PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Possible Impact of Cosmochemistry on Terrestrial Biology: Historical Introduction

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Possible impact of cosmochemistry on terrestrial biology: historical introduction

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Until the middle of the nineteenth century most philosophers, scientists and theologians assumed that life, even intelligent life, was not confined to Earth. Few of them, however, assumed that these organisms affected, or had affected, life here. The absence of human remains in ancient strata led, at the beginning of that century, to the suggestion that people were late intruders: later it was suggested that all life had come from Space. These speculations now seem quaint; our own may seem as quaint to our descendants.

A few thoughtful scientists pointed out that these 'explanations' did not explain anything: they merely transferred problems. The presence of organic matter in meteorites was well known in the nineteenth century. There is now abundant quantitative evidence that molecules of many different types come here from Space; there is no unequivocal evidence that any have a biological origin. Nor is there evidence for the arrival of molecules of types that could not have been synthesized in the probiotic environment here by non-biological processes.

Plutarch says that Alexander, knowing that he had not yet subdued this world, wept when told by the philosopher Anaxarchus that there were other inhabited worlds. The story, like the story of Canute, later got inverted. Wilkins (1638) has it right; Butler in *Hudibras* (1663) and Swift in *A tritical essay upon the faculties of the mind* (1709) have it inverted. It would be interesting to know when and why these inversions became popular. Alexander may not have been distressed only by unfinished business. His teacher, Aristotle, vehemently contradicted most other philosophers, and poets such as Orpheus, who assumed that there was life on bodies other than Earth. The history of this disagreement during the next 18 or 19 centuries is surveyed by Wilkins (1638) who, like Bruno, Galileo, Kant, Kepler and Nicholas of Cusa, was himself a pluralist. McColley (1936) extended the survey to cover Wilkins's contemporaries and immediate successors. Pluralism was the dominant outlook among scientists and non-scientists for two more centuries. It was, for example, supported by Herschel (1795) who postulated life on the Sun, and wrote that comets '...may be directed to carry their salutary influence to any part of the heavens'.

The organisms postulated by these scientists were quasi-human and so, presumably, were thought to have souls. Furthermore, astrology and the general proposition that we are

> 'Servile to all the skyie-influences,
> That dost this habitation where thou keepst
> Hourely afflict:'

had then as great a hold on intellectuals as it has today on non-intellectuals. The distribution of life was therefore a matter that concerned the clergy. Wilkins was, among other things, Bishop of Chester. Godwin, Bishop of Llandaff, published a romance about inhabitants of the Moon in 1638. There is a brief proposal to establish a church there, and later on the stars, in

Ignatius his Conclave by Donne (1611). Donne later became Dean of St Paul's Cathedral and then firmly opposed pluralism – these events are not necessarily connected. Some authorities see a close resemblance between *Ignatius his Conclave* and the *Somnium* in which Kepler contrasts the astronomical sophistication of those living on the side of the Moon from which the daily rotation of Earth is clearly visible, with the obtuseness of those on the other side who, like us, do not have rotation forced on their attention. The *Somnium* was published posthumously in 1634. There is reason to think that it was written in 1609 and that a copy could have reached Donne through his versatile friend Harriot, of whom Aubrey wrote, 'He made a philosophical theologie, wherein he cast-off the Old Testament...'. A connection is possible. Harriot corresponded with Kepler, but the connection seems to me rather tenuous. After the end of the seventeenth century, journeys to the Moon and elsewhere, and encounters with extraterrestrials, became popular themes for novelists.

Speculations about people elsewhere, by both clerics and eminent scientists, deserve attention because, quaint as they may seem today, they came from people who were not our intellectual inferiors. Discussion was conducted in a different intellectual 'climate'. 'Climates' change. Thus Priestley's (1809) phraseology when commenting on Erasmus Darwin's belief in spontaneous generation, '...if there be any such thing as *atheism*, this is certainly it', sounds odd today. Our own speculations about cosmic influences on biology will seem equally quaint to our successors.

