SECTION III

PLANETARY, INTERPLANETARY AND INTERSTELLAR ORGANIC MATTER

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INTRODUCTION

A chemistry of life based on carbon and liquid water, such as the one on Earth, has many objective advantages and consequently it is likely to be the most common life process in the Universe. Other alternatives, a good many of which have been proposed in the literature, can not be completely excluded, but the physical and chemical properties of the chemical elements and their relative abundances in the Cosmos, as well as the chemical complexity required by the process of life (more than 100,000 different proteins for each human being) point clearly toward the carbon-water combination. The reasons, more specifically, are the following:

Hydrogen and Helium, which were formed in the first moments of the Big Bang, are the two most common chemical elements, representing more than 98% of the total mass of the Universe and about 99.9% of all the atoms of the Universe. Of all the others, which collectively are called "heavy elements", Oxygen, Carbon, Nitrogen, Neon, Iron, Silicon, Magnesium and Sulfur are the most common, representing close to 98% of all the heavy elements. Helium and neon are noble gases and therefore inert to chemical reactions. Of the remaining, H, O, C, N, Fe, Si, Mg, and S, only C and Si can form long chains and thus have the ability to produce the complicated molecules required by life. The carbon-carbon bonds, however, are twice as strong and the silicon-silicon bonds, and therefore carbon chains are consistently more stable, In addition the chemistry of Carbon is far more flexible. Carbon dioxide (CO_2), e.g.,is a gas that dissolves easily in water where the carbon chemistry continues, while silicon dioxide (SiO_2) is a solid (sand) which does not disolve in water and the silicon chemistry comes to an end. Also silane (SiH_4), the simplest combination of Si and H (the equivalent of methane, CH_4), is very unstable, and in the presence of water vapor decomposes into SiO_2. This explains why in the atmosphere of Jupiter, where Hydrogen is the dominant chemical element, we have detected H_2O, CH_4, NH_3, PH_3, but no SiH_4. Finally even on the surface of the Earth, where silicon is about 600 times more abundant than carbon (carbon compounds are generally volatile and as a result not easy to incorporate into a planet), life still chose a carbon base rather than a silicon base.

Water on the other hand is a polar molecule (extra negative charge near the Oxygen atom and extra positive charge near near the two hydrogen atoms), which makes it an excellent solvent and therefore an ideal medium for chemistry. In addition, Oxygen, which accounts for nearly 50% of all the heavy elements, and Hydrogen which is the most

M. D, Papagiannis (ed.), The Search for Extraterrestrial Life: Recent Developments, 103–106.

common of all the chemical elements, have a great affinity for each other and therefore water is likely to be one of the most common compounds in the Universe. Other potential competition for the medium of life have several disadvantages plus generally lower abundances than water. Ammonia (NH_3), e.g., liquefies at much lower temperatures where chemical reactions become very sluggish and therefore inappropriate for life. Also, it can not co-exist with free oxygen, while water and oxygen co-exist very nicely.

In summary, it appears that life based on Carbon and water is the most realistic possibility. It is interesting also to note that H, O, C, and N, which excluding the inert noble gases represents about 99.5% by weight of all the active chemical elements in the Universe, constitute also more than 98% of the biomass of the Earth. Water seems to be quite plentiful in our Solar System (in comets, in planets as on Earth and Mars, in moon's as on Europa, Ganymede, Callisto, etc.) but unfortunately most of it is in the form of ice. The frequency of planets with liquid water in our Galaxy, is still an unknown question as we have seen in the previous Section. The formation, however, of complex organic compounds from simple molecules, a process often called "Chemical Evolution", seems to be quite common in the Universe, and as we will see in this and in the next Section has been occurring naturally in a great variety of environments (interstellar space, planetary atmospheres, carbonaceous chondritic asteroids, etc.). The Co-Chairmen of the corresponding Session of the Symposium were William Irvine of the University of Massachusetts-Amherst, and Donald DeVincenzi of the NASA Headquarters.

In the first paper of this Section, Carl Sagan and his colleagues discuss the rich chemistry of Titan, the giant moon of Saturn. Titan has an atmosphere of nitrogen with a considerable admixture of methane, and its surface might be covered by oceans of hydrocarbons. The orange-red color and the opaqueness of its atmosphere are most likely due to an aerosol of complex-organic solids which are called "tholins", from the Greek tholos=murky. Laboratory production of tholins by irradiating a simulated Titanian atmosphere, shows that they contain many aminoacids and other organic molecules of importance to life. Large quantities of these tholins might be precipitating to the bottom of the hydrocarbon oceans of Titan, preserving there in deep freeze the early steps of chemical evolution.

