Journal of Cosmology, Vol. 30, No.10, pp. 30160 - 30174

Life and the Universe: a Final Synthesis

N. C. Wickramasinghe[1,2,3,4], and R.C. Wickramasinghe[4]

1.Buckingham Centre for Astrobiology, University of Buckingham, UK
2.Centre for Astrobiology, University of Ruhuna, Matara, Sri Lanka
3.National Institute of Fundamental Studies, Kandy, Sri Lanka
4.Institute for the Study of Panspermia and Astroeconomics, Gifu, Japan

The long-overdue synthesis between microbiology and the universe, after many setbacks, may at long last be in sight. The full implications of the transition may well lie in the future for the benefit of the coming generations of scientists.

Keywords: cosmology, astrobiology, panspermia

1. Introduction

"Microbiology may be said to have had its beginnings in the nineteen-forties. A new world of the most astonishing complexity began then to be revealed. In retrospect I find it remarkable that microbiologists did not at once recognised that the world into which they had penetrated had of necessity to be of a cosmic order. I suspect that the cosmic quality of microbiology will seem as obvious to future generations as the Sun being the centre of our solar system seems obvious to the present generation."

Fred Hoyle in *Evolution from Space (The Omni Lecture)*, Enslow Publishers, New Jersey, 1982)

In a series of earlier papers and books evidence from a range of new discoveries were reviewed, all of which support the cosmic nature and origin of life (1-6). In this paper we take stock of the full implications that follow from these discoveries, and their possible impact on the future of science and society as a whole. We argue that at the present time in history we are at an important turning point of science, religion and philosophy, all of which appear to be inextricably interlinked.

Panspermia, as a model for the origin and distribution of life throughout the cosmos, has a very long history stretching back over 2500 years in traditions of the West. It is perhaps even older by a thousand years in traditions of the East, possibly dating back to the Vedas of ancient India or even earlier in both Egypt and China (7). The rival or competing model for life's origin – the theory of spontaneous generation - dates back to the Greek Philosopher Aristotle in the 3rd century BCE.

The name that is mainly associated with panspermia in the Western world is that of the pre-Socratic philosopher Anaxagoras, who was born in the city of Clazomenae around 500BCE, when Asia Minor was under the control of the Persian Empire. There is no doubt that Anaxagoras in his time was a towering genius, but he was also a rebel. Besides arguing the logic for panspermia – seeds of life scattered throughout the universe – his other incursions into astronomy included his claim that sun and moon were physical bodies, not deities as was widely believed; and for this heretical pronouncement he was banished from Athens and imprisoned.

Anaxagoras' arguments in relation to panspermia probably held sway in the Greco-Roman world until Aristotle came along two centuries later to argue that life *must* have originated *on the Earth* in a "Primordial Soup", by an unspecified process or processes that he called "Spontaneous Generation". Aristotle's corpus of philosophical work also included the proposition that the Earth was the centre of the universe, and it was his towering influence in maintaining this position that stalled the progress of astronomy for more than 1500 years. The Church in Rome adopted a suitably modified version of Aristotelean philosophy over a very broad front of issues, and any challenge to their authority was met with severe punishment. Galileo Galilei, who used a telescope to discover craters on the Moon as well as moons around the planet Jupiter, was famously imprisoned in 1632 for publishing his results in a book claiming that the heliocentric theory of Copernicus was correct. Giordano Bruno, poet, philosopher, astronomer, was tried by the Inquisition of Rome and was burnt at the stake in 1600 for supporting the heliocentric theory as well as maintaining that there existed other living beings on other planets orbiting distant stars. Such brutal punishments prevented dissent from Church-approved orthodoxy for a long time.

However, it is well documented that critics of spontaneous generation emerged from time to time between 1600 and 1800, as Wainwright and one of us (NCW) has recently reviewed (6). We shall see that this earlier church-enforced stricture in regard to an Earth-centred origin of life has now given way to an orthodox position that is maintained not by the church but by modern scientific institutions with equal rigour and stubbornness. Overcoming such a stumbling block in the future is the challenge we now have to face (8).

2. Louis Pasteur's challenge of spontaneous generation

Historically the first serious challenge of the long-reigning doctrine of spontaneous generation of life emerged after Louis Pasteur's classic experiments on the processes of fermentation (wine and milk) in the mid-nineteenth century. Here he demonstrated that microbial life seems always and everywhere to be derived from microbial life that had existed before (9). When a nutrient broth (in which bacteria can grow) was sealed off from the external atmosphere he showed that no bacteria will grow. It was on the basis of these experiments that Pasteur enunciated his famous dictum - *Omne vivum ex vivo*—"all life is from life that existed before".

Pasteur's experiments and his declaration turned out to be the most powerful *raison d'être* for panspermia, and his case was taken up by a number of leading contemporary physicists including, Helmholtz (10) and Lord Kelvin (11). In 1861 Lord Kelvin, in his presidential address to the British Association, stated thus:

"Hence, and because we all confidently believe that there are at present, and have been from time immemorial, many worlds of life besides our own, we must regard it as probable in the highest degree that there are countess seed-bearing meteoritic stones moving about through space. If at the present instant no life existed upon the Earth, one such stone falling upon it might, by what we blindly call natural causes lead to its being covered with vegetation."

