, Earth's biodiversity suffers a blow in the form of major extinction events, which are an accumulation of smaller extinction events that occur in a relatively short period of time. Each of the five major extinction events on earth was characterized by rounded up 80% or more of the then currently living species being lost. However, life on Earth always recovered and dominance over certain ecological niches simply passed from one group of organisms to another (Purvis et al. 2000; Hart 1996; Crowley & North 1988; Raup 1986).

Biodiversity is a measure of variation at the genetic, species, and ecosystem level. With mass-extinction events global biodiversity has experienced some setbacks, but has gained significantly over the long term (Benton 2010; Courtillot & Gaudemer 1996). The period since the emergence of humans shows a continuous decline in biodiversity and a concomitant loss of genetic diversity. The reduction is mainly caused by human impacts, especially habitat destruction, and is even referred to as the sixth mass extinction (Ceballos et al. 2015; Pievani 2014). The recent era of human influence on its environment reflects multiple geologic changes of global proportions. Our demands for resources and food, necessitating invasive mining and agricultural practices, have altered the surface of the planet today almost everywhere and represent permanent geologic signatures that are global and form a boundary that is readily apparent in surface geology (Crutzen 2006). Like cyanobacteria and later terrestrial plants we humans have shaped this planet to such degree that the change is visible from the Moon. This alone speaks for the fact that human mental capabilities are an evolutionary breakthrough of which the implications are rigorous, but whose extent can hardly be envisioned. No matter if mass extinctions have been initiated due to evolutionary breakthroughs or environmental phenomena, the long-term outcome so far has always been that of a recovery, an increasing biodiversity and an overall tendency towards the emergence of more complex organisms.

3. Conclusions

Given that our human brain carefully selects the information it receives for processing, mostly without us being aware, our understanding of the universe near and distant to us, is customized to our biological predisposition. The brain that guides us is one shaped by evolution, and evolution rewards those that are best suited for survival. The evolutionary breakthrough of this highly complex neuron network was that it allowed us to understand and use our environment so distinctively better than any other contemporary evolutionary novelty that we prospered overpowering everything that was in our way. The brilliance of the human mind therefore must always be considered in the light of it being optimized for grasping things that ensure our survival and reproduction. The very laws of evolution might never even favor the formation of a mind optimized to understand the complexity of the universe that creates it, excluding the latter ensures survival and reproduction of the bearer. A future, instead, in which organisms might have at least a more profound understanding of the cosmos than humans to date, is thinkable, with further increasing neuronal complexity or a novel evolutionary mean for example.

Philosophical questions that have troubled mankind since the dawn of time such as the purpose of life in the universe could still be around for the fact that neuronal networks

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optimized for philosophical problem solving have never given the bearer any advantages in fitness over his contemporaries, or even worse. In that case we can hope that society might provide the required selective pressure or might at least allow a niche for such development.

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References

Allday, Jonathan. *Quarks, leptons and the big bang*. CRC Press, 2016.

Arendt, Detlev, et al. "Evolution of neuronal types and families." *Current opinion in neurobiology* 56 (2019): 144-152.

Benton, Michael J. "The origins of modern biodiversity on land." *Philosophical Transactions of the Royal Society B: Biological Sciences* 365.1558 (2010): 3667-3679.

Birch, Jonathan. "Natural selection and the maximization of fitness." *Biological Reviews* 91.3 (2016): 712-727.

Blankenship, Robert E. "Early evolution of photosynthesis." *Plant physiology* 154.2 (2010): 434-438.

Blankenship, Robert E. "Origin and early evolution of photosynthesis." *Photosynthesis research* 33.2 (1992): 91-111.

Bonner, John Tyler. "The origins of multicellularity." *Integrative Biology: Issues, News, and Reviews: Published in Association with The Society for Integrative and Comparative Biology* 1.1 (1998): 27-36.

Booth, Austin. "Symbiosis, selection, and individuality." *Biology & Philosophy* 29.5 (2014): 657-673.

Bourret, Robert B., and Ann M. Stock. "Molecular information processing: lessons from bacterial chemotaxis." *Journal of Biological Chemistry* 277.12 (2002): 9625-9628.

