Epilogue

Reflections in 2012

"Except for a very few scientists, everybody overlooked a crucial step in the analogy between commercial and natural selection. Commercial selection works only because at the back of it there are human intellects constantly striving to improve the range and quality of their products. Commercial selection is therefore very far from the purposeless affair natural selection is taken to be in biology.

In reality, natural selection acts like a sieve. It can distinguish between species presented to it, but it cannot decide what species shall be sieved in the first place. The control over what is presented to the sieve has to enter terrestrial biology from outside itself — not just from outside the living world, but from outside the confines of our planet.... There is nowadays a mountain of evidence for this view.

Fred Hoyle, The Intelligent Universe, 1983
(Michael Joseph, London)

Search for the Origin of Life

Since the first edition of this book was published there have been many scientific developments that could have tested our thesis that life is a cosmic phenomenon. The fact that every new discovery turned out to support rather than contradict the theory gives added confidence to the belief that we are on the right track towards unravelling our cosmic ancestry.

Following the successes of Harold Urey and Stanley Miller in the 1950's research into the origins of life continues stridently in many laboratories in the hope that a breakthrough will ultimately be achieved in understanding how non-living organic matter turns into life. Spectacular successes in genetic engineering and gene manipulation have been achieved, including the wholesale reconstruction of a genome inside a DNA-free bacterial cell (Gibson *et al.*, 2010). But all this is still a far cry from understanding the origin of life itself. What we may conclude from our current knowledge of biochemistry and microbiology in 2012 is not significantly different from what we had in the early 1980's.

There is no evidence whatsoever that requires life to have started *de novo* on the Earth. Indeed all the evidence from geology and astronomy now points inexorably to an origin of life that lies well outside our planet, exactly as Fred Hoyle and I had first proposed in 1979–1981. The picture emerging is of an initial injection of a viable cellular life form, that takes root on our planet and thereafter begins to evolve, being genetically augmented from time to time by genes of external origin that enable the development of new kingdoms of life, phyla, genus and species. What seemed to be an outrageous heresy 30 years ago is at last coming to be accepted, albeit grudgingly.

Cost of Heterodoxy

The history of science has many examples of innovators whose ideas were so far ahead of their time that they failed to gain acceptance. Such individuals often suffered cruel penalties. Anaxoragas (500–428BC) famously argued that the Sun was a red hot stone, and the Moon was made of earth, and for this impiety he was banished from Athens. Giordano Bruno (1548–1600), who maintained that the universe was full of inhabited planets, was condemned for heresy and burnt to death. In our more civilised world we at least pay lip service to the libertarian principles of toleration of opinion and attempt to encourage a diversity of views. So any ostracism or obstacles Fred and I faced in our own journey must be reckoned to be mild compared to what had gone before! As I pointed out in earlier chapters our work was often seen to be destitute of reverence for authority, and for this reason shunned. However, to have one's work ignored is infinitely better than suffering persecution, including the burning of one's books that had happened in past ages.

Our experience over several decades brought to light a dangerous modern trend in the sociology of 20th and 21st century science. There is a tendency nowadays for authorities wielding power to withhold support or recognition of work that does not conform with orthodox opinion. I have indicated how this had happened at various points in our story.

The idea that the organic building blocks of life were brought to Earth by comets rather than being synthesised in the atmosphere, was first developed by us in our book *Lifecloud* in 1976. Although this was vigorously resisted at the outset, the idea came to be slowly accepted by the scientific community because it was thought to fall within the general paradigm of the ‘‘primordial soup on Earth’’, even though the soup itself had to be imported from space.

Throughout the 20th century and in the first decade of the present century the vastness of the Universe of galaxies, stars and planets has been reaffirmed by every major astronomical breakthrough. And with developments in biochemistry and microbiology the bewildering complexity of molecular arrangements in even the simplest living cell have all pointed to a cosmic rather than a terrestrial origin of life.

It was known for a long time that certain types of microbes possessed properties that were not obviously related to the ‘‘average’’ conditions that prevail on Earth. Research into the properties and distribution of ‘‘extremophiles’’ is now being claimed as evidence that life can indeed survive in the harshest of extraterrestrial environments, and that the transfer of life from one galactic location to another was entirely feasible. In 2010 it was discovered that cyanobacteria placed on the outside of the International Space Station survived alternations of freezing, heating and exposure to harsh ionising radiation for a full 18 months. Scarcely a decade ago the very existence of such microorganisms might have been thought impossible.

