

Directed Panspermia

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It now seems unlikely that extraterrestrial living organisms could have reached the earth either as spores driven by the radiation pressure from another star or as living organisms imbedded in a meteorite. As an alternative to these nineteenth-century mechanisms, we have considered Directed Panspermia, the theory that organisms were deliberately transmitted to the earth by intelligent beings on another planet. We conclude that it is possible that life reached the earth in this way, but that the scientific evidence is inadequate at the present time to say anything about the probability. We draw attention to the kinds of evidence that might throw additional light on the topic.

INTRODUCTION

It was not until the middle of the nineteenth century that Pasteur and Tyndall completed the demonstration that spontaneous generation is not occurring on the Earth nowadays. Darwin and a number of other biologists concluded that life must have evolved here long ago when conditions were more favourable. A number of scientists, however, drew a quite different conclusion. They supposed that if life does not evolve from terrestrial nonliving matter nowadays, it may never have done so. Hence, they argued, life reached the earth as an "infection" from another planet (Oparin, 1957).

Arrhenius (1908) proposed that spores had been driven here by the pressure of the light from the central star of another planetary system. His theory is known as Panspermia. Kelvin suggested that the first organisms reached the Earth in a meteorite. Neither of these theories is absurd, but both can be subjected to severe criticism. Sagan (Shklovski and Sagan, 1966; Sagan and Whitehall, 1973) has shown that any known type of radiation-

resistant spore would receive so large a dose of radiation during its journey to the Earth from another Solar System that it would be extremely unlikely to remain viable. The probability that sufficiently massive objects escape from a Solar System and arrive on the planet of another one is considered to be so small that it is unlikely that a single meteorite of extrasolar origin has ever reached the surface of the Earth (Sagan, private communication). These arguments may not be conclusive, but they argue against the "infective" theories of the origins of life that were proposed in the nineteenth century.

It has also been argued that "infective" theories of the origins of terrestrial life should be rejected because they do no more than transfer the problem of origins to another planet. This view is mistaken; the historical facts are important in their own right. For all we know there may be other types of planet on which the origin of life *ab initio* is greatly more probable than on our own. For example, such a planet may possess a mineral, or compound, of crucial catalytic importance, which is rare on

Earth. It is thus important to know whether primitive organisms evolved here or whether they arrived here from somewhere else. Here we reexamine this problem in the light of more recent biological and astronomical information.

OUR PRESENT KNOWLEDGE OF THE GALAXY

The local galactic system is estimated to be about 13×10^9 yr old (See Metz, 1972). The first generation of stars, because they were formed from light elements, are unlikely to have been accompanied by planets. However, some second generation stars not unlike the Sun must have formed within 2×10^9 yr of the origin of the galaxy (Blaauw and Schmidt, 1965). Thus it is quite probable that planets not unlike the Earth existed as much as 6.5×10^9 yr before the formation of our own Solar System.

We know that not much more than 4×10^9 yr elapsed between the appearance of life on the Earth (wherever it came from) and the development of our own technological society. The time available makes it possible, therefore, that technological societies existed elsewhere in the galaxy *even before the formation of the Earth*. We should, therefore, consider a new "infective" theory, namely that a

primitive form of life was deliberately planted on the Earth by a technologically advanced society on another planet.

Are there many planets which could be infected with some chance of success? It is believed, though the evidence is weak and indirect, that in the galaxy many stars, of a size not dissimilar to our Sun, have planets, on a fair fraction of which temperatures are suitable for a form of life based on carbon chemistry and liquid water, as ours is. Experimental studies of the production of organic chemicals under prebiotic conditions make it seem likely that a rich prebiotic soup accumulates on a high proportion of such Earthlike planets. Unfortunately, we know next to nothing about the probability that life evolves within a few billion years in such a soup, either on our own special Earth, or still less on other Earthlike planets.

If the probability that life evolves in a suitable environment is low we may be able to prove that we are likely to be alone in the galaxy (Universe). If it is high the galaxy may be pullulating with life of many different forms. At the moment we have no means at all of knowing which of these alternatives is correct. We are thus free to postulate that there have been (and still are) many places in the galaxy where life could exist but that, in at least a fraction of them, after several billion years the chemical systems had not evolved to the point of self-replication and natural selection. Such planets, if they do exist, would form an excellent breeding ground for external microorganisms. Note that because many if not all such planets would have a reducing atmosphere they would not be very hospitable to the higher forms of life as we know them on Earth.

