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AEROBIOLOGY TO ASTROBIOLOGY

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INTRODUCTION

The multidisciplinary branch of aerobiology has definitely evoked great interests due to tis variety of practical significance. Considerable development and rapid progess in Aerobiology is mainly due to intensive and extensive works by our agrobiologists. Several branches like Aerobacteriology, Aeroviriolgy, Aerophycology, Aeromycology, and Aeropalynology are the outcome of extensive investigation.

I sincerely hope that you would kindly agree when I lay more emphasis on microbes in the upper air and space. Earlier efforts to search for microbes several kilometers up from the surface of Earth were initiated by aerobiologists with several limitations. Fred C. Miers(1934-38) tried to trace spores in upper airspora by aircraft sampling. Unfortunately, he along with his crew was lost in flight due to aircraft disaster and could be never traced again. However,Miers's idea and hopes have become a reality in Aerobiology.

Some Indian workers like Dr.Mrs. Shymala Chitale of Nagpur and Prof. Agashe of Bangalore also ventured for aircraft sampling and had presented excellent results of airspora from upper atmosphere.

With most modern infrastructure, 'Sky is not the Limit' scientists have now initiated studies for microbes in space, which have provided ample evidence of the existence and spread of .microbiai forms and still surviving under the space environment. I would be more enthusiastic in reviewing the work and dwell upon the new branch Astrobiology which has kept the scientists busy all over the world and Indian Astrobiologists are leading in some forefronts.

"Who can trace the aerial course of The Spore" - Lang (1934).

SPACE ENVIRONMENT

The stratosphere, third major layer of the Earth's atmosphere, is just above the troposphere and ranges in height between 10 km to 50 km. The temperature here rises with altitude-from about –100°C at bottom to 3°C at the top. The heating is due to ozone layer that absorbs ultraviolet radiation from the Sun. Here the environment is hostile for the life forms. Recently, 3 species of bacteria so far unknown on the Earth, have been located from the stratosphere which are highly resistant to ultraviolet radiation. These new species have been named as *Janibacteria hoylei*, *Bacillus isronensis* and *Bacillus aryabhattai.*

In all 12 bacterial and six fungal species were detected, nine of which showed greater than 98% similarity with reported known species from Earth. The findings may not be useful in extraterrestrial origin of microorganisms but may be helpful in revisiting the origin of life.

Flight technology has enabled biological studies of space. It is the urgent need of the hour to define environment envelope for life as well as conditions conducive to the origin of life from the hydrothermal to atmospheric to hypersaline parameters.

Researches for detecting live particles over Earth's surface was a field of a aerobiologist; space biology, exobiology and astrobiology, which are probable culminations of search of live particles, it is hoped, would solve the unsolved extraterrestrial riddles of extraterrestrial life forms and origin of life.

PANSPERMIA

The theory of Panspermia as proposed by Richter (1865), Lord Kelvin (1894) and Arrhenius (1903) holds that reproductive bodies ot living organisms can exist throughout the universe and develop wherever the environment is favourable. This implies that conditions favourable to the development of life prevails at different locations in the universe and at different times. Major criticisms of Panspermia are that living organisms will not survive long exposure to space and that it avoids the issue when life began. However, the results of the long duration Exposure facility and Bio-Pan Space experiments have clearly shown that the microbes can survive in space as well as the fact that organic compounds have been found in meteorites led to the re-examination of the feasibility of interplanetary travel of living microbial forms.

Space as an environment is extremely cold, subjected to unfiltered solar radiation, solar wind, galactic radiation, space vacuum and negligible gravity. Space is a nutritional wasteland with reference to water and organic compounds although comets may provide an oasis when passing a Warming Star.

Only the microbial terrestrial forms are likely to survive these conditions with comets or meteorites as conveyance. Microgravity is not lethal, cold tolerance and anhydrobiosis are survivable. It is not possible to know the nutritional requirements in transit unless we understand transit times. One can hypothesize that with exceedingly low metabolic rates resulting from the extremes in cold and desiccation, nutritional needs would not exist or be minimal. The maximum damage to microbes exposed to space is more due to UV radiation; however, heavy ionizing radiation is probably lethal.

Some terrestrial organisms, however, can survive in this highly extreme environment. The flight experiments by European Space Agency with American collaboration have

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indicated that some terrestrial forms can survive in the extreme environment. Microbes tested in the space and then brought back to Earth include *B. subtilis* spores, Bacteriophage T-1, Tobacco Mosaic Virus and Osmophilic microbes. *B. subtilis*, spores would survive for years in space when in bilayer (or multilayer) or mixed with glucose to protect them against high solar UV radiation flux; however, when they are exposed in a monolayer they are killed instantly. For comparison sake, viruses lose viability by weeks. However, the data is controversial; *D. radiodurans* could not survive 7 months in space and the DNA had extensive breakage. Halophiles can survive for two weeks in space and probably much longer. The halophiles are the first example of a vegetative cell surviving exposure to the space environment.