The most interesting recent intrusion of theology into our subject was the wrangle in the 1850s between Brewster and Whewell. Brewster, like other nineteenth century pluralists, did not contend that beings elsewhere had anything more than a psychological effect on us. He assumed that the Universe was created for the benefit of sentient beings and that it would have been wasteful not to people other parts of it. Whewell, who had been a pluralist 20 years earlier, disputed the validity of this type of argument. In a detailed and amusing discussion of 'natural theology', Brooke (1977) suggests several reasons for Whewell's changed outlook. One was that geological evidence was demonstrating the immense period for which Earth had existed 'wastefully' without human inhabitants. Geology was at that time beginning to assume as much relevance in these matters as astronomy. Another reason for Whewell's opposition to pluralism was personal. It was summed up in the quip, 'Through all infinity, there is nothing so great as the Master of Trinity'. Whewell's point of view prevailed and the presence of intelligence elsewhere was increasingly doubted. Nevertheless, Lord Kelvin was probably nearly correct when, 15 years later (Thomson 1872) he wrote, 'We all confidently believe that there are...many worlds of life besides our own'.

The separation of a belief in life elsewhere from a belief in intelligence elsewhere had to await the resolution of the spontaneous generation controversy. One belief involved people and their souls, the other involved a recognition that it may be possible to distinguish the category *living* from the category *non-living*. Several scientists in the seventeenth century, e.g. Boyle in the *Sceptical chymist* (1661) and Leeuwenhoek in a letter in 1680, had stated their disbelief in spontaneous generation. The matter was gradually put on an experimental basis by Joblot's (1718) experiments with boiled hay, Carter's (1732) introduction of heat sterilization in a closed vessel as a means of preserving food, and the convincing experiments of Spallanzani in the years 1765 and 1776. Pasteur's still more thorough experiments, coupled with his skill as a propagandist, forced scientists to wonder how life had originated on Earth.

Extraterrestrial intrusion had been postulated to explain specific biological phenomena; the general proposition that all life came here from elsewhere seems to have originated with Richter

(1865). It was supported enthusiastically by Lord Kelvin (Thomson 1872) who wrote of 'countless seed-bearing meteoric stones moving about through space'. In the same paper he dismissed the idea of spontaneous generation with the phrase, '...we must not invoke an abnormal act of Creative Power' and dismissed Darwinian natural selection on the grounds that '... proofs of intelligent and benevolent design lie all around us'. It is not clear why he considered scattering what he called 'moss-grown fragments' round Space an example of intelligent design, whereas arranging for spontaneous generation in suitable conditions was abnormal. Arrhenius popularized the idea in many books and articles at the beginning of this century: it has been advocated from time to time since then. It has also been ridiculed. Weismann's (1881) phrase was, '...the mere shifting of the origin of life to some other far off world cannot in any way help us'. Schafer (1912) said that it 'merely serves to banish the investigation of the question to some conveniently inaccessible corner of the universe'.

Surveys such as this often list Liebig and Helmholtz among those who thought of 'seeds' coming to Earth from Space. Some of their phrases can be taken in that sense; others suggest a Kantian hylozoism – the idea that all matter has vital attributes. Liebig remained a vitalist all his life in spite of the laboratory synthesis of many molecules that had been thought of as products of vital synthesis only. He was inexplicit about the nature of the vital essence he postulated. Possibly, like John Hunter, he thought of something similar to magnetism that could be 'superadded' to matter.

Although conditions elsewhere may not have been any more favourable for biopoesis than conditions were on Earth 2 or 3 Ga ago, such conditions probably existed earlier on some of the immense number of planet-like bodies that are postulated in the Universe. On at least one of them, evolution would therefore have had longer to act and presumably produce intelligence. That is the basis for Haldane's (1954) suggestion that Earth could have been deliberately seeded with what he called 'astroplankton' by extraterrestrial intelligent beings, or the suggestion (Oparin 1957) that 'seeds' arrived on an early astronaut's boot. Although such suggestions do not meet the point made by Weismann and Schafer, they are now treated sympathetically by many scientists, and there is no reason to regard them as impossible. Obviously, a culture as advanced as the one postulated would know how to package 'seeds' for travel and impact. That meets the objection, often raised against suggestions such as Kelvin's, that 'seeds' would be too fragile to survive the journey. An obvious corollary to this suggestion is that evolution could have been hastened from time to time by 'reseeding' with organisms preadapted to changed environmental conditions.