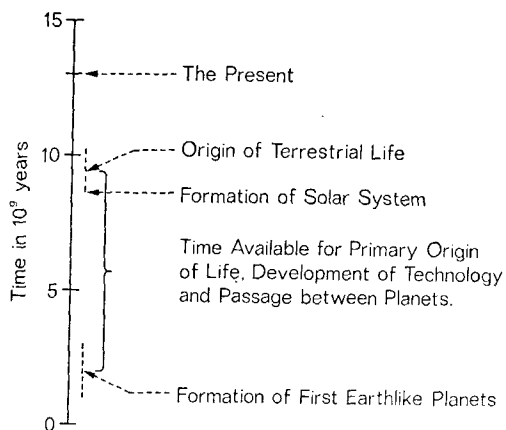


FIG. 1. An approximate time-scale for the events discussed in the paper. To simplify illustration the age of the galaxy has been somewhat arbitrarily taken as 13×10^9 yr.

OUR PROPOSAL

The possibility that terrestrial life derives from the deliberate activity of an extraterrestrial society has often been considered in science fiction and more or less light-heartedly in a number of scientific papers. For example, Gold (1960) has suggested that we might have evolved from the microorganisms inadvertently

left behind by some previous visitors from another planet (for example, in their garbage). Here we wish to examine a very specific form of Directed Panspermia. Could life have started on Earth as a result of infection by microorganisms sent here deliberately by a technological society on another planet, by means of a special long-range unmanned spaceship? To show that this is not totally implausible we shall use the theorem of detailed cosmic reversibility; if we are capable of infecting an as yet lifeless extrasolar planet, then, given that the time was available, another technological society might well have infected our planet when it was still lifeless.

THE PROPOSED SPACESHIP

The spaceship would carry large samples of a number of microorganisms, each having different but simple nutritional requirements, for example blue-green algae, which could grow on CO_2 and water in "sunlight." A payload of 1000 kg might be made up of 10 samples each containing 10^{16} microorganisms, or 100 samples each of 10^{15} microorganisms.

It would not be necessary to accelerate the spaceship to extremely high velocities, since its time of arrival would not be important. The radius of our galaxy is about 10^5 light years, so we could infect most planets in the galaxy within 10^8 yr by means of a spaceship traveling at only one-thousandth of the velocity of light. Several thousand stars are within a hundred light years of the Earth and could be reached within as little as a million years by a spaceship travelling at only 60,000 mph, or within 10,000 yr if a speed of one-hundredth of that of light were possible.

The technology required to carry out such an act of interstellar pollution is not available at the present time. However, it seems likely that the improvements in astronomical techniques will permit the location of extrasolar planets within the next few decades. Similarly, the problem of sending spaceships to other stars, at velocities low compared with that of light, should not prove insoluble once workable

nuclear engines are available. This again is likely to be within a few decades. The most difficult problem would be presented by the long flight times; it is not clear how long it will be before we can build components that would survive in space for periods of thousands or millions of years.

Although there are some technological problems associated with the distribution of the microorganisms in viable form after a long journey through space, none of them seems insuperable. Some radiation protection could be provided during the journey. Suitable packaging should guarantee that small samples, including some viable organisms, would be widely distributed. The question of how long microorganisms, and in particular bacterial spores, could survive in a spaceship has been considered in a preliminary way by Sneath (1962). He concludes "that life could probably be preserved for periods of more than a million years if suitably protected and maintained at temperatures close to absolute zero." Sagan (1960) has given a comparable estimate of the effects of radiation damage. We conclude that within the foreseeable future we could, if we wished, infect another planet, and hence that it is not out of the question that our planet was infected.

We can in fact go further than this. It may be possible in the future to send either mice or men or elaborate instruments to the planets of other Solar Systems (as so often described in science fiction) but a rocket carrying microorganisms will always have a much greater effective range and so be advantageous if the sole aim is to spread life. This is true for several reasons. The conditions on many planets are likely to favour microorganisms rather than higher organisms. Because of their extremely small size vast numbers of microorganisms can be carried, so much more wastage can be accepted. The ability of microorganisms to survive, without special equipment, both storage for very long periods at low temperatures and also an abrupt change back to room temperatures is also a great advantage. Whatever the potential range for infection by other organisms, microorganisms can almost

certainly be sent further and probably much further.

