A MICROBIOLOGIST LOOKS AT PANSPERMIA

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Originally, the term 'panspermia' was used by microbiologists (of the late Victorian period, e.g. Roberts, 1874) to refer to the observation that terrestrial air is full of microorganisms. Panspermia, was later used to cover the view that life on Earth originated from space, while more recently, it has been extended to describe the hypothesis that life continues to rain down to Earth from space. In order to avoid confusion, here I will use the term panspermia in its original astrobiological sense, while adopting the term neopanspermia to refer to the hypothesis that life continues to arrive to Earth from space.

Although belief in both the panspermia and neopanspermia is becoming somewhat fashionable, many authors habitually fail to make reference to the originators of the modern view of these hypotheses, namely Fred Hoyle and Chandra Wickramasinghe (Wainwright, 2001). Some authors instead date the resurrection of panspermia *sensu lattu* to the far more speculative, and essentially unprovable, views of Francis Crick on so-called directed panspermia (i.e. the view that life on Earth was seeded by some unknown, cosmic civilisation) (Crick, 1981). There is no doubt however, that priority of the modern view of neopanspermia belongs to Hoyle and Wickramasinghe (Hoyle and Wickramasinge, 2000). Hoyle and Wickramasinghe (1979) have also championed the view that pathogens arrive to Earth from space; an idea ('pathospermia') that has come in for even more derision than their views on neopanspermia.

Here I intend to discuss both panspermia and neopanspermia from a microbiologist's viewpoint, taking the opportunity to point out the problems inherent in trying to demonstrate that Earth is being continually seeded with space-derived microorganisms.

Survival of Space-borne Micro Organisms

It goes without saying that any microorganism reaching the Earth from space must have survived the extreme rigours of the space environment. Although microorganisms need not grow and reproduce in space, they obviously must survive in a form that can then reproduce on arrival on Earth. The ability of microorganisms to withstand environmental extremes is being increasingly widely recognised. Hoyle and Wickramasinghe (Wickramasinghe, 2001) pointed out that Earth microorganisms (geomicrobes) possess all the characteristics necessary to allow them to survive in space and, by reversing this argument, suggested that the possession of such

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characteristics suggests that microorganisms originated in a more demanding environment, i.e. space. This viewpoint has however, been criticised by, amongst others, Battista et al. (1999) who suggests that microbial resistance to ionising radiation may involve DNA repair mechanisms that are evolutionary responses to other environmental factors, such as water shortage.

Although emphasis is currently being placed on the study of microorganisms, notably bacteria, that can live, and are specifically adapted to growth in, extreme environments (i.e. extremophiles), it is important to note that many common bacteria, inhabiting non-extreme environments, are able to survive extreme conditions. Such organisms can be termed *extremodures*. At the turn of the century for example, scientists showed that common bacteria could survive at a temperature of –252 °C (McFayden and Rowland, 1900). More recently, *Escherichia coli* has been shown to be capable of surviving exposure to high pressure (Al-Mufti et al., 1984).

Exposure to radiation, notably UV, is likely to be the major factor limiting the survival of microorganisms in space. Bacteria can however, resist UV by forming clumps of individual cells (as in *Sarcina* or *Staphylococcus*), while the spores of both bacteria (e.g. *Bacillus*) and fungi are often UV-resistant. The shading provided by adherence to particulates might also help protect microorganisms from UV, as might the formation of a UV-resistant layer resulting from the carbonisation of the outer cells of a mass of space-inhabiting bacteria (Hoyle and Wickramasinghe, 2000). Such considerations suggest that panspermic microorganisms need not be particularly unusual or especially specialised in order to survive the rigours of space.

The greatest degree of protection from the rigours of the space environment will obviously be afforded to microorganisms surviving in comets or laying dormant within masses of interstellar dust or meteorites. It is not surprising therefore to find that bacteria-like fossils have been found in the Murcheson meteorite and in the much discussed Mars meteorite, ALH 84001. There have also been a number of claims that living bacteria (species of *Bacillus* and *Staphylococcus*) have been isolated from meteorites), although these have generally been regarded as being contaminants (Orio and Tornabene, 1965). Nevertheless, claims that ancient living bacteria exist in meteorites continue to appear (Abbott, 2001).

