Researchers propose new mechanism for early chemical evolution

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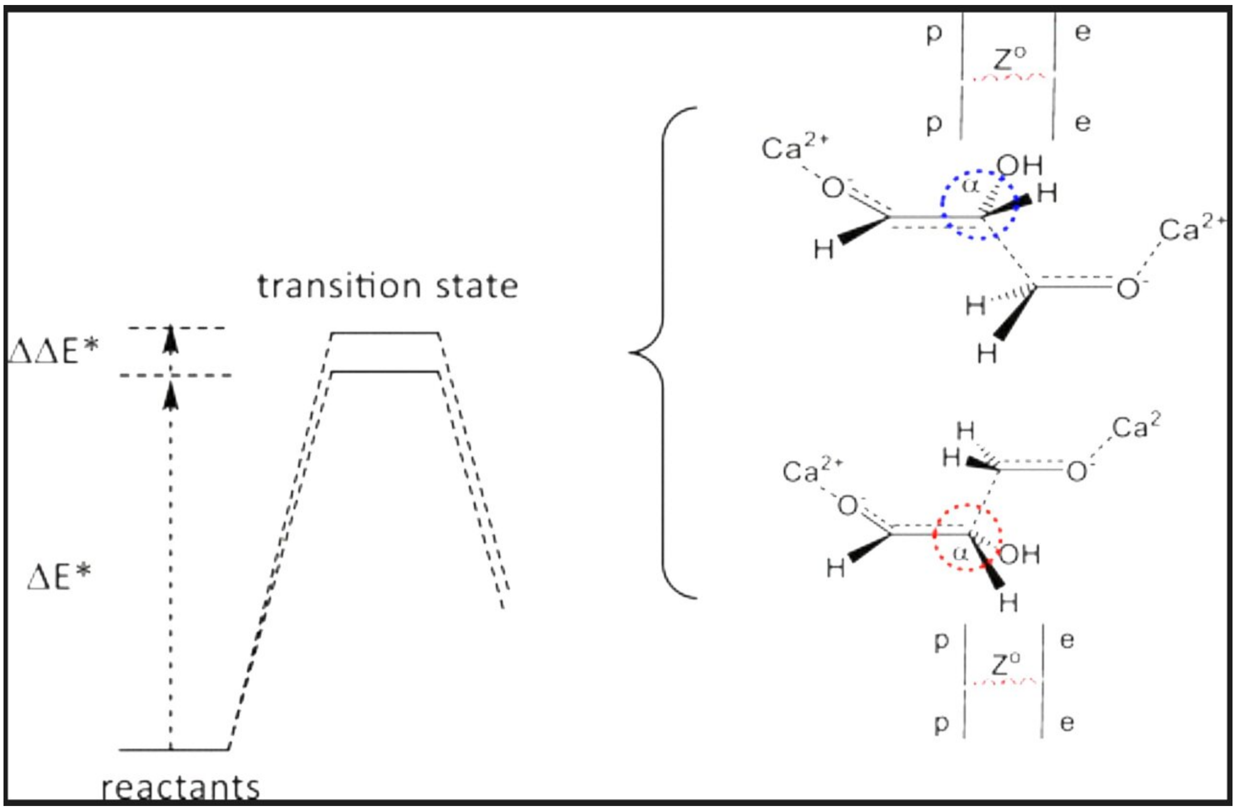

Graphical abstract. Credit: *ACS Earth and Space Chemistry* (2022). DOI: 10.1021/acsearthspacechem.2c00032

Scientists from The Ohio State University have a new theory about how the building blocks of life—the many proteins, carbohydrates, lipids and nucleic acids that compose every organism on Earth—may have evolved to favor a certain kind of molecular structure.

It has to do with a concept called chirality. A geometric property inherent to certain molecules, chirality can dictate a molecule's shape, chemical reactivity, and how it interacts with other matter. Chirality is also sometimes referred to as handedness, as it can be best described as the dichotomy between our hands: Though they are not identical, the right and the left hand are mirror images of each other, and can't be superimposed, or exactly overlaid on one another.

