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Question 2: Relation of Panspermia-Hypothesis to Astrobiology

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Abstract In the answer to major questions of astrobiology and chirality, the panspermia-hypothesis is often discussed as the only proposal of transportation of life to the Earth. On the basis of the known presence of ionizing radiation in the space, assumed on the level calculated by Clark (Orig Life Evol Biosph 31:185–197, 2001), the hypothesis is rejected as the explanation of origins of life on Earth. In fact, comparatively low doses of radiation sterilize irreversibly all biological material. Sufficiently long sojourn in space of objects containing prebiotic chemical blocks also does not contribute to the origins of life on Earth, because of elimination of homochirality, if any, and of radiation induced reactions of dehydrogenation, decarboxylation and deamination of chemical compounds closing with complete decomposition of organics, leaving elementary nano-carbon and/or minerals like calcium carbonate.

Keywords Cosmic radiation · Homochirality destruction · Panspermia · Radiation damage · Radiolysis by ionizing radiation

Astrobiology and the related subject of astrochemistry investigate on several aspects of great relevance in modern science. The first deals more closely with Life in Universe whereas the second considers the study of prebiotic chemical compounds present anywhere in the Universe. Both are closely connected to transportation of the material in any directions, and are involved in the origin of life on Earth. The transportation, as described by the hypothesis of panspermia, i.e. of life coming on Earth from outside, even from galaxies, can be traced to Greek philosophers (Luisi 2006). This very old concept is always widely accepted, as long as it is not confronted with actual conditions in the Universe, i.e. with the fact of the existence of invisible, but chemically and biologically active ionizing radiations, of deep penetration, if of low LET – linear energy transfer value. Their intensities are

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sufficiently to easily kill highly organized life and also to inactivate primitive life, if the time of interaction is long enough. Therefore the concept of panspermia has to be analysed critically.

Quantitative relationships were discussed on ISSOL 05 (Zagórski 2006), stressing the chemical mechanism of the irreversible radiation damage. The best informative approach which helps to make an estimate of chances of survival of spores in their travel to the Earth, has been prepared by Benton C. Clark (2001). His diagram shows the dose received by spores (or other forms of Life able to procreate after coming in contact with water and proper nutrients), in the centre of a well defined object of different size, from cosmic dust to asteroids, after an indicated time of sojourn in space. The dose rate assumed by Clark can be discussed, but it is sufficiently precise for estimation of the dose in the function of time of travelling in space, within the protective walls of the described object. Clark's paper is seldom quoted; it is simply nonexistent among enthusiasts of panspermia. On every point of time and space scale of Life in the Universe, radiation chemistry should be considered (Zagórski 2003, 2005).

Quantitative examples show, that after 10 kyr in space, the dose inside the centre of a silicate grain of 3 mm radius is still 29 kGy. Switching to the information gained from man made technology of industrial sterilization of medical products, the mentioned dose means the full sterilization (one surviving bacteria per one million present initially, SAL – sterility assurance level equal 10^{-6}). The different dose rate in outer space and sterilization plant does not matter because slow hydrogen abstraction in dry spores is not repairable and is accumulating; in other words it is independent from the dose rate. Needles to say, smaller objects, like cosmic dust (10 μm radius) reach the same degree of sterility in shorter time (e.g., in less than one hundred years of accumulating the radiation damage). In that case of small objects, characterized by a high surface area to the volume ratio, the shallow penetrating UV is contributing additionally to the damage.

On the other hand, larger objects shield better the very centre of their volume. For example, according to Clark's table, a cobble of 0.3 m average radius, after 1 Myr in space, experiences in its centre the dose of 35 kGy, that means that there is a chance to find only one sleeping spore in a kilogram of the matter in which one million of spores were originally living. It is doubtful if such a spore would survive the entry of an asteroid-similar object to the Earth surface.