Astronomical Predictions: Comets and Meteorites

Our theory of the cosmic origins of life made a prediction that the infrared and ultraviolet spectral properties of interstellar dust would match biological material, which it convincingly did when the first such spectra were obtained. We further predicted that the dust from comets (hitherto thought to be made of inorganic ices) must in fact be organic, and this prediction too was verified by observations of comet Halley and other comets after 1986.

I referred in Chapter 20 to air samples that may contain comet dust being collected aseptically by the Indian Space Research Organisation (ISRO) from a height of 41 km in the stratosphere and showing evidence of microorganisms of a presumed cometary origin falling over the whole Earth at an average rate of 0.1 tonnes per day (Wainwright *et al.*, 2003). A few years later, in a second stratospheric sampling, three new bacterial species with exceptional ultraviolet resistance properties were isolated, and one of these was named in honour of Fred Hoyle — *Janibacter hoylei* (Shivaji *et al.*, 2009). The decision to name a new bacterium after Hoyle would appear to have been made in recognition of his pioneering contributions to astrobiology, in the same way that naming a main-belt asteroid 8077 Hoyle (1986AW2) was in recognition of his longstanding contributions to astronomy.

The importance of having similar experiments conducted by other independent Space Agencies cannot be overemphasised, particularly in view of the enormous importance of firmly establishing the cometary origin of these organisms. The cost effectiveness of such a project is beyond dispute, and the apparent reluctance to conduct these experiments is, in my view, connected with the fear of decisively overturning the long-held paradigm of Earth-centred life. Significantly no life detection experiment has been included in any of the recent space missions, again reflecting a state of mind of a scientific orthodoxy unwilling to countenance the non-terrestrial origin of life.

In 2006 samples of dust from comet Wild 2, secured in NASA's Stardust Mission, were returned safely to Earth. As expected, the high velocities of impact onto the collecting aerogel blocks left little evidence of any original organic grains or putative cells — only trails of molecular debris. Whilst no living cells were recovered, complex organic molecules were found in abundance in the debris trails, including an amino acid; and all this was consistent with the break-up of biological material. The biological explanation for the genesis of this material is by far more plausible than the claim that the organics may represent products of radiation processing of simpler molecules. In addition to organics, the collected material contained mineral particles, including the mineral known as cubite. Since cubite can only be formed in the presence of liquid water this discovery provides dramatic confirmation of our prediction from the 1970's that liquid water existed in primordial comets and played a crucial role in the replication of cometary bacteria.

Direct evidence of water jets from a comet was discovered in 2011 in a photograph of comet Tempel 1 taken by cameras onboard the same spacecraft that conducted a rendezvous with comet Wild 2 in 2004. These water jets could result from fissures in the comet's crust due to the build-up of gas pressure from bacterial metabolic activity,

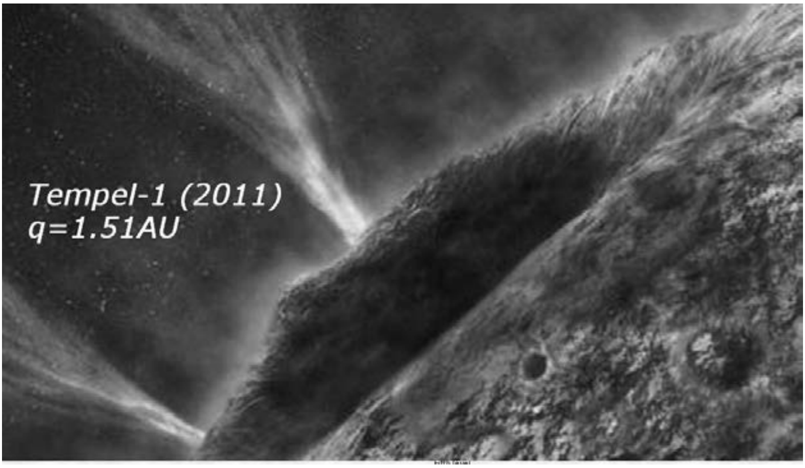

Fig. 21 Braided water jets from comet Tempel-1 photographed in Feb 2011 by *Stardust* spacecraft.

thus leading to the release also of gas and dust (Wickramasinghe, Hoyle and Lloyd, 1996).