EXTREMOPHILES

Extremophiles have provided useful information to molecular biology including information on protein folding. Evolutionary biology has benefited on two fronts. Firstly, in the race to trace the most extreme of extremophiles, new taxa have been discovered increasing phylogenetic enlightenment. Secondly, the ability to survive in some extreme environments has evolved multiple times, leading to a new understanding of chance versus necessity in evolutionary pathways, specially at a molecular level. For example, the ice binding antifreeze proteins are evolutionary convergent with that of the Antarctic notothenioid fish evolving from a pancreatic trypsinogen-like protein (Rothschild and Manchelli, 2001, Nature vol. 40922, Feb 2001).

Extremophiles are most useful in agricultural chemical synthesis, laundry detergents and pharmaceuticals. From 1982, the European Commission has supported research, training and commercialization of technology. The extremophiles projects have been largely funded as "**Cell factories**" and now is in the phase of industry-sponsored technology. Enzymes obtained are stable and functional in economically preferred environments such as high or unstable temperatures.

"Extremozymes" enzymes from extremophiles have the potential to be realized in multiple areas. The fast growth of extremophiles is economically advantageous in gene expression in traceable host such as *E.coli*.

In the recent years, the space scientists are more optimistic about the transport of microbes in space. The seeds of life are meant here as prebiotic chemicals for which enough evidence is available for cometary microorganisms. With the report of the discovery of microfossils in Martian meteoritet (McKay et. al. 1996) "Panspermia" again came to the forefront.

Comet dust was collected by "particle catcher" filled with aerogel, the lowest density material known to exist. Aerogel provides soft loading of collected particles; however, there is no clarity that the integrity and viability of bacterial spore would be preserved after crash in gel. Such discoveries may be helpful for cometary life in future.

In early 1960, experiments were conducted to determine microbial content of the upper space environment. Through simple technology, however, these provided some indications of extraterrestrial microbes in air samples collected at 30 km and above (Bruch,1967; Lysenko, 1979). The detection of microbes at 39 km height and increase in population density is suggestive of a possible extraterrestrial source. However, this programme was not continued as it did not reach the expected results.

Recently, Naralikar *et al*. (2003) conducted a series of balloon experiments using modern microbiological techniques which are now in use by the Indian Space Research Organization (ISRO), the Inter-University Centre for Astronomy and Astrophysics (IUCAA) in collaboration with Cardiff University, Cardiff, U.K. Such samples include cometary aerosols which are analyzed for chemical and microbiological studies.

The results of biological studies of a cryosampler flown with a balloon, in which air samples were collected at altitudes ranging from 20 to 41 km, well above the Tropopause over Hyderabad, are described. In the analysis carried out in Cardiff, voltage-sensitive dyes that could detect the presence of viable cells were used on these air-samples. Clumps of viable cells were found to be present in samples collected at all the altitudes. The images obtained from electron microscopy are consistent with the above finding. Reference is also made to another paper presented at this conference describing the identification of bacterial species in the sample carried out in Sheffield. Counter arguments are discussed against the criticism that the detected cells and microorganisms (in the samples collected above the local tropopause at 16 km) are due to terrestrial contamination.

It has been estimated that for possibly microscopic dust to Earth, average flux is around F = 500 metric tones (Chyuba *et al.,* 1990). Of this, a fraction is of bacterial particles.

There is now increased evidence to suggest that microorganisms in a non-vegetative nutrient -starved condition have smaller sizes. (Pflug, 1984; Pflug and Heinz, 1998; Hoyle *et al*., 1985).

A positive detection of cometary microorganisms would have significantly important scientific consequences. The presence of extraterrestrial life forms and its relationship with terrestrial forms once established would be most fruitful in furthering scientific investigations.

These microbes have been drifted by upward wind currents. The report of microbial forms at high altitudes has aroused great interest with increased activity of space aerobiology.

Another interesting discovery from the outer space in the galaxy of stars is about the live particles. These live particles have been detected in freezing clouds. Micro-particles of ice which were seen floating contained live particles which were in contact with strong UV radiations. This initiated important reaction in particles of ice and atoms were converted into amino acids, which constitute basic substances (Prebiotic Particles) for protein formation, a pre-requisite for life. Scientists claim that from such ice particles, the galaxy and earth might have originated.

Experiments conducted in the laboratory under similar conditions like –258°C temperature, strong radiation produced Glycine, Alenine, Serene and other amino acids. Investigations of meteorite "Marchinson" have indicated presence of 17 types of amino acids. This has again initiated search for life and its origin in meteorites.

Two types of possibilities have been expressed. The theories of water reaction hold that in early years of universe big meteorites were formed or both actions resulted in formation of amino acids.

The discovery of extreme environments and the life forms that inhabit them has again encouraged renewed search for life forms in the Universe. The concept of extremophiles has added new dimensions for space aerobiology.

Extremophiles have also provided useful data of basic importance to molecular biology and a pathway to find out extremophiles (McKay *et al*., 1996; Murschigan, 1997; Munakata *et al*., 2000). The ability of microbes to survive under various extremes of environment is a unique feature. Extremophile research is now entering in an exciting and fascinating phase of agriculture, human health, biotechnology, bioremediation and space aerobiology.

