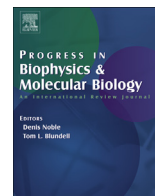




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Reply to commentary by R Duggleby (2019)



Duggleby (2018) has made a numerical analysis of some aspects of the wide range of phenomena we reviewed in Steele et al. (2018) and asserted "that panspermia as proposed by Steele et al. (2018) is extremely implausible." It seems to us that Duggleby has based his viewpoint on a quite narrow and specific model of Panspermia which he supposes to be active in the cosmos. Here we address both his conclusions and his numerical analysis. Our response therefore will be at two levels, his specific analysis and his general conclusions. In the specific section below we show that while Duggleby's numerical analysis appears in part correct it is, in the final analysis, quite irrelevant to Cosmic Panspermia. In the general response which follows we address his unsupported conclusion throughout his critique, namely that ... "none of the examples mentioned by Steele et al. (2018) is decisive enough to allow no other explanation."

1. Statistics of cosmic infection and the comets

Duggleby (2018) addresses the question of planet-to-planet transfer of microbiota - virions and bacteria – and correctly calculates probabilities that are truly negligible. However, he *incorrectly* assumes that we (and the other authors of Steele et al. (2018) were ignorant of this fact. We were always fully aware of these facts, and this is obvious throughout the entire Hoyle-Wickramasinghe et al. corpus of peer-reviewed publications. The mode of transfer of microbiota was via comets, of which over 100 billion surrounds the entire solar system. A related question that is also often raised as a criticism of on-going infection is: how can the influenza virus (or other infective agent) that is apparently very closely adapted to a specific set of earthbound host species have evolved elsewhere in the absence of these hosts? The answer lies of course in the assertion that evolution itself occurs on a cosmic rather than a terrestrial scale. Evolution of all species including humans occurred through the interaction with, and accommodation of, cosmic viruses in prokaryotic and eukaryotic cells (Hoyle and Wickramasinghe, 1980, 1982). The vast abundance of viral and virus-related sequences in the human genome (HERVs, LINES, SINES etc) appears to bear ample testimony of this process (Wickramasinghe, 2012). But this of course transfers the question of ultimate evolutionary origins to an earlier cosmological epoch (Gibson et al., 2010).

Comets, whose infrared spectra were first discovered to match spectra of microbiota in 1986 (D.T. Wickramasinghe and Allen, 1986), are of particular relevance in the present context. Since 1986 space explorations of comets have continued to yield consistency with, although not unequivocal proof, of biology

associated with comets. The emergence of a first "minimal cell" encoding 260 essential proteins entails abiogenesis, or spontaneous emergence and assembly with a probability of less than 1 in 10^{5120} (Mushegian and Koonin, 1996; Hoyle and Wickramasinghe, 1999). This is an astronomically immense number making abiogenesis a rare if not improbable event anywhere in the observable Universe (see Appendix A in our paper). Although the origin and evolution of life against wellnigh impossible odds are still buried deep in the mists of cosmological antiquity, its continuity and cosmic dispersal appears to be well guaranteed (Hoyle and Wickramasinghe, 1985). Comets with their radioactively heated watery interiors provide sites for storage, amplification and dispersal of living entities (Wallis, 1980; Hoyle and Wickramasinghe, 1985; Wickramasinghe et al., 2009).

It is known that over 100 tonnes of debris from comets enters the Earth every day. Most of this burns up as meteors but a significant fraction does indeed survive. Assuming 1% is the form of bacteria and viruses that survive transit through the atmosphere we have an input of $\sim 10^5$ bacteria $\text{m}^{-2}\text{day}^{-1}$, or equivalently $\sim 10^7$ viruses $\text{m}^{-2}\text{day}^{-1}$ averaged over the entire surface of the Earth. We note that the latter figure for viruses is smaller by only a factor of ~ 100 than the recent measurements of the actual flux of recycled terrestrial viruses falling back on the Earth (Reche et al., 2018). It is amply clear that such a flux of viruses cannot be ignored, and it is on this basis that the Hoyle-Wickramasinghe theory of disease transmission was conceived and structured. This is indeed far removed from the planet to planet mode of transfer of microbiota discussed by Duggleby (2018).

Exactly the same logic applies to the second example cited by Duggleby in relation to microbes associated with the International Space Station (ISS) (Grenennikova et al., 2018). The transfer is not from any nearby planet but from the vast reservoir of comets with which the Earth constantly interacts. The direct transfer of bacteria and viruses between neighbouring planets occurs only very infrequently following impacts of asteroids and comets (Napier, 2004; Wallis and Wickramasinghe, 2004). An impact of the type that occurred 65 million years ago, leading to the extinction of the dinosaurs, could also cause the non-destructive expulsion of rocks and debris from the edges of an impact crater. The ejecta will escape Earth's gravity and after several sling-shot interactions with planets could escape from the solar system. Although the cumulative effect of such a process will be to connect the 140 billion exoplanets which are now thought to exist (Kopperrapu, 2013) into a single galactic biosphere over the age of the galaxy, the direct transfer of microbiota between neighbouring exoplanetary systems will be extremely rare and negligible.

