The Future of Life and the Future of our Civilization

JOHANN WOLFGANG GOETHE
UNIVERSITÄT
FRANKFURT AM MAIN

The Future of Life and the Future of our Civilization

Edited by

Vladimir Burdyuzha
Russian Academy of Sciences, Moscow, Russia

Springer

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN-10 1-4020-4967-6 (HB)
ISBN-13 978-1-4020-4967-5 (HB)
ISBN-10 1-4020-4968-4 (e-book)
ISBN-13 978-1-4020-4968-2 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

www.springer.com

Printed on acid-free paper

**Dedicated to the memory of Carl Sagan (USA)
and Joseph Shklovskii (Russia)**

Contents

Preface xiii

Declaration “Protection of Life and our Civilization” xv

Part I Life as a Space Phenomenon

The Spread of Life Throughout the Cosmos 3
Chandra Wickramasinghe

Our Understanding of the Evolution of the Sun and its Death 23
Nami Mowlavi

Planetary Cosmogony: Creation of Homeland for Life and Civilization 31
Alexander V. Bagrov

Impact Phenomena: In the Laboratory, on the Earth, and in the Solar System 41
Jacek Leliwa-Kopystyński

Part II The Origin of Life

The Structural Regularities of Encoding of the Genetic Information in DNA Chromosomes 57
Anatolyj Gupal

The Origin of Life on the Earth: As a Natural Bioreactor Might Arise 63
Mark Nussinov and Veniamin Maron

Volcanoes and Life: Life Arises Everywhere Volcanoes Appear 65
Oleksandr S. Potashko

Lessons of Life 67
Christian de Duve

Human Evolution: Retrodictions and Predictions 69
David R. Begun

Man's Place in Nature: Human and Chimpanzee Behavior are Compared 83
Toshisada Nishida

Creative Processes in Natural and Artificial Systems (Third Signal System of Man) 85
Abraham Goldberg

Part III Conservation of Life

Human Alteration of Evolutionary Processes 97
John Cairns, Jr.

The Danger of Ruling Models in a World of Natural Changes and Shifts 105
Nils-Axel Mörner

Ecological Limits of the Growth of Civilization 115
Kim S. Losev

The Potential of Conversion of Environmental Threats into Socioeconomic Opportunities by Applying an Ecohydrology Paradigm 121
Maciej Zalewski

Advances in Space Meteorology Modeling and Predicting - the Key Factor of Life Evolution 133
Mauro Messerotti

Ocean Circulations and Climate Dynamics 145
Mojib Latif

How We Are Far from Bifurcation Point of the Global Warming? 147
Oleg Ivaschenko

Mankind Can Strive Against the Global Warming 149
Michel E. Gertsenstein, Boris N. Shvilkin

Can Advanced Civilization Preserve Biodiversity in Marine Systems? 155
Menachem Goren

Can We Personally Influence the Future with Our Present Resources? 165
Claudius Gros, Kay Hamacher, Wolfgang Meyer

World Energy Development Prospects 179
Anatoly Dmitrievsky

Energy in the Universe and its Availability to Mankind 187
Josip Kleczek

Deuterium Explosion Power 201
N.P. Voloshin, A.S. Ganiev, G.A. Ivanov, F.P. Krupin, S.Yu. Kuzminykh, B.V. Litvinov, Leonid Shibarshov, A.I. Svalukhin

Accelerating Changes in our Epoch and the Role of Time-Horizons 205
Kay Hamacher

Mathematical and Spiritual Models: Scope and Challenges 217
Jose-Korakutty Kanichukattu

Future of our Civilization: Benefits and Perils of Advanced Science and Technology 219
Ting-Kueh Soon

Dark Energy and Life's Ultimate Future 231
Ruediger Vaas

Digital Aspects of Nature and Ultimate Fate of Life 249
Hoi-Lai Yu

Spirals of Complexity - Dynamics of Change 251
Don-Edward Beck

Part IV How Can We Improve our Life?

Nutrition, Immunity and Health 255
Ranjit Chandra

Human Races and Evolutionary Medicine 257
Bernard Swynghedauw

Bacteria in Human Health and Disease:
From Commensalism to Pathogenicity 263
Helena Tlaskalova-Hogenova

Is there a Solution to the Cancer Problem? 265
Jarle Breivik

Are Embryonic Stem Cells Research and Human Cloning
by our Future? 267
Lyubov Kurilo

Defeat of Aging - Utopia or Foreseeable Scientific Reality 277
Aubrey de Grey

Cardiology in XXI Century 291
Sergei Konorskiy

Cancer Problem in the Eyes of the Skin Multiparameter
Electrophysiological Imaging 307
Yuriy F. Babich

Perspective of Quantum Medicine 321
Volodymyr K. Magas

There are 6 Million Tons of Brain Matter in the World,
Why do We Use it so Unwisely 335
Boris N. Zakhariev

Conservation of Biological Diversity 349
John Skinner

Dialogue among Civilizations as a New Approach
for International Relations 351
Mohammad R. Hafeznia

New Proposals to Conserve Life and Civilization 361
Vladimir Burdyuzha, Oleg Dobrovol'skiy, Dmitriy Igumnov

Part V What is our Future

Eco-Ethics Must be the Main Science of the Future 367
Brian Marcotte

The Vital Tripod: Science, Religion and Humanism for Sustainable Civilization 369
Bidare V. Subbarayappa

HIV/AIDS and the Future of the Poor, Illiterate and Marginalized Populations 379
Rajan Gupta

Ocean Settlements are a Step in the Future 401
Kenji Hotta

Futurology: Where is Future going? 403
Roman Retzbach

Towards Sustainable Future by Transition to the Next Level Civilization 411
Andrei P. Kirilyuk

The Future of Solar System and Earth from Religious Point of View 437
Kamel Ben Salem

Part VI Are We Alone?