It should be noted that most of the earliest "fossils" so far recognized are somewhat similar to our present bacteria or blue-green algae. They occur in cherts of various kinds and are estimated to be up to 3×10^9 yr old. This makes it improbable that the Earth was ever infected merely by higher organisms.

MOTIVATION

Next we must ask what motive we might have for polluting other planets. Since we would not derive any direct advantage from such a programme, presumably it would be carried through either as a demonstration of technological capability or, more probably, through some form of missionary zeal.

It seems unlikely that we would deliberately send terrestrial organisms to planets that we believed might already be inhabited. However, in view of the precarious situation on Earth, we might well be tempted to infect other planets if we became convinced that we were alone in the galaxy (Universe).¹ As we have already explained we cannot at the moment estimate the probability of this. The hypothetical senders on another planet may have been able to prove that they were likely to be alone, and to remain so, or they may have reached this conclusion mistakenly. In either case, if they resembled us psychologically, their motivation for polluting the galaxy would be strong, if they believed that all or even the great majority of inhabitable planets could be given life by Directed Panspermia.

The psychology of extraterrestrial societies is no better understood than terrestrial psychology. It is entirely possible that extraterrestrial societies might infect other planets for quite different reasons than those we have suggested. Alternatively, they might be less tempted than we would be, even if they thought

¹ In a somewhat different context the seeding of Venus and other solar planets has been suggested by C. Sagan (1961), and T. Gold, private communication.

that they were alone. The arguments given above, together with the principle of cosmic reversibility, demonstrate the possibility that we have been infected, but do not enable us to estimate the probability.

POSSIBLE BIOLOGICAL EVIDENCE

Infective theories of the origins of terrestrial life could be taken more seriously if they explained aspects of biochemistry or biology that are otherwise difficult to understand. We do not have any strong arguments of this kind, but there are two weak facts that could be relevant.

The chemical composition of living organisms must reflect to some extent the composition of the environment in which they evolved. Thus the presence in living organisms of elements that are extremely rare on the Earth might indicate that life is extraterrestrial in origin. Molybdenum is an essential trace element that plays an important role in many enzymatic reactions, while chromium and nickel are relatively unimportant in biochemistry. The abundance of chromium, nickel, and molybdenum on the Earth are 0.20, 3.16, and 0.02%, respectively. We cannot conclude anything from this single example, since molybdenum may be irreplaceable in some essential reaction—nitrogen fixation, for example. However, if it could be shown that the elements represented in terrestrial living organisms correlate closely with those that are abundant in some class of star—molybdenum stars, for example—we might look more sympathetically at "infective" theories.

Our second example is the genetic code. Several orthodox explanations of the universality of the genetic code can be suggested, but none is generally accepted to be completely convincing. It is a little surprising that organisms with somewhat different codes do not coexist. The universality of the code follows naturally from an "infective" theory of the origins of life. Life on Earth would represent a clone derived from a single extraterrestrial organism. Even if many codes were represented at the primary site where life

began, only a single one might have operated in the organisms used to infect the Earth.

CONCLUSION

In summary, there is adequate time for technological society to have evolved twice in succession. The places in the galaxy where life could start, if seeded, are probably very numerous. We can foresee that we ourselves will be able to construct rockets with sufficient range, delivery ability, and surviving payload if microorganisms are used. Thus the idea of Directed Panspermia cannot at the moment be rejected by any simple argument. It is radically different from the idea that life started here *ab initio* without infection from elsewhere. We have thus two sharply different theories of the origin of life on Earth. Can we choose between them?

At the moment it seems that the experimental evidence is too feeble to make this discrimination. It is difficult to avoid a personal prejudice, one way or the other, but such prejudices find no scientific support of any weight. It is thus important that both theories should be followed up. Work on the supposed terrestrial origin of life is in progress in many laboratories. As far as Directed Panspermia is concerned we can suggest several rather diverse lines of research.

