PRESS RELEASE

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Title: Study discovers process that may have produced first organic molecules for life on Earth

Subtitle:
New research suggests conditions created naturally in geological settings could have created the conditions for the production of organic compounds which may have been crucial for the origins of life on Earth and other planets in the Universe.

Release summary:
A multidisciplinary team from the US, Japan, the UK and Germany has shown how simple and fundamental organic building blocks of life may have been produced by mixing of hydrothermal fluids emanating from within the Earth coming into contact with primordial ocean. Through an innovative design that re-creates hydrothermal vent pH gradients, the team was able to show that even low H_2 concentrations may naturally lead to the production of reduced carbon compounds from CO_2.

Full-text release:
New research assisted by Earth-Life Science Institute (ELSI) at Tokyo Institute of Technology Professors Shawn McGlynn and Ryuhei Nakamura identified processes that might have been key in producing the first organic molecules on Earth before the origin of life. The process, which is similar to what might have occurred in some ancient underwater hydrothermal vents, may also have relevance to the search for life elsewhere in the Universe. Details of the study were published in the journal *Proceedings of the National Academy of Sciences*.

All life on Earth is built of organic molecules—compounds made of carbon atoms bound to atoms of other elements such as hydrogen, nitrogen and oxygen. In modern life, most of these organic molecules first enter the biosphere via the reduction of carbon dioxide (CO_2) through several "carbon-fixation" pathways (such as photosynthesis in plants). But most of these pathways either require energy from the cell in order to work, or are thought to have evolved relatively late in the history of life. How the first organic molecules originated and became incorporated into the first cells is an open question that continues to perplex scientists.

To tackle this question, American Museum of Natural History Gerstner Scholar Victor Sojo and Professor Reuben Hudson from the College of the Atlantic in Maine devised a novel setup based on microfluidic reactors, tiny self-contained laboratories that allow scientists to study the behaviour of fluids—and in this case, gases as well—on the microscale. Previous versions of the reactor attempted to mix bubbles of hydrogen gas and CO_2 in liquid but no reduction occurred, possibly because the highly volatile hydrogen gas escaped before it had a chance to react. The solution came in discussions between Sojo and Hudson, who had shared a lab bench at the RIKEN Center for Sustainable Resource Science in Tokyo, where McGlynn and Nakamura are also investigators. The final reactor was built in Hudson's laboratory in Maine.
"Instead of bubbling the gases within the fluids before the reaction, the main innovation of the new reactor is that the fluids are driven by the gases themselves, so there is very little chance for them to escape," Hudson said.

The researchers used their design to combine hydrogen with CO_2 to produce an organic molecule called formic acid (HCOOH). This synthetic process resembles the only known CO_2-fixation pathway that does not require an extra supply of energy, called the Wood-Ljungdahl acetyl-CoA pathway. This process resembles reactions that might have taken place in ancient oceanic hydrothermal vents.

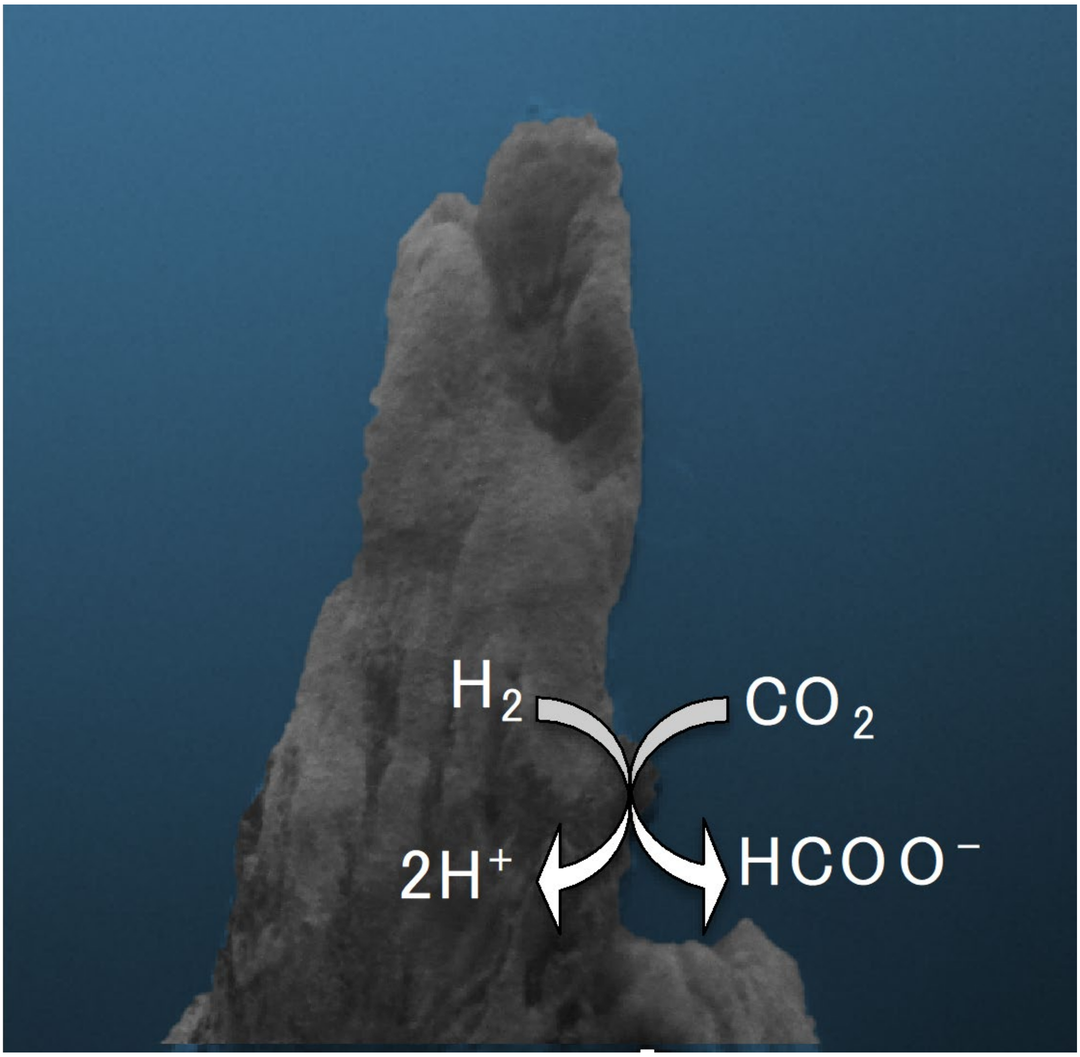
“The consequences of these findings extend far beyond Earth’s biosphere,” Sojo said. “Similar hydrothermal systems might exist today elsewhere in the Solar System, for example in Enceladus and Europa—moons of Saturn and Jupiter, respectively—and in other water-rocky worlds throughout the universe.”