NASA's Deep Impact Mission to Comet Tempel 1 on July 4th 2005 involved a high-speed impact of a probe at 37,000 km/hr onto the comet's surface, rupturing its crust and releasing and exposing its content. The presence of water and complex organics that could be connected life and mineral dust was revealed, although the unambiguous discovery of living cells was precluded by the nature of the experiments (Wickramasinghe, Wickramasinghe, Napier, 2010).

The European Space Agency's ROSETTA mission to comet 67P/ Churyumov-Gerasimenko (on which I am one of a very large team of investigators) was launched in March 2004. It is due to attempt a landing on the comet's surface in November 2014 and carry out a wide range of experiments that could give us a deeper insight into the structure, the chemistry and physics of comets.

It was pointed out in Chapter 13 that a class of meteorite known as carbonaceous chondrites represent relics of comets that had once contained microbial life, and thus we might expect to find fossilized microorganisms in such meteorites (Figure 13). I have already referred to the pioneering work of Hans Pflug in discovering such microfossils in the 1980's using the best equipment available at the time and with the most stringent precautions to avoid contamination. Although Pflug's work did not receive the attention it deserved, being apparently so far ahead of his time, the same programme of work continued at NASA's Marshall Space Flight Centre under the direction of Richard Hoover. Hoover has now published a vast catalogue of fossilized microbial structures which he identifies with various types of microorganisms (Hoover, 2005, 2011). An example of what he finds in a freshly cleaved surface of the Murchison meteorite is given in the SEM (scanning electron microscope) image shown in Fig. 22. The comparison (left frame) is with a modern specimen of living cyanobacteria. Many arguments to support the claim that such organic structures in the meteorite are indigenous to the meteorite and not contaminants have been given. The meteorite structures show chemical signatures (e.g. low nitrogen content) to indicate that they are indeed fossilized structures, and therefore cannot be modern contaminants.

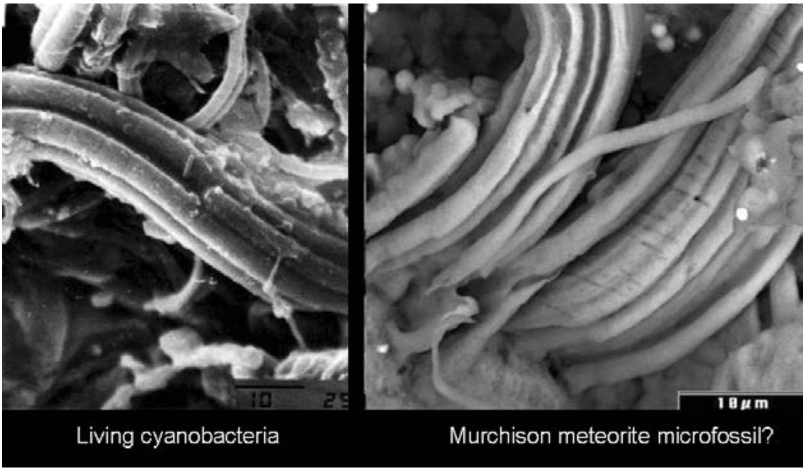

Fig. 22 A structure in the Murchison meteorite (Hoover, 2005) compared with living cyanobacteria (Hoover, 2005, 2011).

Studies of the Mars meteorite ALH84001 that were discussed in Chapter 21 have continued to yield results that are consistent with the original claim of detecting microbial fossils. In July 2011 another meteorite from Mars fell over the desserts of Morocco and was recovered soon afterwards in October near the village of Tissint. This so-called *Tissint* meteorite was blasted off the surface of Mars by a comet or asteroid impact several million years ago. A piece of this meteorite was recently examined by my PhD student Jamie Wallis and other collaborators and we reported the discovery of "signs of extinct life" in this meteorite as well (Wallis *et al.*, 2012).

Spherical globules rich in carbon and oxygen were discovered in the interior of the meteorite embedded in its rocky matrix. Figure 23 shows one such apparenty hollow structure that cracked like an egg when subjected to a high energy electron beam.

