Right-handed building blocks of life might have had a rocky start

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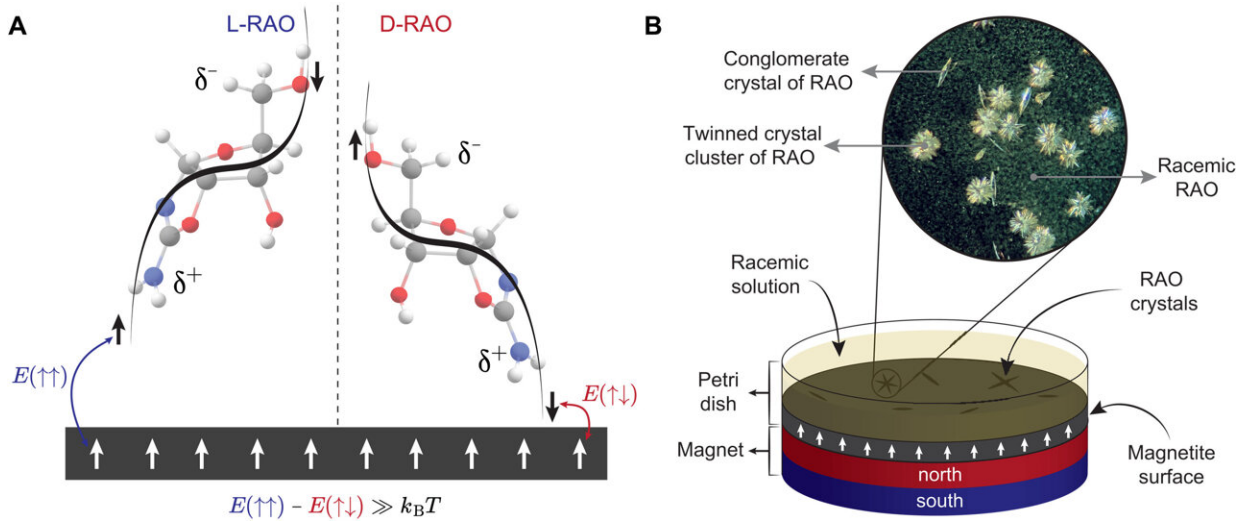

The mechanism of spin-selective crystallization due to the CISS effect and the experimental setup.(A) As molecules approach a surface, they transiently acquire an induced charge polarization. Because of the CISS effect, transient charge polarization of a chiral molecule is accompanied by spin polarization. The spin state associated with the charge poles is determined by the handedness of the chiral molecule. Because the magnetic surface itself is spin-polarized, it kinetically favors (akin to a seed crystal) the enantiomer whose transient spin state results in a lower-energy spin-exchange interaction. The lower-energy overlap with the magnetic surface is singlet-like (red, ↑↓) and the higher-energy overlap is triplet-like (blue, ↑↑). The energy difference between these two configurations is higher than the room temperature, k_BT; therefore, the effect robustly manifests itself. (B) Schematic of the setup used in the crystallization experiments and a sample microscope image of the RAO crystals on a magnetite surface from a direct crystallization experiment. The image shows the magnetite

surface as the black background and the needle-shaped conglomerate crystals of RAO formed on the surface, as well as the twinned crystals with stochastically arranged needles of D- and L-RAO, and racemic RAO in the form of a flaky powder suspended in the water column above the surface. Credit: *Science Advances* (2023). DOI: 10.1126/sciadv.adg8274

Harvard University led research may have solved the puzzle of how life became molecularly right-handed. In the paper, "Origin of biological homochirality by crystallization of an RNA precursor on a magnetic surface," published in *Science Advances*, the researchers explain how it all might have started with the right kind of rocks.

Molecules can be left-handed, right-handed or both. RNA and the sugars that makeup DNA are right-handed molecules. Nobody knows why or if there is a reason beyond chance that life started right-handed.

As an analogy, human hands can be left or right, and they are mirror images of each other, which means that they cannot be superimposed without one facing the wrong way. Molecules can have similar structural symmetry.

In much the same way that right-handed people have difficulty with left-handed scissors, or left-handed guitar players need to reverse strings and play the instrument the other way round, molecules do not interact the same way when they are left or right-handed. Once started, it makes sense that the building blocks of life should continue with the same handedness.

One intriguing idea is that cosmic rays with left-handed spin destroyed left-handed DNA precursors just as life started on Earth.

Ribo-amino oxazoline (RAO) is a crucial RNA precursor for two of RNA's nucleotides, cytosine and uracil. RAO also happens to form a crystalline structure that can be either right-handed or left-handed that, once the crystal starts forming, right or left, only binds with other molecules of the same handedness.

By placing RAO on magnetite (Fe_3O_4) surfaces, researchers could achieve 100% handedness of RAO crystallization, either left or right, depending on the spin-exchange interaction and degree of spin alignment (magnetization) at the active surface.

Earth's most abundant natural magnetic mineral, magnetite, would have had plenty of interaction opportunities with RAO in primordial times. However, the researchers say the effect is not likely to occur in particle solution contact like mud but rather on sedimentary rock surfaces.

Even with the current findings possibly unlocking two of the four RNA nucleotide components, two more are still missing. So far, The origin story finds that common, naturally occurring components at room temperatures can start the process. If the next two are found to have similar requirements, it would indicate that life on any Earth-like planet in the universe could have started just as easily.

More information: S. Furkan Ozturk et al, Origin of biological homochirality by crystallization of an RNA precursor on a magnetic surface, *Science Advances* (2023). DOI: 10.1126/sciadv.adg8274

S. Furkan Ozturk et al, Chirality-Induced Magnetization of Magnetite by an RNA Precursor, *arXiv* (2023). DOI: 10.48550/arxiv.2304.09095