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Did Life Originate in Space? A Discussion of the Implications of Recent Research

ANTHONY MUGAN

Oldham Education Authority, Center for Professional Development, Rosary Rd, Fitton Hill, Oldham, OL4 2QE, United Kingdom

Abstract — At the time of writing the alleged Martian microfossils remain the subject of much debate. If their validity is accepted their existence greatly strengthens the view of the origin and evolution of life proposed by many theorists within the study of complex systems theory. The implications of the complexity theory for the extraterrestrial hypothesis of the origin of life proposed by Hoyle and Wickramasinghe is discussed, together with other lines of evidence for this hypothesis, in the light of the morphological evidence from the alleged Martian microfossils.

Keywords: evolution of life — extraterrestrial hypothesis — interstellar molecules

Introduction

The evidence for, or against the alleged Martian microfossils is complex (McKay *et* al., 1996). The sulfide crystals originally included with other evidence for biological origins of the objects within the meteorite no longer appear to be biological in origin. Other aspects of the evidence, however, appear compelling. In particular the carbon isotope ratio within the carbonate deposits is consistent with biological activity. Some misleading press reports concerning oxygen isotope studies, which determine temperature ranges for the formation of the carbonate, have circulated, suggesting they preclude a biological origin. This is not the case. Two initial studies were contradictory, giving temperature ranges of 0–80 °C and >450 °C. A more thorough examination of the oxygen isotope ratios has subsequently given a temperature range of 40–250 °C. While the upper extreme of this possible range is uncomfortably high, it does not exceed the highest tolerance recorded for thermophilic bacteria, which is 305 °C (Hoyle, 1983). The carbonate has the appearance of a freshwater mineral deposit (McKay *et* al., 1996). The apparent temperature range certainly does not disprove the biological origin of the microfossils, although it does largely remove the possibility that the carbonate may have been a terrestrial contaminant from Antarctica. In addition, supraglacial melt water is usually very pure in terms of calcium carbonate or magnesium carbonate (Collins, 1979) and is typically oxidizing (Mugan, 1997) while the mineral composition of the carbonate globules in ALH84001 includes reduced sulphide minerals. More recently Pillinger, Wright and Grady reported at a conference of the Royal Society in London that carbon isotope ratios consistent with biological activity had been found in another Martian meteorite. The simple existence of the microfossils has profound implications, which will be considered below. However, one further point needs to be mentioned. The microfossils have a noticeable morphological similarity with the alleged micro-organisms discovered by Folk (Folk, 1993; see also McBride et. *al.*, 1994), which were found on ground-water-deposited calcite concretions, limestone and travertine. The biological nature of these latter alleged micro-organisms is still a matter of controversy, due to their small size and the fact that they have yet to be cultured. However, in a recent letter to Science, Folk (1996) refers to a paper in preparation concerning the successful culturing of nannobacteria. Should the validity of both sets of fossils become accepted, some interesting questions concerning the origin and evolution of life and its universality, which have already been raised by developments in complexity theory, will become unavoidable.

Complexity and the Origin of Life

It has often been suggested (Zuckerman & Hart, 1995 and references therein; Hoyle & Wickramasinghe, 1993) that life is an extremely improbable event. This view is based upon information theory, in which the probability of a simple micro-organism forming by chance is viewed as the probability of the random arrangement of its constituent molecules producing a viable organism. In this view, the probability of life forming at any time or place in the history of the universe is extremely remote. The fact that life has not only appeared, here on Earth, but that it appeared very early in the history of our planet, by 3.5 billion years ago at the latest, and probably by 3.85 billion years ago, was a significant difficulty for this point of view. This difficulty, combined with the paleontological evidence for punctuated evolution, led Hoyle and Wickramasinghe (1978, 1993) to propose that as the molecular constituents of life are present within molecular clouds, and therefore presumably in comets, life could have originated in one of the billions of comets that exist in the galaxy that may have had liquid cores (in the case of larger comets) for up to 100 million years after their formation (Hoyle & Wickramasinghe, 1993).