2. Strong features of mature extraterrestrial cell biology in astrophysical phenomena

Here we address Duggleby's (2018) other conclusion ... "none of the examples mentioned by Steele et al. (2018) is decisive enough to allow no other explanation." Our response here also addresses this direct or implied criticism in the other recent Commentaries (Baverstock, 2018; Moelling, 2018).

In our view all the hard and direct evidence for Panspermia we documented in the first half of our long article, which are listed in the contents and throughout our paper (and re-iterated below in a). b). c) and d)) seems to have been overlooked by Duggleby. Just because these data are ignored, it does not follow they are not important and decisive for our understanding of how life on Earth began and further evolved. Thus an often tacit reaction is "... extraordinary explanations such as Panspermia, require extraordinary evidence" to support them. In our view a wide range of extraordinary, and multifactorial, evidence already exists now on Earth, and its immediate environs, requiring a unifying scientific explanation. Hoyle and Wickramasinghe (H-W) and their many collaborators have not only assembled much of this evidence, but also provided a Cometary-origins (and space vector) theory uniting all these facts. So an "extraordinary" explanation fits all these facts reviewed in Steele et al. (2018).

We now highlight the set of data below which can be considered a *demarcation set* defining the divide between the terrestrial (neo-Darwinian) versus the cosmic (Panspermia) evolutionary paradigms.

a). **Carbonaceous Meteorite Fossils** Eukaryotic and prokaryotic micro-fossils have been described in independently curated and examined carbonaceous meteorites, dated at ≥ 4.5 billion years old. These microfossils have been confirmed by experts in four different well curated carbonaceous meteorites: Murchison (Pflug and Heinz, 1997; Hoover 2005, 2011), Murchison, Orgueil, Mighei (Rozanov and Hoover, 2013), Polonnaruwa (Wallis et al., 2013; Wickramasinghe et al., 2013). We should stress the independent confirmations by experts here, and the complete ruling out of terrestrial contamination. While 30–40 years ago some of these findings may have caused emotive controversy, we must now scientifically evaluate these four different and independent "experiments of nature" in a different light than has been seen in the past, and on their own terms. Fossilised eukaryotic species in particular with silica-based hard shells, are prominent in these fossils. Certainly in the Polonnaruwa meteorite (Wickramasinghe et al., 2013) the frustules of clear diatoms are evident. Many of these other eukaryotic fossils are almost certainly related to Foraminifera and are single-celled organisms (protists) with shells or tests (a term for internal shells). If unassigned taxonomically to an extant identifiable species these fossils are termed "Acritarchs." They are abundant as fossils for the last 540 million years, and also abundant in carbonaceous meteorites and also features like them have been seen in recent stratosphere collections of incoming apparently living micro-organisms (Wainwright et al., 2015). Terrestrial "eukaryotic" Acritarch fossils dating to 3.2 billion years ago have been reported (Javaux et al., 2010).

Clearly these are mature biological features in astrophysical phenomena that require a coherent explanation. They strongly imply that complex cell-based life, now immortalised as fossils in carbonaceous meteorites, pre-dates the age of the Earth (and solar system). An explanation based on Panspermia seems unavoidable to us.

b). **The Dust Grains in the Interstellar Medium have an Infrared Absorption Spectrum Typical of desiccated (freeze dried) *E. coli* bacteria** To the corresponding author (EJS) these results, first secured almost 40 years ago, represent the most

extraordinary quantitative scientific data secured since Galileo observed the moons of Jupiter in the first Copernican revolution just over 400 years ago (January through March 1610). Fig. 1 shows the normalised infrared extinction (absorption) flux for two apparently independent data sets. The solid line is the IR absorption spectrum in the wavelength range 2.9–4.0 (μm) for desiccated (freeze dried) *E. coli* bacterial cells determined in the laboratory. Notice this is a spectrum with deep "valleys", "rising walls", "plateaus" and "peaks". It is intricate and complex, reflective of the integrated absorption features of the mix of "living molecules" within living (albeit dried) bacterial cells. The observational data are the points secured at each wavelength indicated for IR electromagnetic radiation emitted 23,000 lights years away near the centre of the Milky Way. As this IR light travels through interstellar clouds containing cosmic dust grains it penetrates the grains and is absorbed in a similar fashion to the IR absorption by dry *E. coli* in the laboratory experiment. The important point to note is that the *E. coli* IR spectrum was secured by Shirwan Al- Mufti during his PhD in Cardiff, Wales, UK, several months *before* the astronomical IR data were collected on GC-IRS7 by Dayal Wickramasinghe and David Allen using the Anglo Australian Telescope in New South Wales, Australia. However it must be emphasised that the exact match of the two spectra seen in the figure was *predicted in advance* by Fred Hoyle and Chandra Wickramasinghe. They predicted that the GC-IRS7 data would be exactly like the IR data on *E. coli* in the lab. The data are a blow up of the data summarised in the inset box of Fig. 1 of Steele et al. (2018).

