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AMINO ACID HOMOCHIRALITY ON EARTH AND MARS

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Did amino acid homochirality originate before, during or after the origin of life on Earth? This question has intrigued scientists ever since Pasteur's discovery of the optical activity of amino acids, but there is still no general consensus. Some researchers consider homochirality as an inevitable consequence of universal fundamental physical processes which took place either directly on the early Earth, or in extraterrestrial environments. Others consider a pure chiral medium to be necessary for the origin of life and that without molecular homochirality there could be no origin of life. A new emerging view is that biochemistry itself played a more important role than abiotic chemical or physical processes, and that biomolecular homochirality is a consequence of life, rather than a prerequisite for life.

In modern terrestrial organisms, amino acid homochirality is important because proteins cannot fold into bioactive configurations such as the α-helix if the amino acids are racemic. Enzymes could not have been efficient catalysts in early organisms if they were composed of racemic amino acids. However, enzymes made up of all D-amino acids function just as well as those made up of only L-amino acids, but the two enzymes react with the opposite stereoisomeric substrates (Milton *et al.*, 1992). There is no biochemical reason why L-amino acids would have been favored over D-amino acids.

The one example of Earth-based amino acid homochirality is inadequate to ascertain how widespread this example of mirror symmetry breaking is in the universe (Bada, 1995). Physical explanations such as those based the parity violation energy differences (PVED) between enantiomers predict that wherever life exists, the molecular handedness should be the same as on Earth. The biotic origins scenario predicts that life throughout the universe would be equally divided with respect to left and right molecular handedness. During the next couple of decades we will explore Mars for evidence of extinct or extant life. The discovery of D-amino acid based Martian life would eliminate the PVED-based arguments for the origin of biomolecular homochirality.

During the early history of Mars, similar planetary conditions may have existed that gave rise to the origin of life on Earth (Pollack *et al.*, 1987), although the chances any organisms still survive seems remote because of the present hostile surface conditions. Amino acids would be a likely candidate for biomolecular components of an ancient martian biota judging from their central role in terrestrial biochemistry. If amino acids can survive in the martian subsurface, their utility as indicators of an extinct martian biota is dependent on their rate of racemization under martian conditions. Terrestrial organisms, and presumably any martian organisms as well, use only one set of amino acid enantiomers (the L-enantiomer in the terrestrial case) in their proteins. We assume that if proteins and enzymes were a component of ancient life on Mars, then amino acid homochirality would have been a requirement.

When an organism dies, its amino acids begin to racemize at a rate which is dependent on the particular amino acid, the temperature, and the chemical environment (Bada, 1991). Racemization reactions are rapid on the terrestrial geologic time scale and even at deep ocean temperatures of 2°C, amino acids are totally racemized (e.g., D/L = 1.0) in about 5-10 million years. Although α-dialkyl amino acids with a chiral center, which are common in carbonaceous meteorites (Cronin and Pizzarello, 1983), are very resistant to racemization (Bada, 1991), these amino acids are not generally found in the proteins of terrestrial organisms. When biogenic amino acids are completely racemized, they would be indistinguishable from a chirality point-of-view from the racemic amino acids produced by abiotic organic synthesis or those derived from exogenous sources.

Using kinetic data, we have estimated the racemization half-lives and times for total racemization of amino acids under conditions relevant to the surface history of Mars (Bada and McDonald, 1995). Amino acids from an extinct martian biota maintained in a dry, cold (<250°K) environment would not have racemized significantly over the lifetime of the planet. Racemization would have taken place in environments where liquid water was present even for time period of only a few million years following biotic extinction. The best preservation of amino acid homochirality associated with extinct martian life would be in the polar regions.

Investigations of amino acid enantiomeric ratios should thus be a central component of future Mars exobiology missions in order to help answer the 150 year old question of how amino acid homochirality originated on Earth.

References

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