Contamination and the Problem of Common Versus Unusual Microorganisms

The theory of neopanspermia predicts that microorganisms are continually raining down upon our planet and that by definition most, if not all Earth microorganisms, are derived from space. Earth organisms are therefore space organisms. The hypothesis states that common Earth organisms such as species of *Pseudomonas, Staphylococcus* and *Bacillus* originate from space. The fact that common geomicrobes can survive under extreme conditions explains how this might be possible. Unfortunately a problem arises with human perception that makes this suggestion unpalatable. Most microbiologists would assume that space-derived microorganisms would *a priori* be a) novel, b) primitive, and c) possess unusual, marker-physiologies. The demonstration that common Earth organisms occur in space would doubtless induce the knee-jerk response of most microbiologists that such isolates were contaminants, or at best originated from Earth. The isolation of space-derived microorganisms would probably only be generally accepted if they proved to be novel or unusual, despite the fact that this is not a requirement of the neopanspermia hypothesis.

Since microorganisms exist everywhere on Earth, any attempt to isolate microorganisms from space-derived samples is obviously bedevilled by problems of contamination. Any claim that geomicrobes have been isolated from space can be readily dismissed by invoking contamination, even where highly rigorous sterile techniques have been employed to exclude this possibility. Although contamination is a real problem it is often too readily used to dismiss all claims for the isolation of ancient, or space-inhabiting, microorganisms.

Recent Studies of the Isolation of Microorganisms from the Stratosphere

Scientists in India recently collected samples at 41 km above the Earth's surface. Every effort was made to avoid contamination of these samples, portions of which were sent to Cardiff University and transferred to filter membranes for microbial analysis. Here, viable, but none culturable bacteria were isolated. The bacterial masses isolates consisted of coccoid clusters with the occasional rod (Harris et al., 2001). Samples of the filters were forwarded to this laboratory where attempts were made to grow bacteria and any other microbial isolates present on the filters. The membrane filters, through which washout from the 4l km was passed, yielded two bacteria and one fungal isolate (Wainwright et al., 2002) The bacterial isolates were independently identified, using 16srRNA analysis, as *Bacillus simplex* (100% similarity) and *Staphylococcus pasteuri* (98% similarity, this isolate would however, have been classified as a *Micrococcus* had traditional identification techniques been employed). The fungal isolate was independently identified as *Engyodontium album.* All of these isolates are common Earth organism found in soil and vegetation.

None of the isolated organisms had ever been used in the laboratory where the work was performed. The work was conducted in a laminar airflow cabinet using standard microbial techniques. The fact that the isolated bacteria were rod and coccoid correlated with observations made at Cardiff on the uncultureable isolates, using scanning electron microscopy. The knee-jerk reaction of critics to the culturing of common bacteria from 41 km would be that they are laboratory contaminants; however, the following evidence suggests otherwise.

The filters were shaken in sterile deionised water; this was transferred to the surface a range of isolation media and incubated at 25 °C. Initially no surface growth and colony formation was observed on the media after 4 days of incubation. The surface of each medium was then removed and examined under the microscope, In the case of the PDA medium alone, two bacteria (mainly cocci with the occasional rod) were seen under the light microscope. These bacteria were then transferred to liquid LB medium and incubated at 30 °C for 4 days. A degree of serendipity was involved in the isolation of the bacteria, since the only PDA available at the time was some 20 years old. When reconstituted, an unusually soft medium resulted, which presumably because of oxidation, was browner in colour than fresh PDA. Bacteria were only isolated when this soft, aged, PDA was employed. Since airborne, or other contaminants, would readily have grown to form colonies on all the media used in this study, the implication is that the organisms isolated were not contaminants, but must have been exposed to unusual conditions and that only soft PDA supported their growth. It is possible that unknown growth promoting oxidation products may have provided the stimulus for growth, alternatively the fact that the medium was soft and wet may have been important. It is noteworthy that freeze-dried cultures are generally resuscitated using liquid media. This suggests the possibility that the isolates have been in freeze-dried state, suggesting that they had a non-terrestrial, i.e. space origin.