Two decades later Nobel Prize winning Swedish Chemist Svante Arrhenius, first in a short paper in 1903 and later in his classic 1908 book "*Worlds in the Making*" (12), followed Kelvin in elaborating on the possible mechanisms by which bacteria and bacterial spores could be transferred between distant planetary systems. He pointed out that bacteria had the right sizes to be propelled by the radiation pressure exerted by sunlight or starlight and could be moved across galactic distances. It is this same mechanism that one of us (NCW) later invoked to discuss the distribution in the galaxy of interstellar dust (13). Long before the discovery of extremophiles (bacteria that can survive extreme environments) in the past half century, Svante Arrhenius had speculated that survival properties including space hardiness must exist for bacteria. He came to this conclusion from experiments that he had himself conducted by taking seeds down to near zero degrees Kelvin and finding them to survive. In this way Arrhenius introduced the concept of interstellar panspermia, a concept that was extended by one of the present authors seven decades later to become the modern theory of cometary panspermia (14).

The work of Pasteur and the powerful arguments advanced by Svante Arrhenius did not however demolish the long-held Aristotelean idea of spontaneous generation – an idea that continued to be epitomised by statements such as "fireflies emerging from a mixture of warm earth and morning dew". An abiding interest in the theory of spontaneous generation continued to persist for centuries and re-emerged with great force in the early decades of the 20th century following the work of the English Biologist John Haldane and Russian Chemist A.I. Oparin.

In the modern version of Aristotelean doctrine developed by Haldane and Oparin, an initially sterile and lifeless Earth was supposed to acquire its first life from non-living inorganic chemicals *in situ* through chemical processes taking place on our planet itself (8). This theory, even after it was later adapted to take account of inputs of organic molecules from comets and meteorites, remains fundamentally inadequate and deeply flawed for reasons that we shall discuss in this review. But first let us look at the facts relating to the history of life on the Earth, which have been unravelled mainly from studies in geology – studies searching for fossil evidence of life from the time the Earth first formed.

3. **The first crucial and historic challenge of spontaneous generation**

The sun and the planetary system began forming about 4.6 billion years ago by the coalescence of smaller bodies within a cloud of interstellar dust and gas known as a molecular cloud. This cloud – the proto-solar nebula as it is called - contracted under its self-gravity with the proto-Sun being formed in the hot dense centre and with the remainder of the cloud forming a "protoplanetary disc" extending out to a fraction of a light year. It is from the material within this extended cloud that planetary bodies were formed. The Earth formed from much smaller rocky bodies (asteroids) and comets colliding and coalescing shortly after the sun itself began to shine as a star.

We now know that microbial life first appeared on the Earth about 4.2 billion years ago during a period of "Late Heavy Bombardment" – period of intense bombardment by comets and asteroids. This crucial new evidence is locked away in the form of carbon spheres within larger crystals of zirconium within rocks that formed 4.1- 4.2 billion years ago (Figure 1) – and are now exposed in the *Jack Hills* outcrop in Western Australia (15). The bacterial origin of these carbon spheres is inferred from very slight departures from atmospheric values in the ratio of C12/C13 that have been found which are appropriate for their biological origin - biology showing a slight preference for C12 over C13. These bacterial fossils were clearly deposited at a time when the planet was being relentlessly bombarded by comets and meteorites and the formation of the crust of the Earth was not yet complete.

