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How Cellular Life Evolved

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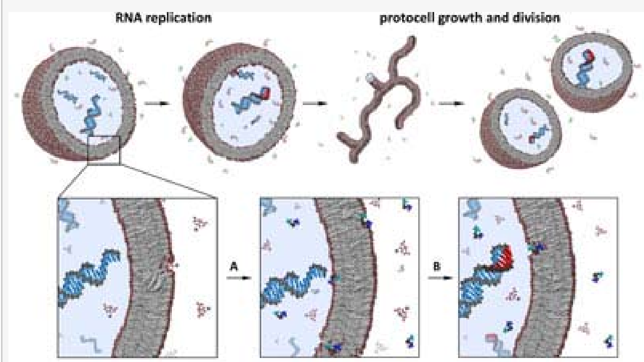
A new study offers clues into how RNA synthesis may have occurred inside protocells, but experts question whether the research realistically captures the chemistry of ancient Earth. Learn more...

According to the RNA world hypothesis, self-replicating RNA molecules capable of catalyzing chemical reactions played a major role in the evolution of cellular life. This process may have occurred in fatty acid vesicles, but RNA copying reactions require high concentrations of magnesium ions, which destroy the vesicles. Now, in a study published in the journal *Science*, researchers identified compounds that protect fatty acid vesicles from destruction by high concentrations of magnesium ions, allowing RNA synthesis to take place inside these vesicles (1).



General scheme for non-enzymatic template-directed RNA synthesis inside vesicles.

“For many years, there have been models of how RNA chains can extend without the use of biology in the lab, and there have been models of how primitive membranes could form and serve as early cell boundaries,” said Jason Dworkin of the National Aeronautics and Space Administration Goddard Space Flight Center, an expert on the origin of life who was not involved in the research. “This report shows how these two models can work together, so it is a step towards merging the theories of the first genetic material with the first cells. This is a necessary step in understanding models of the origin of life on Earth or elsewhere.”

In the study, Katarzyna Adamala and Jack Szostak of Massachusetts General Hospital developed a screen for small molecules that protect fatty acid vesicles from disruption by magnesium ions. They found several chelators—molecules that bind to metal ions—that protected fatty acid vesicles in the presence of high concentrations of magnesium ions. Among these molecules, citrate—a derivative of citric acid—was one of the most effective chelators of magnesium, allowing the vesicles to remain intact. The presence of citrate also allowed RNA copying to proceed within fatty acid vesicles and protected single-stranded RNA from degradation catalyzed by magnesium ions.

“The fact that citrate was the molecule that made it happen coincides with the fact that citrate is a central metabolite in modern biology,” said Ramanarayanan Krishnamurthy of the Scripps Research Institute, who was not involved in the study. “If it had been another molecule that had been totally synthetic, artificial, and not found in modern biology, then one would have to examine how significant the finding is in terms of the origins of life.”

Although the authors acknowledge that there is no known prebiotic citrate synthesis pathway, they suggest that short acidic peptides or other prebiotically available compounds could have similar effects. But in the end, what they presented is only a model. Experts point out that the chemical compounds and reactions used in the study are not likely to have been present or common on ancient Earth.

“It is a very gross simplification of the types of chemistry one might expect on a primitive planet,” said Henderson Cleaves of the Tokyo Institute of Technology, who was not involved in the study. “The idea of the first cells being self-replicating RNA molecules in fatty acid vesicles is certainly popular in some circles, but is by no means obvious or

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proven. The idea is bolstered by the facility of working with these model systems, but this may be more reflective of our biotechnology than the underlying ease or plausibility of this type of chemistry."

Reference

K. Adamala and J. W. Szostak. 2013. Nonenzymatic Template-Directed RNA Synthesis Inside Model Protocells. Science 342(6162): 1098-1100. DOI: 10.1126/science.1241888.

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