Problems Resulting from Attempts to Replicate these Isolations

A technician independently isolated the above named bacteria from the same membrane sample used in the initial isolation; the technician worked in a separate laboratory within this Department. The same isolate protocol was used, but the technician was unaware of any expected outcome. He was able to successfully isolate *S. pasteuri* and *B. simplex* (but not *Engyodontium album*) from the membrane. Subsequently however, workers at two other universities were unable to isolate the organisms when other membranes were sampled. The inability of independent workers, in separate University laboratories would, at first sight, appear to invalidate the original isolation work conducted in Sheffield. However, it must be borne in mind that such attempts at replication represent isolation experiments and that every membrane need not possess viable microorganisms. It may be that, while the majority of organisms present on the membranes are non-viable, viable cells were, by chance present on only one membrane.

If we assume that the isolates were not laboratory or otherwise contaminants then they must have originated at a height of 41 km above the Earth. The obvious question that arises is – how did they get to the altitude? The two obvious conclusions are that they were carried up from Earth and remained, or were falling through, the atmosphere at 41 km from where they were isolated. Alternatively, they may have arrived from space and were sampled at 41 km before falling to Earth. Proof of the latter possibility would of course validate neopanspermia.

The apparently obvious conclusion is that the bacteria and the fungal isolates were carried up from Earth and floated in space at 41 km from where they were collected. However, the only means by which bacteria can achieve a height of 41 km would appear to be via a volcanic eruption. The residence time of such particles, derived from volcanoes, would be only a matter of days. Since no volcanic eruptions occurred on Earth during the years prior to the 41 km-sampling event this would appear to rule out this possibility, although some authorities continue to believe that particles can cross the tropopause and reside at 41 km for longer periods (Gregory, 1961).

The Neopanspermia Paradox

Most microbiologists would assume that the isolates, if not contaminants, must have arrived to a height of 41 km from the Earth's surface. The isolates are regarded as common Earth bacteria. The fact that the *S. pasteuri* isolate is, unlike *S.aureus* and *S.epidermidis* capable of solubilising insoluble phosphates suggests that this isolate is not a skin contaminant, but possesses a property typical of a 'common' environment-derived, isolate. The use of the term, common in relation to microorganisms is however, questionable since microorganisms (with the exception of certain extremophiles) tend to be found ubiquitously over the Earth's surface. Even microorganisms that are regarded as being extremophiles (e.g. halophilic organisms, capable of growing in high salt concentrations) can often be readily isolated from non-saline soils. The ubiquitous distribution of microorganisms would of course support the view that such organisms are continually raining down from space, over the total surface of the Earth. Clearly the suggestion that the bacteria isolated from 41 km cannot have come from space because they are Earth organisms is in direct opposition to the neopanspermia hypothesis. If however, the Earth origin of these isolates is accepted than we are presented with a paradox since this would mean that bacteria are able to leave the Earth and infect space. Such a paradox would in fact demonstrate the correctness of the neopanspermia hypothesis and would suggest that space is contaminated by geomicrobes. Whether or not these organisms would find there way into deep space is however, debatable. In short those who believe that organisms isolated at 41 km must be from Earth are unwittingly validating the neopanspermia hypothesis.

