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Democracy Dies in Darkness

Simple chemistry helps explain the origin of life, new study suggests

Scientists have figured out how proteins may have been created on early Earth.

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By Kasha Patel

When a bone grows, our bodies' proteins help provide the structure. When a muscle tears, proteins help rebuild it. When we fight an infection, transport oxygen in our blood or send messages to a cell, proteins often step up to the plate. But how did these skilled molecules first form on Earth and help give rise to life?

The mystery, which has evaded scientists for more than five decades, can be explained with rather simple chemistry, according to a study published Wednesday in Nature.

In lab experiments, scientists have successfully shown how two basic ingredients of life — ribonucleic acid (RNA) and amino acids — can combine to start protein synthesis.

The basic ingredients and conditions — in water — are thought to have been around on Earth about 4 billion years ago, providing clues to how early life may have been kick-started or could arise on other planets.

"It seems pretty probable" that this reaction would have been occurring on early Earth, said Matthew Powner, a chemist at University College London and an author of the new study.

Powner's lab investigates the chemical processes that lead to life, exploring key mechanisms seen in all living organisms. One of the most fundamental processes is how cells make proteins, the complex molecules responsible for our growth and survival from bone formation to immune support.

Proteins are made of amino acids, which are thought to have been around long before life emerged. Proteins can't replicate themselves and are built from blueprints, provided by nucleic acids like DNA and RNA, that instruct the amino acids to assemble. In fact, Francis Crick, a co-discoverer of the structure of DNA, proposed the theory in the 1950s that information in biology flows from DNA to RNA and then to protein.

But since Crick, the process of moving from RNA to protein hasn't been understood, Powner said. "The information in DNA and RNA is written in a different language than the information in proteins, and so it must be translated."

In living organisms today, amino acids combine with RNA to make a protein. But this translation process requires a set of protein enzymes that, paradoxically, are made by protein synthesis. It becomes a chicken or egg problem: How was a protein made without a protein?

"We wanted to find the chemistry that unites and links" the RNA and amino acid, which would be required to make proteins, Powner said.

First, the team took an amino acid and "activated it" — basically removing a water molecule, which made it reactive and able to form a bond with other molecules. But the activated amino acid wouldn't directly bind to RNA in this form. The team needed to find a helper molecule that would aid the amino acid in binding to RNA.

Powner and his colleagues decided to experiment with a class of compounds called thiols, or molecules with a sulfur attached to a carbon. These molecules are better known for their role in energy production and regulation in cells than for protein synthesis, but the team previously found they are fairly easy to make under basic conditions that would have existed on a baby Earth.

When the thiol was introduced, the team found it first reacted with the activated amino acid in water and then slowly transferred that amino acid to RNA. More of these compounds combine and form proteins in cells.

The binding "was very unexpected [and] wasn't what we set out to achieve," Powner said. He said this mechanism essentially solves how to initiate protein synthesis without another protein.

"In a scenario where you have amino acids, where you have RNA molecules, if you have thiols — sulfur molecules — this is, I think, almost inevitable that this kind of process can happen," Powner said.

Evolutionary evidence indicates this protein synthesis process "is the most ancient feature of molecular biology that is still found in our cells today," said Aaron Goldman, a biologist at Oberlin College who was not involved in the study. Other researchers have even previously proposed that the binding of amino acids to RNA could have been co-opted to establish an early form of genetic code.

Yet although protein synthesis evolved early in the history of life, "we don't have a clear understanding of what preceded it," Goldman said. The new study "identifies intriguing new chemistry that sheds light on a possible forerunner" that enabled this important process.

The team doesn't quite know why the thiol group allows the amino acid to transfer to the RNA. Powner said that in general, the sulfur group is situated in a "sweet spot of reactivity," which allows it to react very slowly and selectively with RNA.

Four billion years ago, these reactions could have taken place in pools or lakes on Earth. Although the concentrations of the chemicals would probably would have been too diluted in oceans.

“Whether or not this specific hypothesis is correct, the binding of amino acids to RNAs appears to have been an important reaction during the early evolution of life, as it still is in every organism today,” Goldman said.

By Kasha Patel
Kasha Patel writes the weekly Hidden Planet column, which covers scientific topics related to Earth, from our inner core to space storms aimed at our planet. She also covers weather, climate and environment news.

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