In the journal *ACS Earth and Space Chemistry*, researchers now propose a new model of how the molecules of life may have developed their "handedness."

This sense of a molecule's right- or left-handedness plays a huge role in biochemistry and is especially important when it comes to helping humans develop drugs to treat molecular diseases, such as cancer. While a molecule in one form might be of therapeutic value to humans, its opposite-handed twin might be inactive or cause unintended birth defects. What's more, as nature often demonstrates a preference for specific symmetries, the molecules that underpin all living beings have only been found to display a strong preference for one form of handedness over another.

Ultimately, although the role of chirality is now greatly recognized, there is no clear consensus among scientists as to how this preferred symmetry may have initially arisen, said co-author of the study James Cowan, a distinguished university professor emeritus in chemistry and biochemistry at Ohio State.

"The reason why many of the key molecules of life only have one preferred handedness is a bit of a mystery," said Cowan. "As to how it came about, the process must reflect something very special about how early chemistry developed a preferred form of nucleic acids and proteins."

Cowan and co-author R.J Furnstahl, a professor of physics at Ohio State, describe a model where the development of preferred chiral molecules evolves through a fundamental interaction called the weak nuclear force. The second weakest interaction after gravity, it's a phenomenon which causes protons to decay into neutrons and vice versa.

This challenges previous thoughts on the origin of Earth's chirality, which suggested it came about following meteorite impacts on the planet during its early formation. Instead, their work is consistent with the RNA-based chemistry in the "RNA World model," in which the formation of ribonucleic acids was a key step in how all the other molecules of life might have been made.

By combining elements of biology, nuclear physics and chemistry, Cowan and Furnstahl provide an explanation for how a preferred handedness in the building blocks of life evolved not from extraterrestrial molecules, or by random chance, but through a fundamental force of nature that laid the molecular foundation that would eventually come to support and influence life on Earth.

"Imagine a universe where there was a right glove, but no left glove," said Cowan. "Over the course of a few million years, this preference for a particular hand becomes apparent, and is then repeated and amplified, and eventually allowed to dominate."

The study concludes that the weak nuclear force, in tandem with Earth-abundant metals like calcium, which amplifies the effect, could have acted like a seed, influencing prebiotic chemistry in a way that prompted preferred chirality to emerge symbiotically with the rest of nature's early building blocks.

"Based in fundamental physics, our model generates the actual chemical building blocks with a preferred handedness that could have resulted in the life processes we know today, and does it in a way that's very satisfying," said Cowan.

Though their research is purely theoretical at the moment, the study notes that with the right technology, there are a few ways their mechanism could be proven. Unfortunately for researchers, it's way too tedious a process to recreate primordial timescales in the lab.

"In terms of making the molecules that living organisms are based on, those reactions are occurring on the timeframes of hundreds of thousands of years," said Cowan. "Of course, we don't have that long to wait around to test the hypothesis in the lab."

While extensive chemistry experiments could potentially be done with the help of heavy elements like uranium, which could help yield a result in only a few years, another more practical way to test the hypothesis behind their research might be to use spectroscopy—splitting light into different wavelengths to study its properties—to look at nearby exoplanets to try and determine if the molecules there exhibit a preferred "handedness" as well.

"If there was a preferred handedness, and it was the same type that we would observe on Earth, then that would be very, very strong evidence that nature actually directs the evolution of biological chemistry," said Cowan.

Going forward, one of their biggest challenges in advancing the work is waiting for the technology needed to do these experiments to catch up, Cowan said. "We were able to establish a feasible physical mechanism that describes how this process could be carried out, but the next obstacle is finding the best way to study it experimentally."

More information: J. A. Cowan et al, Origin of Chirality in the Molecules of Life, *ACS Earth and Space Chemistry* (2022). DOI: 10.1021/acsearthspacechem.2c00032

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