The development of the complex systems theory (Bak & Kan, 1991; Kauffman 1993a, b, and references therein) has largely removed the apparent difficulty posed by information theory to the origin of life. The phenomena known as autocatalytic sets provide the key to this hypothesis. In a relatively small collection of molecules the probability that any one molecule will catalyze the reactions of any others is relatively small. As the number of molecular species in a system (its complexity) increases, the number of possible interactions will increase. The rate of increase has been shown to be exponential so that as the complexity of a system increases, the ratio of interactions (edges) to molecular species (nodes) increases. It has been shown that as the ratio of edges to nodes in a system passes 0.5, the system tends to rapidly develop large interconnected webs of reactions, in a state known as autocatalytic closure. It has been suggested that a complex collection of organic molecules confined in space within, for example, a bilipid layer or a thermal protenoid, both of which tend to form naturally under certain conditions, may become an autocatalytic set. Such sets have been shown to possess the characteristics of simple organisms, including reproduction and evolution (Kauffman, 1993a). Mathematical simulations of organisms produced in this fashion are generally robust to random mutations (Kauffman, 1993b), due to the existence of attractor states, stable states towards which many initial configurations rapidly converge. Evolution in this framework is seen as the result of occasional mutations, which induce a pattern of chaotic disturbance within the system. Most such disturbances return to the original attractor, while occasionally the system returns to a different attractor in a "species jump", as is often observed in the fossil record.

Once formed, an autocatalytic set is subject to a form of chemical natural selection so that over time, primitive autocatalytic sets evolve towards forms that are better able to sustain themselves. Those that succeed in becoming "fitter", are likely to become more numerous. Computer simulations (Kauffman, 1993b) have shown that autocatalytic sets can evolve the power to reproduce. Autocatalytic sets that evolve towards less competitive attractor states will tend to be driven to "extinction" by those that are more competitive in the competition for resources, giving a possible hint of why organisms are descended from a single basic form of genetic material. Significant variations upon the basic genetic code (*i.e.* species) are more probably attracted to nearby peaks on a rugged fitness landscape (Kauffman, 1993b), which form an area of generally high fitness (less fit variations, on more distant, lower fitness peaks, do not survive), again encouraging a broad similarity in the genetic structures between different species.

Many of the above ideas are tentative, but considerable quantities of encouraging data from computer simulations are now available. A prediction of complexity theory is that there should be a limited number of basic morphologies within the plant and animal kingdoms, represented by the various phyla, corresponding to the main attractor states in the phase space of the gene pool (Goodwin, 1994). It is interesting that at the Cambrian "explosion", at which a great diversification of life occurred very abruptly, a large range of new phyla came into existence very quickly (Gould 1989). Some of these have since become extinct, but no new phyla have emerged. The rapid appearance of life on Earth, (and, it now appears — Mars), combined with the paleontological evidence is strong evidence in favor of the hypothesis that life is a natural and predictable outcome of physical processes in environments like the early Earth and Mars. In the words of Kauffman (1993b), "We are at home in the universe." Life should appear in virtually any suitable environment, given a comparatively short period of time, on the order of a few million to 100 million years. Life would appear to be a universal phenomena.

The Implications of Complexity

As Hoyle and Wickramasinghe (1978, 1993) have pointed out, complex organic molecules are present in space (Hoyle, 1983; Hoyle, Wickramasinghe and Watkins, 1985). Many amino acids have now been detected in carbonaceous chondrites, a form of meteorite. (Mason, 1990, and references therein). It is generally accepted that the early Earth had been seeded by complex organic molecules which had greatly accelerated the process of prebiotic chemical evolution (Ponnamperuma & Novarro-Gonzalez, 1995). Such complex organic molecules must have been incorporated into comets, and indeed organic material has been detected in the tails of comets (Mason, 1990; Hoyle & Wickramasinghe, 1993). It appears plausible from the chemical constituents of chondrules within some meteorites that a supernova explosion occurred near the proto solar system (Mason, 1990). The incorporation of radioactive elements, perhaps most importantly aluminum 26, together with exothermic chemical reactions, could have kept the cores of some comets liquid for up to around 100 million years. It is generally thought that only larger comets would have the structural integrity to maintain a solid crust over a liquid core, although much remains to be learned about the actual structure of comets in the light of recent observations (Hoyle & Wickramasinghe, 1993). With an estimated 100 billion comets in the Oort cloud, and a probable interchange of comets between solar systems, the potential number of Darwinian "warm little ponds" is considerable. It is difficult to see why the evolution of life within a comet is prohibited by the known laws of chemistry or physics. The implication of complexity theory is that life should have evolved in comets, and indeed within many of them as well as at many times and places within the universe.

