Astrobiology Perspectives on Life of the Universe

# PLANET FORMATION AND PANSPERMIA

## *New Prospects for the Movement of Life through Space*

Edited by
Branislav Vukotić
Joseph Seckbach
Richard Gordon

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**Astrobiology Perspectives on Life of the Universe**

**Series Editors: Richard Gordon and Joseph Seckbach**

In his 1687 book *Principia*, Isaac Newton showed how a body launched atop a tall mountain parallel to the ground would circle the Earth. Many of us are old enough to have witnessed the realization of this dream in the launch of Sputnik in 1957. Since then our ability to enter, view and understand the Universe has increased dramatically. A great race is on to discover real extraterrestrial life, and to understand our origins, whether on Earth or elsewhere. We take part of the title for this new series of books from the pioneering thoughts of Svante Arrhenius, who reviewed this quest in his 1909 book *The Life of the Universe as Conceived by Man from the Earliest Ages to the Present Time*. The volumes in ***Astrobiology Perspectives on Life of the Universe*** will each delve into an aspect of this adventure, with chapters by those who are involved in it, as well as careful observers and assessors of our progress. Guest editors are invited from time to time, and all chapters are peer-reviewed.

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# Planet Formation and Panspermia

## New Prospects for the Movement of Life through Space

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# Preface

The panspermia hypothesis dates back to the works of ancient philosophers. In the 1800s, organics in meteorites were considered by the Swedish chemist Jacob Berzelius [1.3] [1.4] and later German physician Hermann E. Richter [1.15] speculated on the possibility of life transport by meteors. Lord Kelvin [1.9], discussed the possibility of panspermia in his Presidential Address to the British Association for the Advancement of Science. At the beginning of the next century, Swedish physicist/chemist Svante August Arrhenius (1908) presented his book on the panspermia theory [1.2]. There is a long history from before this time through the last century of claims of finding life in meteorites [1.6]. Astronomical sciences also developed significantly during this period to the point where we can observe gravitational waves from merging black holes, which was hardly imaginable just a few decades ago, and visualize black holes. With the discovery of many exoplanets astrobiology has matured as a scientific discipline. A tentative discovery of the intergalactic meteor particle in 2007 [1.1] and recent discoveries of an anomalous object ‘‘Oumuamua [1.11] and comet 2I/Borisov [1.8], that appear to have visited us from outside the Solar system, point out that our planet and its host star may not be an isolated island, in an otherwise lifeless universe. They are likely to exchange matter with the other stars from their vicinity as probably is the case with other stellar systems too, perhaps containing life. There is currently a bias that any such panspermia, if they exist, are prokaryotes [1.13] [1.16] or rugged, microscopic Eukaryotes [1.14].

In addition to transporting the physical bodies of microorganisms, another important aspect is the transport of biological information about these living systems. After all, the evolution of life on Earth is about altering the genetic code, either by natural or artificial means. Given that the organic matter, the building blocks for living organisms, is omnipresent in the universe, the aforementioned information might in some way be considered as the essence of life, at least in our current genocentric view of life [1.5]. The aspect of sending just the information signal in order to spread life is investigated in the visionary sci-fi novel “His Master’s Voice” by Polish writer Stanislaw Lem, first published in 1968 [1.10]. Contemporary with the beginning radio SETI searches [1.18], this offered a convergence point between sending and receiving SETI signals and the panspermia hypothesis. Information panspermia was later born in 2005 with the work of Vahe Gurzadyan [1.7].

In times when a number of exciting new discoveries are made and the new ones seem to be just around the corner, the millenia old panspermia hypothesis has not yet matured into a full fledged theory and some of its aspects might still not have been envisioned. Along the lines of scientific falsificationism, we can consider that no evidence against panspermia are found to date and that much of the controversy still remains [1.12]. The search is even more active in the opposite direction but still there is an evident lack of convincingly non-terrestrial microorganisms on Solar system bodies other than Earth. The recent experiments with micro-organisms exposed to space conditions at the International Space Station offer accumulating evidence that these organisms can withstand the harsh conditions of open space for long periods of time while preserving their biological potential. Even more, there are mounting concerns that human made space

vehicles can spread life from our biosphere to other bodies of the Solar system, the most recent one being that the Israeli space mission that transported tardigrades to the Moon [1.17].

