**Article type** : *Essay- Perspective and/or Opinion* (Nov 25 2018)
Words - 3143 (text body), Abstract145 words, Refs - 56, Figures -2

# Hoyle-Wickramasinghe Panspermia is far more than a Hypothesis

## *Features of Mature Cell Biology in Astrophysical Phenomena*

Edward J. Steele,[1,2] Reginald M. Gorczynski,[3] Gensuke Tokoro,[4] Dayal T. Wickramasinghe,[2, 5] N. Chandra Wickramasinghe[2,5,6]

[1]C.Y.O'Connor ERADE Village Foundation, Piara Waters, Perth 6112 WA, AUSTRALIA

[2]Centre for Astrobiology, University of Ruhuna, Matara, SRI LANKA

[3]Department of Surgery & Immunology, University of Toronto, Toronto, Ontario, CANADA

[4]Institute for the Study of Panspermia and Astrobiology, Gifu, JAPAN

[5]College of Physical and Mathematical Sciences, Australian National University, Canberra, AUSTRALIA

[6]Buckingham Centre for Astrobiology, University of Buckingham, UK

**Running Head**: *Demarcation Data for Panspermia*

**Correspondence** : Edward J Steele PhD, ejsteele@cyo.edu.au

**Key words**: Panspermia, Lamarckian Inheritance, Carbonaceous meteorite fossils, Infrared Spectroscopy, Cosmic dust

**Abstract:**

The hypothesis of life being a cosmic rather than a terrestrial phenomenon has evolved from the mid 1970's onwards and is documented in an extensive body of publications by Fred Hoyle, Chandra Wickramasinghe and their many collaborators and students in the columns of *Nature* and other peer-reviewed journals. After nearly 5 decades of pursuing a rigorous Popperian prediction/verification cycle, and the emergence of a vast body of astronomical and biological evidence, the reigning Aristotelean dogma of Earth-bound abiogenesis is now seriously threatened. A paradigm shift to the H-W theory of cosmic life (H-W Panspermia) has been long overdue, and is currently held back mostly by sociological impediments. Here we outline the special subset of scientific facts which constitute, in our minds, *the demarcation data set* which distinguishes the terrestrial theory of evolution (neo-Darwinism) based on abiogenesis from the new cosmic theory of evolution (H-W Panspermia).

--------

**What is a "Hypothesis"? and What is a "Theory"?**

We assert that a scientific theory is a "mature hypothesis" surviving rigorous critical analyses and hard observation and experiment. However, it is still in essence Popperian and thus vulnerable. It can, in principle, be refuted or modified from its original form, as for instance Einstein's modification/generalisation of Newtonian mechanics. On the other hand, a hypothesis is usually the first tentative public utterance of a provisional explanation of a given set of natural phenomena. It will only mature to a "theory" if it survives refutation by severe demarcation tests involving further critical analyses, observation and experiment. By these criteria the modern field of Cosmic Biology/Panspermia, first clearly advanced by Hoyle and Wickramasinghe in a series of peer-reviewed papers and definitive books (Hoyle and Wickramasinghe 1979, 1981, 1993, 2000 ) is underpinned by a mature scientific theory which we shall refer to here as "H-W Panspermia." It provides a coherent explanation for both the origin of life on Earth and its further non-linear progress of terrestrial evolution and adaptation Steele et al 2018).

The H-W thesis has survived numerous demarcation tests, and it has made many predictions that have been subsequently fulfilled. A successful demarcation test is defined as a positive affirming result by an experiment or critical observation ('experiment of nature') which is not well encapsulated within the reigning terrestrial neo-Darwinian evolutionary paradigm; but is an expected outcome of the H-W Cosmic/Panspermia paradigm. H-W theory thus has strong explanatory and predictive power. For example, a key prediction concerns the distribution and number of living systems in the known Universe: this distribution is dictated *solely by* the "inhabitability" or otherwise of available viable Comic niches (comets, moons, planets - both orbiting or wandering). This is an important prediction.

H-W Panspermia theory thus brings together a range of multifactorial biological facts and phenomena, at first sight unrelated, providing a coherent explanation for their existence, their biological form and their ongoing evolutionary features (Steele et al 2018). It therefore provides a "general mechanism" for the widely accepted evolutionary pattern of "Punctuated Equilibrium" described clearly by Eldridge and Gould (1972, 1977). It also predicts and qualifies the 'genetic' boundaries of H-W theory. Thus extraterrestrial life is expected to possess the same biochemistry, genetic code, the same DNA and RNA as life on Earth. A radically different life form discovered would be significant evidence against a universal Galactic panspermia and the H-W theory would require modification (Wickramasinghe et al 2018).