However, Clarks table shows more than the time scale and typology of objects where spores will be inactivated. What happens during longer stays, especially to objects of small size like cosmic dust, easily penetrated not only by electromagnetic ionizing radiations like gammas, but also by particles like protons and by heavier ions, present in galactic cosmic rays? These small objects are absorbing mammoth doses of radiation energy, which causes many chemical reactions. Next to the sterilization dose there is the dose (not very much higher) that causes abstractions of fragments of biopolymers or of organic compounds in general. There are many examples of such reactions, the most general is the well known abstraction of a group of atoms which leaves in the molecule a site with unpaired electron.

Another example is the destruction of homochirality. Abstraction of a group, e.g. of ammonia from the α-carbon in an amino acid, turns off the asymmetry of the remaining radical. If the original amino acid was a pure enantiomer, any products of the subsequent reaction will be chiral, but racemic, 1:1 D to L mixture. Hypothetical homochirality of a compound achieved (perhaps) far from the Earth (Keszthelyi 2001) will be lost during the travel.

Moving to higher doses resulting from even longer stays in the Universe, we are turning into the zone of complete degradation, and sometimes even to the disappearance of an organic compound. Radiation induced reactions are dehydrogenations, decarboxylations, deaminations, all irreversible. The final result can depend on the surrounding, whether oxidative in the presence of oxygen, or reducing, or vacuum. In both of these two cases, the final product can be nano-sized carbon dust, and such reaction is called radiation-induced carbonization.

Large objects staying for a long time in space obtain highest dose of ionizing radiation at the surface, gradually diminishing towards the inside. Therefore we can define the profile of effects. The depth dose can be estimated from the Clark table. The surface of the object is the most irradiated part and the best known object is the planet of Mars. Its regolith is not only completely sterilized but also relieved from organics. Perhaps part of organics has been degraded to elementary carbon, present, if so, as black dust moved with thin Martian CO_2-wind. Anyway, chances for detection of organics on the surface of Mars are poor. Similar conclusions have been drawn by photochemists, assuming devastating chemical influence of deep UV reaching the surface of Mars. Their argument is not as strong, because supposed Martian organics show usually no absorption in UV but even in the presence of chromophoric groups the effect is of low importance, because the depth of penetration is shallow. Therefore the deciding influence of ionizing radiation is more important.

The common reaction of abstraction of hydrogen, mentioned in several places in this summary, corroborates well with characteristic feature of organic compounds, identified in interstellar spaces of the Universe. These compounds are as poor in hydrogen as possible, e.g. methyltriacetylene C_7H_4, methylcyanodiacetylene C_6NH_3, cyanoallene C_4NH_4, ketenimine C_2NH_3, cyclopropenone C_6OH_2 and many polyaromatics. The remaining hydrogen atoms are difficult to detach during absorption of ionizing radiation, because they usually belong to structures, mainly polyunsaturated and aromatic, which posses the ability to dissipate the absorbed high energy radiation without ionization, into simple heat, of low quality energy.

The low temperature of space on the route of objects moving in the space is not a protecting factor, neither for spores, nor for simple organic compounds, because radiation induced reactions proceed with low activation energy and chemical effects observed at liquid nitrogen temperatures are not dramatically lower in comparison to those at ambient temperatures. For instance, hydrogen abstraction curves from DNA in the function of dose, at ambient temperature and at 77 K, do not differ very much.

The question remains why the Life on Earth is not destroyed after sufficiently long action of ionizing radiation. The ionizing radiation which impregnates the Universe is reaching the Earth in much reduced intensity, due to the shield of the atmosphere, equivalent to 3 meters of concrete. Even the most penetrating galactic cosmic rays, which reach the Earth in cascades of secondary ionizing radiations are responsible for only small contributions to phenomena in living organisms. Other ionizing radiations coming from outer space, like gamma bursts, proton beams from events in the Sun and other stars, are almost fully absorbed in the shield. Therefore the contribution of space radiation to the radiation background on Earth is only similar to the level supplied by radioactive material on Earth. The fact, deciding of no inactivation of Life on Earth but, vice versa, of even some positive effects, is explained by the mechanism of interaction of radiation with living matter. Whereas the DNA in the living species, i.e. in aqueous suspensions, when damaged slightly by ionizing radiation, indirectly, via radicals from water, can be repaired, the DNA in dry spores is effectively, irreversibly damaged by very first doses of radiation. The effect is additive, and even low doses are damaging, after accumulation of elementary acts, mainly of hydrogen abstraction, over ages. The byproducts of low level radiation damage in solution are possible mutations, like due to many other factors in the environment. Again, they occur only due to the action on living organisms, they do not occur when dry spores are irradiated, where irreversible changes take place.