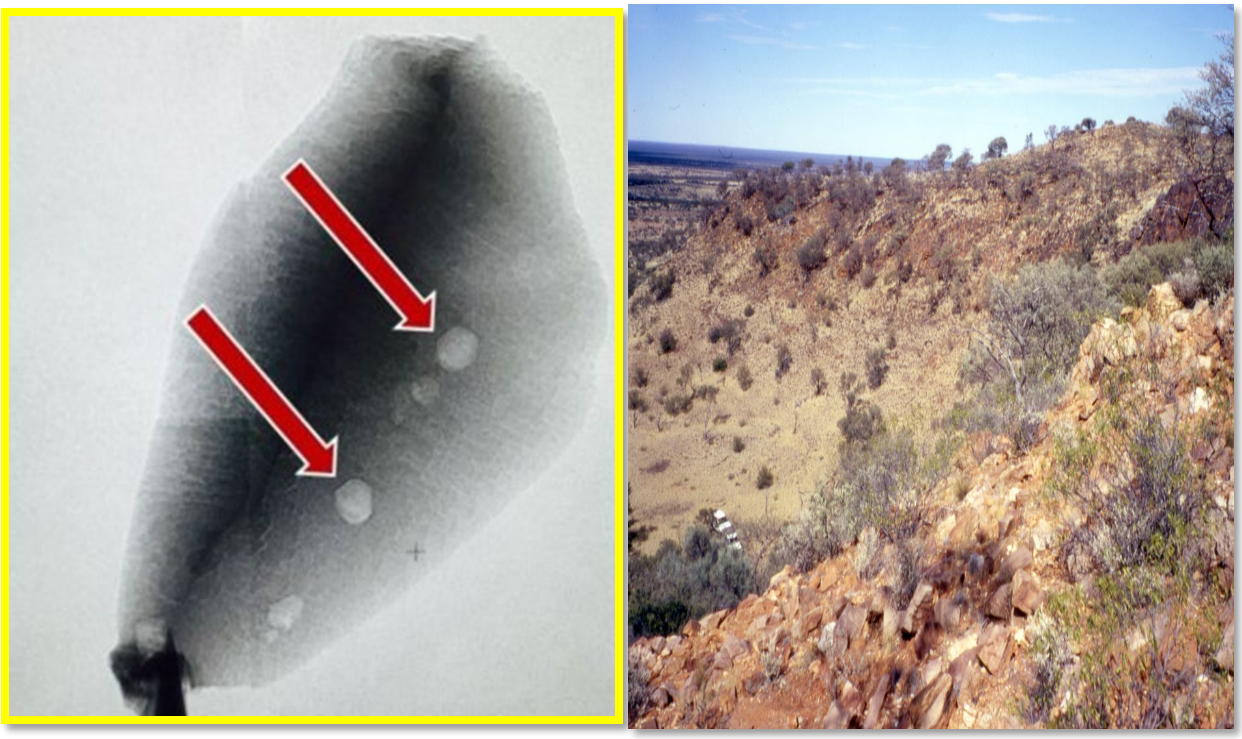

Fig. 1. Microbial carbon spherules which are inferred to be relics of bacteria within zirconium crystal from the rocks in the Jack Hills outcrop in W. Australia

It was a short while after this first injection of life that comet impacts had also delivered large quantities of water and other volatiles. This probably marked the beginnings of a habitable Earth, one that eventually became endowed with oceans and an atmosphere - a planet ideally suited for biology to take root and flourish.

4. Long periods of evolutionary stagnation – a puzzle and a clue

During an entire 2 billion-year timespan from the arrival of the first microbes 4.2 billion years ago, single-celled micro-organisms – bacteria and protozoa - were the sole life-form that inhabited our planet. At the end of this long timespan – extending over 2 billion years - we see the arrival of the first eukaryotes in the fossil record – single-celled organisms which are now endowed with a nucleus within which the cell's DNA is confined.

The first multicellular organisms appear in the fossil record as late as 700 million years before the present. Standard theories of spontaneous generation, including purely Earth-based ideas of Darwinian evolution, have great difficulty in accounting for the extraordinarily long delay in appearance between the first bacteria arriving at the Jack Hills site 4.1-4.2 billion years ago, and the first eukaryotes (cells with nuclei) a full two billion years later. Thereafter another two billion years must lapse before a veritable flood of multi-celled lifeforms including a wide variety of modern living forms suddenly appears - the so-called Cambrian explosion of life 540 million years ago.

This latter most remarkable event in the history of life on Earth marks the separation between the Pre-Cambrian and Cambrian geological epochs, and there are strong indications (from the Earth's impact history) that this event occurred during a period of *intense* comet/asteroid impacts. In our view it is such impacting bodies, bunched in time, that could have delivered new phenotypes (either intact organisms in freeze-dried condition, or new genes to be implanted in pre-existing phenotypes) – phenotypes that were hugely transformative in relation to the history of life on the Earth. The long separations between such major life-injection events on Earth are a clear indication of an astronomical phenomenon controlling the process.

5. Formidable information content of life

Proteins and enzymes, upon which the operation of all life depends, are made from folded chains of some 20 amino acids, and the precise order of these amino acids is crucial for life. Proteins are known to be coded via the precise ordering of four separate nucleotides in DNA – adenine, thymine; cytosine, guanine. After the structure of proteins and DNA came to be understood in the middle of the 20th century the mind-blowing complexity of life was revealed, and if rationality prevailed this *should* have shown the way to a cosmic view of life.

The operation of a living system depends on thousands of chemical reactions taking place within a membrane-bound cellular structure – e.g. a bacterial cell. Such reactions, determined ultimately by the order of nucleotides in DNA, are grouped into metabolic pathways that have the ability to harness chemical energy from the surrounding medium. This happens in a series of very small steps: transporting small molecules into cells, building long-chain biopolymers of various sorts, and ultimately making copies of themselves. Batteries of enzymes, composed of chains of amino acids, play a crucial role as catalysts precisely controlling the rates of chemical reactions. Without enzymes, and the specific arrangements of amino acids within the enzymes dictated by DNA, there could be no life.

In present-day biology, the precise "information" contained in enzymes—the arrangements of amino acids into folded chains—is transmitted by way of the coded ordering of the four nucleotides (A,T,G,C) in DNA. In a hypothetical RNA world, that some biologists think may have predated the DNA-protein world, RNA has been argued to serve a dual role - as both enzyme and transmitter of genetic information. If a few such ribozymes are regarded as precursors to all life, one could attempt to make an estimate of the probability of the assembly of a simple ribozyme composed of 300 bases. This probability turns out to be 1 in 4^{300}, which is equivalent to 1 in 10^{180}, which can hardly be supposed to happen even once in the entire 13.8-billion-year history of a Big-Bang universe. And this is just for a single enzyme.