The Life-Time of Technological Civilizations 457
Guillermo A. Lemarchand

Calculating the Number of Habitable Planets in the Milky Way 469
Siegfried Franck, Werner von Bloh, Christine Bounama and Hans-Joachim Schellnhuber

Participants 483

Index 489

Preface

Our second Symposium "The Future of Life and the Future of our Civilization" was held in May of 2005 year in Germany (Frankfurt am Main). The first one "The Future of the Universe and the Future of our Civilization" was held in July of 1999 year in Hungary (Budapest and Debrecen). The late professor George Marx from Eotvos University was Chairman of Local Organizing Committee (LOC) in Budapest. In Debrecen professor Denes Berenyi from Institute of Nuclear Research was Chairman of LOC.

After Symposium in Hungary a thought was created to hold a new one to discuss the Future of Life. Practically 6 years came after Budapest's meeting. At first the thought was to hold such Symposium in two stages. The Symposium might be begun in India (Rerikh's places in Himalaya) and then might be continued in Greece since Greece is a motherland of our Civilization. But India and Greece were rejected owing to financial problems. It is necessary to remember the late French professor Michel Bounias from University of Avignon who took in participation on all stages of organization of these Symposiums. Professors Jiannis Seiradakis also as and Athina Geronikaki of Thessaloniki University helped me very much before transfer of Symposium of Greece in Germany.

In January of 2004 year was a critical moment since Symposium in Thessaloniki might be wrecked (any money were absent). In this moment professor Claudius Gros of Saarland University proposed to transfer our Symposium in Germany. We quickly wrote the proposal to Volkswagen Foundation and in November of 2004 year a positive reply was already. Thus Claudius Gros saved this situation and our Symposium was held in Frankfurt/Main in May (2-6) of 2005 year where Claudius was Chairman of Local Organizing Committee.

The Scientific Org. Committee (SOC) had 13 members: Mohammed Al-Malki (S.Arabia); Michel Bounias (France); Vladimir Burdyuzha (Russia); Claudius Gros (Germany); Rajan Gupta (USA); Mohammad Reza Hafeznia (Iran); Hans Haubold (Austria); Vadim Kvitash (USA/Ukraine); Elia Leibowitz (Israel); Nils-Axel Morner (Sweden); Bidare Subbarayappa (India); Helena Tlaskalova (Czech Rep.) and Maciej Zalewski (Poland).

Advisory Committee had 11 members: Georgio Bertorelle (Italy); John Cairns (USA); Anatoliy Dmitrievsky (Russia); Lev Fishelson (Israel);

brey de Grey (UK); Guillermo Lemarchand (Argentina); Emil Skamene (Canada); Marcelo Sorondo (Vatican); Jiannis Seiradakis (Greece); Hoi-Lai Yu (Taiwan) and Raymond Zeltz (France).

The Symposium in Frankfurt/Main "The Future of Life and the Future of our Civilization" (modeling and predictions) was dedicated to the memory of outstanding Scientists: CARL SAGAN (USA) and JOSEPH SHKLOVSKII (RUSSIA).

This Symposium was an interdisciplinary one. Questions of Life safety were discussed in detail. As the professor George Marx in Budapest as and the professor Claudius Gros in Frankfurt have shown self sacrifice practically in all questions of holding of the Symposiums. In Frankfurt more than 50 scientists of different countries have participated. Among participants a Nobel Prizeman -Christian de Duve (Belgium) was also.

After long discussions we have prepared a Declaration "Protection of Life and our Civilization" which is opened for a signature in Internet - **http://archive.future25.org/Symposium05/declaration.html**

In preparation of the Declaration Ruediger Vaas (Germany), Bidare Subbarayappa (India), Lev Fishelson (Israel), Aubrey de Grey (UK) and Rajan Gupta (USA) have taken in part very actively.

The main thought of the last Symposium can be formulated as: conservation of the natural biota in the sufficient volume is the key problem of Life preservation and stability of our Civilization. Besides, an ecological sustainable development in our anthropogenic systems is impossible in principle after excess of a carrying ecological capacity. Unfortunately we have already overstepped the first ecological limit. Other words a new history of our Civilization must be built that would agree with laws of the biosphere.

A superior science and technology and an inferior moral are a combination that dynamically unstable. Unfortunately this is our modern world. The analysis of Dr. G. Lemarchand has shown that we would need to wait between 30-500 years in order to generate a violent event at which the whole human population will disappear.

In conclusion the quotation of Dr. J. Kleczek is appropriate: "The Earth is our cosmic home moving around Sun like a lonely spaceship with 6 billion human beings on board. It is a blue fragile Beauty with its own energy sources which are limited and soon will be depleted"

Oleg Ivaschenko (Ukraine) and Alexei Alakoz have helped me very much for the preparation of the Proceedings. Besides, I would like to thank Professor C. Gros and Frau M. Kolokotsa for excellent organization of our Symposium in Goethe University of Frankfurt/Main in May of 2005 year.

Vladimir Burdyuzha, Chairman of SOC, 20 March of 2006 year.

DECLARATION
PROTECTION OF LIFE AND OUR CIVILIZATION

Preamble

The world-wide community of scientists forms a unique society that aims to discover universal truths. Academic Andrei Sakharov once noted that “The formula $E = mc^2$ holds true on all continents”. Sadly, some important discoveries of this community continue to be used for destructive purposes. The three particularly alarming issues that we wish to raise are:

(I) The application of science for the production of armaments and other military technology that have not succeeded in preventing human conflicts and wars;

(II) The fast pace of application of technology leading to degradation of the environment and emerging ecological imbalances that continue to erode the symbiotic relationship between man and nature; and

(III) The continued poor state of value placed on life and on the basic human right to live with dignity, freedom and harmony.