Bromm, Volker. "Formation of the first stars." *Reports on Progress in Physics* 76.11 (2013): 112901.

Caetano-Anollés, Gustavo. "Tracing the evolution of RNA structure in ribosomes." *Nucleic acids research* 30.11 (2002): 2575-2587.

Catterall, William A., Goragot Wisedchaisri, and Ning Zheng. "The chemical basis for electrical signaling." *Nature chemical biology* 13.5 (2017): 455-463.

Cavalier-Smith, Thomas. "The phagotrophic origin of eukaryotes and phylogenetic classification of Protozoa." *International journal of systematic and evolutionary microbiology* 52.2 (2002): 297-354.

Ceballos, Gerardo, et al. "Accelerated modern human–induced species losses: Entering the sixth mass extinction." *Science advances* 1.5 (2015): e1400253.

Chyba, Christopher, and Carl Sagan. "Endogenous production, exogenous delivery and impact-shock synthesis of organic molecules: an inventory for the origins of life." *Nature* 355.6356 (1992): 125-132.

Clarke, Ellen. "The problem of biological individuality." *Biological Theory* 5.4 (2010): 312-325.

Colín-García, María, et al. "Hydrothermal vents and prebiotic chemistry: a review." *Boletín de la Sociedad Geológica Mexicana* 68.3 (2016): 599-620.

Courtillot, Vincent, and Yves Gaudemer. "Effects of mass extinctions on biodiversity." *Nature* 381.6578 (1996): 146-148.

Cox, Cymon J., et al. "The archaebacterial origin of eukaryotes." *Proceedings of the National Academy of Sciences* 105.51 (2008): 20356-20361.

Crowley, Thomas J., and Gerald R. North. "Abrupt climate change and extinction events in earth history." *Science* 240.4855 (1988): 996-1002.

Crutzen, Paul J. "The "anthropocene"." *Earth system science in the anthropocene*. Springer, Berlin, Heidelberg, 2006. 13-18.

Davidov, Yaacov, and Edouard Jurkevitch. "Predation between prokaryotes and the origin of eukaryotes." *Bioessays* 31.7 (2009): 748-757.

De Duve, Christian. "The origin of eukaryotes: a reappraisal." *Nature Reviews Genetics* 8.5 (2007): 395-403.

Demetrius, Lloyd. "Directionality principles in thermodynamics and evolution." *Proceedings of the National Academy of Sciences* 94.8 (1997): 3491-3498.

Fischer, Woodward W., James Hemp, and Jena E. Johnson. "Evolution of oxygenic photosynthesis." *Annual Review of Earth and Planetary Sciences* 44 (2016): 647-683.

Florio, Marta, and Wieland B. Huttner. "Neural progenitors, neurogenesis and the evolution of the neocortex." *Development* 141.11 (2014): 2182-2194.

Fox, George E. "Origin and evolution of the ribosome." *Cold Spring Harbor perspectives in biology* 2.9 (2010): a003483.

Garlick, S., A. Oren, and E. Padan. "Occurrence of facultative anoxygenic photosynthesis among filamentous and unicellular cyanobacteria." *Journal of Bacteriology* 129.2 (1977): 623-629.

Gigerenzer, Gerd, et al. *The empire of chance: How probability changed science and everyday life*. No. 12. Cambridge University Press, 1990.

Gilbert, Walter. "Origin of life: The RNA world." *nature* 319.6055 (1986): 618-618.

Glansdorff, Nicolas, Ying Xu, and Bernard Labedan. "The last universal common ancestor: emergence, constitution and genetic legacy of an elusive forerunner." *Biology direct* 3.1 (2008): 29.

Grillner, Sten, and Brita Robertson. "The basal ganglia downstream control of brainstem motor centres—an evolutionarily conserved strategy." *Current opinion in neurobiology* 33 (2015): 47-52.

Hart, Malcolm B., ed. "Biotic recovery from mass extinction events." Geological Society of London, 1996.

Harter, M. Russell, and Cheryl J. Aine. "Brain mechanisms of visual selective attention." *Varieties of attention* (1984): 293-321.