A similar calculation for the precise ordering of amino acids in a minimal set of bacterial enzymes even for one of the simplest known bacteria *Mycoplasma genitalium* which has only ~ 500 genes gives an even more ridiculous probability ~1 in 10^{1000} with plausible assumptions being made (16). On the basis of such considerations, it is impossible to avoid the conclusion that the emergence of the first *evolvable* cellular life form had of necessity to be a unique event in the cosmos. If this did indeed happen on Earth for the first time, it must be regarded as a near-miraculous event and one that could not be repeated elsewhere, let alone in any laboratory simulation on the Earth. To overcome improbabilities on the scale that is involved here, it stands to common sense that we would gain immensely by going to the biggest system available—the universe as a whole.

6. Missing trunk of the tree of life?

Charles Darwin proposed that life, once it began (assumed to be on the Earth), grew like a tree from a central trunk over billions of years. The tree of life as interpreted today is divided into three distinct branches. Our own branch the eukarya, include plants, fungi and all animals including humans all comprised of cells possessing nuclei; bacteria and archaea are made up entirely of single-celled organisms lacking a nucleus, archaea being more closely related to Eukaryotes. Eukaryotes all have a distinct cell structure with organelles and a nucleus. Most of the DNA of eukaryotes are stored in their nucleus, and the cells contain a wide range of other compartments where proteins are assembled and energy is generated.

New groups of species and individual species as they emerge appear throughout the past 4.2 billion years seem to have branched off like branches of the tree of life. Sporadically we find some branches of this tree to have been pruned by extinction events, almost certainly caused by collisions, like the K/T boundary event that led to the disappearance of the dinosaurs 65million years ago.

With the introduction of new genes in other impact episodes, new shoots and new branches and have emerged like a branching tree as shown in Fig.2. This seemingly elegant analogy of a tree of life does not, however, explain any fundamental process that is involved in the origin or evolution of life. It merely offers an admittedly graphic metaphoric representation of some of the facts of terrestrial biology, facts that are indeed self-evident. To understand what really takes place, or has taken place, one has necessarily to adopt the cosmic view of life.

In our view the Earth is merely a receiving station for cosmic genes from an essentially infinite set of cosmic genes that come to be assembled over time into the magnificent panorama of life we see around us. The three kingdoms of terrestrial life – bacteria, archaea and eukaryotes – stem from an *unknown and unidentified trunk* with no discernible common ancestor, either in the genetic material of present-day life or in the fossil record. This is one more blow to theories of Earth-centred origins and evolution of life; one more way in which the Universe ultimately has its say, ultimately forcing the correct point of view to emerge.

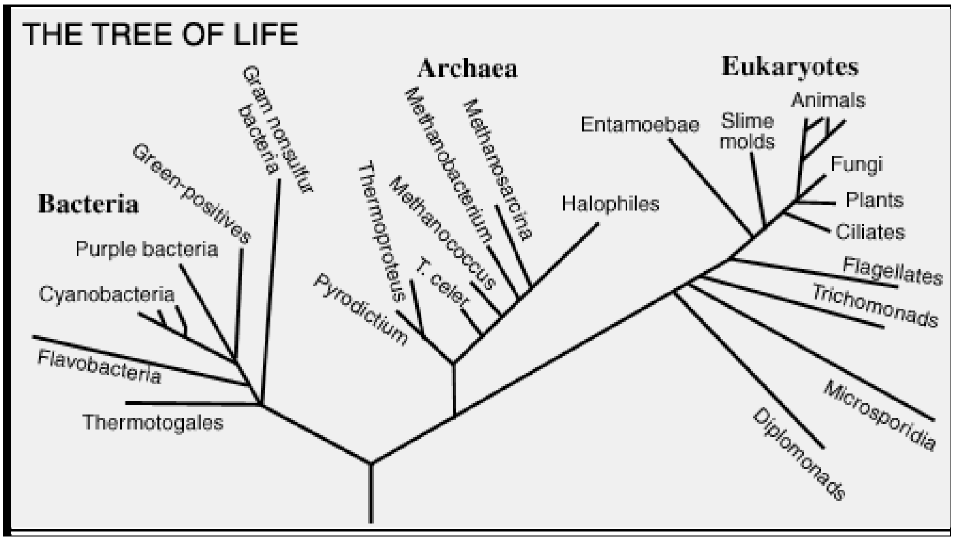

Fig.2. The schematic tree of life

7. Growing astronomical evidence for panspermia

When the senior author (NCW) first began to explore the nature of interstellar dust in 1960 the vast amounts of dust that exist in the Milky Way were thought to be comprised of micrometre sizes ice particles, similar to the ice grains found in the cumulous clouds in the Earth's atmosphere (13). Work carried out in the 1960's eventually showed that this model of cosmic dust was wrong, and instead the emerging idea was that the cosmic dust was made up mainly of the element carbon. The form of carbon in cosmic dust was next studied by examining the light from distant stars as it traversed the dense clouds in interstellar space, leaving signatures revealing the chemical make-up of the dust.

By the mid-1970's there was clear astronomical evidence for the widespread occurrence in the galaxy of organic molecules (17). At about this time Infrared Astronomy was "born" and infrared observations of interstellar dust were beginning to show spectral features in the mid- and near-infrared wavelength region which could not be reconciled with a combination of inorganic silicates and water-ice as was previously believed.

