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ESSAY REVIEW

The origins of life on Earth

Peter V. E. McClintock

Department of Physics, Lancaster University, Lancaster LA1 4YB, UK

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A review of **The Search for our Cosmic Ancestry** by Chandra Wickramasinghe, World Scientific, Singapore, 2014, pp. xx + 196. Scope: monograph, £25.00, ISBN 978 981-4616-97-3 (Paperback). Also available in hardcover ISBN 978 981-4616-96-6, and as an ebook ISBN 978 981-4616-99-7. Level: undergraduate, postgraduate, teacher, general reader.

Where we came from, and the origins of life itself, are eternal questions that have perplexed humans since the earliest recorded history and probably earlier. Of course, a great deal is now known about the nature of life, and how it functions, on all scales from the molecular upwards. Combining the known error rate of about 1 in 10^9 in the copying of DNA (giving rise to mutations in reproduction) with the notion of Darwinian evolution (survival of the fittest), it is possible to envisage, and to describe in a broad-brush kind of way, a sequence of processes leading inexorably from simple forms of life to multicellular creatures, intelligence and, eventually, us. But there remains a fundamental unanswered question. As Pasteur concluded, "All life [comes] from life". It may be assumed that immediately following the Big Bang the matter in the Universe was entirely inorganic, so how did life get started in the first place? Here, there are many interesting ideas but all is speculation. Nothing is known for sure.

For a long time, the most widely-accepted picture for the origin of life has been that proposed by Haldane and by Oparin: that life somehow arose by chance, through a random fluctuation in a "primordial soup" of pre-biotic molecules somewhere on the early Earth, and then spread to colonise the entire surface. It was subsequently shown that the stimulation of inorganic mixtures of gases with sparks, ultraviolet radiation, or electron bombardment – all processes that were occurring in the early atmosphere – can give rise to complex organic molecules including nucleic acids. These would then have been rained down into the oceans, ready for the life-creation event. Thus, in terms of chemistry, there is seemingly no difficulty in creating the building blocks of life, e.g. its amino acids, nucleotides and sugars. But to get from there to the first self-replicating (living) molecular structure is still a huge step. Possibly, an "RNA world" may have come first, where function and heredity were both combined in a single RNA ribozyme, prior to the evolution of our present universally-DNA-based life. How the genetic code originated remains unknown, but the overall picture seems generally plausible.

One problem, however, is that the earliest known forms of life (bacteria) are themselves far too complex to have arisen by chance through random fluctuations. The initial life-form must have been something much simpler but, alas, it is no longer around for us to study. This is particularly unfortunate because, without knowing its structure, there is no reliable way of calculating the probability of the life-formation event, and thus the average length of time needed for it to occur in a known volume of "soup".

Another major problem is that, from the geological and fossil record, bacteria evidently appeared at a *very* early stage, almost as soon as the Earth's surface had cooled enough for life to survive without being cooked. This fact is extremely difficult to square with the seemingly-

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well-justified belief that the life-formation event was highly improbable; and the difficulty is of course exacerbated by the time subsequently required for the initial self-replicators to evolve into bacteria.

One way out of these difficulties is to postulate that life arrived on Earth from somewhere else. If it arose and evolved in some larger context, perhaps over a longer period, then the likelihood of the life-creation event is much higher and perhaps it then becomes inevitable rather than improbable. The idea of *panspermia* – literally "seeds everywhere – is ancient, going back at least to the Greek philosopher Anaxagoras in the 5th century BC. Many others have developed the idea but, in its modern scientific form, Chandra Wickramasinghe is one of the leading proponents. Together with Fred Hoyle, he proposed in 1974 that there is dust in space that is largely organic. Since then, there has been a steadily growing body of evidence that much of it is biological in origin, and that some of it is desiccated microbes, of which a significant fraction are viable and can grow and reproduce under favourable conditions. The idea is still not, however, widely accepted among scientists.

In his new book, Wickramasinghe, brings together his arguments in favour of panspermia for the non-expert and presents a coherent and compelling vision of how life on Earth began and evolved. He considers possible origins of life in different contexts. In a purely galactic context, as in our own Milky Way, the first objects to condense around a nascent star would have been comets. Composed mainly of ice, they would also have accreted any organic molecules together with the dust of the interstellar cloud from which the Solar System and other planetary systems were formed. If even the tiniest number of microbes was present, they could have prospered and multiplied within the biologically-friendly watery interiors of the comets, which were being warmed by radioactive decay of ^{26}Al. It is known that the first appearance of life on Earth, around 3.8 billion years ago, coincided with a period of heavy cometary bombardment. So, if there was life on any of the comets, it is extremely likely that it would have "seeded" life on Earth as soon as the temperature was low enough, consistent with the geological record.

Even if no life was present initially in the parent interstellar cloud, the comets would, by their sheer number and volume, have provided a much more likely (by a factor of 10^{25}) cradle for the generation of life somewhere in the galaxy than all the shallow ponds and edges of oceans on the Earth. There are then several mechanisms that could have provided for the spread of life within the galaxy. Another possibility that Wickramasinghe confronts is the possibility that the life-creation event might have been so improbable that it only happened once within the entire Universe. He points out that there is at least one Big Bang cosmology that could have led to its non-horizon-limited spread to all parts of the Universe.

Wickramasinghe argues that a large fraction of the interstellar dust grains are not just organic, but of biological origin. Much of the material will consist of biological degradation products, perhaps on the way to being rather like coal, but some non-zero proportion will be desiccated but potentially viable microbes. Thus he envisages a Universe pervaded throughout by biology of a hardy but primitive kind that is ready to flourish, evolve, and lead to the eventual appearance of complex organisms whenever it encounters the right environmental conditions, e.g. the watery surface of a planet at the right distance from its star.