Hartwig, Tilman, et al. "Descendants of the first stars: the distinct chemical signature of second-generation stars." *Monthly Notices of the Royal Astronomical Society* 478.2 (2018): 1795-1810.

Herron, Matthew D., et al. "De novo origins of multicellularity in response to predation." *Scientific reports* 9.1 (2019): 1-9.

Hooshangi, Sara, and William E. Bentley. "From unicellular properties to multicellular behavior: bacteria quorum sensing circuitry and applications." *Current Opinion in Biotechnology* 19.6 (2008): 550-555.

Iwamoto, Nobuyuki, et al. "The first chemical enrichment in the Universe and the formation of hyper metal-poor stars." *Science* 309.5733 (2005): 451-453.

Jerison, Harry. *Evolution of the brain and intelligence*. Elsevier, 2012.

Kerr, B. J., et al. "Brain-derived neurotrophic factor modulates nociceptive sensory inputs and NMDA-evoked responses in the rat spinal cord." *Journal of Neuroscience* 19.12 (1999): 5138-5148.

Knoll, Andrew H. "The multiple origins of complex multicellularity." *Annual Review of Earth and Planetary Sciences* 39 (2011): 217-239.

Konn, Cecile, et al. "The production of methane, hydrogen, and organic compounds in ultramafic-hosted hydrothermal vents of the Mid-Atlantic Ridge." *Astrobiology* 15.5 (2015): 381-399.

Koonin, Eugene V. "Comparative genomics, minimal gene-sets and the last universal common ancestor." *Nature Reviews Microbiology* 1.2 (2003): 127-136.

Kopp, Robert E., et al. "The Paleoproterozoic snowball Earth: a climate disaster triggered by the evolution of oxygenic photosynthesis." *Proceedings of the National Academy of Sciences* 102.32 (2005): 11131-11136.

Kristan Jr, William B. "Early evolution of neurons." *Current Biology* 26.20 (2016): R949-R954.

Küppers, Bernd-Olaf. *Information and the Origin of Life*. Mit Press, 1990.

Lane, Nick. *Power, sex, suicide: mitochondria and the meaning of life*. Oxford University Press, 2006.

Lane, Nick, and William F. Martin. "The origin of membrane bioenergetics." *Cell* 151.7 (2012): 1406-1416.

Lane, Nick, John F. Allen, and William Martin. "How did LUCA make a living? Chemiosmosis in the origin of life." *BioEssays* 32.4 (2010): 271-280.

Langerhans, R. Brian. "Evolutionary consequences of predation: avoidance, escape, reproduction, and diversification." *Predation in organisms*. Springer, Berlin, Heidelberg, 2007. 177-220.

Lee, Michael SY, Julien Soubrier, and Gregory D. Edgecombe. "Rates of phenotypic and genomic evolution during the Cambrian explosion." *Current Biology* 23.19 (2013): 1889-1895.

Lemons, Derek, and William McGinnis. "Genomic evolution of Hox gene clusters." *Science* 313.5795 (2006): 1918-1922.

Lewis, Laurence PC, et al. "A higher brain circuit for immediate integration of conflicting sensory information in Drosophila." *Current biology* 25.17 (2015): 2203-2214.

Libby, Eric, and Paul B. Rainey. "A conceptual framework for the evolutionary origins of multicellularity." *Physical biology* 10.3 (2013): 035001.

Lissauer, Jack J. "Planet formation." *Annual review of astronomy and astrophysics* 31.1 (1993): 129-172.

Lynch, Michael, and John S. Conery. "The origins of genome complexity." *science* 302.5649 (2003): 1401-1404.

Marshall, Charles R. "Explaining the Cambrian “explosion” of animals." *Annu. Rev. Earth Planet. Sci.* 34 (2006): 355-384.

Martin, William, and Michael J. Russell. "On the origins of cells: a hypothesis for the evolutionary transitions from abiotic geochemistry to chemoautotrophic prokaryotes, and from prokaryotes to nucleated cells." *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 358.1429 (2003): 59-85.