Astronomical Spectroscopy

It is exactly 50 years since we published our paper on carbon grains in the Universe (Hoyle and Wickramasinghe, 1962). It is this original work that led to the development of the organic theory of interstellar

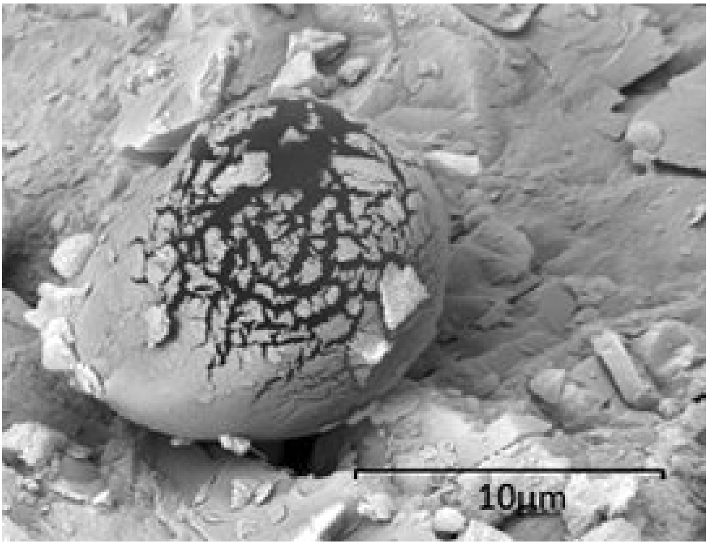

Fig. 23 A carbon-oxygen rich particle in the interior of the Tissint meteorite: An ovoid shaped carbon-oxygen rich globule cracking under gold coating in a scanning electron microscope examination (Wallis *et al.*, 2012).

dust, and eventually the theory of cosmic life. The correspondences of the predictions of our model with astronomical observations, discussed earlier in this book, continue to be verified as the quality of data has improved with the use of new telescopes such as the Spitzer Space Telescope. The high resolution infrared spectra of galactic and extragalactic sources show spectral features of dust (''unidentified infrared bands'', UIB's, principally at 3.3, 6.2, 7.7, 8.2 and 11.3 micrometres) that can only reasonably be interpreted as biologically generated heteroaromatic molecules (Wickramasinghe, 2010; Rauf and Wickramasinghe, 2011). Non-biological explanations that are on offer are contrived and, moreover are inconsistent with *all* the findings.

Amongst the most distant galaxies displaying aromatic/biomolecular infrared signatures is a high red-shift infrared luminous galaxy at redshift $z = 2.69$, the spectrum of which is shown in Fig. 24 (Teplitz *et al.*, 2007). This galaxy emitted its light when the Universe was at the tender age of 2 billion years according to standard Big Bang

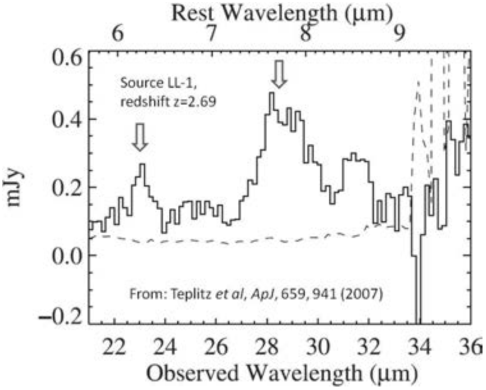

Fig. 24 Redshifted 6.2, 8.7, 11.3 micron bands in the source (Teplitz *et al.*, 2007).

cosmology. Another spectral signature in the ultraviolet (absorption at 2175 Å) pointing to biochemicals has also been found in galaxies at similar great distances (Elíasdóttir *et al.*, 2009; Motta *et al.*, 2002; Noterdaeme *et al.*, 2009).

The idea that the material causing such emissions represents the degradation products of biology, as we had originally suggested, and continue to stress, can be challenged only on the grounds that extraterrestrial life is an "extraordinary hypothesis" requiring "extraordinary evidence" to support it. The confinement of life to the Earth is indeed the more extraordinary hypothesis, and far less justifiable since mechanisms of viable transfer of microbes across the galaxy have been clearly identified (Wickramasinghe *et al.*, 2010).