**Permeability of the *Weismann Barrier*?**

We discuss below key demarcation evidence that needs to be confronted by each new scientific generation. But first we need to discuss the relevance of Lamarck. Two of us (EJS, RMG) are attracted to the H-W Panspermia paradigm because unlike neo-Darwinism, it provides a cogent biological rationale for the existence of Lamarckian modes of inheritance of acquired characteristics - its *raison d'être*. As Immunologists we were on the ground floor 40 years ago penetrating the soma-germline *Weismann Barrier* (Steele 1979, Gorczynski & Steele 1980, 1981, Gorczynski et al 1983, Steele, Gorczynski and Pollard 1984) when the paradigm shift to the now accepted Lamarckian evolutionary paradigm first began (Jablonka and Lamb,1995, Steele, Lindley & Blanden 1998, Steele and Blanden 2000, Lindley 2010, Spadafora 2008, Mattick, 2012, Cossetti et al 2014, Dias and Ressler 2014, Skinner 2015, Steele and Lloyd 2015, Liu and Li, 2016, Noble et al 2016, Vargas et al 2017). In our view the Lamarckian inheritance experiments in rabbits by Guyer and Smith at the University of Wisconsin in 1918-1924 are on a level with the foundation work in genetics by Gregor Mendel. These experiments showed definitively the transmission via the male line (up to 9 breeding generations) of maternal autoantibody-induced eye defects. Yet these experiments were performed and reported in an earlier age antithetical to Lamarck. This was the time of the emergence of Mendel's rediscovery, the rolling controversies around the now vindicated mid-wife toad experiments of Paul Kammerer (Koestler 1971, Vargas et al 2017), and the birth of neo-Darwinism. The latter then became the dominant biology paradigm of 20th century, based in large part on an abiogenic begining in one of Darwin's postulated "warm little ponds", the selection of random germ cell mutations and the assumed genetic impermeability of the *Weismann Barrier* (Steele 2016). We assert there is a strong *conceptual link* between rapid Lamarckian-based evolutionary processes dependent on reverse transcription-coupled mechanisms among others and the effective cosmic spread of living systems viz. Panspermia. For example, a viable, or cryo-preserved, living system travelling through space in a protective matrix will need to rapidly adapt and proliferate on a landing in a new cosmic niche. Lamarckian mechanisms of environmentally-driven inherited rapid adaptation thus come to the fore and supersede the slow (blind and random) genetic processes expected under a neo-Darwinian evolutionary paradigm.

**Abiogenesis?**

The minimal-sized living cell capable of an independent existence, is a theoretical bacterium with 256 protein coding genes (Mushegian and Koonin 1996). As argued earlier (Hoyle and Wickramasinghe 1981, 1999) from a "….chance of random assembly of a single enzyme from its component amino acids of about one part in $10^{20}$ we can arrive at a probability of assembly of this minimal enzyme set of one part in $10^{5120}$, which is argued to be the minimum information content of life". This number is so large it far exceeds the estimated number of protons, neutrons and electrons in the known universe ( $\sim 10^{80}$ - $10^{90}$). Resorting to the optimistic emergence on the early Earth of self-replicating functional RNA-sequences that undergo self assemblies in a "primordial RNA world" (Todisco et al 2018) is hardly likely to budge or come near the improbabilities of this super-astronomical number. The novel attempt by McFadden (2016 ) to reduce these formidable odds by invoking quantum mechanics as some type of naturally emerging "quantum computing search algorithm" to uncover the first viable RNA replicator seems to us to require too many conceptual leaps of faith.

Indeed the improbability argument is often also countered by the assertion that a process of chemical natural selection of macromolecules preceded the emergence of the first self-replicating living cell. Such an assertion is without empirical evidence and indeed all laboratory experiments directed to simulating abiogenesis that have thus far led to failure. Abiogenesis is therefore *exceedingly* improbable *anywhere* in the known Universe, let alone on Earth over the past 4 billion years (since the Hadean Epoch). The whole issue of the likelihood of a biochemical origin of life seems simply too improbable to be a practical hypothesis at this point in our scientific development (see Appendix A, Steele et al 2018). But the standard cosmic model defining research in contemporary Physics and Astrobiology assumes that "life emerges from non-life" regularly and can spring up everywhere, under “favourable” conditions all over the known Universe (Walker 2017).

