

THE ORIGIN OF LIFE ON EARTH: NATURE'S AGENCY AND/OR DIVINE INTERVENTION?

RAFAEL VICUÑA

In *Laws*, his last and longest dialogue, Plato asserts that all things that take place in the universe are the result of art, nature or chance.¹ In contrast to his predecessors and contemporaries, Plato gives God's art preeminence over nature and chance to explain the origin of the material world and its unfolding events. Later, Aristotle will argue that beings that exist by nature, either inert or living, differ from those that exist due to other causes in that they possess an intrinsic principle of motion which is not accidental but essential. This principle is responsible for the tendency of beings to behave in fulfillment of an intrinsic finality.²

In the Middle Ages, St. Thomas Aquinas offers a definition of nature based precisely on this tendency, which according to him operates with an internal drive that is intrinsic to natural beings: "Nature is nothing but the plan of some art, namely a divine one, put into things themselves, by which those things move towards a concrete end: as if a man who builds up a ship could give to the pieces of wood that they could move by themselves to produce the form of the ship".³ Although the existence of finality in nature as a feature of a divine plan is not widely accepted among scholars, there is wide concurrence in the realization of the extraordinary dynamism of natural processes. This dynamism builds on events of cooperation, synergism and contingency, all of which contribute to the progression of the evolutionary processes of both inert and living beings.

One of the most prominent manifestations of creative power of the natural order so understood concerns the origin of life on Earth. As it occurs with other areas of inquiry dealing with origins (of the universe, of man, etc.), the birth of life out of inert matter represents a privileged area of interaction among theologians, philosophers and scientists. From a scientific standpoint, this subject remains one of the most inscrutable endeavors of contemporary research. The innovative experiments of Stanley

¹ Plato, *Laws*, Book X.

² Aristotle, *Physics*, Book II.

³ Thomas Aquinas, *Commentary on Aristotle's Physics*, book II, chapter 8, lectio 14.

Miller 60 years ago gave rise to high expectations for an experimental approach. However, in spite of significant progress in prebiotic chemistry, we are still far from proposing a robust hypothesis accounting for the self-organization process that gave rise to the first living organisms. It is surely for this reason that the field is full of controversies, such as “panspermia *vs* origin on Earth”, “metabolism first *vs* RNA world”, “initial heterotrophy *vs* initial autotrophy”, “origin in a soup *vs* in hydrothermal vents” and “determinism *vs* chance”. There are abundant arguments for each of these viewpoints, which is a sign of insufficient knowledge about each of them. In any event, it should be born in mind that even if a consensual hypothesis is attained, its validity would be hard to confirm due to an historical component that escapes the criterion of falsifiability typical of the empirical sciences.

The three fundamental questions that are most often addressed when analyzing the origin of life on Earth are those of when, where and how. With respect to the “when” question, there are isotopic data as well as bacterial microfossils preserved in ancient rocks. Determinations of the ratio $^{13}\text{C}/^{12}\text{C}$ in 3,700 million years (my) old sedimentary rocks from Akilia Isle⁴ and of the ratio $^{34}\text{S}/^{32}\text{S}$ in the Isua Belt,⁵ both in Greenland, suggest biological activity. Analyses of pre-metamorphic dolomite in these rocks⁶ and of 3,400 my old pyrite from South Africa, point into the same direction.⁷ On the other hand, stromatolites from Australia contain conclusive evidence of microfossils of bacteria that metabolized sulphides 3,430 my ago.⁸ We can safely state, therefore, that life appeared early on Earth, possibly before the

⁴ Rosing M. ^{13}C -depleted carbon in $>3,700$ -Ma sea-floor sedimentary rocks from West Greenland. *Science* 283:674-76, 1999.

⁵ Grassineau NV, Abell P, Appel PWU, Lowry D, Nisbet EG. Early life signatures in sulphur and carbon isotopes from Isua, Barberton, Wabigoon (Steep Rock) and Belingwe greenstone belts (3.8 to 2.7 Ga). In *Evolution of Early Earth's Atmosphere, Hydrosphere and Biosphere – Constraints from Ore Deposits*, ed. SE Kesler, H Ohmoto, pp. 33-52. 2006. Boulder, CO: Geol. Soc. Am. Spec. Publ.

⁶ Nutman, AP, Friend, CRL, Bennet, VC, Wright, D, Norman, MD. ≥ 3700 Ma pre-metamorphic dolomite formed by microbial mediation in the Isua supracrustal belt (W. Greenland): Simple evidence for early life? *Precambrian Research* 183, 725-737, 2010.