Biological molecules may well have existed even much earlier in the history of the universe, but the discovery of such molecules is still to come. Evidence of dust extinction has indeed been found in very distant galaxies, and a high concentration of the life-element carbon has recently been detected in the most distant radio galaxy at a redshift of $z = 5.19$ (Matsuoka *et al.*, 2011). If the existence of life is judged by carbon abundance, then we can infer that the first signs of life appear within a billion years after the Big Bang — ready for cometary panspermia thereafter.

Big Bang Cosmology

The Big Bang itself is an idea that Fred Hoyle continued to question throughout much of his career, and the term ‘‘*Big Bang*’’ was in fact coined by Hoyle as a disparaging description of this model of the Universe that he disliked! However, in 2012 a vast body of modern observations in astronomy can be interpreted to imply a Big Bang-style origin of the Universe 13.75 billion years ago. Most (if not all) the matter we can observe with our most powerful telescopes originated in a gigantic ‘‘explosion’’ in this way. However, whether this was a unique ‘‘creation’’ event or one of an infinite set of similar events (multiverse, oscillating universe or Quasi Steady State Cosmology) still remains open to question.

The 2011 Nobel Prize for Physics was awarded to Saul Perlmutter, Brian Schmidt and Adam Reiss for their work on measuring the redshifts (distances) of the faintest Type 1a supernovae in the Universe. This led to the conclusion that the universe was accelerating or speeding up in the rate of its expansion. If the universe is dominated by normal matter this will not be possible — gravity must inevitably slow down, not speed up, the expansion rate. To resolve the dilemma a repulsive source of ‘‘dark energy’’ was invoked to overcome gravity, and this led the so-called ‘‘standard concordance model’’ which is comprised of 23% dark energy, 73% dark matter and 4% normal matter. As I pointed out in Chapter 19 an origin of life will be difficult to envisage in any such Big Bang cosmology that contains only 10^{40} grammes of carbonaceous material — that too existing in a highly dilute and dispersed state.

A variant of the standard Big Bang cosmology that has recently interested me is the so-called Hydro Gravitational Dynamics (HGD) cosmology of Carl Gibson and Rudy Schild (Gibson, 1996; Gibson and Schild, 2010). In the HGD cosmology models, the ionised gas of the early universe becomes unstable at the epoch when recombination from ionised to neutral gas occurred some 0.3 million years after the Big Bang. The whole universe was essentially transformed at this time into a ‘‘sea’’ of Earth-mass planetary objects resembling giant comets — 10^{80} in all. A fraction of these planetary bodies collide and coalesce into rapidly evolving massive stars, in which the chemical elements of life are synthesised by nuclear reactions on a short timescale. Explosions of supernovae then disperse these chemical elements into the great mass of primordial planets, and it is within the warm watery interiors of these objects — forming a sort of cosmological primordial soup — that an origin of life would have the best chance to happen (Gibson *et al.*, 2010).

According to this type of HGD cosmology the dark matter in the Universe is made up of life-bearing primordial planets. In our galaxy such planets are located in the a gigantic halo that continually feeds the spiral arms with material out of which stars and planetary systems form. Microbial life that originated within the first million years of the history of the Universe remains deep frozen and dormant until it is distributed within comets of newly forming planetary systems, and thence transferred to habitable planets like the Earth.

Planets

The cosmic theory of life discussed in earlier chapters requires microbial life to colonise every habitable niche within our own solar system. I have already discussed evidence of microbes in comets, in comet dust that enters the stratosphere, and in the residues of comets in the form of carbonaceous meteorites. Moon rocks brought back to Earth many years ago show no signs of life because particles of life-bearing comet dust impact the moon's airless surface at speeds of over 10 kilometres per second, with no atmosphere to break the speed and ensure a soft landing. Such high impact speeds are enough to rupture the bonds of organic compounds, leading only to a mysterious excess of carbon in moon rock that has often been claimed.

Mars is most likely to be the first external planet where the detection of life will be confirmed. In view of recent discoveries of microbial life in the harshest environments on the Earth, the possibility of microbial life on Mars must be close to certain. A major goal of the space probes Viking 1 and Viking 2 that landed on Mars on 20 July and 3 September 1976 was in fact to search for microbial life. Indeed the discovery of life on Mars may have already been made in 1976 by

Gil Levin, a Principal Investigator on this mission, but regrettably went unnoticed. A recent thorough re-examination and reappraisal of all the 1976 Viking data has confirmed that the only viable explanation of the results obtained from the Viking probes is on the basis of extant life on Mars.