“Understanding how carbon dioxide can be reduced under mild geological conditions is important for evaluating the possibility of the origins of life on other worlds, which feeds into understanding how common or rare life may be in the universe,” added Laurie Barge from NASA’s Jet Propulsion Laboratory, another co-author on the study.

The researchers turned CO_2 into simple organic molecules using relatively mild conditions, which means their findings may also have relevance for environmental chemistry. In the face of the present climate crisis, there is an ongoing search for new methods of CO_2 reduction to remove CO_2 from the atmosphere.

“The results of this paper touch on multiple themes: from understanding the origins of metabolism, to the geochemistry that underpins the hydrogen and carbon cycles on Earth, to green chemistry applications, where this bio-geo-inspired work could help promote chemical reactions under mild conditions”, added McGlynn.

Images:



Title: A new mechanism of hydrothermal CO_2 reduction
Caption: The pH difference between the inside and outside of a hydrothermal vent is sufficient to reduce CO_2 with H_2 in a process that may have formed the first organics required for life.
Credit: Shawn E. McGlynn/ELSI

Reference

Reuben Hudson [1,2,3], Ruvan de Graaf[1], Mari Strandoo Rodin[1], Aya Ohno[3], Nick Lane[4], Shawn E. McGlynn[3,5,6], Yoichi M. A. Yamada[3], Ryuhei Nakamura[3,5], Laura M. Barge[7], Dieter Braun[8], and Victor Sojo[3,8,9], CO_2 reduction driven by a pH gradient, *PNAS*, DOI: 10.1073/pnas.2002659117

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More information

Tokyo Institute of Technology (Tokyo Tech) stands at the forefront of research and higher education as the leading university for science and technology in Japan. Tokyo Tech researchers excel in fields ranging from materials science to biology, computer science, and physics. Founded in 1881, Tokyo Tech hosts over 10,000 undergraduate and graduate students per year, who develop into scientific leaders and some of the most sought-after engineers in industry. Embodying the Japanese philosophy of “monotsukuri,” meaning “technical ingenuity and innovation,” the Tokyo Tech community strives to contribute to society through high-impact research.

The Earth-Life Science Institute (ELSI) is one of Japan’s ambitious World Premiere International research centers, whose aim is to achieve progress in broadly inter-disciplinary scientific areas by inspiring the world’s greatest minds to come to Japan and collaborate on the most challenging scientific problems. ELSI’s primary aim is to address the origin and co-evolution of the Earth and life.

The World Premier International Research Center Initiative (WPI) was launched in 2007 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to help build globally visible research centers in Japan. These institutes promote high research standards and outstanding research environments that attract frontline researchers from around the world. These centers are highly autonomous, allowing them to revolutionize conventional modes of research operation and administration in Japan.

American Museum of Natural History (AMNH), founded in 1869 and currently celebrating its 150th anniversary, is one of the world's preeminent scientific, educational, and cultural institutions. The Museum encompasses over 40 permanent exhibition halls, including those in the Rose Center for Earth and Space, as well as galleries for temporary exhibitions. The Museum's approximately 200 scientists draw on a world-class research collection of more than 34 million artifacts and specimens, some of which are billions of years old, and on one of the largest natural history libraries in the world. Through its Richard Gilder Graduate School, the Museum grants the Ph.D. degree in Comparative Biology and the Master of Arts in Teaching (MAT) degree, the only such free-standing, degree-granting programs at any museum in the United States. The Museum's website, digital videos, and apps for mobile devices bring its collections, exhibitions, and educational programs to millions around the world.