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Can Chirality Give Proof of Extinct or Extant Life?

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Finding an excess of one chiral isomer over its sister isomer of an organic compound has been advanced as a life detection method. This "biomarker" approach is based on the known, but yet not understood, preference of all examined life forms for L-amino acids and D-carbohydrates. However, this method faces a number of problems. First, rapidly-improving methods are demonstrating abiotic synthesis of chiral amino acids with strong excesses of one isomer. Furthermore, racemization of ancient samples over time may elude the method. Also, the chiral test may produce a false negative should the alien life not be based on a preferential chiral biochemistry. In any event, the method cannot determine whether the organism detected is alive or a fossil. Finally, like all biomarkers, the finding of chiral preference suffers from a fundamental flaw: chiral preference, and all other biomarkers, will fail the test of Occam's Razor. All such evidence will be deemed as more likely to have occurred through abiotic happenstance rather than having required the development of a living entity to produce it. Thus, simple asymmetry of chirality has become less convincing as evidence for life.

A method to detect extant life based on chiral preference was first proposed by the writer at the L&PI meeting in 1987. Since then, it has gone through a number of iterations. A new version is proposed that can offer more convincing evidence than can chiral biomarkers, and render near nil the possibility of a false positive. The method is based on the legacy of the 1976 Viking Labeled Release (LR) experiment. The LR applied a solution of ^{14}C-labeled substrates to Mars surface material. Dosed samples were then monitored for the evolution of labeled gas as evidence of metabolism. Positive results were obtained at both Viking landing sites, but the scientific community generally attributed the responses to a chemical reaction, not life. However, with new data from Mars, and the discovery of extremophiles on Earth living under conditions vying those on Mars, renewed interest has been developing in the LR.

The Chiral LR (CLR) experiment is designed to resolve unambiguously the issue of extant life. The CLR is based on the wide acceptance that all known life forms show a metabolic preference for left-handed amino acids and right-handed carbohydrates, while chemical reactions show no such preference. Unlike the LR, the CLR adds each of its labeled substrates separately to its respective sample of surface material. The Viking LR substrates (among them L/D alanine and L/D lactate) are included in an effort to determine which had produced the 1976 results. To extend the life detection net, samples are tested with other enantiomeric organic substrates (such as cysteine, because of the high concentration of sulfur on Mars, and sulfur's involvement in the metabolism of early photosynthetic microorganisms on Earth). The key evidence sought is whether any response from an isomeric substrate shows a chiral preference. Such a finding would then be tested by independent controls to distinguish life from abiotic chemistry.

In the Viking Mission, all life detection experiments were assigned a heat "sterilization" control. Should any sample give a positive signal for life, a duplicate sample of the same surface material was to be heated to a regimen designed to destroy microorganisms, but not so high as to destroy chemicals that might have caused the reaction. When cooled, the control sample was to be subjected to the life detection procedure. Should the response be greatly attenuated compared to the initial positive response, this would be accepted as confirmation that the first response had been from living organisms. If the control response duplicated, or nearly duplicated the initial response, this was to be considered evidence for an abiotic, not a living reaction. Although the Viking LR controls were essentially nil, the pre-mission rationale did not prevail. The consensus was that additional, unambiguous evidence was required. The development of the CLR is an effort to supply such evidence. The major nuance of this iteration of the CLR design lies in the concept of a more rigorous control system.

Multiple controls are proposed. Each of the chiral substrates contains its own control in that, as already discussed, extant biology would be strongly indicated by a preferential response to only one of the mirror-image molecules. However, as also stated above, an alien life might not exhibit a chiral preference. Hence, a second control, the Viking heat "sterilization" concept, would be applied, but in step-wise heating to determine the thermal endpoint of the active agent. Other environmental conditions would serve as important controls. These could include moisture, humidity, atmospheric composition and the like. Additional controls could consist of adding anti-metabolites to the samples. While these are more Earth-centric, a variety of them could offer the evidence sought, especially in that a differential reaction to only one of them would supply strong additional evidence for life. Toxic metals, cyanide, antibiotics and enzyme inhibitors are candidates, as is the de-coupling agent 2,4-dinitrophenol. A thus supported chiral preference could indicate whether the life detected were likely related to terrestrial life, or of independent origin. Results from the various tests and controls could begin a study of comparative biology with terrestrial forms.

The instrumentation proposed for the CLR consists of multiple, small dart-type probes, launched upwind from a landed spacecraft to prevent contamination from the spacecraft, or launched from orbit. Each dart would have two cavities which would be filled with sample by the impact of landing. By the same impact, or administered separately after control treatment, the substrate, D- and L- isomers contained in vials, or the non-chiral substrate and its control, could be applied to the sample One cavity would thus serve as the test and the other as the control. The darts would communicate with the spacecraft through separate radio frequencies. The darts would be packaged in a canister that would be heat-sterilized before launch, thereby avoiding the necessity to sterilize the entire spacecraft. On deployment, the darts would be ejected through the canister cover, thus maintaining their sterility. Pre-mission studies would establish priorities for the test and control darts. Availability of instrument weight would determine the final package.

The CLR, thus, inverts the normal concept of an experiment. Multiple controls are applied to each test. A positive result combined with more than one nil control would be difficult to explain away abiotically.