The arguments we have employed here are, of necessity, somewhat sketchy. Thus the detailed design of a long-range spaceship would be worth a careful feasibility study. The spaceship must clearly be able to home on a star, for an object with any appreciable velocity, if dispatched in a random direction, would in almost all cases pass right through the galaxy and out the other side. It must probably have to decelerate as it approached the star, in order to allow the safe delivery of the payload. The packets of microorganisms must be made and dispersed in such a way that they can survive the entry at high velocity into the atmosphere of the planet, and yet be able to dissolve in the oceans. Many useful feasibility studies could be carried out on the engineering points involved.

On the biological side we lack precise

information concerning the life-time of microorganisms held at very low temperatures while traveling through space at relatively high velocities. The rocket would presumably be coasting most of the time so the convenient temperature might approximate to that of space. How serious is radiation damage, given a certain degree of shielding? How many distinct types of organism should be sent and which should they be? Should they collectively be capable of nitrogen fixation, oxidative phosphorylation and photosynthesis? Although many "soups" have been produced artificially in the laboratory, following the pioneer experiments of Miller, as far as we know no careful study has been made to determine which present-day organisms would grow well in them under primitive Earth conditions.

At the same time present-day organisms should be carefully scrutinized to see if they still bear any vestigial traces of extra-terrestrial origin. We have already mentioned the uniformity of the genetic code and the anomalous abundance of molybdenum. These facts amount to very little by themselves but as already stated there may be other as yet unsuspected features which, taken together, might point to a special type of planet as the home of our ancestors.

These enquiries are not trivial, for if successful they could lead to others which would touch us more closely. Are the senders or their descendants still alive? Or have the hazards of 4 billion years been too much for them? Has their star inexorably warmed up and frizzled them, or were they able to colonise a different Solar System with a short-range spaceship? Have they perhaps destroyed themselves, either by too much aggression or too little? The difficulties of placing any form of life on another planetary system are so great that we are unlikely to be their sole descendants. Presumably they would have made many attempts to infect the galaxy. If the range of their rockets were small this might suggest that we have cousins on planets which are not too distant. Perhaps the galaxy is lifeless except for a local village, of which we are one member.

One further point deserves emphasis. We feel strongly that under no circumstances should we risk infecting other planets at the present time. It would be wise to wait until we know far more about the probability of the development of life on extra-solar planets before causing terrestrial organisms to escape from the solar system.

ACKNOWLEDGMENTS

We are indebted to the organisers of a meeting on Communication with Extraterrestrial Intelligence, held at Byurakan Observatory in Soviet Armenia in September 1971, which crystallized our ideas about Panspermia. We thank Drs. Freeman Dyson, Tommy Gold, and Carl Sagan for discussion and important comments on our argument.

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workload involves the care of individuals with various stages of dementia, though the potential symptomatic benefits of cholinesterase inhibitors are denied my patients through inadequate resourcing of memory clinics and the artificially restrictive constraints of prescribing the drugs; National Institute of Clinical Excellence (NICE) guidelines use a mini-mental state examination as the principle criterion for deciding appropriateness of a therapy, for which the practical benefits are with behavioural improvements and reductions in anxiety.² As a result, a 75 year old with mild dementia is more likely to receive a cocktail including aspirin, an angiotensin converting enzyme inhibitor, a statin, and a β blocker as preventive therapy for their possible angina, than medication with potential symptomatic benefits that could have a great effect on their independence and functional state.

Unfortunately, we will probably continue with the simplistic application of evidence-based medicine through guidelines and misguided rationing. We are now in a position in which we have to justify the withholding of potentially protective cardiac medications, where general consensus and guidelines have that everyone receives them, often despite a fairly small reduction in risk. Guidelines seem to be getting priority over the individual patient, and the problem is compounded through audit and targets. We should focus our limited resources better, though to do so will require a major change to our approach to modern medicine. We are already losing our clinical freedom, and look back fondly to the days when we could use our experiential knowledge and prescribe the treatments felt to be most beneficial to the patient.

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SARS—a clue to its origins?

Sir—We detected large quantities of viable microorganisms in samples of stratospheric air at an altitude of 41 km.^{1,2} We collected the samples in specially designed sterile cryosamplers carried aboard a balloon launched from the

Indian Space Research Organisation/Tata Institute Balloon Facility in Hyderabad, India, on Jan 21, 2001. Although the recovered biomaterial contained many microorganisms, as assessed with standard microbiological tests, we were able to culture only two types; both similar to known terrestrial species.² Our findings lend support to the view that microbial material falling from space is, in a Darwinian sense, highly evolved, with an evolutionary history closely related to life that exists on Earth.