Martin, William, et al. "Hydrothermal vents and the origin of life." *Nature Reviews Microbiology* 6.11 (2008): 805-814.

Martin, William F., and Filipa L. Sousa. "Early microbial evolution: the age of anaerobes." *Cold Spring Harbor Perspectives in Biology* 8.2 (2016): a018127.

Mazzarello, Paolo. "A unifying concept: the history of cell theory." *Nature cell biology* 1.1 (1999): E13-E15.

Miljkovic-Licina, Marijana, Dominique Gauchat, and Brigitte Galliot. "Neuronal evolution: analysis of regulatory genes in a first-evolved nervous system, the hydra nervous system." *Biosystems* 76.1-3 (2004): 75-87.

Montmerle, Thierry, et al. "3. Solar System formation and early evolution: the first 100 million years." *Earth, Moon, and Planets* 98.1-4 (2006): 39-95.

Moroz, Leonid L. "On the independent origins of complex brains and neurons." *Brain, behavior and evolution* 74.3 (2009): 177-190.

Mulkidjanian, Armen Y., and Michael Y. Galperin. "Physico-chemical and evolutionary constraints for the formation and selection of first biopolymers: towards the consensus paradigm of the abiogenic origin of life." *Chemistry & biodiversity* 4.9 (2007): 2003-2015.

Nagy, Laszlo G. "Evolution: Complex multicellular life with 5,500 genes." *Current Biology* 27.12 (2017): R609-R612.

Niklas, Karl J. "The evolutionary-developmental origins of multicellularity." *American journal of botany* 101.1 (2014): 6-25.

Niklas, Karl J., Edward D. Cobb, and A. Keith Dunker. "The number of cell types, information content, and the evolution of complex multicellularity." *Acta Societatis Botanicorum Poloniae* 83.4 (2014).

Northcutt, R. Glenn, and Jon H. Kaas. "The emergence and evolution of mammalian neocortex." *Trends in neurosciences* 18.9 (1995): 373-379.

Nuñez, Angel, and Eduardo Malmierca. *Corticofugal modulation of sensory information*. Vol. 187. Springer Science & Business Media, 2007.

Och, Lawrence M., and Graham A. Shields-Zhou. "The Neoproterozoic oxygenation event: environmental perturbations and biogeochemical cycling." *Earth-Science Reviews* 110.1-4 (2012): 26-57.

Oparin, Aleksandr Ivanovich. "The origin of life on the earth." *The origin of life on the earth.* 3rd Ed (1957).

Orgel, Leslie E. "The origin of life—a review of facts and speculations." *Trends in biochemical sciences* 23.12 (1998): 491-495.

Passingham, Richard E., and Steven P. Wise. *The neurobiology of the prefrontal cortex: anatomy, evolution, and the origin of insight*. No. 50. Oxford University Press, 2012.

Pei, Yichuan C., S. Michael Fall, and Michael G. Hauser. "Cosmic histories of stars, gas, heavy elements, and dust in galaxies." *The Astrophysical Journal* 522.2 (1999): 604.

Penny, David, and Anthony Poole. "The nature of the last universal common ancestor." *Current opinion in genetics & development* 9.6 (1999): 672-677.

Petrov, Anton S., et al. "History of the ribosome and the origin of translation." *Proceedings of the National Academy of Sciences* 112.50 (2015): 15396-15401.

Pievani, Telmo. "The sixth mass extinction: Anthropocene and the human impact on biodiversity." *Rendiconti Lincei* 25.1 (2014): 85-93.

Podlech, J. "Origin of organic molecules and biomolecular homochirality." *Cellular and Molecular Life Sciences CMLS* 58.1 (2001): 44-60.

Povinelli, Daniel J., and Jennifer Vonk. "Chimpanzee minds: suspiciously human?." *Trends in cognitive sciences* 7.4 (2003): 157-160.

Preiner, Martina, et al. "Catalysts, autocatalysis and the origin of metabolism." *Interface focus* 9.6 (2019): 20190072.

Pross, Addy, and Robert Pascal. "The origin of life: what we know, what we can know and what we will never know." *Open biology* 3.3 (2013): 120190.