While panspermia is related to microorganisms and small scale processes on one end, on the other end, the transport of material depends on environmental conditions in galaxies. The evolution of galaxies depends on the interaction of galaxies within galaxy clusters and the overall evolution of matter in the universe. The galaxies are the main building blocks of our universe, analogous to cells in a human body. The stars and their planets are condensed from the clouds of galactic gas and dust that are rich in organics. The process of planetary formation is at the middle among the above stated scales that are relevant for panspermia. Starting from planetary formation, studies can go in either direction, to larger or smaller scales, to investigate phenomena that could spread life.

This collection of chapters incorporates studies from biology, astronomy and geology that investigate the possibility of panspermia, with most of them directly investigating phenomena related to the process of planetary formation. The processes described in these chapters permit the panspermia hypothesis, but empirical confirmation is still lacking at the level of our current knowledge. The basic aim of this book is to provoke readers to contemplate their respective research fields that are related to panspermia. For that matter it presents the basics of panspermia but also the advanced studies in the research fields presented. The chapters are comprehensible on a student level but at the same time they might be very interesting to experienced researchers. Possibly, some of them are already working on current and future space missions that may offer an empirical

vindication of extra-terrestrial life transfer through the vastness of space.

**Branislav Vukotić**
**Richard Gordon**
**Joseph Seckbach**
September 1, 2021

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# Part I
# PHILOSOPHICAL ASPECTS OF PANSPERMIA

# 1
# “On the Origin of Life”

### By Lord Kelvin (William Thomson)

**Excerpt.** From the Presidential Address to the British Association for the Advancement of Science; held at Edinburgh in August, 1871 Reprinted in Kelvin’s ***Popular Lectures and Addresses***, p. 132-205. (Bracketed additions are from reprint.)

[p. 197.]

> Think now of the admirable simplicity with which Tait’s beautiful “sea-bird analogy,” as it has been called, can explain all [?] these phenomena.

The essence of science, as is well illustrated by astronomy and cosmical physics, consists in inferring antecedent conditions, and anticipating future evolutions, from phenomena which have actually come under observation. In biology the difficulties of successfully acting up to this ideal are prodigious. The earnest naturalists of the present day are, however, not appalled or paralysed by them, and are struggling boldly and laboriously to pass out of the mere “Natural History stage” of their study, and bring zoology within the range of Natural Philosophy. A very ancient speculation, still clung to by many naturalists (so much so that I have a choice of modern terms to quote in expressing it) supposes that, under meteorological conditions very different from the present, dead matter may have run together or crystallised or fermented into “germs of life,” or “organic cells,” or “protoplasm.” But science brings a vast mass of inductive evidence against this hypothesis of spontaneous generation, as you have heard from my predecessor in the Presidential chair.

Careful enough scrutiny has, in every case up to the present day, discovered life as antecedent to life. Dead matter cannot become living without coming under the influence of matter previously alive. This seems to me as sure a teaching of science as the law of gravitation. I utterly repudiate, as opposed to all philosophical uniformitarianism, the assumption of “different meteorological conditions”—that is to say, somewhat different vicissitudes of temperature, pressure, moisture, gaseous atmosphere—to produce or to permit that to take place by force or motion of dead matter alone, which is a direct contravention of what seems to us biological law. I am prepared for the answer, “Our code of biological law is an expression of our ignorance as well as of our knowledge.” And I say yes: search for spontaneous generation out of inorganic materials; let any one not satisfied with the purely negative testimony of which we have now so much against it, throw himself into the inquiry. Such investigations as those of Pasteur, Pouchet, and Bastian are among the most interesting and momentous in the whole range of Natural History, and their results, whether positive or negative, must richly reward the most careful and laborious experimenting. I confess to being deeply impressed by the evidence put before us by Professor Huxley, and I am ready to adopt, as an article of scientific faith, true through all space and through all time, that life proceeds from life, and from nothing but life.