Ronald D. Brown of Monash University, Australia discusses the more than 60 different interstellar molecules that have been discovered in interstellar space and in dark nebulae from which new stars and probably planetary systems are formed. Theoretical models developed by R.D. Brown and his colleagues predict with high accuracy the evolution with time of the abundances of different complex organic molecules in dark nebulae. He also discusses the gas phase production of aminoacids and the unsuccessful so far radio search for glycine ($H_2N\text{-}CH_2\text{-}COOH$), the simplest aminoacid, and for glycinonitrile ($H_2N\text{-}CH_2\text{-}CN$), a close relative of glycine, which under certain conditions can polymerize to form directly polypeptides. It seems possible that a significant fraction of the complex organic molecules found in dark nebulae survives the condensation process that leads to the formation of a Solar System, and through impacts by comets and meteorites could become a contributing source of prebiological products on the surface of a young planet. It seems feasible, therefore, that the ancestry of life on a planet could be going all the way back to the molecular cloud from which the Solar System was born.

An international group of radioastronomers from Nobeyama, Japan, the University of Massachusetts, USA, and the Herzberg Institute for Astrophysics, Canada, describes their recent radio searches for organic compounds in nearby cold, dark interstellar clouds, such as the Taurus Molecular Cloud 1 (TMC-1) and report the detection of Tricarbon monoxide (C_3O), acetaldehyde (CH_3CHo) ,cyanadiacetylene (HC_5N) and the setting of upper limits in the first search for cyanocarbene (HCCN).

J. Mayo Greenberg and William Schutte of the University of Leiden, Holland discuss the identification through infrared spectroscopy of complex organic molecules in interstellar grains. These interstellar grains consist typically of a silicon core 0.1 microns in diameter surrounded by coats of molecular ices about 0.05 microns thick. Interstellar grains have lifetimes of about five billion years and regenerate continuously from products of stellar mass-loss. During their long lifetimes, the ultraviolet photoprocessing of their ice coat transforms it into a refractory residue of complex organic compounds. It is estimated that organic refractory material on interstellar grains represents approximately 0.25% of the entire mass of the Galaxy. Direct accretion of such products by planets during passages through dense molecular clouds might be a significant source in enriching their planets with organic compounds of importance to life. Interstellar grains may also aggregate into comets which on occasional impacts might bring large, concentrated quantities of organic compounds to planets.

Clifford N. Mathews of the University of Illinois proposes that heteropolypeptides, potential ancestors of biological proteins, can be synthesized directly from hydrogen cyanide (HCN) and water, with the intermediate formation of polynitriles, without the need to form first alpha aminoacids and then polymerize them into proteins. The direct synthesis of these protein ancestors appears to occur in a variety of cosmic environments, including planetary atmospheres and dusty molecular clouds. This possible pathway suggests that the chemical evolution which may lead to life is a widespread phenomenon in the Universe.

J. Mayo Greenberg and Peter Weber of the University of Leiden, Holland discuss the theory of Panspermia (the idea that spores might carry the seeds of life from one solar system to another) in the light of experimental measurements in their laboratory on the survival of spores under cosmic conditions, i.e., very low temperatures ($10^{\circ}K$) and ultraviolet radiation. In open interstellar space the survival is less than a few thousand years, which is totally inadequate for interstellar trips, but within dense molecular clouds the survival may increase to tens of millions of years. The factors contributing to the much increased longevity are the blocking of the UV radiation by the cloud and the accretion by the spores of a protective molecular coat from the cloud, exactly as it happens with interstellar grains. Molecular clouds therefore might be able to carry live, but dormant, spores from one solar system to another, though there are still considerable hazards at the beginning of the trip, as spores are swept by a molecular cloud from a solar system, and at the end of the trip when they are deposited on a planet of another solar system.

R.E. Davies, A.M. Delluva and R.H. Koch of the University of Pennsylvania present an analysis of UV laboratory spectra of numerous organic compounds, viruses and microorganisms which refute the contention of Karim, Hoyle and Wickramasinghe that UV spectra reveal the presence of proteins, viruses and bacteria in interstellar space.

In the last paper of this Section Ramon D. Wolstencroft of the Royal Observatory, Edinburgh, Scotland, examines the possibility that the chirality of life, i.e., the exclusive selection by all living organisms of only L-aminoacids and D-sugars, might be the result of asymetric photolysis of their D and L counterparts by weakly cirularly polorized daytime light produced by local geomorphological features which celectively obstruct certain path of the sky and thus develop a net polorization for the daylight over the period of a day.

THE EDITOR