**Some Key Demarcation Data**

The first bio-signatures (e.g. formaldehyde polymers, polysaccharides) were detected in the cosmos and interstellar dust medium some 45 years ago by Chandra Wickramasinghe and Fred Hoyle (Wickramasinghe 1974, Hoyle and Wickramasinghe 1976, 1977a, 1977b, 1978). It is now common place to find evidence for multiple complex carbon-based organic molecules and polymers (and possibly key molecules in photosynthesis such as porphyrins, Johnson, 1972; Hoyle and Wickramasinghe, 2000) which are typical of the biochemistry of living cells permeate the Cosmos, in both the cosmic dust and interstellar medium, and on extra-terrestrial bodies in our Solar System. The key issue is this: Is this extensive array of organic/biochemical molecules and polymers evidence for a plentiful supply of the building blocks of life? That is to say, their formation is posited to occur by purely inorganic physical processes, thereby lowering the statistical improbabilities of an abiogenesis event (as is commonly believed without any evidence and assumed in contemporary Astrobiology)? Or are they the simple molecular debris of dead and dying cells, an all-pervasive detritus of pre-existing mature biology? In our view the latter explanation is more reasonable and infinitely more likely.

Unlike our earlier wide ranging review (Steele et al 2018) our focus here is to discuss the small number of hard facts and observations on astrophysical features that cannot be explained in any other way - these data clearly differentiate the terrestrial neo-Darwinian paradigm or from the H-W Cosmic (Panspermia) paradigm.

The scientist is thus put in the position of choosing which overarching paradigm to adopt. Which paradigm best explains key facts that constitute an enigma within the alternate paradigm? This is indeed the 'art of science' and always has been since time immemorial. We reduce and simplify our concepts to cover the broadest possible explanatory domain - and at the same time make predictions that allow the discovery of new facts. That is, or should be, the overarching 'aim of science'.

This means we do not sample the multitude of ALL facts, but only a defined relevant set of KEY facts. Indeed the extant set of key relevant facts demarcating the Terrestrial v Cosmic origins paradigms is actually very small at this stage in the development of modern science. But they are key and relevant facts nevertheless and require us to evaluate them dispassionately on their own terms.

So here we now discuss the demarcation set of hard scientific data that allow us to see features of mature cell-based biology (including on rare occasions whole extant or prior living cells) in astrophysical phenomena.

**Cell Biology of the Interstellar and Cometary Dust**

The current biophysical evidence strongly suggests that the dust grains in the interstellar medium have an infrared (IR) absorption spectrum typical of desiccated (freeze-dried) *E. coli* bacteria (secured in the laboratory by PhD student Shirwan Al-Mufti). These data, following age-old standard procedures in Astronomy, were predicted by Hoyle and Wickramasinghe *in advance* of the interstellar dust observations by DT Wickramasinghe and DA Allen, is shown in Figure 1 (from Steele et al 2018 Fig 1 insert). This figure shows the normalised IR extinction (absorption) flux for two independent data sets. The IR absorption spectrum in the wavelength range 2.9 to 4.0 ($\mu$m) for desiccated (freeze dried) *E. coli* bacterial cells (solid line). This is an intricate and complex, IR absorption spectrum of living albeit dried and dormant, living cells. The observational data points were secured at each wavelength indicated for IR electromagnetic radiation emitted 23,000 light years away near the centre of the Milky Way. As this IR light traverses through clouds of the dust grains it is absorbed in a similar fashion to the IR absorption by dry *E. coli* cells in the laboratory experiment on Earth.