⁷ Ohmoto, H, Kakegawa, T, Lowe, DR. 3.4-billion-year-old biogenic pyrites from Barberton, South Africa: Sulphur isotope evidence, *Science* 262, 555-557, 1993.

⁸ Allwood, AC, Grotzinger, JP, Knoll, AH, Burch, IW, Anderson, MS, Coleman, ML, Kanik, I, Controls on development and diversity of early Archean stromatolite. *Proc Natl Acad Sci USA* 106, 9548-9555, 2009.

end of the late bombardment,⁹ about 4,000 my ago. This early appearance of life suggests an expeditious path leading to self organization and allows speculations on the possibility that life may have arisen repeated times after massive sterilization events caused by falling meteorites.

On the other hand, assuming that life started on Earth and did not come from outer space, a possibility that cannot be ruled out, the question regarding the most likely scenario remains the most contentious among specialists. Those that are in favor of the so-called primordial soup, among them Oparin, Haldane, Miller and Lazcano, advocate an origin in solution associated to heterotrophic metabolism.¹⁰ In turn, there are scientists that propose an origin on the solid surface of hydrothermal vents, in this case associated to autotrophic metabolism. The most eminent among the latter are Günter Wächtershäuser, with his iron-sulphur or pyrite world typically found in hydrothermal vents known as “black smokers”¹¹ and William Martin and Michael Russell for the “Lost City” type vents, with conditions that are less extreme than the black smokers.¹² Both theories, the soups and the vents, have some experimental support. There have also been proposals for scenarios related to aerosol particles and terrestrial hot springs, although they seem to attract fewer followers.

The question dealing with the “how”, nevertheless, is certainly the most essential one. It is one criterion satisfied to have the necessary chemical components, but it is something completely different to have them undergo self-organization to give rise to a living entity.¹³ One way of approaching this subject is to think about known mechanisms of self-organization. There is one that is spontaneous, namely thermodynamically favored,

⁹ Sleep NH. 2010. The Hadean-Archaean environment. *Cold Spring Harb. Perspect. Biol.* 2:a002527.

¹⁰ Lazcano, A, Miller, SL, The origin and early evolution of life: Prebiotic chemistry, the pre-RNA world and time. *Cell* 85, 793-798, 1996.

¹¹ Wächtershäuser, G. From volcanic origins of chemoautotrophic life to Bacteria, Archea and Eukarya. *Phil. Trans. Royal Soc. B* 361, 1787-1808, 2006.

¹² Martin, W., Russell, M.J. On the origin of biochemistry at an alkaline hydrothermal vent. *Phil. Trans. Royal Soc. B* 362, 1887-1925, 2007.

¹³ Immanuel Kant's reflection on this specific topic serves to illustrate the enormous task it represents to philosophers and scientists: “That crude matter should have originally formed itself according to mechanical laws, that life should have sprung from the nature of what is lifeless, that matter should have been able to dispose itself into the form of a self-maintaining purposiveness – this he rightly declares to be contradictory to Reason”, in *Critique of Judgement* §81, 1790. In this citation, Kant is referring to the opinion of the German naturalist J.F. Blumenbach (1752-1840).

which can be found in situations such as protein folding, formation of vesicles, assembly of ribosomes and viruses, etc. All these are amazing molecular structures that elicit admiration for their beauty and functionality, but they are just structures. On the other hand, there are the so-called dissipative structures described by Ilya Prigogine,¹⁴ in which a certain degree of order is attained as long as there is a provision of external energy. Typical examples of the latter are Bénard cells and tornados, systems that are enormously simpler than living cells. Even more important, these systems are incapable of maintaining themselves autonomously far from equilibrium. There are other models of self-organization, such as Stuart Kauffman's metabolic networks¹⁵ and Manfred Eigen's hyper cycles.¹⁶ Encompassing high creative value, these models can be simulated in computers but have not yet been reproduced experimentally in the laboratory.

One aspect that contributes significantly to our difficulties in understanding life's emergence is its extraordinary complexity. One could theorize that the simplest cell could consist of an informational polymer that self-replicates and replicates also a second polymer involved in the biosynthesis of a lipid membrane that confines both biopolymers.¹⁷ This minimal cell would require the nucleotide precursors of the biopolymers to be synthesized abiotically using some energy source available. However, extant cells are considerably more complex than this hypothetical primitive cell. For example, the bacterium *Mycoplasma genitalium*, one of the simplest known to date, cannot thrive with less than 425 genes.¹⁸ Moreover, in any cell, gene products, being proteins or RNAs, interact among themselves and with the genome through intertwined networks that are regulated by feedback mechanisms to assure the cell's homeostasis in spite of various environmental stimuli. It seems then that life as we know possesses a complexity threshold. On the other hand, the metabolism-genetics duality that is essential to life contributes decisively to this complexity. It is possible

¹⁴ Prigogine, I. *Order out of chaos: Man's new dialogue with Nature*. Toronto, Bantam Books, 1984.