Some other speculations have a more solid factual basis. About 1 Mt of cosmic dust may now reach Earth's surface daily (Sackett 1964); about one tenth of that mass comes in as meteorites (Breger *et al.* 1972). The rate of infall was presumably greater during earlier phases of the evolution of the solar system. Fortunately, large meteorites are infrequent and their most noticeable effects, e.g. a world-wide dust cloud which has been suggested as a cause of mass extinctions, are not, strictly speaking, examples of cosmochemistry. Nor are mutations caused by radiation and radioactive isotopes from supernova explosions. However, Gilvarry & Hochstim (1963) calculate that a meteorite 1 km in diameter would make 100 kt of nitric oxide during its passage through terrestrial air. Such an accession of fertilizer nitrogen could explain the more exuberant growth of those trees that survived along the flight-path of the Tunguska meteorite or comet fragment (Fesenkov 1971), compared with other trees in the neighbourhood.

Unless there is substance in the suggestion that some of the meteorites that contain organic matter, and which may contain biological structures, were originally ejected from Earth, meteoric organic matter is part of cosmochemistry. It may be more relevant to our theme than simple substances such as nitric oxide. Substances variously described as resembling humus, hydrocarbons and ozokerite were isolated from meteorites by Berzelius, Wohler and Berthelot before 1870. They discussed the possibility that these substances were, as on Earth, biological products. But they were aware of the formation of similar substances when cyanide solutions are aged or when cast iron is attacked by acid. Since that time, more interest has been taken in the minute amounts of simpler molecules that can be extracted with water and other solvents from meteorites. Obviously, the smaller the quantity found, and the more closely the molecules are related to those involved in present-day biological processes, the greater the risk that they are not genuine meteoric components but the result of terrestrial contamination. The 2–6 % of insoluble organic material that is distributed throughout some meteorites cannot be a contaminant; it closely resembles sporopollenin from present-day and fossil spores and pollen, and material from ancient terrestrial sediments (Brooks & Shaw 1969, 1973).

This meeting is concerned with the impact that components of meteorites and cosmic dust may have had on biology rather than with the possible biological origin of these objects. Nevertheless, if it could be demonstrated that biological material is present, the probability that it affected the development of organisms here would presumably be increased. The chemical studies do not give unequivocal evidence. Microscopic structures in some meteorites resemble biological structures closely, and they are too abundant and uniformly distributed throughout the stone to be contaminants. As Gregory (1975) suggested, we need an atlas of curiously shaped microscopic objects both biological and non-biological, with which objects of uncertain origin could be compared. The soft, intricate internal structure of the metabolizing organism, rather than the framework, or the minimal reproductive unit, is the essence of an organism. The framework is the part most likely to be preserved and it may be too simple to be wholly convincing. To take a terrestrial example: we would form an inadequate picture of a forest if spores and pollen were the only evidence we had. If there was life on the extraterrestrial object(s) from which these meteorites came, it is a pity the organisms had not developed so far as to make something like a bone or a shell.

It is now generally agreed that u.v. light and other sources of energy would have synthesized an immense range of organic molecules from the components of the pristine atmosphere and that, in the absence of organisms and free oxygen, these molecules would accumulate and interact until an equilibrium mixture was established. Some of the published timetables for this process, if taken literally, suggest that many millions of years elapsed between the synthesis of small molecules and their association into polymers. That suggestion is absurd. Gums, tars and substances such as azulmic acid form in such mixtures in a few hours or days. In a few articles (e.g. Pirie 1948, 1957) and many book reviews, I have argued that the oils and tars made during *in vitro* experiments are much more likely to have a bearing on biopoesis than the small molecules to which so much attention is usually paid. Most pictures of the process call for an interface of some sort with ionizable groups on it: that also would be supplied by some tars. They are now getting more adequate attention (Sagan & Khare 1979).

Organic matter indubitably comes to Earth in meteorites now and presumably did so in the past. There is no evidence that it differs in composition from the organic matter that it is reasonable to suppose was already present, or that it influenced the rate or direction of evolution. The concentration of organic matter on the surface of the probiotic Earth is controversial.