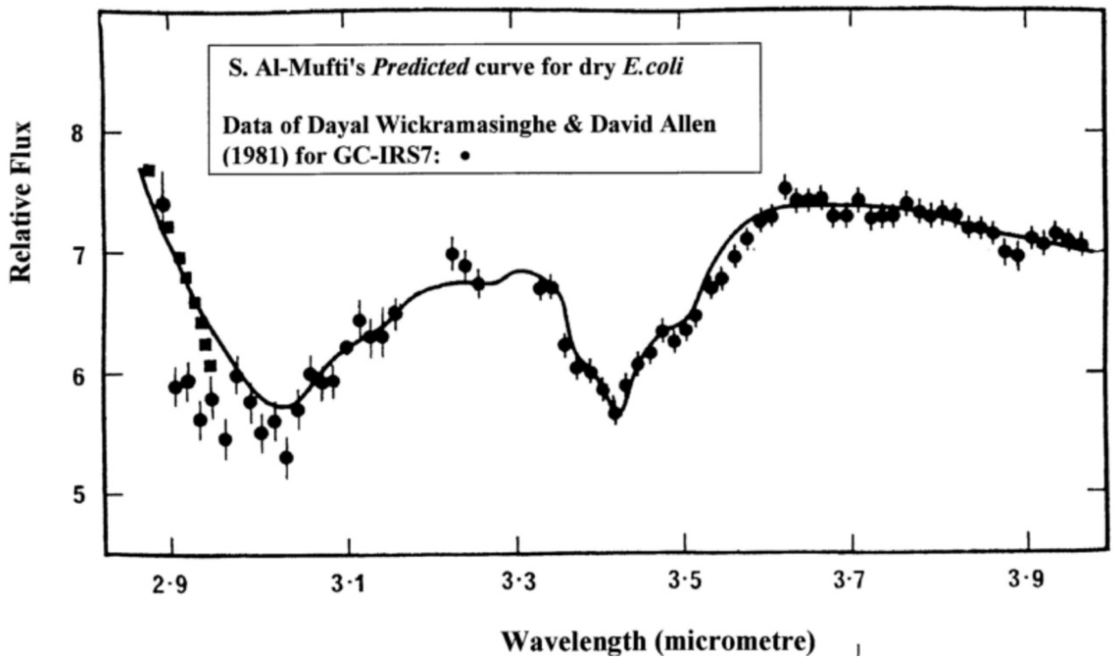


**Figure 1. Comparison of the infrared flux (arbitrary units) from the astronomical source GC-IRS7 near the galactic centre, with the curve predicted for freeze dried *E. coli* cells** (Allen D.A. and D T Wickramasinghe 1981). Also see Wickramasinghe, D.T., Allen, D.A., 1983. This is a blow up of the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

The data shown in Fig.1, was confirmed independently by the team of Okuda et al (1990) (and see Figure 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 $P$ values for both are $< 10^{-9}$. 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 unpublished calculations).

Thus the dust grains in the interstellar medium have – whether one likes it or not - IR absorption properties identical to dried living bacterial cells. In the intervening years many of the features seen in the spectra of interstellar dust in other wavebands have also found ready explanations in terms of dust particles of biological origin. We note in particular the IR absorption spectral matches of larger eukaryotic cells such as diatoms (algae) for the 8-13 um infrared range (e.g.

Hoyle et al 1982, Hoover et al 1985, Majeed et al 1988, and see Wickramasinghe and Hoyle 1998).

To our knowledge no other artificial modelling of compound organic mixtures will produce such exact matches with any reasonable set of assumptions. A skeptic must therefore provide a credible scientific alternative explanation that avoids Panspermia.

A strong prediction of the HW panspermia model was that comets would acts as sites for the amplification of life.  IR emission spectra of grains in the dust coma of the tail of Comet Halley during its visit on 31 March 1986 was found to be remarkably similar to that of unirradiated *E coli* (see Figure 2 of Steele et al 2018) providing strong confirmation of these expectations (Wickramasinghe and Allen 1986).  So again the obligation of a skeptic is to provide an alternative plausible scientific explanation for the match that avoids Panspermia. As they stand these biophysical data contradict a purely terrestrial-based neo-Darwinian theory of evolution.

**Carbonaceous Meteorites Harbour Prokaryotic and Eukaryotic Fossils**

Four independently curated and examined carbonaceous meteorites, dated at ≥ 4.5 billion years old, can be shown to contain Eukaryotic and Prokaryotic micro-fossils. In each case the independent confirmation is by experts: Murchison (Pflug and Heinz 1997, Hoover 2005,

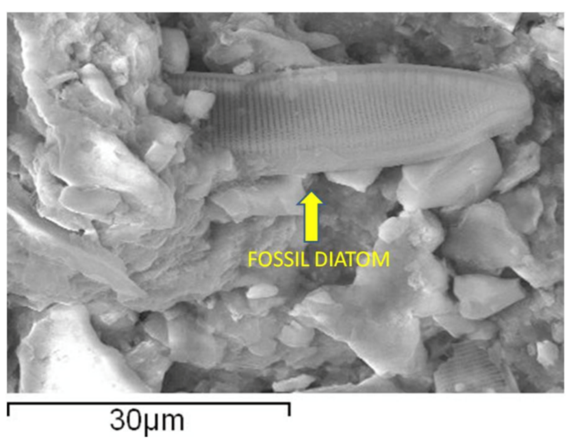


**Figure 2  Ovoidal-shaped ribbed structure embedded in the rock matrix of the Polonnaruwa carbonaceous meteorite, Wickramasinghe et al (2013)**