¹⁵ Kauffman, SA. *The origins of order: Self-organization and selection in evolution*. New York-Oxford University Press, 1996.

¹⁶ Eigen, M. *Steps towards life. A perspective on evolution*. Oxford University Press, 1992.

¹⁷ Szostak, J.W., Bartel, D.P., Luisi, P.L. Synthesizing life. *Nature* 409, 387-390, 2001.

¹⁸ Glass, J.I., Assad-García, N., Alperovich, N., Yooseph, S., Lewis, M.R., Maruf, M., Hutchinson, C.A., Smith, H.O., Venter, J.C., Essential genes of a minimal bacterium, *Proc. Natl. Acad. Sci. USA* 103, 425-430, 2006.

that informational polymers may have preceded metabolism in a kind of RNA world, even though the self-replication of these polymers appears problematic. The opposite is also possible, namely, that a rudimentary metabolism preceded the RNA world. Whichever may have been the case: Could self-replicating polymers be considered alive? Conversely, would a system of chemical reactions supported by some kind of energy that lacks informational polymers be considered to have life, even though it could conceivably evolve to become more complex? In any event, even though the birth of life may have proceeded through stages of lesser complexity, it is hard to believe that it suddenly started by chance. It seems more logical to think that once certain environmental conditions were attained, there were successive steps preparatory to the change which resulted in the appearance of life, all fully complying with the laws of physics and chemistry. However, this way of reasoning has a caveat: a gradual transition from inert matter to life would require defining the precise moment in which the entity becomes alive, because it would not seem logical to think of half alive or half inert entities.

This dilemma leads us directly to the very concept of life. There are some that believe that life is just matter organized in a sophisticated way. We could safely assume that supporters of this contention consider biology to be one of the various branches of physics. Lord Rutherford once said that physics is the only science there is and all the rest is stamp collecting.¹⁹ But if life consisted only in organized matter, it could be fully understood from its molecular components, a goal that has not been accomplished yet. There is no question that life obeys the laws of physics and chemistry. However, these laws do not suffice to grasp the whole of life. This is not the case of machines, which can be fully comprehended by the interaction of their parts, regardless of their sophistication. This difficulty in reducing all aspects of life to mechanical causes has been manifested by numerous scholars, among them Immanuel Kant²⁰ and Niels Bohr.²¹ To think that life is more than molecules does not imply support for some type of vitalism, as the one proposed by Bergson.²² But properties of life such as self-or-

¹⁹ Birks, J.B. *Rutherford at Manchester*, Ed. Heywood. London, 1962.

²⁰ Kant, I. *Critique of Judgement*, 1790.

²¹ Bohr, N. Light and life. *Nature* 133, 421-423, 457-459, 1933.

²² Bergson, Henri. *Creative Evolution* [L'évolution créatrice, 1907]. Trans. A. Mitchell, ed. K. Ansell Pearson, M. Kolkman, and M. Vaughan. Basingstoke: Palgrave Macmillan, 2007.

ganization, self-maintenance in a far from equilibrium state, a dualist metabolic-genetic character and its capacity to undergo Darwinian evolution, among others, seem to indicate that life possesses an ontological category that is superior to that of its organized material components.

Those who defend a reductionist standpoint often manifest that life's origin did not require the intervention of a supernatural Creator. The prestigious North American scientist Stuart Kauffman, well known for his contributions in the fields of complexity and self-organization, offers of good example of this approach: "(life) is a natural, emergent expression of the routine creativity of the universe ... To the devout who require that a Creator God have brought it forth, science says, wait – we are coming to understand how it all arose naturally with no Creator's hand".²³ This sort of reasoning is difficult to understand, because the scientific method does not have the power to either confirm or refute God's participation in natural phenomena. Stated in another way, would life have to violate some physico-chemical law and therefore seem miraculous to us in order to conclude that it is the work of a Creator?