The Earth is seldom hit by comets these days, fortunately for us, but it is nonetheless subject to continuous bombardment from space. The incoming flux includes something like 100 tons per day of smaller objects ranging from individual molecules, through dust grains, up to meteorites that can penetrate the atmosphere and cause damage. So, if Wickramasinghe's thesis is correct, the seeding of Earth with bacteria from space is still continuing.

As mentioned, many of Wickramasinghe's ideas, and those of Hoyle before him, have been considered heretical. Yet he has already unexpectedly (to most scientists) been proven correct in several instances, including e.g. his 1986 prediction with Hoyle that, contrary to general expectation, the surface of Halley's Comet would be dark, roughened, and generally coal-like – subsequently confirmed by the Giotto spacecraft. So we should ask what evidence exits to support his picture of a Universe pervaded by biology? In fact, there is a wealth of such evidence, not all of it indirect. Only a few examples of the evidence discussed in the book can be summarised here.

First, the interstellar dust gives rise to infra-red absorption spectra for radiation coming from distant astronomical sources that are exactly what would be expected of desiccated bacteria. Spectra in the optical range are also consistent with biological material, and it seems plausible that some 25–30% of the carbon in interstellar clouds is of biological origin. Of particular interest is the fact that extragalactic sources also display signatures of living material, right out to where the Universe was only 2.5 billion years old.

Secondly, several experiments have been carried out to intercept particles entering the atmosphere e.g. from the dusty tails of comets, at heights well above those where they could be confused with terrestrial equivalents lofted by air currents. Particles were found ranging in size from clumps of bacteria, through individual cells, to viral sized structures. Some of the bacteria were culturable and similar to bacteria found on Earth; others were shown to contain nucleic acid and were deemed to be viable but non-culturable. The similarity of some of the bacteria to known terrestrial bacteria cannot be considered surprising if there is continuing seeding of the Earth with bacteria from space.

Thirdly, several meteorites have been found and investigated that are definitely made of non-terrestrial material (based on measurements of isotope ratios) but which show clear microscopic evidence of biological structures. Although the possibility of contamination with terrestrial material is a perpetual concern, it can be minimised by preparing fresh surfaces in a contaminant-free environment and by cutting ultra-thin sections of the meteorite. Some of the distinctly biological structures enmeshed with the rock matrix of the 2012 Polonnaruwa meteorite, for example, are those of diatoms. This may be of particular significance given that diatoms are formed of eukaryotic cells, like plants and people, rather than the more primitive bacterial cells.

Fourthly, Wickramasinghe considers the evidence from epidemics. At an earlier stage, when they first introduced and discussed these ideas, he and Hoyle were derided for their ignorance of epidemiology and they were not taken seriously. In the light of the wider vision of, and the other evidence for, a biologically-pervaded Universe, the question of epidemics is surely worth revisiting. Basically, it is suggested that they can develop as the result of bacteria or viruses coming from space, which would be expected to survive entry to the atmosphere to a significant degree. How fast they then fall depends on their size. Viral-sized particles would drift around in the stratosphere and in practice would need a seasonal down-draught to bring them to the surface of the Earth. Particles of bacterial size (0.3–1.0μm) would reach the surface under gravity in about a year. Larger bodies would fall much faster with considerable surface heating, but even delicate biological material would have good chance of survival in their interiors. The idea is that the latter kind of body could result in an epidemic spreading from a single source; the descent of bacteria, individually or in small clumps, could account for the epidemics that start almost simultaneously in geographically separated places; and the arrival of viruses would be essentially seasonal, being pulled down at times of mixing between the upper and lower air, consistent with December–March as the European influenza season.

Fifthly, the author discusses “red rain”. A recent example was the red rain in Kerala, on 25 July 2001, which followed a sonic boom apparently associated with a meteoroid. The red material consisted of what appeared under the microscope to be biological cells of an unusual kind. Wickramasinghe suggests that the meteoroid may have been a porous cometary bolide that disintegrated high in the atmosphere, releasing the red cells, which then nucleated rain clouds in the troposphere. An estimated 50 tons of red cell material came down in total. Many features of the red rain are unusual. For example, the cells have particularly thick walls. There is some evidence that they can replicate, but they have not been identified with any known species. It has proved impossible to extract DNA for sequencing. The indications point strongly to the red rain cells being of extraterrestrial origin, as would of course be the case if they had indeed arrived with the meteoroid.

An interaction of external life forms such as the bacteria or viruses with humans might seem at first sight implausible except, however, for the inferred continuous arrival of biological material from space. In this picture, evolution on Earth does not proceed independently but, rather, there is a continuing opportunity for interaction of terrestrial biology with a diversity of genetic material arriving from space. The author also throws in the idea that the "punctuated equilibria" of evolution, that is, the observed long periods of stasis punctuated by sudden marked changes, could sometimes result from the arrival of new genes from space and their incorporation in the genome of a species.

The book is engagingly written for the general reader. Obviously, it contains a great deal more that the highly selective summary given here, and there are extensive references to original papers where arguments are laid out in greater detail. There are interesting historical allusions from time to time, e.g. referring to the reactions and arguments of other scientists trying to resist the Hoyle/Wickramasinghe vision. Gradually, many aspects of that vision are being confirmed, for example by the confirmation of huge amounts of organic material in space, and by the very recent reports that the Rosetta spacecraft's Phylae lander has detected organic molecules on Comet 67P/Churyumov-Gerasimenko. So one cannot help wondering whether we are now approaching a tipping point at which yesterday's heretical vision will become the new orthodoxy.

Peter V. E. McClintock
Lancaster University
p.v.e.mcclintock@lancaster.ac.uk