Today we are witness to many bloody conflicts and other destructive activities (trans-national criminals, drug-dealers, terrorism, etc). Even the basic human right - the right to life - is often not guaranteed. It is important that scientists all over the world collaborate to protect and improve our lives and our civilizations, based on the common moral principles as defined in the UN declaration of the rights of man. Many of these intertwined issues were deliberated upon by a group of scientists, technologists and environmentalists at an International Symposium “The Future of Life and the Future of our Civilization” held at the Goethe University in Frankfurt/Main (Germany) during 2-6 May 2005 and they unanimously adopted the following Declaration.

Declaration

Being deeply concerned over the poor state of national and international affairs, global changes, ecological catastrophes, continued investment in ever more powerful weapons, arms races and international conflicts that are undermining the future of mankind; and recognizing the paramount importance of the active involvement of scientists, technologists and other intellectuals in addressing these problems and finding viable solutions to them:

We, the participants in the Symposium on "The Future of Life and the Future of our Civilization", unanimously recommend at an "INTERNATIONAL CENTER FOR STUDY OF THE FUTURE" be established under the auspices of the UN or one of its Agencies.

This Center should draw upon the expertise of leading scientists, technologists, economists, sociologists, and others from different parts of the world to suggest effective measures for the protection of life and our civilization.

Such a Center should be international and independent of political and religious influences, and through careful and unbiased analysis create consensus that advises governments and other policy making bodies or individuals.

The Center should track, analyze and provide long term prognosis of the spectrum of events that may affect the safety and well being of life on the Earth. These should include catastrophes due to military applications in space or to events of ecological, technological, atmospheric or hydrospheric nature.

The Center should seek to bring together preeminent specialists from throughout the world, and bring to bear all available methodologies to provide solid, scientifically-based predictions and proposed solutions.

THE OBJECTIVES OF THE PROPOSED CENTER SHOULD BE:

a. to collect and analyze information about any events with the potential to threaten the safety of life on Earth;
b. to provide scientific and analytical support to the many branches of the UN;
c. to reduce and mitigate losses due to ecological and socio-economic disasters;
d. to reduce and eventually to stop the production and distribution of all weapons. In particular international controls and restrictions on the weapons of mass destruction should be adhered to, starting first by the actions of scientists.

e. to strengthen efforts towards promotion of peace and harmony among all different peoples of the world.

f. to protect basic human rights and to evolve an international order built upon a solid foundation of openness, dialogue, transparency and good-neighbourly relations.

We express our hope that international laws will be enacted and acknowledged by all nations. Violation of the safety of our planet should be considered a grave crime against humanity.

We propose that all countries reduce their military investments by 0.1 % every year and the money thus saved should be used to provide health care and education to all people. In addition, individuals, foundations, and non-governmental organizations should be encouraged and empowered to continue to work with the poor and the needy.

We consider that a scientific approach to analyzing, anticipating and resolving issues related to the long term health and safety of our planet and its citizens must constitute the very foundation of the center.

We have a choice: to stress the environment beyond its capacity for regeneration and to live with conflict, war, poverty, hunger and disease, as we are doing today, or to embrace a new dawn and create freedoms and opportunities for all. It is time to take a stand!

In full concurrence and support thereof, we affix our signature below.

Affiliation	Name and Family Name	Country	Signature

This variant of Declaration was prepared by Rajan Gupta. It is practically the same as and in Internet and it is open for a signature.The Internet address is: **http://archive.future25.org/Symposium05/declaration.html**

I

LIFE AS A SPACE PHENOMENON

The Spread of Life Throughout the Cosmos

Chandra Wickramasinghe

*Cardiff Center for Astrobiology, Cardiff University, 2 North Road,
Cardiff, CF10 3DY, UK*

There is growing evidence for the widespread distribution of microbial material in the Universe. A minuscule ($<10^{-21}$) survival rate of freeze-dried bacteria in space ensures the continual re-cycling of cosmic microbial life in the galaxy. Recycling and amplification occurs within comets during the early phases of the formation of a new planetary system. Evidence that terrestrial life may have come from comets has accumulated over the past decade. The implications of this point of view, which was developed in conjunction with Fred Hoyle since the 1970's, are now becoming amenable to direct empirical test by studies of cometary material collected in the stratosphere.

1. Introduction

The standard theory for the origin of life begins with a primordial atmosphere on the Earth in which the synthesis of the chemical building blocks of life (e.g. amino acids) from inorganic gases occurs through the action of solar ultraviolet radiation and electric discharges. Organic molecules so formed are then supposed to rain down into the primitive oceans producing a dilute soup. In such an exceedingly dilute solution reaction rates would be minimal and biochemistry hard put to produce all the complex chemical transformations needed for an origin of life. It is therefore proposed that evaporation of water from shallow lakes and ponds, and at the margins of the sea led to sufficient concentrations of organics for prebiotic chemistry to proceed, and after millions of years a self-replicating living cell is postulated to arise. This was essentially the model proposed by Oparin and Haldane [1], which was at least partly vindicated by the work of S.L. Miller [2] over 50 years ago. The formation of the relatively simple chemical

V. Burdyuzha (ed.), The Future of Life and the Future of Our Civilization, 3–21.

building blocks of life was demonstrated, but the further steps leading to life remained elusive.

The highly specific and exceedingly intricate complexity of living organisms at a molecular level is self-evident, and it is clear that no significant progress has been made in 50 years towards understanding how the information gap between a non-living mixture of organic molecules and life could be achieved. For instance, Margulis [3] has stated that to proceed "….from a bacterium to people is less of a step than to go from a mixture of amino acids to that bacterium". Moreover we have no definite knowledge by which we can assert that this step ever happened on the Earth – namely that a *de novo* origin was localized to a tiny speck of 'cosmic dust' that is the Earth. The super astronomical information gap between non-life and life provides, in the view of the author, the main justification for considering theories of origin that involve the universe as the whole. The final information content of life could have been arrived at by a cumulative addition of truly minuscule probabilities in self-replicable partial stages that are repeatedly and serially impressed on a vast cosmic system. This process must be envisaged to take place over cosmological timescales, and to involve the resources of all the stars in all the galaxies in the entire universe.

