Key early steps for origin of life occur under a variety of conditions

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Potential precursors to life on Earth form from a variety of complex mixtures, according to a team of scientists who say this could point to the development of building blocks crucial to forming genetic molecules for the origins of life on Earth.

Genetic molecules provide the ability to store and replicate information and may have been critical for the origin of life, but it is unclear how they arose from complex chemical environments that existed on early Earth. New findings, published this week in the journal *Scientific Reports*, suggest the answer may start with nitrogen heterocycles, ringed molecules believed to be common on young Earth and elsewhere in the solar system. Several types of heterocycles serve as nucleobases, or subunits, of DNA and RNA, the genetic molecules used by life as we know it.

"One of the challenges of studying the origin of life is deciphering what reactions were key steps," said Christopher House, professor of geosciences at Penn State. "Our work here identified the most likely next steps these molecules could and would take."

A team of researchers found that nitrogen heterocycles may have served as building blocks toward life in a series of tests that generated complex chemical mixtures like those possibly created by lightning strikes passing through early Earth's atmosphere. Dozens of different heterocycles produced similar primitive genetic precursors even when the atmospheric composition was varied in the study.

"The real surprises were that so many different such ringed molecules were found to be reactive and that they formed the same next step regardless of what simulated atmosphere we used," said House, who also serves as director of the Penn State Astrobiology Research Center and the NASA Pennsylvania Space Grant Consortium.

The results support a hypothesis that simpler genetic structures could predate the formation of DNA and RNA and suggest that similar prebiotic reactions could happen elsewhere in the solar system.

Unlike previous studies, which have explored similar reactions in isolated conditions, the team used organically complex mixtures that better simulate early Earth chemistry not knowing whether the reactions would represent a constructive step toward life or a dead end.

In the study, the heterocycles reacted in the complex mixture to form chemically reactive side chains, structures that link heterocycles together and facilitate the formation of more complex molecules, the researchers said.

These modified heterocycles could serve as the subunit of peptide nucleic acids (PNAs), a proposed precursor to RNA. That they formed so readily in different atmospheric conditions supports the theory that PNAs could have formed on prebiotic Earth.

"Our findings hint at the possibility of PNA on the early Earth since we observed many robust synthetic pathways for some of its components," said Mike Callahan, assistant professor of chemistry at Boise State University.

The findings also have implications for similar genetic precursors on other worlds.

"The organics reacting with the heterocycles and forming these side chains have also been identified in the interstellar medium, comets, and even Titan's atmosphere," said Laura Rodriguez, who led the research as a doctoral student studying geosciences at Penn State. "And since the reactions were robust in complex mixtures under a broad range of conditions, our results may have implications for the formation of PNAs beyond Earth."

Also contributing to this research were Karen Smith, a senior research scientist, and Melissa Roberts, a graduate student, both at Boise State.

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More information: Laura E. Rodriguez et al, Nitrogen heterocycles form peptide nucleic acid precursors in complex prebiotic mixtures, *Scientific Reports* (2019).
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