COMPUTATIONAL MODELS FOR THE COEXISTENCE AND COMPETITION OF MIRROR-IMAGE LIFEFORMS. P.R. Esch[1] and S.I. Walker[2,3,4,*], [1] School of Life Sciences, Arizona State University, Tempe AZ USA, [2]School of Earth and Space Exploration, Arizona State University, Tempe AZ USA, [3]Beyond Center for Fundamental Concepts in Science, Arizona State University Tempe, AZ USA, [4]Blue Marble Space Institute of Science, Seattle WA USA.
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Introduction: All life on Earth shares a unique chirality, or handedness, of its fundamental biomolecules: amino acids are left-handed (levorotary) and sugars, such as those found in DNA and RNA, are right-handed (dextrorotary). The origin of this asymmetry is unknown and presents one of the longest standing mysteries in the emergence of life. Most work on the origin of biomolecular homochirality focuses on symmetry breaking in chemical systems [1,2]. However, prebiotic synthesis experiments, modeling conditions that might have occurred on the early Earth, often yield a nearly equal mixture of both chiralities. Meteorites, which represent our most pristine samples of prebiotic chemistry from the early Solar System, have relatively low chiral asymmetries (typically around 5%) as compared to biotic systems (~100%) [3]. It is therefore unclear at present how chiral symmetry breaking may have emerged through the processes of prebiotic evolution.

In this project, we take an alternative approach and ask how homochirality may have emerged not as a result of prebiotic processes, but instead as the product of competitive selection in early life forms. We build from recently published results identifying racemase enzymes that act to convert one molecular handedness into the other [4]. We hypothesis that if mirror image life forms co-existed in the past, or co-exist elsewhere, racemase enzymes might play a dominant role in the interaction between mirror image biospheres.

We thus implemented agent based computational simulations, which include two mirror image chiral organisms that compete for food of the same and opposite chirality, and determine the conditions under which a homochiral biosphere emerges. Our model includes organisms (agents) that can best reproduce in the presence of the same chirality food, but also may reproduce with a slower metabolic efficiency by utilizing a racemase enzyme in the presence of food of the opposite chirality, as suggested by [4]. Our model thus includes four key parameters—*rf:* reproduction rate in the presence of the same chirality of food, *rs:* reproduction rate in presence of opposite chirality food, *df:* dispersal rate of individuals in the presence of the same chirality food, *ds:* dispersal rate of individuals in the presence of the opposite chirality food.

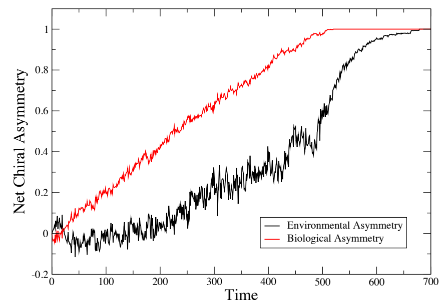

Fig 1: Time evolution of chiral asymmetry for organisms and environment. The biosphere becomes homochiral on a more rapid timescale than the environment, which is converted to the chirality of the victors.

Our numerical simulations demonstrate regimes of coexistence of both mirror-image organisms or extinction of one, depending on the relative values of these model parameters, which would be tuned by evolution and environment in real systems. The data gathered suggests that we must be careful in using homochirality as a biosignature due to the possibility of false negatives, as two homochiral life forms may co-exist in some planetary contexts. Interestingly, for cases where a homochiral biosphere emerges, the environment is converted to a homochiral state of the same signature on a timescale that lags behind biology due to finite resource constraints in our model (Fig 1.). This suggests that once a homochiral biosphere emerges, much of its evolutionary past will be erased by conversion of the planetary context to favor the winning chirality.

The results suggest a complex story of the interaction between mirror-image life and the environment, in cases where mirror-image life forms emerge in the same planetary context. In particular, our results shed new light on the processes underlying the origins of life's homochirality, which may have arisen late in the early evolution of life as a result of competition of competing chiral life forms. A hypothesis consistent with the results reported observed features of the biosphere and the results reported here.

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