The Cosmic History of the Biogenic Elements and Compounds

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Preface

In inviting me to submit these prefatory remarks, the editors were most generous to recall the speculations (Lederberg, J. and Cowie, D. B., *Moondust,* Science 127:1473-1475 (1958)) that had inspired my own interest in the biological exploration of space 25 yr ago. These started from nothing more tangible than staring at the tables of cosmic abundance of the nuclides, and pondering how condensed matter could have evolved without the production of macromolecules.

Few astronomers then unified their images of condensation with the valence theory of chemistry. The overabundance of hydrogen is indeed an embarrassment to remind us that the prevalence of any organic molecules less reduced than methane is out of equilibrium: that fact given, we should be little more surprised to find complex organic molecules in interstellar space than on Jupiter or in the comets. From that perspective, Earth's advantage is in having most of its hydrogen blown away, though not to the extremes that Mars seems to show. That is, an Earth more reduced than our planet would have difficulty in sustaining organic molecules beyond methane: a model inverted from some other conventional representations. If we accept the stability of such molecules on a reduced Earth, why not also in space? Why look later than the primary condensation for the abundance of carbonaceous species that we must postulate as a precondition for the emergence of life? Indeed, any process that permits the large-scale production of oligomeric carbon could hardly avoid its polymerization, opening further questions as to the selective factors that would condition the chemical forms of large-scale condensed matter. Planetary bodies would furnish idiosyncratic local environments; but most of that matter would be found in the relatively homogeneous interstellar space. We could then ask for a unifying cosmic description of the primary modality of chemical evolution. To the biologist, this perspective does not yet advance our understanding of the origin of life — the really difficult enigma remaining still being the progression from random to well-ordered and self-replicating polymers. A cosmic seat of early biological evolution does alter the locus of improbabilities, from the anthropic curiosity that life could start on one planet, to an improbable universe which nevertheless generated life. With what a priori probability we cannot say: does the cosmic condensation already furnish enormous quantities of matter preadapted to the requirements of biological macromolecules? Will we find the raw material of DNA already present there?

These were naive and elementary questions, hardly to be justified even as assertions. Nevertheless, they have been greatly bolstered by the experimental and observational work of the last two decades, as evidenced by the report of this study group.

Perhaps the most foolish bit of wishful thinking expressed in 1958 was the expectation that the surface of the Moon, presumably unweathered, would show some accumulation of primitive condensate. At that time, regolith models with extensive reworking of planetary surfaces by tectonic and meteoritic activity were less widely understood. For the same reason today, we should perhaps be cautious in our expectations of cometary composition; nevertheless,

this doubtless provides the closest approximation to accessible samples of "interstellar matter" we are likely to achieve for some time.

As to Mars, the possibility of life (and certainly of fossil life) should not be written off as quickly as some authors might admit. We have as yet sampled only two (very similar) habitats; there remain many enigmas of fossil drainage patterns, as well as the unexplored polar cap zones.

Altogether, we are at a stage at which each new finding raises many more new questions than it puts to rest; and many of the most trenchant questions are well stated in the study. The greatest value of the intellectual synthesis given in this volume is its provocation of new experiments and measurements focused on very large and important aims – important for theoretical understanding of our own origins, and with grave practical import ranging from earthquakes to energy sources on our own planet.

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