We estimate that a tonne of bacterial material falls to Earth from space daily, which translates into some 10^{19} bacteria, or 20 000 bacteria per square metre of the Earth's surface. Most of this material simply adds to the unculturable or uncultured microbial flora present on Earth.

The injection from space of evolved microorganisms that have well-attested terrestrial affinities raises the possibility that pathogenic bacteria and viruses might also be introduced. The annals of medical history detail many examples of plagues and pestilences that can be attributed to space incident microbes in this way. New epidemic diseases have a record of abrupt entrances from time to time, and equally abrupt retreats. The patterns of spread of these diseases, as charted by historians, are often difficult to explain simply on the basis of endemic infective agents. Historical epidemics such as the plague of Athens and the plague of Justinian come to mind.

In more recent times the influenza pandemic of 1917–19 bears all the hallmarks of a space incident component: “The influenza pandemic of 1918 occurred in three waves. The first appeared in the winter and spring of 1917–1918 . . . The lethal second wave . . . involved almost the entire world over a very short time . . . Its epidemiologic behaviour was most unusual. Although person-to-person spread occurred in local areas, the disease appeared on the same day in widely separated parts of the world on the one hand, but, on the other, took days to weeks to spread relatively short distances.”³

Also well documented is that, in the winter of 1918, the disease appeared suddenly in the frozen wastes of Alaska, in villages that had been isolated for several months. Mathematical modelling of epidemics such as the one described invariably involves the ad hoc introduction of many unproven hypotheses—for example, that of the superspreader. In situations where proven infectivity is limited only to close contacts, a superspreader is someone who can, on occasion, simultaneously infect a large number of susceptible individuals, thus causing the sporadic emergence of new clusters of disease. The recognition of a

possible vertical input of external origin is conspicuously missing in such explanations.^{4,5}

With respect to the SARS outbreak, a prima facie case for a possible space incidence can already be made. First, the virus is unexpectedly novel, and appeared without warning in mainland China. A small amount of the culprit virus introduced into the stratosphere could make a first tentative fall out East of the great mountain range of the Himalayas, where the stratosphere is thinnest, followed by sporadic deposits in neighbouring areas. If the virus is only minimally infective, as it seems to be, the subsequent course of its global progress will depend on stratospheric transport and mixing, leading to a fall out continuing seasonally over a few years. Although all reasonable attempts to contain the infective spread of SARS should be continued, we should remain vigilant for the appearance of new foci (unconnected with infective contacts or with China) almost anywhere on the planet. New cases might continue to appear until the stratospheric supply of the causative agent becomes exhausted.

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DEPARTMENT OF ERROR

Donnelly CA, Ghani AC, Leung GM, et al. *Epidemiological determinants of spread of causal agent of severe acute respiratory syndrome in Hong Kong*. *Lancet* 2003; **361**: 1761–66—In this Article (May 24), in the sixth sentence in the fifth paragraph of the Results section (p 1763), 48·5 days should be: “4·85 days”, and 10·71² days should be “10·71 days²” (p 1764). In the first sentence of the sixth paragraph of Results (p 1764), 572·9² days should be “572·9 days²” and 62·1² days should be “62·1 days²”.

Ruan YJ, Wei CL, Ling AE, et al. *Comparative full-length genome sequence analysis of 14 SARS coronavirus isolates and common mutations associated with putative origins of infection*. *Lancet* 2003; **361**: 1779–85—In figure 3 of this Mechanisms paper (May 24), the sequence for the Hong Kong CUHKW1 isolate should be, from top to bottom: “TCTGCCCGCAACCCA”.

These findings indicate that, even in formerly endemic areas, iodine deficiency is no longer a problem in Greece, mainly because of improved socioeconomic and nutritional conditions, and increased use of industrially produced foods.

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Panspermia—true or false?