The Problem of Phylogeny

From the biologists point of view the major limitation on the view that modern microorganisms can arrive from space relates to evolution and phylogeny. Essentially, because it should have evolved, any ancient microorganism should, in terms of its nucleotide sequence, be markedly different from modern microorganisms. If an organism has a very similar nucleotide sequence to a modern organism then it must, according to current molecular biology, be a modern organism. Similarly, an organism originating from space would be expected to possess nucleotide sequences which differ from modern organisms found on Earth, simply because one would not expect the direction and rates of evolution to be the same in space as on Earth. An example of how such considerations can lead to conflict is provided by the recent findings of bacteria in ancient salt crystals. Vreeland et al. (2000) isolated a bacterium from a 250 million year old salt crystal. They claimed that the bacterium was not a contaminant, but was the same age as the crystal. Graur and Pupko (2001) however, claim, based on the use of molecular methods, that the bacterium is modern and, despite the fact that Vreeland et al. (2000) used extremely rigorous sterile technique, must be a modern contaminant. Similar findings have been reported following the examination of Permian salt crystals by Fish et al. (2001). Clearly, if the bacterium is not a contaminant then there must be something wrong with our current understanding of molecular phylogeny and palaeontology. The general acceptance of the viewpoint that the nucleotide sequences of microorganisms must have changed over time (due to evolution) makes most microbiologists believe that any microorganism with nucleotide sequences close to that of modern microorganisms must, by definition, be a modern microorganism. Invoking Occam's Razor, most biologists would state that if an Earth-like organism is found at 41 km above the Earth's surface then it is an Earth organism; anyone who believes that the tropopause acts as a barrier to such contamination must as a result, alter their own, rather than the evolutionary paradigm. Similarly, the presence of a modern organism in an ancient salt crystal must, say the biologists, indicate only thing, contamination; it should however, be noted that the whole question of molecular phylogeny is in a sate of constant flux (Maher, 2002).

Panspermia and the Origin of Life

As was mentioned above, the term panspermia was originally used in its astrobiological connotation to refer to the view that life did not originate on Earth, but was seeded by organisms (and not just microorganisms) from space. A small number of microorganisms arriving in this way would have been capable of replicating at an incredibly rapid rate and would, in the absence of any competition from native organisms, have rapidly colonised the planet. It is noteworthy that many microorganisms have the ability to grow at very low nutrient concentrations (i.e. they are oligotrophic). Such oligotrophic growth would have been essential because nutrients to support microbial growth would have been present at very low concentrations in the un-inoculated prebiotic soup. It is generally accepted that heterotrophic life predated life based on photosynthesis, a view that ties in well with the view that heterotrophs arrived exogenously.

Wainwright and Falih (1997) showed that a fungus could grow, without added nutrients, on buckminsterfullerene. Since fullerenes have been transported to Earth in meteorites and could protect bacteria from UV, this novel carbon allotrope may have played an important role in the early origin of life on Earth.

Once the conditions on Earth were suitable life took off remarkably quickly; a fact that is in agreement with the view that it arose exogenously with Earth having been continually showered with microorganisms which lay inert until the point at which conditions were suitable to support their growth.

The fact that life got going so quickly has been used recently to suggest that the origin of life is a simple and frequent event, a viewpoint that is not however, supported by any compelling evidence. Finally, it has been suggested that if living organisms did not make the journey through space to begin life on Earth then perhaps DNA or RNA may have rained down on the prebiotic Earth and given life a 'kick-start' (Gribbin, 2001).

Conclusion

In 1928, a certain Professor F.G. Donnes had this to a say about panspermia:

> Perhaps the chief objection to the doctrine of panspermia is that it is a hopeless one. Not only does it close the door to thought and research, but also it introduces a permanent dualism into science and so prejudices important philosophical issues.

Many scientists clearly continue to express this viewpoint. It is often said for example that panspermia solves nothing simply because it does not answer the question of how life arose; if life arose in space, it is argued, then it could just as easily have arisen on Earth. Of course such arguments ignore the contrast between the finite nature of Earth and the infinity of space, in terms of both time and the limitless variety of astronomical bodies on which life could have arisen.

Donnes was clearly wrong when he said that panspermia closes the door to thought and experimentation. Such is the current level of theoretical and practical work being devoted to the question of neopanspermia that much new knowledge will be gained from its study, even if it does eventually prove to be a 'false doctrine' Neopanspermia is a scientifically valid idea simply because it can be refuted by experimentation.

Unfortunately, microbiological studies on Earth are unlikely to provide overwhelming evidence of the validity of the neopanspermia hypothesis. This is simply because cynics can dismiss any results by invoking contamination, especially because the Hypothesis predicts that microorganisms found in space will be identical to those found on Earth. As a result, the only way to convincingly demonstrate panspermia is to conduct experiments in space where the problems of contamination can be eliminated. However, in the absence of the facilities to study microorganisms *in situ* in space, evidence can only be accumulated from Earth-based experiments. If the neopanspermia is correct then a critical mass of information will accumulate that hopefully, will be sufficient to convince even the most diehard sceptic.

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