2. Rationale for Panspermia Theories

There is no logic that demands an origin of life on the Earth. The fact that life is found on the Earth does not mean that life necessarily started here. The Earth is not disconnected from the wider Universe, or sealed away from cosmic contaminants. Even today cometary organic molecules arrive here plentifully, at an average rate of tens of tones per day. Thus a chain of connection:

Earth → Comets → Presolar nebula → Interstellar clouds → stars → Galaxy → Universe can be envisaged.

Living material contains about twenty different types of atoms, the most important being carbon, nitrogen, oxygen and phosphorus. The ultimate source of origin of these chemical elements is stellar nucleosynthesis – the process by which the primordial element H is converted first to He and then to C, N, O and heavier elements in the deep interiors of stars. Thus at the level of the constituent atoms we are indisputably creatures derived from the cosmos.

From the 1970's onwards, astronomers discovered a host of organic molecules in interstellar clouds, and since 1986 similar molecules were also found in comets. These discoveries prompted Fred Hoyle and the present author [4-5] to re-examine the ancient theory of panspermia, which insists that life is a cosmic phenomenon, and that life on Earth is derived from a vast cosmic system.

Louis Pasteur's classic experiments [6-7] in the 1850's and 1860's, in which he showed that microorganisms are always derived from pre-existing microorganisms, provided perhaps the most important experimental basis for panspermia. Indeed this was a conclusion that was reached quite early in 1874 by the German physicist Hermann Von Helmholtz [8]:

"It appears to me to be fully correct scientific procedure, if all our attempts fail to cause the production of organisms from non-living matter, to raise the question whether life has ever arisen, whether it is not just as old as matter itself, and whether seeds have not been carried from one planet to another and have developed everywhere where they have fallen on fertile soil...." (these ideas were also discussed in [9].)

The next noteworthy proponent of panspermia at the dawn of the 20th century was the Swedish Chemist Svante Arrhenius [10]. In 1908 Arrhenius noted that microorganisms possess unearthly properties, properties that cannot be explained by natural selection against a terrestrial environment. The example for which Arrhenius himself was responsible for taking seeds down to temperatures close to zero Kelvin, and of then demonstrating their viability when reheated with sufficient care. Arrhenius conceived of microorganisms travelling individually through the galaxy from star system to star system. He noticed that organisms with critical dimensions of 1 micron or less are related in their sizes to the typical radiation wavelengths from dwarf (sun-like) stars in such a way that radiation (light) pressure can have the effect of dispersing these particles throughout the galaxy.

3. The Survival Problem

Space-travelling individual bacteria would be susceptible to deactivation and damage from the ultraviolet light of stars, and this was already known in the first decades of the twentieth century. Becquerel [11] criticized panspermia on the basis of possible ultraviolet damage of space-travelling microbes, and similar criticisms were repeated ever since, even in modern times [12]. These arguments are either flawed or highly insecure, however. Even under normal laboratory conditions microorganisms are not readily killed by ultraviolet, they are mostly deactivated due to the dimerization of pyrimidine bases. No genetic information is lost in the process and in many instances the damage can be repaired by the operation of specialized enzymic systems. Dimerization of bases distorts the DNA configuration and has the effect of impeding transcription. Exposure of UV radiated bacteria to visible sunlight is known to promote repair.

No data exists at the present time relating directly to the effects of ultraviolet radiation on bacteria under cryogenic conditions and in the absence of air and water, conditions such as would apply in interplanetary or interstellar space. It should also be pointed out that microorganisms are easily shielded against ultraviolet light. Indeed molecular clouds in the galaxy are highly effective in this respect, both in cutting out the glare of ultraviolet radiation and permitting the growth of protective mantles around bacterial particles. Thin skins of carbonized material around individual bacteria, only 0.02 μm thick, would also effectively block the damaging ultraviolet light [13].

On the whole microbiological research of the past 10 years has shown that microorganisms are remarkably space-hardy. Thermophiles are present at temperatures above boiling point in oceanic thermal vents, and as we have already pointed out entire ecologies of psychrophilic and psychrotrophic microorganisms are present in the frozen wastes of Antarctica. A formidable total mass of microbes also exists at great depths in the Earth's crust, some 8 kilometers below the surface, greater than the biomass at the surface [14]. A species of phototrophic sulfur bacterium has been recently recovered from the Black Sea that can perform photosynthesis at exceedingly low light levels, approaching near total darkness [15]. There are bacteria (e.g. *Deinococcus radiodurans*) that thrive within the cores of nuclear reactors [16]. Such bacteria perform the amazing feat of using an enzyme system to repair DNA damage, in cases where it were estimated that the DNA was experienced as many as a million breaks in its helical structure.

Most modern objections to panspermia have been based on arguments relating to cosmic ray survival [12] – it being claimed that cosmic ray exposures in space over hundreds of thousands of years would prove fatal for microorganisms. These criticisms are again highly dubious and, moreover, fail to take account of the fact that the replication power of bacteria is so great that only a minute ($\sim 10^{-21}$) survival is required at each regeneration site between periods of freeze-dried dormancy in the interstellar medium.

Ionizing radiation limits viability by dislodging electrons, causing bond breaks in the DNA and by forming reactive free radicals. The radiation doses that seriously compromise viability in cultures depend critically on the particular bacterial species, and as mentioned earlier some species such as *B. subtlis* and *D. radiodurans* are more resistant than others. In vegetative cultures, under laboratory conditions, doses equivalent to 2 megarads (2Mr) have been found to limit residual viability of *Streptococcus faeciuim* by a factor of 10^{-6} (Christensen [17]), whereas similar doses have little or no effect on cultures of *D. radiodurans* or *M. radiophilus* (Lewis [18]).

The doses of ionizing radiation received by a bacterium in interplanetary space within the solar system depends on distance from the Sun and the phase of solar activity, being highest at times near the peak of the solar sunspot cycle. In a recent NASA/LDEF (Long Duration Exposure Facility) experiment, direct exposure of spores of *B. subtilis* to unshieded solar radiation for 2107 days was found to lead to significant rates of survival (Hornek et al., [19]). The survival of common species of bacteria near the Earth's orbit for about a decade therefore seems well-attested.