It is a sad commentary that in the many robotic missions that have since landed on Mars not a single life-detection experiment was included. There is a touch of irony in that in future sample-return missions to Mars, in which rock samples will be brought back to Earth, elaborate "planetary protection" measures are to be adopted to take care of the contingency that microorganisms might be brought back from Mars — even, perhaps, microbes that may be pathogenic to humans!

Since 1976 there been many space missions to Mars. They have found evidence of subsurface water, dried-up river beds as well as methane in the upper atmosphere, all of which suggest that microorganisms could still live in specialised niches close to the surface. And in the distant past, when rivers flowed on Mars, much more abundant life was possible.

NASA's Curiosity Rover equipped with the most sophisticated mobile laboratory landed on the Gale crater of Mars on 6 August 2012 and is billed to spend several years probing for signs of past and even present life — albeit indirectly. If extant Martian life is found it can only be regarded as a long overdue confirmation of a discovery already made by Levin in 1976.

Another project of considerable interest is the proposed *in situ* exploration of three of Jupiter's icy moons, Callisto, Europa and Ganymede, the funding for which was approved by ESA (the European Space Agency) in 2012. All three of these Jovian moons have tidally-heated subsurface liquid oceans, and so are likely homes for life. Although this mission will not be launched for another decade and would reach Jupiter only in 2030, the prospect of a major astrobiology breakthrough at this time remains a strong possibility.

The search for habitable planets outside our solar system has gathered momentum following the launch of NASA's Kepler Mission in 2009. This mission deploys a 0.95 metre orbiting telescope to detect planets using "the method of transits", a procedure that looks for periodic dips in a star's brightness as an orbiting planet comes in front to partially block out the light from the star. Over 1000 definite detections of extra-solar system planets (or exoplanets) have been confirmed up to August 2012. Due to an observationally determined selection bias, most of the planets so found happen to be gas giants (Jupiter-like or Neptune-like) in close orbits around their parent stars. However, a few planets have been detected that are similar to giant Earths orbiting their parent stars at a distance that would permit liquid water to exist at the surface, and therefore capable of supporting life.

Perhaps the most interesting recent exoplanet discovery is Kepler 22b, a planet orbiting a G-type (Sun-like) star (Kepler 22) located in the constellation of Cygnus about 600 light years away. This planet has a radius roughly 2.4 times that of the Earth and lies within the habitable zone of a Sun-like star (G-dwarf). Further searches are expected to show up many similar exoplanets in the near future, and current estimates of the total number of such alien Earths in the galaxy run into tens of thousands, within a radius of 1000 light years from the sun. With the deployment of larger space telescopes for exoplanet studies as are currently being planned, spectra of planets like Kepler 22b could be obtained in the near future. We may hope to find chemical fingerprints of gases like water vapour, oxygen, ozone, carbon dioxide and methane that could reveal signs of life.

Besides planets that are in orbit around parent stars there is also a great deal of evidence of free-floating interstellar planets, and their total number could exceed the number of stars by factors of thousands (Wickramasinghe *et al.*, 2012). Such interstellar planets would not have their surfaces heated by the radiation of parent stars, but they could have interior domains of water kept liquid and warm by radioactive heat sources.

Evolutionary Predictions

The predictions of the cosmic-life theory included those related specifically to biological evolution (Hoyle and Wickramasinghe, 1979, 1981). We argued that if comets brought the first life to Earth 4 billion years ago, the process of microbial additions from comets must have continued throughout geological time, and consequently played a role in evolution. Such considerations were later extended to a model where genetic products of local evolution on a planet like the Earth were distributed and mixed on a galactic scale. We argued that comet impacts, such as happened at the K/T boundary 65 million years ago leading to the extinction of the dinosaurs, causes the inevitable splash back into space of DNA fragments that carry the products of local evolution (Wallis and Wickramasinghe, 2004; Napier, 2004; Wickramasinghe *et al.*, 2010). Even partially destroyed DNA strands belonging to life-forms that evolved locally could carry the information of life far and wide (Wesson, 2011). In this model similar impact episodes and gene distribution events would happen recurrently whenever the cloud of comets surrounding our planetary system is disturbed by the gravitational effect of a passing interstellar cloud. We estimate the *average* time interval between successive impact episodes to be about 40 million years, so that from the time when life first appeared on Earth some one hundred such gene distribution events would have taken place (Wickramasinghe *et al.*, 2010). We estimate that genes from Earth would thus have infected millions of nascent planetary systems throughout the Milky Way.