How, then, did life originate on the Earth? Tracing the physical history of the Earth backwards, on strict dynamical principles, we are brought to a red-hot melted globe on which no life could exist. Hence when the Earth was first fit for life, there was no living thing on it. There were rocks solid and disintegrated, water, air all round, warmed and illuminated by a brilliant Sun, ready to become a garden. Did grass and trees and flowers spring

into existence, in all the fulness of ripe beauty, by a fiat of Creative Power? or did vegetation, growing up from seed sown, spread and multiply over the whole Earth? Science is bound by the everlasting law of honour, to face fearlessly every problem which can fairly be presented to it. If a probable solution, consistent with the ordinary course of nature, can be found, we must not invoke an abnormal act of Creative Power. When a lava stream flows down the sides of Vesuvius or Etna it quickly cools and becomes solid; and after a few weeks or years it teems with vegetable and animal life; which, for it, originated by the transport of seed and ova and by the migration of individual living creatures. When a volcanic island springs up from the sea, and after a few years is found clothed with vegetation, we do not hesitate to assume that seed has been wafted to it through the air, or floated to it on rafts. Is it not possible, and if possible, is it not probable, that the beginning of vegetable life on the Earth is to be similarly explained? Every year thousands, probably millions, of fragments of solid matter fall upon the Earth—whence came these fragments? What is the previous history of any one of them? Was it created in the beginning of time an amorphous mass? This idea is so unacceptable that, tacitly or explicitly, all men discard it. It is often assumed that all, and it is certain that some, meteoric stones are fragments which had been broken off from greater masses and launched free into space. It is as sure that collisions must occur between great masses moving through space as it is that ships, steered without intelligence directed to prevent collision, could not cross and recross the Atlantic for thousands of years with immunity from collisions. When two great masses come into collision in space it is certain that a large part of each is melted; but it seems also quite certain that in many cases a large quantity of debris must be shot forth in all directions, much of which may have experienced no greater violence than individual pieces of rock experience in a land-

slip or in blasting by gunpowder. Should the time when this Earth comes into collision with another body, comparable in dimensions to itself, be when it is still clothed as at present with vegetation, many great and small fragments carrying seed and living plants and animals would undoubtedly be scattered through space. Hence and because we all confidently believe that there are at present, and have been from time immemorial, many worlds of life besides our own, we must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about through space. If at the present instant no life existed upon this Earth, one such stone falling upon it might, by what we blindly call *natural* causes, lead to its becoming covered with vegetation. I am fully conscious of the many scientific objections which may be urged against this hypothesis, but I believe them to be all answerable. I have already taxed your patience too severely to allow me to think of discussing any of them on the present occasion. The hypothesis that [some] life [has actually] originated on this Earth through moss-grown fragments from the ruins of another world may seem wild and visionary; all I maintain is that it is not unscientific, [and cannot rightly be said to be improbable.]

# 2
# Why We Should Take Interstellar Panspermia Seriously

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***Abstract***

After a long period of neglect, the hypothesis of interstellar panspermia has gained new consideration in recent years, due to a series of theoretical and observational developments. In this chapter, I briefly outline why this possibility should not be dismissed, especially in regions of the Galaxy with higher stellar density than average. Furthermore, I give some motivations for taking the mechanism into account when developing theoretical models of the distribution of life in the Galaxy (such as in studies of the galactic habitable zone) and in drawing implications from the results of future searches for biosignatures in exoplanets. This theoretical work should be complemented by experimental studies, in order to assess the concrete feasibility of panspermia with higher confidence.

***Keywords***: Astrobiology, extraterrestrial life, galactic habitabile zone, biosignatures, interstellar panspermia

## 2.1 Introduction

The idea that biological material—and even living organisms—can be exchanged between planetary systems is more than one century old, but it has not been part of the mainstream discussion in astrobiology for long [2.28, 2.43].

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