A similar epistemological mistake comes about when God is made responsible for a natural process that escapes scientific explanation. This attitude corresponds to the doctrine known as the God of the gaps, which paradoxically leads to a gradual decline of God's role as scientific knowledge advances. This fault has been committed by distinguished men of science, among them Isaac Newton. At present, the best advocate of this doctrine is the contemporary Intelligent Design movement, with supporters mainly in the USA.²⁴ Intelligent Design concedes that an evolutionary process has taken place on Earth during billions of years. However, some molecular structures that exhibit an irreducible complexity have required the direct intervention of a supernatural designer at the natural level. With this standpoint they are not only denying Nature's autonomy, but they are also revealing some degree of ingenuousness, because science has already provided explanations for the development of these structures by means of Darwinian evolution.

On the other hand, there is also the Argument of Design. Also known as the physico-theological or teleological argument, it must not be confused

²³ SA Kauffman, *Reinventing the sacred. A new view of science, reason and religion*. Basic books, New York, pp. 59, 89, 2008.

²⁴ Behe, MJ, Dembski, W, Meyer, S. *Science and evidence for design in the universe*. Ignatius Press, San Francisco, 2002.

with the Intelligent Design doctrine. The physico-theological argument is founded on the apparent design, order and purpose observed in Nature. One of the earliest insinuations regarding a divinity responsible for these attributes was made by Plato, who asserted that “the earth and the sun, and the stars and the universe, and the fair order of the seasons, and the division of them into years and months, furnish proofs of their existence”. Later, Cicero²⁵ and St. Augustine²⁶ made similar remarks. A variant of this argument was used by Thomas Aquinas in his fifth way to prove God’s existence.²⁷ Nonetheless, the argument of design is most identified with the English clergyman William Paley, whom early in the 19th century published his most prominent book entitled *Natural Theology, or Evidences of the Existence and Attributes of the Deity collected from the Appearances of Nature*. In this work, Paley expresses his amazement with the extraordinary complexity of living beings and of biological processes. Such complexity and perfection, he reckoned, could not have arisen by pure chance. Instead, they are a clear manifestation of design. Since there cannot be design without a designer; contrivance without a contriver; order without choice

²⁵ “But can there be any person ... who can consider the regular movements of the heavenly bodies, the prescribed courses of the stars, and see how all is linked and bound into a single system, and then deny that there is any conscious purpose in this and say that it is the work of chance?” ... “What could be more clear or obvious when we look up to the sky and contemplate the heavens, than that there is some divinity of superior intelligence?” Cicero, *On the nature of the gods (De Natura Deorum)*, 45 BC.

²⁶ “Question the beauty of the earth, question the beauty of the sea, question the beauty of the air, amply spread around everywhere, question the beauty of the sky, question the serried ranks of the stars, question the sun making the day glorious with its bright beams, question the moon tempering the darkness of the following night with its shining rays, question the animals that move in the waters, that amble about on dry land, that fly in the air; their souls hidden, their bodies evident; the visible bodies needing to be controlled, the invisible souls controlling them; question all these things. They all answer you, ‘Here we are, look; we’re beautiful’. Their beauty is their confession. Who made these beautiful changeable things, if not one who is beautiful and unchangeable?” St. Augustine, *Sermo* 241,2.

²⁷ “We see that things which lack intelligence, such as natural bodies, act for an end, and this is evident from their acting always, or nearly always, in the same way, so as to obtain the best result. Hence it is plain that not fortuitously, but designedly, do they achieve their end. Now whatever lacks intelligence cannot move towards an end, unless it be directed by some being endowed with knowledge and intelligence; as the arrow is shot to its mark by the archer. Therefore some intelligent being exists by whom all natural things are directed to their end; and this being we call God”. St. Thomas Aquinas, *Summa Theologica, First Part, question 2*.

or arrangement without anything capable of arranging, they constitute the proof of the work of an intelligent Creator. This way of reasoning in relation to the argument of design brings to mind passages of the Holy Scriptures, such as “For from the greatness and beauty of created things comes a corresponding perception of their Creator” (Wisdom 13,5) and “For since the creation of the world God’s invisible qualities – his eternal power and divine nature – have been clearly seen, being understood from what has been made” (Romans 1,20).