Since we cannot consider the Earth or our own solar system to be unique in this regard, it has to be assumed that similar gene dissemination processes operate for every life-bearing planet in the galaxy. As a consequence, the biosphere in which Darwinian evolution occurs must extend beyond our solar system to encompass a large fraction of the volume of the Milky Way. The stochastic nature of gene acquisition events resulting from encounters with molecular clouds leads naturally to a stochastic component of biological evolution — e.g. sudden jumps, as is apparently observed in the Earth's record of life.

Explicit Predictions from 1982

In *Proofs that Life is Cosmic*, (Hoyle and Wickramasinghe, 1982) pp. 73, 74 we wrote as follows:

“If we had knowledge that evolution was an entirely terrestrial affair then of course it would be hard to see how viruses from outside the Earth could interact in an intimate way with terrestrially-evolved cells, but we have no such knowledge, and in the absence of knowledge all one can say is that viruses and evolution must go together. If viruses are incident from space then evolution must also be driven from space. How can this happen? Viruses do not always attack the cells they enter. Instead of taking over the genetic apparatus of the cell in order to replicate themselves, a viral particle may add itself placidly to one or other of the chromosomes. If this should happen for the sex cells of a species, mating between similarly infected individuals leads to a new genotype in their offspring, since the genes derived from the virus are copied together with the other genes whenever there is cell division during the growth of the offspring....

A gene that happens to be useful to the adaptation of one life-form may be useless to another. Incidence from space knows nothing of such a difference, however, the gene being as likely to be added to the one form as the other. So genes that become functional in some species may exist only as nonsense genes in other species. This again is true. Genes that are useful to some species are found as redundant genes in other species. Suppose a new gene or genes to become added to the genotype (genome) of a number of members of some species. Suppose also that one or more of the genes thus added could yield a protein or proteins that would be helpful to the adaptation of the species. The cells of those members of the species possessing the favourable new genes operate, however, in accordance with the previously existing genes, and thus a problem arises as to how the new genes are to be switched into operation so as to become helpful to the species.... As potentially favourable genes pile up more and more, a species acquires a growing potential for large advantageous change, it acquires the potential for a major evolutionary leap, thereby punctuating its otherwise continuing state of little change — its 'equilibrium'...."

The process of horizontal gene transfer (HGT), which is now amply documented (Keeling and Palmer, 2008; Boto, 2010), provided the commentary to this quotation. The cosmic theory of life *requires* that genes which are the products of evolution in some distant cosmic location (comets or planets) can, on occasion, be transferred to evolving lifeforms on the Earth (Hoyle and Wickramasinghe, 1979, 1982).

In this way evolutionary advantage or novelty could be acquired by terrestrial organisms on a stochastic basis, whenever alien genetic material carrying new information is introduced to the Earth and becomes accessible to terrestrial biology. We thus inadvertently proposed an astronomical process of horizontal gene transfers — transfer of genetic information across normal mating barriers on a cosmological scale — before it was firmly demonstrated to operate as a process within terrestrial biology.

There is now compelling evidence to support a once contentious view that HGT provides an important source of new genes and functions to recipient organisms and also a driving force for evolution. It has also been recognized that the operation of horizontal gene transfer has foiled attempts to reconstruct ancient phylogenetic relationships in the search for a Last Universal Common Ancestor (LUCA) in the tree of life (Jain *et al.*, 2003). It is becoming clear that there was probably no such entity localized on the Earth but rather a cosmic ensemble of genes that has an antiquity comparable perhaps with the age of the Universe itself (Joseph and Wickramasinghe, 2011; Gibson *et al.*, 2011).