It is important to stress again the predictive nature of this experimental set up. Indeed much of our knowledge of the chemical and physical composition of celestial bodies has been determined this way: establish the electromagnetic absorption, or emission, spectrum of substances or contrived mixtures of phenomena, here on Earth, then turn the telescope to an object in the sky and ask "Can we find the same spectrum in the celestial body or interstellar medium?" This, for instance, is how the element He was discovered in the spectrum of the Sun. Some years after Dayal Wickramasinghe and David Allen obtained the spectrum (points) shown in Fig. 1, this was confirmed independently by the Japanese led team of Okuda et al. (1990) (and see Fig. 4.3b page 43 in Hoyle and Wickramasinghe, 1993). The Pearson correlation of this paired comparison data gives r as 0.9324 for $N = 77$ pairs. For Okuda et al. (1990) the r value is 0.9275 for $N = 35$ pairs. The P value is $< 10^{-9}$. That is, we would expect to see such an exact spectral match by chance alone in more than one billion similar trials (DT Wickramasinghe, G Briggs, NC Wickramasinghe, EJ Steele

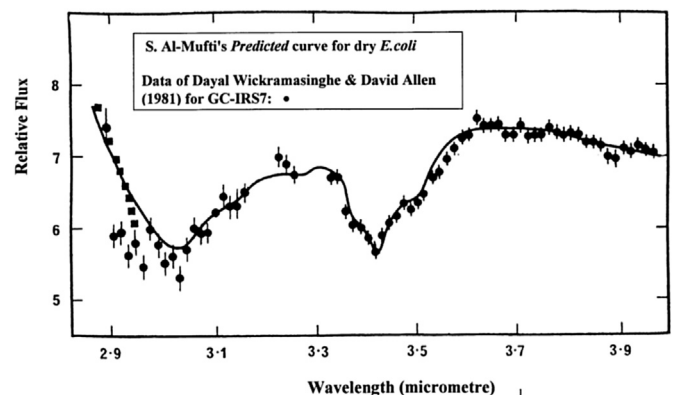


Fig. 1. Comparison of the infrared flux (arbitrary units) from the astronomical source GC-IRS7 near the galactic centre, with the curve predicted for freeze dried *E. coli* cells. (Allen and Wickramasinghe, 1981). Also see Wickramasinghe and Allen (1983). This is a blow up of the inset in Fig. 1 Steele et al. (2018).

unpublished calculations).

But we do not need to do any sophisticated statistics to know we have a very close to exact match - we can see it by eye. Ergo, the dust grains in the interstellar medium are exactly like dried bacterial cells here in the laboratory on Earth. Similar experiments, with similar very good matched results, have been done by Hoyle and Wickramasinghe with the IR absorption spectral matches of larger eukaryotic cells such as diatoms (algae) for the 8–13 μm infrared range (e.g. Hoyle et al., 1982; Hoover et al., 1986; Majeed et al., 1988, and see Wickramasinghe and Hoyle, 1998). Indeed the massive and sudden appearance of multiple novel diatom species (Perasso et al., 1989) in the fossil record about 100–200 million years ago suggests a Panspermic infall explanation (Hoyle and Wickramasinghe, 1993 p.136–139), and is compatible with previous IR absorption astrophysical observations on “diatom” IR signatures in the interstellar medium.

To our knowledge no other artificial modelling of compound organic mixtures will produce such exact matches with any reasonable set of assumptions. In our view it is difficult to provide a credible scientific explanation that avoids Panspermia.

c). The Grains in the Dust Coma of the Tail of Comet Halley

The data in Fig. 2 of Steele et al., (2018) shows the IR emission by the dust coma of Comet Halley during its visit on 31 March 1986. Again the same type of match seen for the interstellar dust (Fig. 1) is replicated. Thus the dust ejected from Comet Halley has a similar spectrum for unirradiated *E. coli*. Again the skeptic must provide an alternative scientific explanation for the match that avoids Panspermia.

Notice that the quite diverse sets of data of a), b), and c) can all be unified and rationalised by the Cosmic Panspermia Theory of Hoyle-Wickramasinghe.

d). In-fall Microorganisms Detected at 41 Km in the Stratosphere.