Hoover 2011), Murchison, Orgueil, Mighei (Rozanov and Hoover 2013), Polonnaruwa (Wallis et al 2013, Wickramasinghe et al 2013). In these independent confirmations terrestrial contamination can be ruled out. A diatom fossil is shown Figure 2. These scientific findings need to be evaluated objectively on their own terms. This needs to be stated because 30-40 years ago they would have generated destructive emotive controversy. These are four different and independent "experiments of nature". Prominent in these fossils are eukaryotic species, in particular with silica-based hard shells. For example in the Polonnaruwa meteorite (Wickramasinghe et al 2013) the frustules of diatoms are evident (Figure 2). Many of these other eukaryotic fossils are termed "Acritarchs" of unassigned single-celled organisms (protists) with shells or tests (a term for internal shells). Acritarchs are particularly abundant as fossils for the last 540 million years, and also abundant in carbonaceous meteorites. Terrestrial "eukaryotic" or Arcritarch fossils have been reported by Javaux et al (2010) dating to 3.2 billion years ago.

These are all unequivocal examples of mature cell biology in astrophysical phenomena. They require a coherent explanation. The existence of such clear fossils in carbonaceous meteorites strongly imply that complex cell-based life pre-dates the age of the Earth (and solar system). These are defining biophysical demarcation data. An explanation based on Panspermia thus seems unavoidable.

In closing this section we revive some not widely publicized facts gathered by NASA's Opportunity Martian rover (See https://www.panspermia.org/whatsnew83.htm#20151028.) The Martian fossil was photographed on February 27, 2004 with the Microscopic Imager camera of NASA's Opportunity rover on sol 34 of that mission, at Mars' Meridiani Planum, once a wet environment. By comparison with Earthly fossils it is identified as *Reteocrinus elongatus*, a marine animal in the crinoid family, which flourished in the paleozoic era.

**Near Earth Neighbourhood?**

In our view the research budgets directed to the search for extant and living extra-terrestrial life needs to be far more focused on the near Earth neighbourhood. The experiments are relatively cheap and will be definitive and unequivocal. They offer real-time experimentation in standard biological laboratories. Here we discuss the most promising data emerging.

Microorganisms have been detected by Milton Wainwright and colleagues in-falling from space at 41 Km in the Stratosphere (Wainwright et al 2015). These data were secured in balloon-lofted experiments and conducted to avoid contamination. They were set up technically to establish that the microorganisms and other cellular and viral aggregates *were observed following in-fall not by upwelling*. Critics may conclude it is all due to terrestrial contamination, but the data need to be dispassionately evaluated in their own terms. Many of the eukaryotic species detected can be classed as unassigned Acritarch, and appear viable on impact with the collection medium. The data more readily fit with Panspermia theory (Wainwright et al 2015).

However experiments can also be conducted on the International Space Station (ISS) to sample the zodiacal cometary dust trails through which the Earth continuously passes in its orbit around the Sun. Such initial experiments are reported (Grenennikova et al, 2018). Bacteria in the cosmic dust have been detected by standard PCR techniques on the external surface of the ISS. These are ground breaking experiments. Contamination has been ruled out. Uplifting of micro-organisms to 360-400 km seem quite improbable on physical grounds (Wickramasinghe and Rycroft 2018). These data offer the promise that such ISS microbiological phenomena can be confirmed or refuted by independent teams of scientists. We can imagine ISS real-time biological laboratories conducting routine genetic analyses and tissue cultures using the portable Next Generation Sequencing (NGS) machines now available. The range of microbial life, prokaryotic and eukaryotic, in the near Earth cosmic environment can become part of the proposed "Hoyle Shield", predicting potential pandemics from space (Hoyle and Wickramasinghe 1979, Smith 2013).

**Cosmic Octopus?**

Here we have only considered demarcation data. But there are a plethora of multifactorial awkward facts and observations, biological and biophysical, which fit neatly into the Hoyle-Wickramasinghe Panspermia paradigm but are often puzzling or inexplicable under a pure neo-Darwinian terrestrial evolution paradigm - anchored to a super-astronomically improbable and unproven abiogenesis event producing the first cell here on Earth about 4 billion years ago. Thereafter it is posited that by replication, gene duplication, random genetic variation, and

Darwinian selection this produced all the other millions of exceedingly diverse and varied life forms on the planet, alive and extinct, plant and animal. Most of the relevant problems and contradictions in this viewpoint are covered in our recent paper (Steele et al 2018).