From all the available data we can infer that sudden shifts in evolution, the emergence of new traits and even the arrival of new species occurs through horizontal gene transfers rather than by the slow neo-Darwinian process of mutations and natural selection (Keeling and Palmer, 2008). Although the occurrence of neo-Darwinian evolution is not denied, it would probably be dwarfed by horizontal gene transfers in the long term. The phenomenon described by biologists as "punctuated equilibrium", where long periods of evolutionary stagnation are punctuated by sharp episodes of innovation and progress, is consistent with cosmically mediated gene transfers. The long periods of slow evolution are due to Earth-bound neo-Darwinian processes where no external gene inputs occurred (Wickramasinghe, 2012).

Viral Sequences in Genomes

Sequencing the human genome has been one of the most remarkable scientific developments of the new millennium. It has led to a wide range of discoveries that are transforming our ideas about viruses, disease and evolution (Venter *et al.*, 2001). One surprise was that the number of genes in human DNA (sequences coding for proteins) was as small as 20,000–25,000 rather than over 100,000 as had hitherto been suspected. Another surprise was that 50% of our DNA consists of sequences ultimately attributable to viruses. The best documented sequences correspond to so-called endogenous retroviruses — RNA viruses that reverse transcribe their RNA into DNA — which make up 8% of our DNA. Their significance in causing disease as well as contributing to evolution is only just coming to be understood, and many astounding correspondences with our 1979–81 statements quoted earlier cannot be overlooked (Wickramasinghe, 2012).

The new evidence from genome sequence studies points to frequent episodes of retroviral infections (of which HIV is an example) not only in humans, but in almost all mammalian species. De Groot *et al.* (2002) have identified an entire repertoire of genes known as (MHC class 1 genes) in chimpanzees that confer immunity against chimpanzee-derived simian immune deficiency virus (similar to human HIV). The inference is that modern chimp populations represent descendents from the survivors of a HIV-like pandemic that very nearly culled the entire ancestral chimp line in the distant past. The Hoyle–Wickramasinghe contention that HIV was an invader from space was much ridiculed when we first suggested it, but recent developments would appear to restore it at least to the realm of reasonable hypothesis.

The process by which viruses are “endogenised” and included in host genomes is not confined to retroviruses. A non-retrovial RNA transcript appears to have been incorporated in the germ line of several mammalian species, including rodents around 40 million years ago (Horie *et al.*, 2010). Bacterial infection can also leave an imprint on genes. A recent paper has shown that two immunomodulatory genes (known as SIGLEC), related to bacterial infection, are inactive in humans, but not in related primates (Wang *et al.*, 2012). The conjecture is that these genes when they were fully active could have been targets for a lethal bacterial infection that nearly culled the human population in the past, perhaps 100,000 years ago.

In our writings in the 1980's and 1990's we suggested that it would be prudent to maintain a microbiological surveillance of the stratosphere in a search for incoming potential pathogens so that vaccines may be developed, if necessary, to avert a future pandemic (Hoyle, Wickramasinghe and Watkins, 1986; Hoyle and Wickramasinghe, 1990). We predicted that, in general, weeks to months would elapse between the introduction of viral particles at the top of the stratosphere and their descent to ground level. This would give enough time for action. The time may well be ripe to consider instituting planetary protection protocols for such a contingency, before a devastating pandemic provides macarbe proof the theory of cometary panspermia.

My journey that began in the serene tranquillity of the English Lake District in autumn of 1961 has, after more than half a century, led to where I now stand. The rustic charm of the Old Dungeon Ghyll Hotel and my fireside discussions with Fred on cosmic dust are now distant memories, and so also is my first experience of wearing mountaineering boots and clambering up the craggy peaks of Langdale. The journey described in this book in search of our cosmic origins led far beyond Langdale pikes, through wild, unchartered and treacherous country. We faced danger at every turn, and conflict with adversaries. But true to the spirit of the indomitable mountaineer we plodded on, resolutely overcoming obstacles, our sights set on a distant Utopia where the true nature of our cosmic origins will be revealed for all to see. Such a goal at last appears within reach, and our ideas that were once considered heretical are moving imperceptibly into the realms of orthodox science. Our cosmic ancestry can no longer be denied. Terrestrial life originated and evolved from cosmic bacteria, augmented by genes that were also of cosmic origin. But the precise manner and process by which non-living matter in Universe turned into life in the first instance may remain a problem that eludes us for generations to come.