This astonishing hypothesis, that life originated in space and seeded the early Earth (and any other suitable habitat) must be thoroughly tested before it can be considered plausible. Fortunately many tests are possible. Hoyle and Wickramasinghe (1978) initially developed the hypothesis in order to explain the pattern of absorption found in the spectra of interstellar clouds. The combination of molecules found in bacteria, together with the optical properties of dehydrated bacteria, mixed with small quantities of other, plausible materials such as silica, carbon and ice, produces an extremely close match with the observed spectra. Perhaps most fundamentally, if bacteria are hypothesized to have originated in space, they should possess evolutionary adaptations to it, for which there would be no explanation if they originated on Earth. When the camera unit on the lunar probe Surveyor 3 was returned to Earth in quarantine conditions by Apollo 12, it was found to contain live bacteria that had survived two years in deep space conditions (Hoyle, 1983). Micro-organisms are known to posses high, though variable tolerance of radiation, extremes of temperature, dehydration and exposure to vacuum (Hoyle & Wickramasinghe, 1993).

Other tests of this hypothesis are possible. The tropopause marks a temperature inversion in the atmosphere, above which convection is extremely limited (Barry & Chorley, 1982). The density of micro-organisms should be very low above the tropopause, while quite the reverse is found (Hoyle, 1983). In 1961 Claus and Nagy (Hoyle, 1983) claimed to have found microfossils within a meteorite. The rejection of these findings rested upon the contamination of the meteorite with terrestrial organic material, and upon the similarity of the structures to thermal protenoids. Structures remarkably similar to microfossils, including Pedomicrobium, which is hard to account for as a chemical microfossil, have been found in the Murchison meteorite (Hoyle, 1983) in what appears to be a methodologically sound study.

The extraterrestrial hypothesis for the origin of life can also be tested against the incidence of disease from influxes of space born viruses, (Hoyle, Wickramasinghe and Watkins, 1985) and against the fossil record. In addition, the extraterrestrial hypothesis predicts species jumps by the disruption to genes caused occasionally by viruses. It also addresses one of the remaining difficulties of complexity, namely how likely is it that two mutated specimens will find each other in order to reproduce? In the extraterrestrial hypothesis large sections of a population may find themselves transformed.

Hoyle and Wickramasinghe (1993) begin their argument by suggesting that the origin of life is extremely improbable on Earth, and that it needs to be a cosmic phenomena. I believe this assumption is flawed, but that the implications of complex systems theory leads us inevitably back to an extraterrestrial origin of life, and indeed perhaps many origins through space and time.

It has been clearly established (Hoyle & Wickramsinghe, 1978) that objects up to 0.1 mm in diameter can soft-land on Earth without exceeding the heating tolerances of micro-organisms. Thus there is no reason why, if they exist in space, viruses, bacteria and even whole bacterial colonies, could not survive entry to the atmosphere.

The extraterrestrial hypothesis can also make predictions. If the Martian microfossils are biological in origin, then that species could probably also have existed on Earth, and its fossils will be found. Examples may indeed already have been found by Folk (1993). Life will probably also exist on Europa, which appears to possess liquid water beneath an ice crust, due to tidal effects from Jupiter, and possibly in the atmospheres of the giant planets.

It is not inconceivable that niche environments exist today on Mars. The biological experiments from the Viking landers are very unclear on this issue, despite popular misconceptions. The gas chromatograph indeed showed a negative result, while the labeled release experiment (where radionuclide labeled nutrients were placed on the Martian soil, and the gases given off monitored) gave a positive result. Subsequent control experiments showed that the gas chromatograph had a sensitivity of 10 million microbes per gram, while the

LR experiment was a thousand times more sensitive, at 10,000 microbes per gram. No inorganic method has been found to replicate the LR results (Levin & Straat, 1976, 1977). At best these results should be regarded as inconclusive, but suggestive.