We note the recent observations on the viable recovery of nematodes from 42,000 year old Late Pleistocene Siberian permafrost (Shatilovich et al 2018). Such findings need to be replicated at other locations and with other species. Nevertheless the implications under the Hoyle-Wickramasinghe paradigm suggest that the transportation of cryopreserved complex mature animals within protective matrices (e.g. comets, moons and planets) or minimally their genes encoded in viruses via undisturbed space travel extending to hundreds of millions if not billions of years is the favoured"cross infection" mode across the Cosmos. Such mature animals will land and thaw out in a favourable cosmic habitat for growth and further cosmic Lamarckian evolution. We speculated on such a scenario for the emergence of Cephalopods on Earth 275 mya viz. cryopreserved Octopus eggs (Steele et al 2018). Although this possibility has provoked ridicule in some circles there is no logic whatsoever by which it can be excluded.

We rest our case. We cannot but conclude that the demarcation data set outlined favours the Hoyle-Wickramasinghe theory of Panspermia for the origins and further evolution of life on Earth.

**References**

Allen, D.A., and Wickramasinghe, D.T. (1981). Diffuse interstellar absorption bands between 2.9 and 4.0 mm. *Nature* 294, 239-240.

Cossetti, C., Lugini, L., Astrologo, L., Saggio, I., Fais, S., and Spadafora, C. (2014). Soma-to-Germline Transmission of RNA in Mice Xenografted with Human Tumour Cells: Possible Transport by Exosomes. *PLoS ONE* 9(7), e101629. doi:10.1371/journal.pone.0101629

Dias, B.G., and Ressler, K.J. (2014). Parental olfactory experience influences behavior and neural structure in subsequent generations. *Nat Neurosci*. 17 , 89-96.

Eldredge, N., and Gould, S.J.(1972). Punctuated equilibria : an alternative to phyletic gradualism. In: Schopf, T.J.M. (Ed.), *Models in Paleobiology*. Freeman Cooper, San Francisco, pp. 82-115.

Gorczynski, R.M., Kennedy, M., MacRae, S., and Ciampi, A. (1983). A possible maternal effect in the abnormal hyporesponsiveness to specific alloantigens in offspring born to neonatally tolerant fathers. *J. Immunol.* 131 (3) , 1115-1120.

Gorczynski, R.M., and Steele, E.J. (1980). Inheritance of acquired immunologic tolerance to foreign histocompatibility antigens in mice. *Proc. Natl. Acad. Sci. U.S.A.* 77, 2871-2875.

Gorczynski, R.M., and Steele, E.J. (1981). Simultaneous yet independent inheritance of somatically acquired tolerance to two distinct H-2 antigenic haplotype determinants in mice. *Nature* 289, 678-681. https://doi.org/10.1038/289678a0.

Gould, S.J., and Eldredge, N. (1977). Punctuated equilibria: the tempo and mode of evolution reconsidered. *Paleobiology* 3, 115-151.

Grebennikova, T.V., Syroeshkin, A.V., Shubralova, E.V., Eliseeva, O.V., Kostina, L.V., Kulikova, N.Y., et al. (2018). The DNA of bacteria of the World Ocean and the Earth in cosmic dust at the International Space Station, *The Scientific World Journal*, Volume 2018, Article ID 7360147, 7 pp. https://doi.org/10.1155/2018/7360147

Hoover, R.B. (2005). Microfossils, biominerals, and chemical biomarkers in meteorites. In: Hoover, R.B., Rozanov, A.Y., Paepe (Eds.), *Perspectives in Astrobiology*. RR IOS Press, Amsterdam, pp. 43-65.

Hoover, R.B. (2011). Fossils of cyanobacteria in CI1 carbonaceous meteorites: implications to life on comets, Europa and Enceladus. *J. Cosmology* 16, 7070- 7111.

Hoover, R.B., Hoyle, F., Wickramasinghe, N.C., Hoover, M., and Al-Mufti, S. (1986). Diatoms on Earth, Comets, Europa and in interstellar space. *Earth, Moon, and Planets* 35, 19-45.

Hoyle, F., and Wickramasinghe, N.C. (1976). Primitive grain clumps and organic compounds in carbonaceous chondrites. *Nature* 264, 45.

Hoyle, F., and Wickramasinghe, N.C. (1977a). Polysaccharides and the infrared spectra of galactic sources. *Nature* 268, 610-612.

Hoyle, F., and Wickramasinghe, N.C. (1977b). Identification of the 2200A interstellar absorption feature. *Nature* 270, 323.

Hoyle, F., and Wickramasinghe, N.C. (1978b). Calculations of infrared fluxes from galactic sources for a polysaccharide grain model. *Astrophys. Space Sci.* 53, 489-505.

Hoyle, F., and Wickramasinghe, N.C. (1979). *Diseases from Space*. J.M. Dent Ltd, London.

Hoyle, F. and Wickramasinghe, N.C. (1981). *Evolution from Space* J.M. Dent, London.