This exceedingly modest requirement of microbial survival would be impossible to violate particularly for freeze-dried microorganisms embedded within particles of interstellar dust. The vast majority of bacteria in interstellar space does not, and need not, persist in viable state. Interstellar clouds could be filled overwhelmingly with the detritus of life which takes the form of genetic fragments that could include viruses and viroids, as well as a wide range of organic molecules.

8. Direct spectroscopic proof

By the early 1980's we had accumulated enough evidence to claim that the chemical make-up of cosmic dust judged by the way they absorbed light was uncannily similar to bacteria and viruses as for instance shown in the comparison displayed in the left-hand panel of Fig.3 (18).

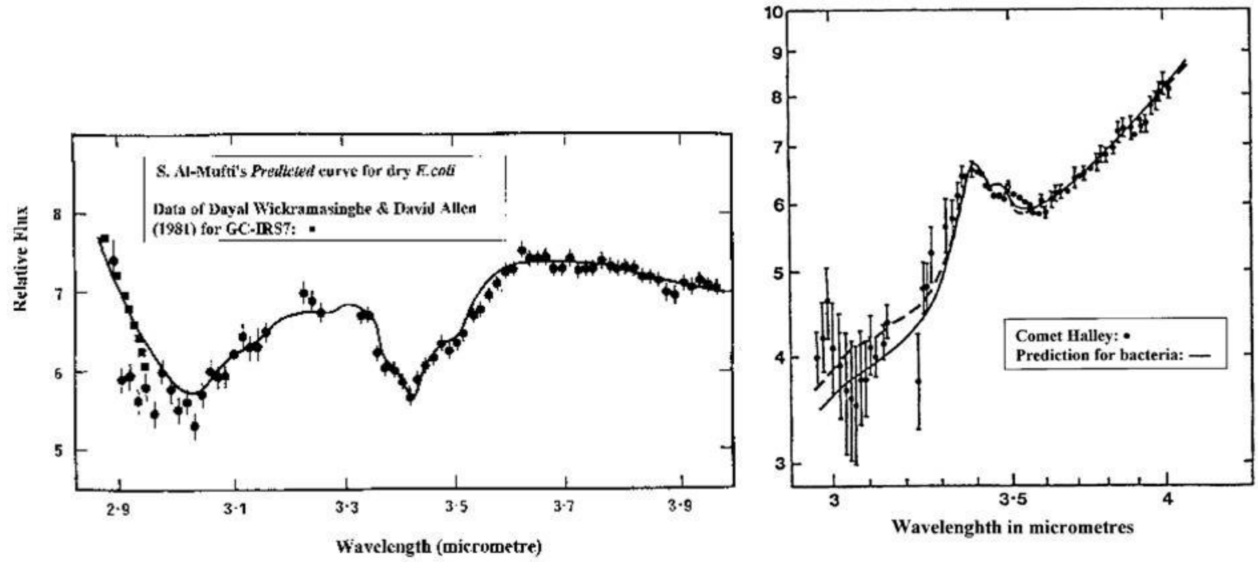

Fig. 3 Left panel: Comparison of the normalized infrared flux from GC-IRS7 (ref.18) with the laboratory spectrum of *E coli*. Right panel: Emission by dust coma of Comet Halley observed by D.T.Wickramasinghe and D.A. Allen on March 31, 1986 (points) compared with normalized fluxes for desiccated E-coli at an emission temperature of 320K. The solid curve is for unirradiated bacteria; the dashed curve is for X-ray irradiated bacteria.

Today, a wide range of astronomical observations of a similar kind all point to the widespread existence of cosmic dust with a composition resembling that of living material (see review in Wickramasinghe (19)). The prevailing reluctance, however, is to admit that that the distribution of organic molecules reflected in Fig.3 are really the products of biology. The fashionable and conventional point of view nowadays is to assert without any proof that organic chemistry is occurring everywhere, and the resulting chemicals happen perchance to match exactly the spectral behaviour of desiccated bacteria! Furthermore, it is maintained against all the odds that terrestrial life originated in a geological instant *in situ* on the Earth, after organic molecules from space came to be delivered possibly by the agency of comets.

More recent studies of other comets have yielded generally similar results. The European Space Agency's Rosetta Mission to comet 67P/C-G has provided the most detailed observations that satisfy all the consistency checks for biology and the theory of cometary panspermia (20).

A further prediction of cometary panspermia is that microbial life must be transferred beyond Earth to other planetary bodies in the solar system. Mars, Venus, and the Jovian moon Europa are a sample of the "nearby" places that are by no means written off in regard to the possibility of extant microbial life (5). We are confident that future space exploration in the coming decades will undoubtedly result in discovering long-awaited positive results for the widespread occurrence of microbial life in solar system.

9. Habitable exoplanets and transfer of genes on a galaxy-wide scale

Figure 4: Artist's impression of a habitable planet orbiting a red dwarf star Proxima Centauri (Courtesy NASA).