The soon coming Fifth anniversary of the COST action D27 (Origin of life and early evolution) asks for formulation of conclusions. Intensive, also experimental, investigations connected with panspermia and more, i.e. the chemical actions of ionizing radiation in the Universe, on objects travelling in space, demands revision of some well established opinions. Theoretical considerations as well as experimental simulations show that these objects are not only sterilized, what demands comparatively low doses, but also deprived of its homochirality, if any, and eventually even made free from organic compounds. Therefore there are examples of defined conclusions: The first one considers the hypothesis of the origin of certain meteorites. Extensive analytical work published allows to compare results to the rules of radiation chemistry and estimated times of sojourn in the space. The voluminous literature on Murchison meteorite mentions detection of an ESR signal of free radical entity, indicating that the object was irradiated in the space and the high temperature during the entry did not cause subsequent reactions, perhaps because of lack of a reagent or because of insensitivity of the radical towards the oxygen. Our experimental simulations are in progress and preliminary results are in preparation for publication.

The second, but not last conclusion refers to Mars, an object under the ionizing radiation lasting for Giga years, practically without atmospheric shield present in the case of the Earth. Assume that 4 Gyr or so ago, Mars had plenty of water, and that the organic soup was formed, not concluding into creation of life. If water has evaporated and disappeared, the organic matter should remain, but in next millions of years it was radiolysed. Therefore there should be no hope to find organic matter whatsoever on Mars. And really, no traces of organics have been found yet. Actual efforts to refine methods of investigation look like waste of money. The regolith of Mars seems to be an inorganic desert.

The third conclusion is, that any object staying in space shows a well defined profile of radiation induced changes. The surface is completely mineralized, organics-free. Going deeper we can meet organics with reduced content of hydrogen, then compounds of no homochirality, next dead tissues and spores and eventually, in the centre, traces of still sleeping only, but live, spores. In the case of an asteroid of average radius of 3 m, staying for 1 Myr in space, containing 0.1% of live dry spores before space odyssey, the depth–dose profile starts at the surface dose of 1 GGy (total mineralization), reaches at ca. 1 m the

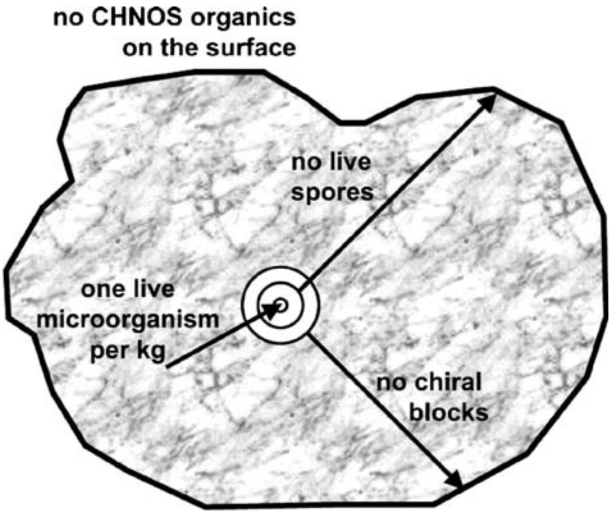

Fig. 1 Pictorial representation of an asteroid (estimates in order of magnitude). See details in the text

threshold of dehydrogenated organic matter, at ca. 2 m threshold of homochiral blocks and close to the centre the region of possibly 1 live microorganism per kilogram of the material (Fig. 1).

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