Hoyle, F., and Wickramasinghe, N.C. (1993). *Our Place in the Cosmos : the Unfinished Revolution*. J.M. Dent Ltd, London.

Hoyle, F., and Wickramasinghe, N.C. (1999). Panspermia 2000. *Astrophys. Space Sci*. 268, 1-17

Hoyle, F., and Wickramasinghe, N.C. (2000). Astronomical origins of life : steps towards panspermia. Reprints from *Astrophys. Space Sci* 268, 1-3, 1999, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Hoyle, F., Wickramasinghe, N.C., and Al-Mufti, S. (1982) Organo-siliceous biomolecules and the infrared spectrum of the Trapezium Nebula. *Astrophys. Sp. Sci*. 86, 63-69

Javaux, E.J., Marshall C.P., and Bekker, A. (2010). Organic-walled microfossils in 3.2-billion-year-old shallow-marine siliciclastic deposits *Nature* 463, 934 - 939. doi:10.1038/nature08793

Johnson, F.M. (1972). Interstellar molecules and cosmochemicals. *Ann. New York Acad. Sci*., 194, 3-4. https://doi.org/10.1111/j.1749-6632.1972.tb12684.x

Koestler, A. (1971) *The Case of the Midwife Toad*. Pan Books, London.

Liu,Y., and Li, X. (2016). Darwin's Pangenesis as a molecular theory of inherited diseases. *Gene* 582, 19-22. https://doi.org/10.1016/j.gene.2016.01.051.

Majeed, Q., Wickramasinghe, N.C, Hoyle, F., and Al-Mufti, S. (1988) A diatom model of dust in the Trapezium Nebula. *Astrophys.Sp.Sci*. 140 , 205-207.

McFadden, J. ( 2016) Quantum Leap: Could quantum mechanics hold the secret of (Alien) life? In , Ed. Al-Kahalili, J, *Aliens*, Profile Books Ltd, London, 2016

Mushegian, A.R. and Koonin, E.V. (1996) A minimal gene set for cellular life derived by comparison of complete bacterial genomes. *Proc. Natl. Acad. Sci. U.S.A*. 96, 10268-10273.

Noble, D., et al., 2016. New Trends in Evolutionary Biology: Biological, Philosophical and Social Science Perspectives. The Royal Society, London, 6e9 Carlton House Terrace, London, SW1Y 5AG Nov 7 -9, 2016. Editors-Organisors. https:// royalsociety.org/science-events-and-lectures/2016/11/evolutionary-biology/.

Okuda, H., Shibai, H., Nakagawa, T., Matsuhara, H., Kobayashi, Y., Kaifu, T., et al. (1990). An infrared quintuplet near the galactic center. *Astro. Phys. J*. 351, 89-97

Pflug, H.D., and Heinz, B. (1997). Analysis of fossil organic nanostructures: terrestrial and extraterrestrial. *SPIE Proc. Instrum. Methods Missions Investigation Extraterr. Microorg*.. 86, 3111. https://doi.org/10.1117/12.278814. July 11, 1997.

Rozanov, A. Y., and Hoover, R.B. (2013) Acritarchs in carbonaceous meteorites and terrestrial rocks Instruments, Methods, and Missions for Astrobiology XVI edited by Richard B Hoover, Gilbert V Levin, Alexei Yu Rozanov, Nalin C Wickramasinghe. *Proc of SPIE* Vol 8855, 886507-7 doe: 10.1117/12.2029608

Shatilovich, A.V., Tchesunov, A.V., NeretinaI, T.V.,Grabarnik, I.P., Gubin, S.V., Vishnivetskaya , T.A., et al. (2018). Viable nematodes from Late Pleistocene permafrost of the Kolyma River Lowland. *Doklady Biol. Sci* 480, 100- 102. https://doi.org/10.1134/S0012496618030079

Smith, W.E. (2013). September 26, 2013. Life is a cosmic phenomenon: the "Search for Water" evolves into the "Search for Life". In: Hoover, R.B., Levin, G.V., Rozanov, A.Y., Wickramasinghe, N.C. (Eds.), *Proc. SPIE 8865, Instruments, Methods, and Missions for Astrobiology* XVI. San Diego, California, United States. https://doi.org/10.1117/12.2046862.

Spadafora, C. (2008). Sperm-mediated "reverse" gene transfer: a role of reverse transcriptase in the generation of new genetic information. *Hum. Reprod.* 23, 735-740. https://doi.org/10.1093/humrep/dem425.