The dose of cosmic rays received by a naked bacterium in a typical location in interstellar space, over a timescale of a fraction of million years, can at present be only very poorly estimated. It is possibly in the range 10-45 Megarad per million years. Doses of this order are of course higher that the doses that have been delivered to laboratory cultures where survival is well-attested. Yet the exposure conditions in space, where two successive cosmic ray ionizing events are separated by about 100 years, would be dramatically different from those pertaining to the laboratory experiments.

A low flux of ionizing radiation in space delivered over astronomical timescales to dormant freeze-dried bacteria (in the absence of H_2O and air) would perhaps bear no comparison with equivalent doses on vegetative cultures in the laboratory. The nearest terrestrial analogue might be for microbial spores that have been exposed to the natural radioactivity of rocks for geological timescales. Indeed viable cultures of bacteria have been recovered from ice drills going back 500,000 years, from isolates in amber over 25-40 million years [20, 21] and from 120 million year old material [22]. Similarly bacteria have been recovered in salt crystals from a New Mexico salt mine dated at 250 Myr (Vreeland et al., [23]). The present day dose rate of ionizing radiation on the Earth arising from natural radioactivity is in the range 0.1-1 ryr^{-1}. These well-attested recoveries of dormant bacteria/spores after 10^8 yr must therefore imply tolerance to ionizing radiation with total doses in the range ~10-100Mr.

4. Interstellar Organic Molecules and Dust

Notwithstanding the remarks of the previous sections some fraction of cosmic bacteria which have no protective coatings and which are exposed remorselessly to cosmic rays and to the background of starlight in unshielded regions of interstellar space would be subject to degradation and eventual destruction. The polyaromatic hydrocarbons that are so abundant in the cosmos could have a similar origin to the organic pollutants that choke us in our cities – products of the degradation of biology, biologically generated fossil fuels in the this case, cosmic microbiology in the interstellar clouds. The theory of cosmic panspermia that we propose leads us to argue that interstellar space serves both as a graveyard of cosmic life as well as its cradle. Only the minutest fraction (less than one part in a trillion) of the interstellar bacteria needs to retain viability, in dense shielded cloudlets for instance, for panspermia to hold sway.

My own interest in panspermia began with attempts to understand the nature of cosmic dust [24]. Interstellar dust grains populate the vast open spaces between stars of the Milky Way, showing up as a cosmic fog, dense enough in many directions to blot out the light of distant stars. Remarkably these dust grains can be shown to be of a size that would be typical for a bacterium, a micrometer or less.

A fact that impressed me from the outset was that the total mass of interstellar dust in the galaxy is as large as it possibly can be if all (or nearly all) the available carbon, nitrogen and oxygen in interstellar space is condensed in the grains. The amount is about three times too large for the grains to be mainly made up of the next commonest elements, magnesium and silicon, although magnesium and silicon could of course be a component of the particles, as would hydrogen, and also many less common elements in comparatively trace quantities.

If one now asks the question: what precisely are the dust grains made of, a number of inorganic molecules composed of C, N, O in combination with hydrogen present themselves as possible candidates. These include water ice, carbon dioxide, methane, ammonia, all such materials being easily condensable into solids at temperatures typically of about 20-50 degrees Kelvin, which is the average temperature of the dust grains in space. During the decade starting from the early 1960's Fred Hoyle and I studied the properties of a wide range of inorganic grain models, comparing their electromagnetic properties against the formidable number of observations that were beginning to emerge. Such models stubbornly refused to fit the available data to anything like the precision that was required. The correspondences between predictions for assemblies of inorganic particles and the observations could be lifted to a certain moderate level of precision but never beyond that, no matter how hard one tried.

It was a milestone in our progress towards interstellar panspermia when I realized that there is another very different class of materials that can be made from the same four commonest elements - C, N, O, H, namely organic materials, possibly of a polymeric type [25]. Of course there are a vast number of organic compositions that are possible, making for a great number of further investigations that could be done. By the mid-1970's, the astronomical observations were spanning a large range in wavelength, from 30 microns in the infrared, through the near infrared, into the visible spectrum, and further into the ultraviolet. So a satisfactory theory of the nature of interstellar dust grains had by now to satisfy a very large number of observational constraints.

In 1979 Fred Hoyle and I stumbled on a result that led to many further discoveries, all of which pointed in the direction of panspermia. As already noted bacterial grains in interstellar space would be freeze-dried. Freeze drying of a bacterium would ensure that free water in the cell diffuses out of the porous cell wall leading to the development of a vacuum cavity.

The volume of the vacuum cavity for a typical bacillus amounts to about 60% of the total, and the resulting average refractive index of the entire structure is readily calculated as $n = 1.16$. Next we require a distribution of sizes for the bacteria, which was available in the literature for spore-forming microorganisms (see Figure 1).

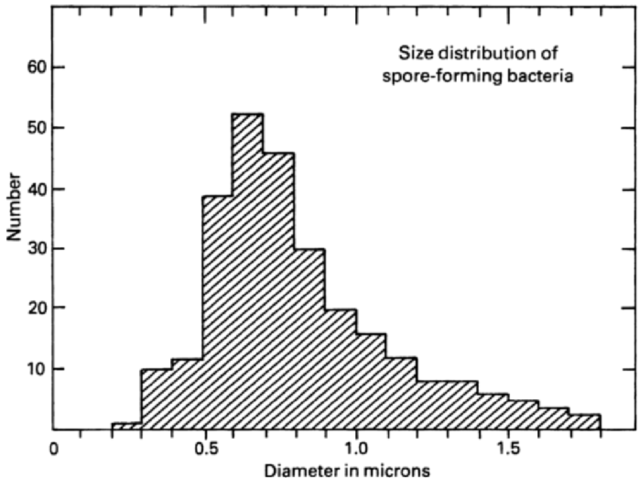

Fig. 1. Histogram of diameters of spore forming bacteria.