We must next ask the question: outside of the confines of our solar system, where is the evidence that other suitable homes for life exist? In 2009 NASA launched its orbiting Kepler telescope, which was specifically designed to discover planets that are the size of Earth. The detection process involved tracking down minute blinks (dimming) in the star's light when a planet transited periodically in front of it during its orbit. At the present time nearly 4000 definite as well as probable detections of habitable planets have been made within only a very small sampling volume of our Milky Way (21). Most of these planets orbit red dwarf stars that are on the average twice the age of our sun. Extrapolating from the sample of detections in our local vicinity the estimated total number of habitable planets in the entire Milky Way galaxy is reckoned to be in excess of 100 billion. *Proxima Centauri b* (also called *Proxima b*) is closest habitable exoplanet orbiting the red dwarf star Alpha Centauri at a distance of some 4.2 light years from the Sun. (Fig.4).

Whilst comets could supply a source of primitive life (bacteria, viruses and genes) to interstellar clouds, and thence to new planetary systems and embryonic exoplanets, the genetic products of evolved life (local evolution) could also be disseminated on a galaxy-wide scale (22). At the present time our solar system, which is surrounded by an extended halo of some 100 billion comets (the Oort Cloud) replete with microbial content as we have seen, moves around the centre of the galaxy with a period of 230 My (See Fig.5).

Every 40 million years, on the average, the cloud of comets in our solar system becomes gravitationally perturbed due to the close passage of a giant molecular cloud. Such gravitational interactions lead to hundreds of comets from the Oort Cloud being thrown into the inner regions of our planetary system, some to collide with the Earth. Such collisions do not only cause extinctions of species (as one impact surely did 65 million years ago, killing the dinosaurs), but they could also result in the expulsion of surface material containing viable bacteria and spores back into deep space.

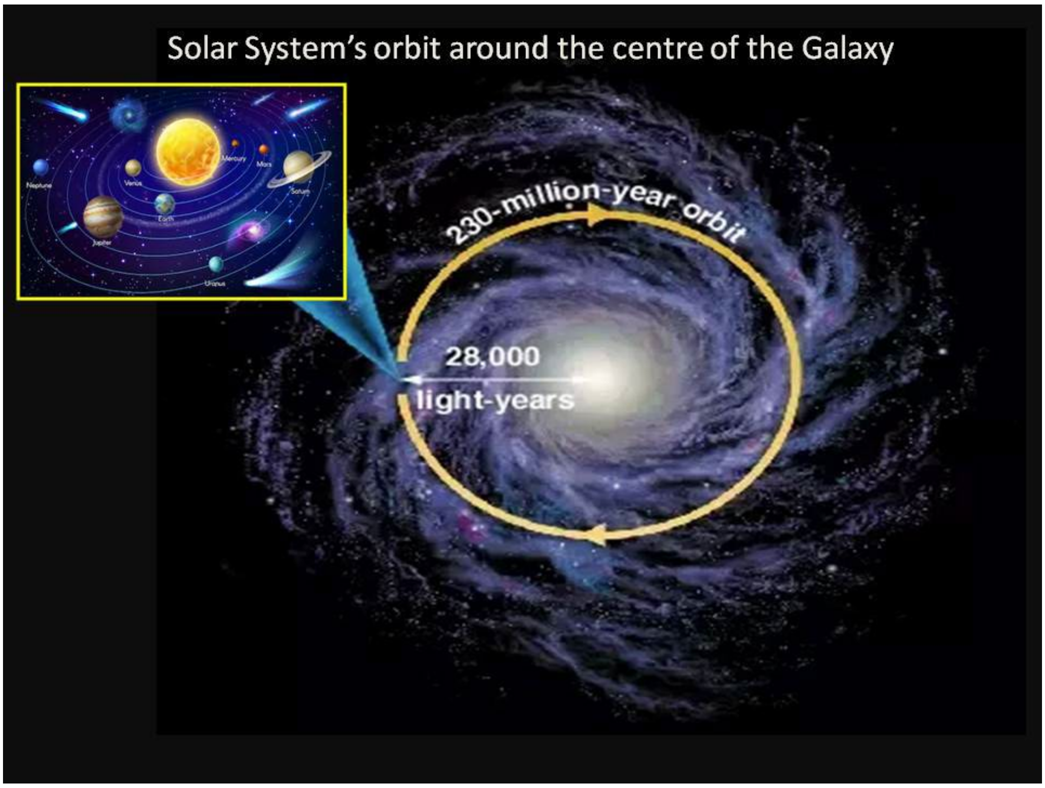

Fig.5: Path of the solar system around the centre of the Galaxy

A mechanism can thus be identified for the genes of evolved Earth-life to be transferred to alien habitable exoplanets. A fraction of the Earth-debris so expelled survives shock-heating and could be laden with viable microbial ecologies as well as the genes of evolved life. Such life-bearing material from the Earth could reach newly forming planetary systems in the passing molecular cloud within a million years of the ejection event. A habitable exoplanet could then become infected with terrestrial microorganisms and terrestrial genes that can contribute to the process of local biological evolution on a distant exoplanet. Once life has got started and evolved on an alien planet or planets of a new system, the same process can be repeated (via comet collisions) transferring a new compliment of genetic material carrying local evolutionary 'experience' to other molecular clouds and other nascent planetary systems.

If every life-bearing planet transfers viable genes in this way to more than one other planetary system (say 1.1 on the average), with a characteristic time of 40My then the number of seeded planets after 9 billion years (lifetime of the galaxy) is $(1.1)^{9000/40} \sim 2\text{x}10^{9}$. Such a large number of 'infected' planets illustrates that Darwinian evolution, involving horizontal gene transfers, must operate not only on the Earth or within the confines of our solar system, but on a truly galactic scale. Life throughout the galaxy on this picture would inevitably constitute a single connected cosmic biosphere.