Sir—In their Correspondence letter (May 24, p 1832),¹ Chandra Wickramasinghe and colleagues suggest that many microbial eukaryotes, bacteria, and viruses that are found on Earth could be of extraterrestrial origin. Their conclusion is based on an observation that bacterial and fungal microorganisms with known affiliations on Earth (*Bacillus simplex*, *Staphylococcus pasteurii*, and *Engyodontium album*) were cultured from samples of stratospheric air (altitude 41 km).² If substantiated, this idea has several important implications.

First, the extraterrestrial source of DNA/RNA-based life must sustain ecological conditions similar to Earth, allowing for cellular growth and divisions to create a continuous flow of viable cells and viruses to Earth (about 1 tonne of bacterial material daily, according to Wickramasinghe and co-workers). However, unlike Earth, this extraterrestrial source of life must allow vast amounts of biological material to

leap off into space. The similarity in DNA sequences between the space-derived cells and microorganisms found on Earth (99.9–100%, 16S rDNA)² also presuppose the latter to have derived from space fairly recently to account for lack of evolutionary genomic change.

Second, specialised pathogens must have extraterrestrial hosts similar to those on Earth, such as vertebrates, to evolve and survive.

Third, the extraterrestrial source must be quite close to Earth, since vertebrate-specific RNA viruses can only survive hours to days outside of their hosts.

Finally, any space-derived life needs to cope with high degrees of ultraviolet radiation in the stratosphere³ known to modify cellular DNA/RNA in a lethal manner. Although cells with special adaptations, such as bacterial endospores—eg, of type bacillus and staphylococcus—might have such abilities,⁴ the ultraviolet barrier is likely to be a mortal constraint for most cell types.

No extraterrestrial source with the above-mentioned Earth-like characteristics has been identified, despite numerous long-distance observations and missions to space. The conclusion by Wickramasinghe and colleagues rests on the fundamental assumption that terrestrial life cannot cross the tropopause, a natural barrier about 17 km above the Earth's surface, and hence life above this point must originate from space. However, NASA has collected dust in the stratosphere since 1981, including large amounts of terrestrial dust (wind-blown dust, volcanic ash, and aerosols).⁵ Since wind-blown terrestrial dust can reach the stratosphere, terrestrial single cells are likely to as well, providing a simpler and more credible explanation of the results referred to by Wickramasinghe and his team.

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Sir—Chandra Wickramasinghe and colleagues¹ suggest that the causative agent of the severe acute respiratory syndrome (SARS) epidemic might have an extraterrestrial origin. Their unstated assumption is that the emergence of life and the sudden appearance of several global epidemics are the outcomes of a continuous bombardment of Earth with bacteria and viruses, originating in the interstellar grains and comets.²

This theory is unlikely. Delivery of exogenous material to the Earth's surface is a well documented phenomenon. It includes extraterrestrial organic compounds present in carbonaceous chondritic meteorites and interplanetary dust particles, which seem to be related to cometary nuclei. However, there is no basis for the claim made by Wickramasinghe and colleagues that there is a daily influx of about 1 tonne of extraterrestrial microbes, which they assume corresponds to one hundredth of the daily infall of cometary material. The present dust infall is 4×10^7 kg per year and, although its organic composition is poorly understood, there is no evidence that it includes extraterrestrial prokaryotes or other forms of microbial life.³ The few individual molecules that have been characterised in interplanetary dust particles are polycyclic aromatic hydrocarbons,⁴ none of which are bona-fide biosignatures. Although this material could have played a part in the origin of life, its connection with extant evolutionary processes is tenuous at best, and probably has no relevance in the appearance of infectious diseases.

Wickramasinghe and co-workers also argue that the microorganisms they collected at high altitude lend support to their hypothesis of an extraterrestrial origin of epidemics. The organisms they found include two bacteria that are firmly placed within the bacillus and the staphylococcus clades on the basis of 16S rRNA sequence comparisons. The presence of these microbes at 41 km from the Earth's surface is consistent with the presence of different bacterial species and fungal spores collected from clouds,⁴ but cannot be evidence of an extraterrestrial origin. If life exists

elsewhere in the Universe, it is extremely unlikely that it would have independently evolved macromolecules, such as 16S rRNA, or other intracellular components homologous to those of their terrestrial counterparts. This would be especially true of viruses, whose dependence on the intracellular molecular machinery of their hosts to complete their biological cycles would make their survival and evolution within the terrestrial biosphere unlikely should they have an independent, extra-terrestrial origin.