When the extinction of this ensemble of freeze-dried bacteria was calculated, the result compared with the astronomical data on the dimming of starlight is shown in Fig. 2.

I was indeed dumbfounded to find a result so good after so many years of failure to obtain a satisfactory fit using highly contrived inorganic models. Once the proposition is made that "interstellar grains are bacteria" there is no further room for maneuver – the model is completely defined. But for the astronomical data further in the ultraviolet another refinement was required. Added to the bacterial population we need two further components derived from biology: non-hollow viruses and/or nanobacteria contributing 29% to the total mass, and free biological aromatic molecules, which would be the most stable subunits and molecules to result from the degradation of unshielded bacteria in space. The combination of these components leads to the curves depicted in Fig. 3

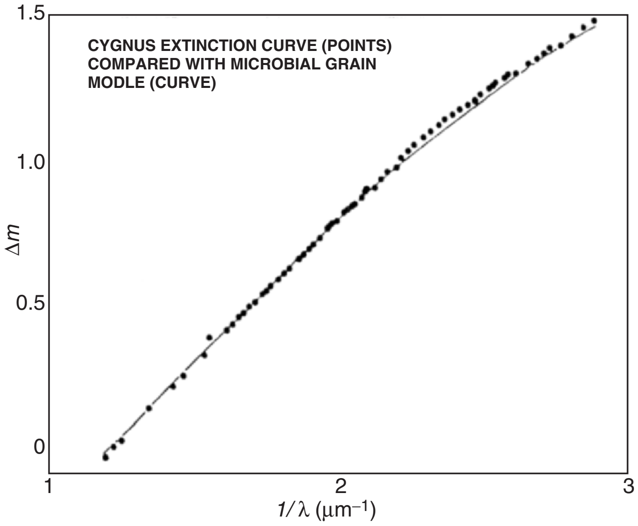

Fig. 2. Bacterial extinction over the visible spectrum compared with interstellar extinction data.

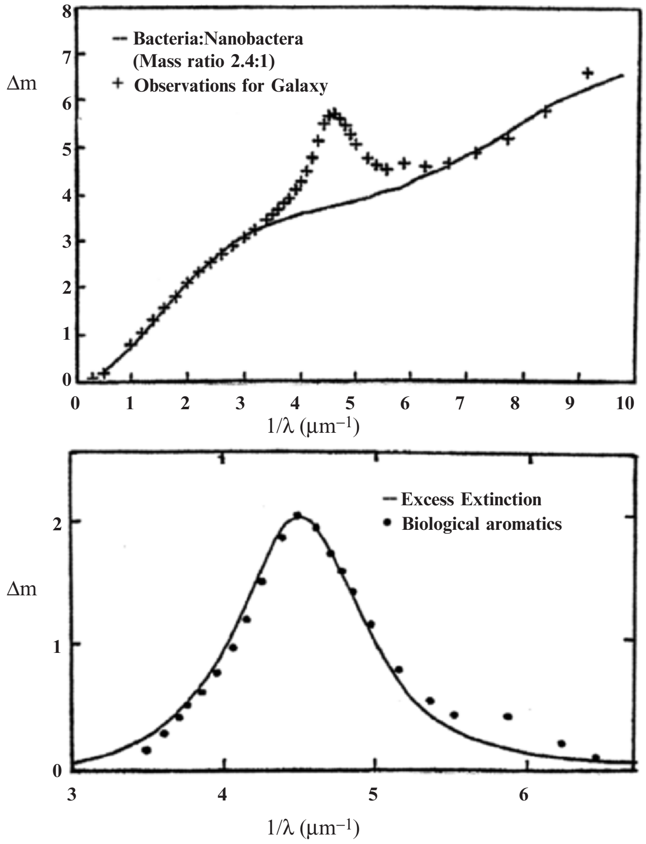

Fig. 3. **Top**: Interstellar extinction data over the 0.2-10 μm waveband compared with scattering by freeze-dried bacteria and nanobacteria. **Bottom**: Excess extinction over the mid UV band compared with absorption by an ensemble of biologically derived aromatic molecules.

Perhaps the most startling confirmation of the bacterial model followed the observations [26] of a source of infrared radiation, GC-IRS7, located near the center of our galaxy. The spectrum of this source revealed a highly detailed absorption profile extending over the 2.9-3.8 micrometre wavelength region, indicative of combined CH, OH and NH stretching modes. A laboratory spectrum of the desiccated bacterium *E. Coli*, together with a simple modeling procedure provided an exceedingly close point by point match to the astronomical data over the entire 2-4 micron waveband (Fig. 4).

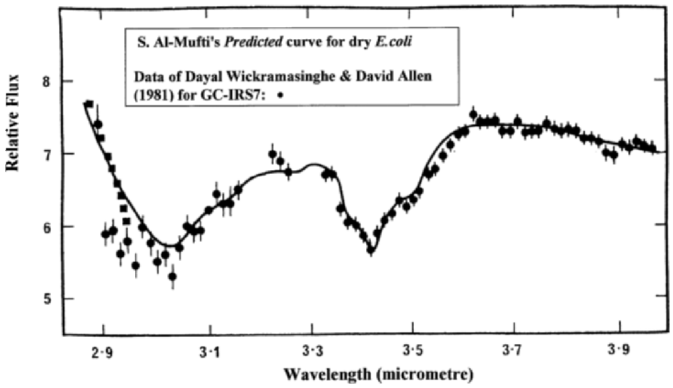

Fig. 4. Infrared spectrum of GC-IRS7 compared with bacterial model.

At this stage we found there was no alternative but to face up squarely to the conclusion that a large fraction of the interstellar dust was not merely hollow and organic, but they *must* spectroscopically be indistinguishable from freeze-dried bacterial material. In our galaxy alone the total mass of this bacterial type material had to be truly enormous, weighing a formidable 10^{33} tons.