10. Cosmic bacteria entering Earth's stratosphere

One crucial test of the theory of cometary panspermia is to probe the stratosphere for currently in-falling alien genetic systems – bacteria and viruses. The first such dedicated effort to test the idea of bacterial in-fall from comets was made in 2001 by a group of UK scientists in collaboration with scientists at ISRO (Indian Space Research Organisation). Unequivocally positive detections of in-falling microbiota were made, and the number of bacterial cells collected in a measured volume of the stratosphere at 41km led to an estimate of a total in-fall rate over the whole Earth of 0.3-3 tonnes of microbes per day (23). This converts to some 20-200 million bacteria *per square metre* arriving from space every single day!

Bacteria have also been recovered more recently from the exterior of the international space station which orbits at a height of 400 km above the Earth's surface (24). More expensive and sophisticated tests need to be carried out even on the samples collected so far, if we are to prove beyond a shadow of doubt that these microbes are unequivocally alien. One such test involves the deployment of a rather rare laboratory resource – a *NanoSIMS* machine. This will determine the isotopic composition of carbon, oxygen and other constituent elements within the individual bacterial cells, and if the composition turns out to be non-terrestrial, it is QED! We have finally won, and our opponents can go home! The tight control of the relevant experimental resources worldwide has so far prevented access to this equipment.

In the absence of such experiments being done sceptic is thus left in a seemingly comfortable position to assert, if he so wished, that what we have found in our balloon samples in 2001 and 2009 were terrestrial contaminants (23,24). The situation we have described is just one instance of a totalitarian control of science that is hindering progress.

11. Relevance of new developments

Recent observations using the James Webb Space Telescope have challenged the conventional model of the singular Big-Bang cosmological model in which the universe originated some 13.8 billion years ago, giving it an age close to three times the age of the Earth (5). Galaxies observed at very high redshifts have pushed this age estimate to >> 13.8 billion years, supporting alternative models of the Universe which have an open timescale (Hoyle et al (25)). The beginnings of life in such a universe would imply the genetic components of life (spermata) are probably eternally present, so a discrete moment of origin becomes irrelevant.

It is obvious that much work still remains to be done to understand the evolution of the Universe at large. So far as the Earth is concerned the picture emerging is in a sense creationary - fully created genetic components relevant for all evolutionary contingencies were already at hand available from an external eternal universe. It might be argued that this is not really an explanation in any very deep sense of the ultimate origin and evolution of life such as orthodox biology incorrectly claims to offer. Rather it is a logical and rational *rejection* of those claims that form an impediment to gaining any deep understanding of the real nature of life and its inexorable cosmic heritage. It is a gateway leading to a different landscape with new vistas beckoning that will be the privilege of future generations to explore.

We have pointed out earlier that non-scientific constraints have all too often stood in the way of exploring new conceptual landscapes. For nearly three quarters of the 20th century during the *first* Copernican revolution enormous difficulties were experienced in getting the simplest of facts accepted when they ran counter to established religious belief. Science was of course nurtured within cultures that were predominantly Judeo-Christian and they accordingly championed a world view that was both Earth-centred as well as human-centred. The subsequent acceptance of a heliocentric world view, and later of Darwinian evolutionary thinking, already represented uneasy compromises. As we have discussed in this article the further extension of the Copernican revolution to remove Earth from the centre of biology is meeting a similar hostility as we have discovered over the past few decades.

In the 13th century CE Thomas Aquinas had integrated Aristotelean philosophy into Christian theology and this gave added weight to an Earth-centred Ptolemaic world view. In this emergent world view the Earth was both the physical and also the biological centre of the universe. As we have stated earlier the Copernican revolution of the 16th century eventually removed the Earth from its position of physical centrality in the Universe, but biology continued to remain firmly Earth-centred with spontaneous generation holding sway almost to the present day.

It is, however, a fact that science in the modern world is no longer the monopoly of Christendom nor of Judeo-Christian philosophy. At the present time we are witnessing the rapid emergence of scientific and technological cultures that have non-Christian roots, as for instance in India, Japan and China. As these new scientific cultures expand and grow in influence, we can wonder what their effect on the world scene would be. It is worth noting that Buddhism, which is an important cultural force in Japan, China, India and Sri Lanka, maintains a refreshingly open attitude and is relatively free of dogma. Siddharth Gautama Buddha, the founder of Buddhism, stressed the importance of discovering truth for oneself. On his deathbed he instructed his chief disciple Ananda thus:

“You should live as lamps unto yourselves. Hold fast to the lamp of Truth. Take refuge only in Truth. Look not for refuge to anyone beside yourself…. And those who now in my time or afterwards live thus, they will reach greatness if they are desirous of knowledge.” – *Mahaparinibbana sutra No.16*). This is of course exemplary advice to scientists even in the present day.

