Dust, chemical evolution and origins of life on Earth

Michael B. Simakov

Group of Exobiology, Institute of Cytology RAS, Tikhoretsky Av., 4, St.Petersburg, 194064, Russia

Since cosmic dust is the most primitive matter of the Solar System it could played a major role in bringing organic matter to the early Earth, enabling the prebiotic synthesis of the biochemical compounds. The dust particles are composed of a heterogeneous mixture of amorphous and crystalline silicates, organic material, and other minor constituents.

All young solar system objects are subjected to energetic processing by photons and ions. As a result, the chemical and physical properties of the materials composing these objects will change over time significantly. Energetic processing of organic compounds into more complex species can be driven by significantly enhanced UV field in star-forming regions, high energy particle bombardment and UV-radiation from the T-Tauri phase in stellar birth, and UV-radiation of different wavelengths, protons of Solar wind and flares at early stage of evolution and at present days. The «simulated space ice conditions» experiments have shown the synthesis of simple biochemical compounds in the form of amino acid's precursors (Bernstein et al., 2002; Munoz Caro et al., 2002) and pyrimidine bases (uracil, cyrosine and thymine) of the nucleic acids (Kobayashi et al., 2004). Our investigation dealt with further reaction of nucleic acid components to nucleotides – main components of RNA and DNA, and single amino acids to oligopeptides.

We have shown experimentally that the solid mixtures of amino acids produce more complex compounds when they are exposed to open space energy sources. Both irradiation and photolysis may destroy molecules as well as allow the synthesis of new and more complex ones. The chemical reaction of solid-state amino acids induced by different energy sources has been of increasing interest in several fields such as chemical evolution, polymerization of simple molecules, origin of homochirality in biomolecules and so on.

We investigated two types of reactions: (1) abiogenic synthesis of nucleotides from mixtures of nucleoside + inorganic phosphate; (2) abiogenic synthesis of dipeptides from mixtures of simple amino acids. As a result of VUV irradiation of the mixture of nucleoside and inorganic phosphate the natural monophosphates of corresponding nucleosides were found. The films containing a mixture of amino acids yielded various oligopeptides with summary yields of ~2.5% and ~2% after they were exposed to protons and VUV-radiation, respectively. Polymerization is an essential step in prebiological evolution and we have shown that this process probably could take place even at early stage of the Solar system formation, before planet accretion, on surface of cosmic dust.

In space flight experiment onboard of «BION-11» satellite the solid films from mixtures of different nucleosides and inorganic phosphate were exposed to space conditions. The abiogenic synthesis of the full set of the natural nucleotides is observed. In the last space experiments we also studied the in influence of mineral substrates on the reaction of oligomerization of amino acids in open space/ Simple oligopeptides can be formed on solid material not only by VUV-light but also by proton radiation, heat, and gamma-radiation. Thus, it can be assumed that the chemical evolution would have taken place during the early stage of the Solar system on the surface of dust particles.