5. Replication in Comets

By far the simplest way to produce such a vast quantity of small organic particles everywhere of the sizes of bacteria is from a bacterial template. The power of bacterial replication is immense. Given appropriate conditions for replication, a typical doubling time for bacteria would be two to three hours. A continued cascade of doublings with unlimited access to nutrients would lead to a culture that enveloped the interior of a 10km radius comet in less than a week. No abiotic process remotely matches this replication power of a biological template. Once the immense quantity of organic material in the interstellar material is appreciated, a biological origin for it becomes an almost inevitable conclusion.

An individual comet is a rather insubstantial object. But our solar system possesses so many of them, perhaps more than a hundred billion of them, that in total mass they equal the combined masses of the outer planets Uranus and Neptune, about 10^{29} grams. If all the dwarf stars in our galaxy are similarly endowed with comets, then the total mass of all the comets in our galaxy, with its 10^{11} dwarf stars, turns out to be some 10^{40} grams, which is just the amount of all the interstellar organic particles.

How would microorganisms be generated within comets, and then how could they get out of comets? We know as a matter of fact that comets do eject organic particles, typically at a rate of a million or more tons a day. This was what Comet Halley was observed to do on March 30-31, 1986. And Comet Halley went on doing just that, expelling organic particles in great bursts, for almost as long as it remained within observational range. The particles that were ejected in March 1986 were well placed to be observed in some detail. No direct tests for a biological connection had been planned, but infrared observations pointed unexpectedly in this direction. An independent analysis of dust impacting on mass spectrometers aboard the spacecraft Giotto also led to a complex organic composition that was fully consistent with the biological hypothesis [27]. Broadly similar conclusions have been shown to be valid for other comets as well, in particular Comet Hyakutake and Comet Hale-Bopp. Thus one could conclude from the astronomical data that cometary particles, just like the interstellar particles, are *spectroscopically* identical to bacteria.

In summary, the logical scheme for the operation of cometary panspermia is as follows: The dust in interstellar clouds must always contain the minutest fraction of viable bacteria (less than one in 10^{21}) that retain viability despite the harsh radiation environment of space. When a new star system (e.g. a solar system) forms from interstellar matter, comets condense in the cooler outer periphery as a prelude to planet formation. Each such comet incorporates, at the very least, a few billion viable bacteria, and these bacteria are quickly reactivated and begin to replicate in the warm interior regions of the comets, thus producing vast numbers of progeny. As a fully-fledged stellar or planetary system develops, comets that plunge into the inner regions of the system release vast quantities of bacteria. Some of the evaporated bacterial material is returned into the interstellar medium. New stars and star systems form and whole cycle continue with a positive feedback of biologically processed material.

6. Oldest Life on Earth

Along with the accumulation of astronomical evidence supporting panspermia in one form or another there has also been evidence from geology. The earliest evidence for terrestrial life has now been pushed back beyond 3.83 billion years BP, well into an epoch when we know for certain that the Earth was severely pummeled by comet and meteorite impacts [33]. This evidence comes in the form of a slight enhancement of the lighter isotope of carbon 12C relative to 13C in the oldest metamorphic rocks. The argument is that life has a slight preference for the lighter isotope of carbon and this is reflected in the carbon extracted from rocks that could date back to about 4 billion years. Whilst the early epoch of heavy bombardment would not have been conducive to prebiotic chemistry, it would nevertheless have offered ample scope and many occasions for the transfer of cometary life to Earth. It is interesting to note that this mechanism for transfering life from comets to Earth would permit some types of microbial life adapted to high pressures and subsurface conditions to become trapped in a stable way. As the impacts of comets and asteroids continued to add material to the Earth's crust in the last stages of the "late accretion epoch" a deep hot biosphere [14], such as we now have, would easily have been generated. So also could microbial life in thermal vents of a deep sea to be explained as representing a primordial habitat that accommodated the most heat resistant of the microbes that arrived from space.

7. More Evidence of Microbiology Outside the Earth

We have discussed earlier how modern microbiology has yielded a wealth of new discoveries relating to 'unearthly properties' of microorganisms. Furthermore, from recent explorations of the solar system we know that other planetary bodies besides Earth might have conditions appropriate to serve as habitats for microbial life. For instance, the Jovian satellite Europa, with growing evidence of its subsurface oceans beneath a frozen crust, provides many opportunities for a highly developed microbiota. Life may even be present in the clouds of Venus. Whilst the surface of Venus is too hot to sustain life, there is an intriguing possibility of an aerobiology thriving in the Venusian clouds. Dirk Schulze-Makuch and his colleagues have recently pointed out that 30 miles above the surface there are droplets of water and chemical tell-tale signs of life. They had expected to find high levels of carbon monoxide, but instead found hydrogen sulphide and sulphur dioxide, gases normally not found together and also carbonyl sulphide, a gas so difficult to produce by inorganic chemistry that it is generally considered to be a marker for living organisms. Likewise with new evidence of liquid water on Mars, there could be plenty of scope for microbial life in secluded subsurface niches.

According to theory described in this paper life on Earth began with the introduction of microorganisms from comets. It is clear, however, that this process could not have stopped at some distant time in the past. Comets have been with us throughout, and the Earth has continued to plough through interplanetary and cometary dust. In our view the evolution of terrestrial life is controlled and directed by the continuing input of cometary debris in the form of bacteria, fragments of bacteria, nanobacteria and smaller particles such as viruses and viroids. It is well known that viral genes sometimes come to be included in the genomes of cellular lifeforms, and that such genes could serve as potential for further evolution. Without this input of cometary genes life on Earth could not have evolved beyond the stage of a simple ancestral microbe.