Well known philosophers, among them David Hume²⁸ and Immanuel Kant,²⁹ have criticized the Argument of Design. More recently, Paley has been censured by the Spanish-American biologist Francisco Ayala and by the Chilean philosopher Roberto Torretti. According to Ayala, Darwin’s greatest accomplishment was to resolve the conceptual schizophrenia of supernatural explanations by showing that the complex organization and functionality of living beings can be explained as the result of a natural process – natural selection – without any need to resort to a Creator or other external agent.³⁰ A similar reasoning has been advanced by Torretti. However, this author admits that a scientist may believe in a personal God maker of the laws of Nature, although he has to acknowledge that science is unable to contribute to support this conviction.³¹

Although it is legitimate to disagree with Paley on philosophical grounds, one cannot affirm that Darwin proved the teleological argument to be mistaken, simply because the latter does not deal with the natural mechanisms leading to the apparent design. For this very same reason, one can neither argue that the argument of design contradicts Darwin. Unfortunately, contemporary debates on this subject most often fail to make this

²⁸ In *Dialogues concerning natural religion* (1779), Hume states that artifacts made by men differ substantially from things in nature. Therefore, design cannot be inferred from the latter. Moreover, the fraction of the Universe known to humans is too small and there could perfectly be other parts of it that do not possess the observed harmony of the known part.

²⁹ Kant not only criticized the teleological argument, but the ontological and cosmological arguments as well. In his *Critique of Pure Reason* (1781) he asserts that the argument of design is not conclusive to infer the existence of a supernatural Creator, since our perception can only assign causalities in a sensitive world. Later, in his *Critique of Judgement* (1790), he stated that to place another intelligent being above Nature as its Architect would be presumptuous.

³⁰ Ayala, F.J. Darwin’s greatest discovery: Design without a designer. *Proc. Natl. Acad. Sci. USA* 104, 8567–8573, 2007.

³¹ Torretti, R. Diseños y designios. *Estudios Públicos* 115, 49–74, 2009.

epistemological distinction. Even Darwin himself succumbed to the allure of thinking that the existence of God could be discerned based on scientific criteria. In his autobiography³² he mentions that when being young he considered himself a theist based on the extreme difficulty of conceiving man and the universe as the result of blind chance. However, later in his life he had come to the conclusion that the old argument from design in Nature, as given by Paley, had ceased to be valid since the discovery of the law of natural selection. According to elderly Darwin, “there seems to be no more design in the variability of organic beings, and in the action of natural selection, than in the course which the wind blows”.

An authentic conviction on the existence of a divine Creator of life and the universe can only be attained after thorough philosophical reflection, conducted with an open mind, free of prejudice. This brings to mind the frequent invitations made by Pope Emeritus Benedict XVI to accompany scientific progress with critical philosophical reasoning, open to dimensions that can only be partially unfolded by science.³³ In his renowned address at Regensburg University in 2006, he was particularly explicit in his demand of widening the use of reason going beyond experimental testing as the only way to reach full capacity to access truth and understanding.

Should philosophical reflection lead to the belief in a supernatural designer, how does this reconcile with nature's autonomy? Saint Thomas Aquinas has proposed a clear mode of reasoning to deal with this issue, which is not in the realm of natural philosophy as the Argument of Design, but in that of metaphysics. According to this philosopher, the radical dependence on God of whatever exists is absolutely compatible with the causality of natural events, since divine causality and causality in nature operate at different levels. This does not imply that a particular event occurs partially in fulfilment of natural causes and partially in fulfilment of divine causes. Rather, every event takes place in complete fulfilment of both, each being exerted in its own way. God transcends nature in such a way, that even random events appear as such, that is, random events. Thus, Nature's autonomy does not challenge divine agency. The same argument

³² Darwin, Charles, *The Autobiography of Charles Darwin 1809-1882*. Ed. Barlow, Nora. London: Collins, 1958.

³³ Ratzinger, J. That which holds the world together: the pre-political moral foundations of a free state, in Habermas, J. and Ratzinger, J., *The dialectics of secularization. On reason and religion*. Ed. Florian Schuller, Ignatius Press, San Francisco, 2006.

affirms that human free will is indeed free.³⁴ The International Theological Commission has judiciously adopted this doctrine stating recently that “divine causality and created causality radically differ in kind and not only in degree. Thus, even the outcome of a truly contingent natural process can nonetheless fall within God’s providential plan for creation”.³⁵

Those of us who believe that there is a Creator of life and the universe think that He acts in the world in accordance to the natural laws designed by Him. This belief is the result of a profound conviction that transcends the natural sciences and that offers a meaning to the great harmony that we observe in the cosmos. A belief which is reminiscent of Psalm 104, 29-30: “When you take away their breath, they die and return to the dust. When you send your Spirit, they are created, and you renew the face of the earth”.

³⁴ Thomas Aquinas, *Summa against the gentiles*, Book 1, Chapter 85, Book 3, Chapters 70-77.

³⁵ International Theological Commission. *Communion and stewardship*, N°69, 2004.