Space is extremely cold with unfiltered solar radiations, solar wind, galactic radiation, space vacuum and negligible gravity. Space forms a nutritional wasteland with respect to water and organic compounds although comets may provide an oasis when passing a warming star.

Recently Naralikar (2003) had announced about the extraterrestrial origin of "Sars" virus ("Lancet" Jan, 2003). The evidence suggests that extraterrestrial microbes can reach Earth's surface in viable condition and can initiate deadly diseases not known earlier.

Influenza virus in 1918 which reached Bombay and Boston is also suggestive of extraterrestrial origin. Sars virus reached Himalayan Peaks and then reached the Plains of Himalayas subsequently reaching China and India causing epidemics.

Search for "Alien" is now on about the microbial life on other planets. Dust of comets and meteorites may be useful sources for extraterrestrial life and may serve as evidences of possible life forms.

The occurrence of Nanobacteria of an average radius 10^{-6} cm as an important component of microbial form in space is significant.

Several examples of the Extremophiles both from Earth's environment and space environment in stratosphere have come forth. The report of Nanobacteria in the Stratosphere is an important discovery. It has been also noted that bacteria in comet dust and meteorite dust are well protected from extreme environment and can survive for many years.

Continuous search for life is on, on several planets like Mars, Jupiter and Moon which are mostly considered as unsuitable for any life forms with the good news about ISRO's launch of Oceasat -2 and nine other Satellites, ISRO's Chandrayan has played important part in confirming water traces below the Martian surface. Water is expected subject to confirmation. Space voyages are now poised between barren Moon and Promising Mars. The implications of the possibility of existence of water on Moon would make the Moon as a space station. (Better Environment is the prime concern : 27/ 9/2009).

Liquid water is the "*sine qua non*" of life on Earth and also of any life in the solar system. Life requires energy input and it must be able to control energy flow. As life is based on organic chemistry, such chemistry must be allowed to operate. An extremophile must either live within these parameters or guard against the outside world in order to maintain these conditions intracellularly.

Could life survive the extreme conditions of the Martian Surface? Hypothetically it is suggested that it may be possible. Moncinelli and Klovstad (2000) observed that monolayer of 10 µm thick can help survival by UV radiation flux for weeks and some terrestrial microbes might survive on Mars.

Soon we would be able to establish the truth behind "Panspermia". Some examples are coming forth for the establishment of the migration of live spores. On the other hand, some reports of extraterrestrial life forms are also reaching the Earth's surface. Question remains to be answered about the origin of life on Earth. With the establishment of space stations, space biology would certainly contribute in solving several riddles. The time is not far off and, any moment firm answers would be ready.

Vatican's Pontifical Academy of Science was holding first ever conference on alien life in November 2009. (DNA 11 Nov. 2009, Pune). This discovery would have profound implications from the Catholic Church (The Telegraph).

Louis (2003; 2009) reported **RED RAIN** phenomenon from Kerala. The first rain fell in the district of Kottayam and Idduki in the Southern Part of the State. Other colours including yellow, green and black were reported. The occurrence of the coloured rain were witnessed over the first ten days of the phenomenon. This was followed by less frequent downpours until late

September. The colouration of the rain was due to particles in suspension in the rain water. At times, the collected water was as red as blood. Typically, it fell in very localized areas, not more than a few square kilometers and for about 20 minutes per shower.

The mysterious red rain of Kerala is due to cometary delivery of red spores into the stratosphere above Kerala.

Shivaji *et al*. (2006) isolated four novel bacterial strains from cryogenic tubes used to collect air samples at altitudes of 24, 28 and 41 km. The four strains were identified as members of the genus *Bacillus* and are new species.

Qualitative and quantitative distribution of microorganisms in the upper troposphere-stratosphere (10- 85 km) altitude in various parts of Earth are significantly important as these are helpful: (a) in determining the role of various atmospheric strata in the transport of microorganisms from one part of the globe to another (b) to test the theory that microorganism might exist in space (Hoyle and Wikramsinghe, 1986, 1993, 1999) and constitutes a part of hundred of tons of materials that enters the atmosphere each day from space (Love and Brown lee, 1993). It is now well recognized that microorganisms can survive the harsh adverse conditions of the upper atmosphere and the rigors of the Outer Space (Bruch, 1967). Theoretical studies by Bruch (1967) indicated that it is possible for microorganisms of appropriate size to escape outer space and thus be transported from one planet to another.

Shivaji *et al*. (2009) isolated three novel bacterial strains from cryotubes from 27 to 41 km, based on phenotypic characteristics and chemotaxonomic features. The three strains identified represent 3 novel species e.g., *Janibacter hoylei* sp. nov. *Bacillus isronensis* sp.nov. and *Bacillus aryabhattai*.

Conclusions: 1. Bacteria and viruses are airborne and also reach upper air and space. Unique inherent ability helps them to survive hostile environment. 2.Utility of Extremophiles in health bioremediation and agriculture led to the establishment of "Cell Factories". 3.Travel of microbes in space and from one planet to another - "Panspermia" is now a reality. The initial role of aerobiologists in tracing microbes in upper air laid the foundation of modern Astrobiology.

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