These data secured by Milton Wainwright and colleagues in balloon lofted sampling experiments are truly fascinating, both for the care taken to avoid contamination, and, to establish that the observed microorganisms and other cellular and viral aggregate collections at 41 km were by in-fall not by upwelling. Skeptics of course can say it is all contamination, but again the data stand by themselves and more easily fit a Panspermia paradigm than a terrestrial explanation (Wainwright et al., 2015).

Bacteria in the cosmic dust on the external surface of the International Space Station (Grennikova et al., 2018), another 360 km further out from Earth than the Wainwright collections, would thus be a result predicted and expected in advance. The Earth traverses numerous cometary debris trails in its orbit around the Sun (these dust trails have their own crossing orbits).

In our review article we covered a much larger sweep of data than we are able to reiterate here in relation to Duggleby's criticism. We have not added here a list of other data, including the space hardness of bacteria, viruses, seeds, eukaryotic cells and even tardigrades. To be added also to this list are recent data relating to possible life habitats on Mars, the well known data on the patterns of “punctuated equilibria” of the evolution of life on Earth in the past 4 billion years (Fig 6 in Steele et al., 2018, and instance the sudden appearance of the diatoms recounted already above). Nor have we included other very strange phenomena such as the apparent unique evolutionary features of the Octopus RNA editing data or discussed features of the Cambrian explosion itself (which is covered in Steele et al., 2018). We can only add that the just published paper by Russian scientists which describes the viable recovery of nematodes from Late Pleistocene Siberian permafrost dated at 42,000 years (Shatilovich et al., 2018). Of course these results needs to be confirmed at other locations for other multicellular eukaryotic animals and plants but the big implication is that

cryopreservation may be the favoured way of transporting complex mature animals across the cosmos in protective matrices (e.g. comets, moons and planets) entailing undisturbed space journeys that could extend to hundreds of millions to billions of years before landing in a cosmic habitat favourable for growth and further cosmic evolution. So the cryopreserved Octopus egg idea we proposed (Steele et al., 2018) may not be so crazy after all.

This collection of data sets a)-d) above, all unrelated and independently reported, can be easily understood under a Panspermia paradigm but not readily by a purely terrestrial paradigm based on neo-Darwinian evolutionary theory.

To return again to Duggleby's second specific criticism concerning the recent data published by Russian space scientists who report bacterial DNA related to terrestrial species in the cosmic dust on the external surface of the International Space Station (Grebennikova et al., 2018). This finding was reported as our paper was in Proof, and so it was a late breaking important addendum to the main body of our review. The importance of the finding is both immediate and long term. In the long term it says that the phenomenon can be confirmed or refuted by other teams of scientists visiting the ISS or similar orbiting laboratories. So it is important epistemologically - scientists can bring with them portable Next Generation Sequencing (NGS) machines to the space laboratory and conduct controlled microbiology sampling and experiments (including tissue culture of space samples). They can thus determine the range of microbial life in the cosmic dust in our neighbourhood (prokaryote and eukaryote that may be present) and establish or not the generality of Cosmic Biology based on established molecular biology of DNA, RNA replication and base sequence copying, and the known rules of the Genetic Code and protein structure (Wickramasinghe et al., 2018a). This trawling for species by their DNA/RNA sequence signature is akin to the deep ocean trawls (Ainsworth, 2015) of recent years by J. Craig Venter and others (and see the estimates of the magnitude of the invertebrate virome analyses in Shi et al., 2016). Given the enormous scientific interest in this venture the possibility of terrestrial contamination will be completely ruled out (as contaminations of PCR and tissue culture are now minimized and controlled in high-standard laboratories here on Earth). We wish to re-emphasize that the hard physics of the situation make “... a terrestrial origin seems most unlikely.” Studies by Wickramasinghe and Rycroft (2018) have shown that all possible mechanisms for lofting these organisms against gravity to heights of 400km in the ionosphere fall short by many orders of magnitude.” Duggleby questions the importance and significance of this result. We estimate that the probability of lofting from the ground is well below one chance in a million.

In summary, we see no arguments advanced in the critique by Duggleby which alters our overall conclusions concerning the existing (and growing) evidence in favour of the Hoyle-Wickramasinghe Theory of Panspermia, along with the additional strong implication that the Cosmos is likely to be teeming with Life: every observed Star with an accretion plane of planets, moons, comets (and an Oort-like spherical comet cloud) is predicted to display a complex orbiting ecosystem harbouring its own characteristic range of diverse and evolving living systems (Wickramasinghe et al., 2018b). The rebuttal we offer here highlights some additional features expanded on further and some of which we had not included in our previous article.

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