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If it was as small as is sometimes suggested, one possible biological effect of the intrusion of meteoric organic matter is that, by producing larger and more persistent organic pockets than would have resulted from adsorption on mineral crystals or at a water surface, developments would have been hastened.

More specific influences are also possible. The idea that a meteorite could bring in a viable seed, in the literal sense, i.e. a structure able to survive harsher conditions than the developed form of the species that it perpetuates, has already been mentioned. Metaphorical use of the word 'seed' raises more possibilities. Those who assume that an eobiont must have depended on proteins and nucleic acids suggest that a 'seed' could be a piece of informational nucleic acid that acted as a matrix on which an integrated set of syntheses started. It seems to me that life, if any, anywhere in the Universe, will be confronted, as on Earth, with the problem of packaging literal seeds, and that meticulously packaged reproductive units would be more likely to survive the hazards of Space than bare nucleic acid. Other familiar types of primer, e.g. the traces of polysaccharide that are needed to start some types of polysaccharide synthesis (Hanes 1940), are equally vulnerable.

More robust types of 'seed' can be imagined. An obvious example is the introduction of a crystalline particle into a gum in which crystallization does not start spontaneously. It is historically interesting that the analogical connection between the two types of 'seeding' became explicit when Schroeder (1859) found that those treatments that robbed air of its ability to initiate crystallization, also robbed it of the ability to initiate fermentation. The essential characteristics of the 'seeding' process were discussed by Penrose (1958) and he made some ingenious mechanical models to illustrate them. Energy was supplied by gentle shaking. Jacobson (1958) made a rather more elaborate model. Each system demonstrates that a 'seed' or 'primer' can easily be made that starts a process producing more copies of itself. Ordinary catalysts usually do not do this. Therefore, however relevant some catalytic processes may seem to be, the formation of eutactic polymers for example, they are not truly relevant unless they are autocatalytic, so that the polymer made is itself the catalyst. Speculations such as these could be extended greatly – but unprofitably.

Cosmic influence has often been invoked to explain puzzling phenomena: hence the use of such words as *disaster* and *ill-starred*. For example. Paracelsus suggested that manna was the slime mould and that it fell from the stars (manna = Hebrew *man hu* = *what is it?* = dog Latin *noste hoc?* = *Nostoc*). Sales-Guyon de Montlivault (1821) was struck by the absence of human remains in strata that contained animal remains. He suggested that earth originally contained animals only, but the Moon had people. Gravitational interference by a passing comet caused the lunar ocean to slop over on to Earth, bringing our ancestors with it. There have been more recent, and somewhat less fanciful, invocations of cosmochemistry as the cause of supposed terrestrial phenomena, for example the apparent increase in the rate of evolution at the beginning of the Cambrian (this worried Darwin), and the capriciousness of epidemics. These suggestions will be discussed by others at this symposium. The structural use of calcium phosphate appeared in several phyla in different parts of the world within a span of about 100 Ma. Mourant (1971) suggested that this may have been the result of virus transduction spreading the necessary enzyme(s). Among possible sources for the initiating 'seed', intrusion from Space might be considered.

There is now little support for the idea that life is an entity that has of necessity always existed somewhere in the Universe, and that its dissemination depends simply on there being a means of transport. If that idea is rejected, is there any reason for assigning to cosmochemistry an essential role in any terrestrial biological phenomena? That is to say: is there an answer to the objection raised by Weismann and Schafer? The ancients arbitrarily attributed special qualities to extraterrestrial sites. Can we now suggest anything more in accord with today's intellectual 'climate'? The significance, if any, of cosmochemistry depends on its duration and abundance, not on uniqueness. If, as is generally assumed, the appearance of an eobiont by random synthesis is immensely improbable, and if its further evolution depends on the integration of other improbable processes, the greater the number and diversity of the sites of random syntheses, the more probable the necessary coordination becomes. Planets, comets, dust grains, etc., offer a diversity of environments, and many of them have existed for much longer than Earth. Nevertheless, there is no reason to assume that any relevant processes are more probable, in similar times and volumes, elsewhere than here.

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