There are several recent reports of genes that appear to be older, when dated by the rate of sequence variation, than the composite systems or species, in whose genomes they are included [34, 35]. Other reports show that genes required by more highly evolved species may reside without evident function in the genomes of prokaryotes [36] or viruses [37]. One cannot help but notice that these findings corroborate the concept of cosmic bacteria and cosmic genes.

8. Present-Day Tests

A direct way to test the theory of cometary panspermia is to examine a sample of cometary material under the microscope and search for signs of microbial life. Comets are literally at our doorstep and the technology to carry out the relevant microbiological experiments has been available for at least a decade. The basic procedure would involve collection of cometary material as it enters the stratosphere, with suitable precautions being taken to eliminate spurious contamination from terrestrial sources, and then examine the samples for extraterrestrial microorganisms. With a daily input of cometary debris averaging some 100 tons, the possibility of detecting infalling microbes must surely exist.

The earliest experiments to search the upper atmosphere for microorganisms were carried out using high altitude balloons in the early to mid-1960's. Although microbiological techniques available at the time were primitive compared to the present, there were already some intriguing indications of the presence of extraterrestrial microbes in air samples collected at heights of 30 km and above [38]. Positive detection of microorganisms at 39 km and a population density that increased with height pointed to a possible extraterrestrial source. Not surprisingly these early results were not taken seriously, nor were they followed up at a later date by NASA with more refined experiments as the relevant microbiological techniques evolved.

The sample return mission "Stardust", which was launched on 7 February 1999 heading to Comet Wildt-2 (rendezvous date, 2 January 2004;

return 2006) was conceived and planned before a change of attitude to panspermia took place. In the event no microbiological experiments as such were catered for. The comet dust is to be captured in a "particle catcher" filled with aerogel, a material of extremely low density. The hope is that the aerogel would act as a soft landing cushion to show down particles from an initial relative speed of 6.1 km/s to rest fairly gently, without significantly modifying original chemical structures. The thinking behind the experiment was to bring back prebiotic organic molecules. No provisions were made for the possibility that living cells might be present, so the best one might hope for when we get samples back in 2006 is the intervention of serendipity. Perhaps one might find evidence of "dead bacteria" or other clues for life in the molecules that are recovered.

The stratospheric collection experiments of the 1960's have also been resumed by the Indian Space Research Organization (ISRO) in collaboration with groups at Cardiff and Sheffield. The aim was to collect stratospheric air aseptically, and to examine it in the laboratory for signs of life [39]. The sample collection was done using a number of specially manufactured sterilized stainless steel cylinders that were evacuated to almost zero pressures and fitted with valves that could be open and shut at different heights in the atmosphere. An assembly of such cylinders was suspended in a liquid Ne environment to keep them at cryogenic temperatures, and the entire payload launched from the TATA Institute Balloon launching facility in Hyderabad, India on 20 January, 2001. As the valves of the cylinders are opened upon ground telecommand at predetermined heights, ambient air rushes in to fill the vacuum, building up high pressures within the cylinders. The valves are shut after a prescribed length of time, the cylinders hermetically sealed and parachuted back to the ground.

Back on the ground the cylinders were carefully opened and the collected air made to flow through sterile membrane filters in a contaminant free environment. Any bacteria or clumps of bacteria present in the stratosphere would then be collected on these filters.

In the first phase of this investigation evidence for the presence of clumps of viable cells were discovered in air samples collected from as high as 41 kilometres, well above the local tropopause (16 km), above which no aerosols from lower down would normally be transported [40, 41]. The detection was made using a fluorescent dyes which are only taken up by the membranes of living cells. When the isolate treated with the dye is examined under an epifluourescence microscope the picture on the left of Fig. 5 is obtained. The picture on the right is an image from an electron microscope which shows a similar structure comprised of cocci and rods. The variation with height of the distribution of such cells indicates strongly that the clumps of bacterial cells are falling from space.

Dr. Milton Wainwright of the University of Sheffield was further able to isolate a culture of two organisms: one micrococcus and one microfungus closely related to known species which must therefore have fallen from the skies. The daily input of such biological material is provisionally estimated to be in the range one third to one ton over the entire planet.

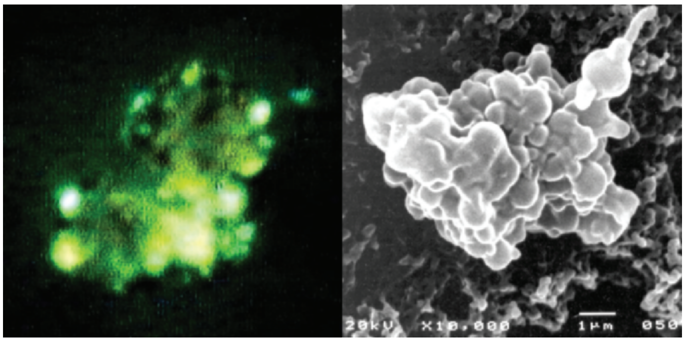

Fig. 5. **Left:** Clump of viable bacteria fluorescing in cyanine dye. **Right:** Scanning Electron Microscope picture of similar structure showing clump of cocci and a rod.

Work to verify these results are in progress, with ISRO launching a new balloon-borne cryosampler in April 2005. If these findings are confirmed panspermia would cease to be a theory, it would have become a fact.

9. Distribution of Life Beyond the Galaxy

The transfer of life across extragalactic distances requires the pre-existence of the elements C,N,O and other metals in adequate quantity, which implies access to regions where star-formation is under way. Spectroscopic studies of nearby galaxies have also shown evidence of advanced stages of nucleosynthesis and chemical evolution involving large quantities of carbonaceous material suitable as a feedstock for life, often including evidence of CO and H_2CO and other organic molecules in the gas phase.

The most efficient intergalactic transport of biological information can be achieved with microbes attached onto iron whiskers, such as are important for explaining aspects of the cosmic microwave background. Such metallic whiskers have diameters typically 0.02μm and lengths about a millimeter and they condense naturally in expanding envelopes of supernovae, as metallic vaporous cool [42]. These whiskers, along with their