Buddha’s own vision of the world was also remarkably post-Copernican, even in the 5th century BCE. He described a Universe comprised of billions of “Minor World Systems” each resembling our own solar system. In the oldest Buddhist texts, which are in the form of dialogues with his disciples, it is stated that in the infinite space of the Universe there exists “billions of suns, billions of moons, billions of Jambudhipas, billions of Aparagoyanas, billions of Uttarakurus, billions of Pubbavidehas….” Jambudhipa and the other names are words to describe the inhabited regions of the Earth known to the people living in North India at the time. Throughout the extensive dialogues of the Buddha, it is amply clear that the Buddha viewed life and consciousness (which he thought was associated with all life) as cosmic phenomena, linked inextricably to the structure of the universe as a whole.

It is thus clear that in many important respects the traditions of Buddhism are well suited to extending the Copernican revolution to its next phase – accepting life as a cosmic phenomenon. If such traditions prevail astronomy and biology may at last be freed of its medieval fetters.

References

(1) Wickramasinghe, N.C., Narlikar, J.V. and Tokoro, G., 2023. Cosmology and the Origins of Life, *Journal of Cosmology*, Vol. 30, No. 1, pp. 30001 - 30013

(2) Wickramasinghe, N.C., 2023. Life beyond the limits of our planetary system, *Journal of Cosmology*, Vol. 30, No. 1, pp. 30020 - 30024

(3) Wickramasinghe, N.C. and Tokoro, G., 2023. Quest for life on Jupiter and its moons, *Journal of Cosmology*, Vol. 30, No. 3, pp. 30030 - 30034

(4) Wickramasinghe, C., Tokoro, G., Temple, R. and Schild, R., 2023. Reluctance to admit we are not alone as an intelligent lifeform in the cosmos, *Journal of Cosmology*, Vol. 30, No. 4, pp. 30040 - 30053

(5) Wickramasinghe, C., Schild, R. and Forrington, J.H., 2023. Second Copernican Revolution, *Journal of Cosmology*, Vol. 30, No. 5, pp. 30060 - 30071

(6) Wainwright, M and Wickramasinghe, N.C., 2023. Life comes from space – The decisive evidence, *World Scientific Publishers*, Singapore

(7) Temple, R., 2007. The history of panspermia: astrophysical or metaphysical, *International Journal of Astrobiology*, 62, 169-180

(8) Wickramasinghe, C., Wickramasinghe, K. and Tokoro, G., 2019. Our cosmic ancestry in the stars, *Bear & Co.*, Rochester, USA

(9) Pasteur, L., 1857. *C.R.Acad.Sci.,* 45, 913-916, 1857

(10) von Helmholtz, H., 1874. In *Handbuch de Theortetische Physik*, (eds W. Thomson and P.G. Tait Vo1 (Part 2) Brancscheig

(11) Thomson, W., 1871. *British Association for the Advancement of Science*, Presidential Address

(12) Arrhenius, S., 1908. Worlds in the Making, *Harper*, London

(13) Wickramasinghe, C., 1967. Interstellar Grains, *Chapman and Hall*, London

(14) Wickramasinghe, C. (ed.), 2015. Vindication of Cosmic Biology, *World Scientific Press*, Singapore

(15) Bell, E.A., Boehnke, P., Harrison, T. et al, 2015. Potentially biogenic carbon preserved in a 4.1 billion-year-old zircon, *PNAS*, 112 (47) 14518-14521 www.pnas.org/cgi/doi/10.1073/pnas.1517557112

(16) Hoyle, F. and Wickramasinghe, N.C., 1982. Evolution from Space, *J.M. Dent*, London

(17) Wickramasinghe, N.C., 1974. Polyoxymethylene polymers as interstellar grains, *Nature* 252, 462–463.

(18) Hoyle, F., Wickramasinghe, N.C., Al-Mufti,S., Olavesen, A.H. and Wickramasinghe, D.T.,1982. Infrared spectroscopy over the 2.9-3.9 micron waveband in biochemistry and astronomy, *Astrophys. Sp.Sci*., 83, 405

(19) Wickramasinghe, C., 2010. The astrobiological case for our cosmic ancestry, *Int.J.Astrobiol*., 9(2), 119.

(20) Wickramasinghe, N.C., Wainwright, M., Smith, W.E., Tokoro, G., Al Mufti, S. and Wallis, M.K., 2015. Rosetta Studies of Comet 67P/Churyumov–Gerasimenko: Prospects for Establishing Cometary Biology, *J.Astrobiol Outreach*, 3:1

(21) Kopparapu, R.K. et al., 2013. Habitable zones around Main-Sequence stars: New estimates, *Astrophys.J.* 765, 131.

(22) Wallis, M.K. and Wickramasinghe, N.C., 2004. Interstellar transfer of microbiota, *Mon.Not. R.A.S*, 384(1), 52-61

(23) Harris, M. J., Wickramasinghe, N. C., Lloyd, D., *et al.*, 2002. Detection of living cells in stratospheric samples. *Proc. SPIE*. 4495, 192–198. doi: 10.1117/12.454758

(24) Wickramasinghe, N.C., Rycroft, M.J., Wickramasinghe, D.T., *et al*, 2018. Confirmation of Microbial Ingress from Space, *Ad.Ap,* 3(4), 206

(25) Hoyle,F., Burbidge,G. and Narlikar,J.V., 2008. A different approach to cosmology, *Cambridge University Press*