Purvis, Andy, Kate E. Jones, and Georgina M. Mace. "Extinction." *BioEssays* 22.12 (2000): 1123-1133.

Puy, Denis, and Monique Signore. "From nuclei to atoms and molecules: the chemical history of the early Universe." *New Astronomy Reviews* 46.11 (2002): 709-723.

Rakic, Pasko. "Evolution of the neocortex: a perspective from developmental biology." *Nature Reviews Neuroscience* 10.10 (2009): 724-735.

Raup, David M. "Biological extinction in earth history." *Science* 231.4745 (1986): 1528-1533.

Roger, Andrew J., and Laura A. Hug. "The origin and diversification of eukaryotes: problems with molecular phylogenetics and molecular clock estimation." *Philosophical Transactions of the Royal Society B: Biological Sciences* 361.1470 (2006): 1039-1054.

Roth, Gerhard, and Ursula Dicke. "Evolution of the brain and intelligence." *Trends in cognitive sciences* 9.5 (2005): 250-257.

Ruddle, Frank H., et al. "Evolution of Hox genes." *Annual review of genetics* 28.1 (1994): 423-442.

Ruiz-Trillo, Iñaki, et al. "The origins of multicellularity: a multi-taxon genome initiative." *TRENDS in Genetics* 23.3 (2007): 113-118.

Sarnat, Harvey B., and Martin G. Netsky. "When does a ganglion become a brain? Evolutionary origin of the central nervous system." *Seminars in Pediatric Neurology*. Vol. 9. No. 4. WB Saunders, 2002.

Schönheit, Peter, Wolfgang Buckel, and William F. Martin. "On the origin of heterotrophy." *Trends in microbiology* 24.1 (2016): 12-25.

Shields-Zhou, Graham, and Lawrence Och. "The case for a Neoproterozoic oxygenation event: geochemical evidence and biological consequences." *GSa Today* 21.3 (2011): 4-11.

Simberloff, Daniel. "A succession of paradigms in ecology: essentialism to materialism and probabilism." *Synthese* 43.1 (1980): 3-39.

Smith, Britton D., and Steinn Sigurdsson. "The transition from the first stars to the second stars in the early Universe." *The Astrophysical Journal Letters* 661.1 (2007): L5.

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Smith, John Maynard, and Smith John Maynard. *The theory of evolution*. Cambridge University Press, 1993.

Sogin, Mitchell L. "Early evolution and the origin of eukaryotes." *Current opinion in genetics & development* 1.4 (1991): 457-463.

Striedter, George F. *Principles of brain evolution*. Sinauer associates, 2005.

Susa, Hajime. "The mass of the first stars." *The Astrophysical Journal* 773.2 (2013): 185.

Van Dover, Cindy. *The ecology of deep-sea hydrothermal vents*. Princeton University Press, 2000.

Vastel, Charlotte, et al. "The origin of complex organic molecules in prestellar cores." *The Astrophysical Journal Letters* 795.1 (2014): L2.

Ward, Lewis M., Joseph L. Kirschvink, and Woodward W. Fischer. "Timescales of oxygenation following the evolution of oxygenic photosynthesis." *Origins of Life and Evolution of Biospheres* 46.1 (2016): 51-65.

Weil, Kari. *Thinking animals: Why animal studies now?*. Columbia University Press, 2012.

Weiss, Madeline C., et al. "The physiology and habitat of the last universal common ancestor." *Nature microbiology* 1.9 (2016): 1-8.

Weisskopf, Victor. “The Origin of the Universe.” *Bulletin of the American Academy of Arts and Sciences*, vol. 42, no. 4, 1989, pp. 22–39. *JSTOR*, www.jstor.org/stable/3823140. Accessed 21 Jan. 2021.

Wetherill, George W. "Formation of the Earth." *Annual Review of Earth and Planetary Sciences* 18.1 (1990): 205-256.

Yin, Qingzhu, et al. "A short timescale for terrestrial planet formation from Hf–W chronometry of meteorites." *Nature* 418.6901 (2002): 949-952

Zimmer, Carl. "On the origin of eukaryotes." (2009): 666-668.