Steele, E.J., Al-Mufti, S., Augustyn, K.A., Chandrajith, R., Coghlan, J.P., Coulson, S.G., et al (2018) Cause of Cambrian Explosion - Terrestrial or Cosmic? *Prog. Biophys. Mol. Biol.* 136, 3-23. https://doi.org/10.1016/j.pbiomolbio.2018.03.004

Steele, E.J. (1979). *Somatic Selection and Adaptive Evolution : on the Inheritance of Acquired Characters*, first ed. University of Chicago Press, Chicago. Williams- Wallace, Toronto, 1979; 2nd Edit.

Steele, E.J. (2016). Origin of congenital defects: stable inheritance through the male line via maternal antibodies specific for eye lens antigens inducing autoimmune eye defects in developing rabbits in utero. In: Levin, M., Adams, D.S. (Eds.), *Ahead of the Curve -Hidden Breakthroughs in the Biosciences* Chapter 3. Michael Levin and Dany Spencer Adams IOP Publishing Ltd 2016, Bristol, UK.

Steele, E.J. and Blanden, R.V. (2000) Lamarck and Antibody Genes. *Science* 288 , 2318 -2319.

Steele, E.J., and Lloyd, S.S. (2015). Soma-to-germline feedback is implied by the extreme polymorphism at IGHV relative to MHC. *Bioessays* 37, 557-569.

Steele, E.J., Gorczynski, R.M., and Pollard, J.W. (1984). The somatic selection of acquired characters. In: Pollard, J.W. (Ed.), *Evolutionary Theory: Paths into the Future*. John Wiley, London, pp. 217e237.

Steele, E.J., Lindley, R.A., and Blanden, R.V., (1998). *Lamarck's Signature : How Retrogenes Are Changing Darwin's Natural Selection Paradigm*. Allen & Unwin, Frontiers of Science Series, Ed P.C. Davies, Sydney, Australia.

Todisco M, Fraccia TP, Smith GP, Corno A, Bethge L, Klussmann S, et al (2018)

Non-enzymatic Polymerization into Long Linear RNA Templated by Liquid Crystal Self-Assembly *ACS Nano*, Article ASAP DOI: 10.1021/acsnano.8b05821 Publication Date (Web): October 3, 2018

Vargas, A.O., Krabichler, Q., and Guerrero-Bosagna, C. (2017) An Epigenetic Perspective on the Midwife Toad Experiments of Paul Kammerer (1880-1926). *J Exp Zool B Mol Dev Evol*. 328(1-2), 179-192. doi: 10.1002/jez.b.22708.

Wainwright, M., Rose, C.E., Baker, A.J., Wickramasinghe, N.C., and Omairi, T. (2015). Biological entities isolated from two stratosphere launches-continued evidence for a space origin *J. Astrobiol Outreach* 3 (2). https://doi.org/10.4172/2332-2519.1000129.

Walker, S.I. (2017) Origins of life: a problem for physics, a key issues review. *Rep. Prog. Phys.* 80, 092601 (21pp) https://doi.org/10.1088/1361-6633/aa7804

Wallis, J., Miyake, N., Hoover, R.B., Oldroyd, A., Wallis, D.H., Samaranayake, A., et al (2013). The Polonnaruwa meteorite ; Oxygen isotope, crystalline and biological composition. *J Cosmology* Vol. 22, No. 2 published, 5 March 2013

Wickramasinghe, N.C., (1974). Formaldehyde polymers in interstellar space. *Nature* 252, 462-463.

Wickramasinghe, D.T., and Allen, D.A. (1983). Three components of 3-4 um absorption bands. *Astrophys. Space Sci.* 97, 369-378

Wickramasinghe, D.T., and Allen, D.A., (1986)_. Discovery of organic grains in Comet Halley. *Nature* 323, 44-46.

Wickramasinghe, N.C., and Hoyle, F. (1998) Infrared evidence for Panspermia: An update. *Astrophys.Sp.Sci.* 259, 385-401

Wickramasinghe, N.C., and Rycroft, M. (2018). On the difficulty of the transport of electrically charged submicron dust, including bacteria, from the Earth's surface to the high ionosphere *Adv. Astrophysics* 3 (3), 150-153, August 2018 https://dx.doi.org/10.22606/adap.2018.33003

Wickramasinghe, N.C., Wallis, J., Wallis, D.H., and Samaranayake, A. (2013). Fossil diatoms in a new carbonaceous meteorite. J Cosmology. Vol 21. No. 37 published, 10 January 2013.

Wickramasinghe, N.C., Wickramasinghe, D.T., Tout, C.A., Lattanzio, J.C., and Steele, E.J. (2018) Cosmic Biology in Perspective https://arxiv.org/abs/1805.10126