The comment that some epidemics “bear the hallmarks of a space incident component” is particularly amusing. Our inability to reconstruct the complete chain of events cannot be considered evidence of an extraterrestrial origin for a disease. In the case of SARS the development of the pandemic can be traced almost on a day-by-day basis.

Evolutionary analysis of several protein-coding features of the sequences of the SARS-associated virus has provided clear evidence of its phylogenetic affinities with other mammalian and avian coronaviruses.⁵ Reconstruction of viral evolution can be notoriously complicated, but the evidence suggests that the SARS-associated coronavirus jumped into the human population from felines, which are considered a delicacy by many Asiatic gourmets.

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Sir—I and my former colleagues at the Centre for Cellular and Molecular Biology (CCMB) worked with Chandra Wickramasinghe and colleagues on the experiment they describe.¹ We helped to design the cryosampler experiment and, unlike the authors of the above-mentioned

letter, were present at the time of the balloon flight from Hyderabad. On that day, 16 samples were collected, of which eight were kept in Hyderabad for analysis at the CCMB; the remaining samples were sent to Wickramasinghe's group in Cardiff, UK.

The CCMB's expertise in working with exotic microorganisms, such as those from Antarctica and glacial regions, is widely recognised. The basic method for analysis of cryosampler samples collected at various altitudes was developed at the CCMB by Shivaji, who also established its validity with help from his colleagues through analysis of samples collected at lower altitudes (10–20 km); as expected at this altitude, Shivaji's group isolated various clones of an organism (*Pseudomonas stutzeri*) commonly found on Earth (Shivaji S, personal communication). However, using the same method, the CCMB group was unable to detect any microorganisms in any of the cryosampler samples from the experiment referred to by Wickramasinghe and colleagues.

Shivaji and I have asked the Cardiff group many times to repeat the work in the CCMB, but they declined to do so, leading us to believe that their results might not be reproducible. For this reason, we declined to be co-authors on the article they published in *FEMS Microbiology Letters*. In fact, the organisms that the Cardiff group isolated from the samples, which they claim came from space, are all normal residents of the surface of our planet.

If SARS came from space, cases of the disease should have occurred independently and concurrently in more than one location on our planet. The fact is that all cases (without exception) can be traced to a single location of an extremely small size in China. Furthermore, if Wickramasinghe and colleagues were correct, new foci of SARS should have appeared by now; on the basis of what we know about the virus, this possibility would decrease exponentially with every passing day.

Finally, SARS is a coronavirus. No such virus—or for that matter any RNA virus—unlike bacteria, is known to be resistant to the kind of radiation present in space.

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Author's reply

Sir—All of the points your correspondents raise have been answered elsewhere.^{1–3} In particular, a full explanation of the view that viral diseases could have a non-terrestrial origin can be found in *Diseases from Space*.⁴

Eske Willerslev and colleagues claim that NASA scientists have, since the late 1980s, shown that non-volcanic dust can reach, and remain in, the stratosphere. If this statement is true, then an Earth origin for our bacteria becomes likely. However, the dust referred to was sampled at between 17 km and 19 km above the Earth's surface⁵—that is barely, if at all, into the stratosphere—whereas our sampling height was 41 km.

Willerslev and co-workers, and Samuel Ponce de Leon and Antonio Lazcano maintain that since the bacteria we found in the stratosphere have the same 16s rRNA sequence as bacteria found on Earth they must originate from Earth, simply because bacteria from space would be expected to have evolved at different rates from those on Earth. We have commented elsewhere³ that bacteria with the same sequences as their modern counterparts have also been found in Oligocene amber and Permian salt crystals. These independent findings suggest our understanding of bacterial evolution and phylogeny might be erroneous and that criticisms based on it might yet prove wide of the mark.

In his letter, Pushpa Bhargava does not mention that the pseudomonas work he refers to was offered for publication as evidence for life in the stratosphere, yet remains unpublished. Our work, by contrast, has been printed in an international, peer-reviewed journal.³ We cannot explain why Bhargava's group are unable to replicate the isolation of viable, but non-cultureable, bacteria achieved independently by microbiologists here and in Cardiff.

All the correspondents seem determined to attack panspermia. The evidence will eventually accumulate to show who is right.

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