A note of caution needs to be raised at this point. While complexity theory tells us how reproducible complex systems can arise, it does not yet allow us to precisely quantify the probability of life itself (a very particular complex system) arising in a given environment in a certain length of time. If the number of possible attractor states for complex organic systems is exceptionally high, then the origin of life becomes less probable in a particular location and time scale. There is clearly a need for empirical data to attempt to address this question. If the number of attractor states is so high as to give odds on life forming comparable to those suggested by information theory, then we are still faced with a need to invoke an origin of life away from our own planet in order to explain the observed data.

Conclusions

Life appears to be a natural and probable outcome of physical and chemical laws, an attractor state for complex organic systems. Life should, therefore, be expected elsewhere in the universe — as there are plausibly 600,000 to 2.5 million planets offering long term habitability (2 billion years or more) in our galaxy alone (Zuckerrnan &Hart, 1995). Furthermore life had the opportunity to arise within many comets, and should have done so on many occasions throughout the universe, assuming the number of possible attractor states for complex organic systems is not super-astronomical. The implications of both complexity, and even more so the extraterrestrial theory, for areas of study as diverse as biology and Ufology need hardly be specified. Perhaps not least amongst the implications is the possibility of broad morphological similarities between extraterrestrial and terrestrial species, though detailed evolutionary differences should remain.

References

Bak, P., & Kan, C., (1991). Self-organized criticality. ***Scientific American,*** January 1991, 40.

Barry, R. G., & Chorley, R. J., (1982). ***Earth Weather and Climate.*** 4th edition, London and New York: Methuen.

Collins, D. N., (1979). Quantitative determination of the subglacial drainage system of two Alpine glaciers. ***Journal of Glaciology,*** 23, 347.

Folk, R. L., (1993). SEM imaging of bacteria and nannobacteria in carbonate sediments and rocks ***Journal of Sedimentary Petrology,*** 63,990.

Folk, R. L., (1996). In defense of nannobacteria. ***Science,*** 274, 1288.

Goodwin, B., (1994). ***How the Leopard Changed its Spots.*** New York: Charles Scribners.

Gould, S. J., (1989). ***Wonderful Life: The Burgess Shale and the Nature of History.*** New York: Norton.

Hoyle, F., & Wickramsinghe, C., (1978). ***Lifecloud.*** London: J. M. Dent and Sons.

Hoyle, F. (1983). ***Intelligent Universe.*** London: Cambridge University Press.

Hoyle, F., & Wickramsinghe, C., (1993). ***Our Place in the Cosmos.*** London: J. M. Dent and Sons.

Hoyle, F., Wickramsinghe, C. and Watkins, J., (1985). ***Diseases From Space.*** London: J. M. Dent and Sons.

Kauffman, S. A., (1993a). ***The Origins of Order: Self Organization and Selection in Evolution.*** New York: Oxford University Press.

Kauffman, S. A., (1993b). ***At Home in the Universe: The Search for the Laws of Complexity.*** Penguin Science, New York.

Levin, G. V., & Straat, P. A., (1976). Viking labeled release experiments: Interim results. ***Science,*** 194,1322.

Levin, *G.* V., & Straat, P. A., (1977). Recent results from the Viking labeled release experiments on Mars. ***JGR, Journal of Geophysical Research,*** 82,4663.

Mason, E., (1990). ***Evolutionary Chemistry.*** London: Cambridge University Press.

McBride, E. F., Dane Picard, M. and Folk, R. L., (1994). Oriented concretions, Ionian coast, Italy: Evidence of groundwater flow direction. ***Journal of Sedimentary Research,*** 64A, 535.

Mckay, D. S., Gibson, E. K. Jr., Thomas-Keprta, L. L., Vali, H., Romanek, C. S., Clemett, S. J., Chillier, X. D. F., Maechling, C. R., and Zare, R. N., (1996). Search for past life on Mars: Possible relic biogenic activity in Martian meteorite ALH84001. ***Science,*** 273,924.

Mugan, A., submitted. Dissolved oxygen in the meltwater of an Alpine glacier. ***Earth Surface Processes and Landforms.***

Ponnamperuna, C. & Novarro-Gonzalez. R., (1995). Primordial organic cosmochemistry. In Zuckerman, B. and Hart, M., (eds.), 1995. ***The Extraterrestrials; Where Are They?*** 2nd edition. London: Cambridge University Press. p.108-123.

Zuckerman, B., and Hart, M., (eds.), (1995). ***The Extraterrestrials: Where Are They?*** 2nd edition. London: Cambridge University Press.