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Origin of life: The importance of interfaces

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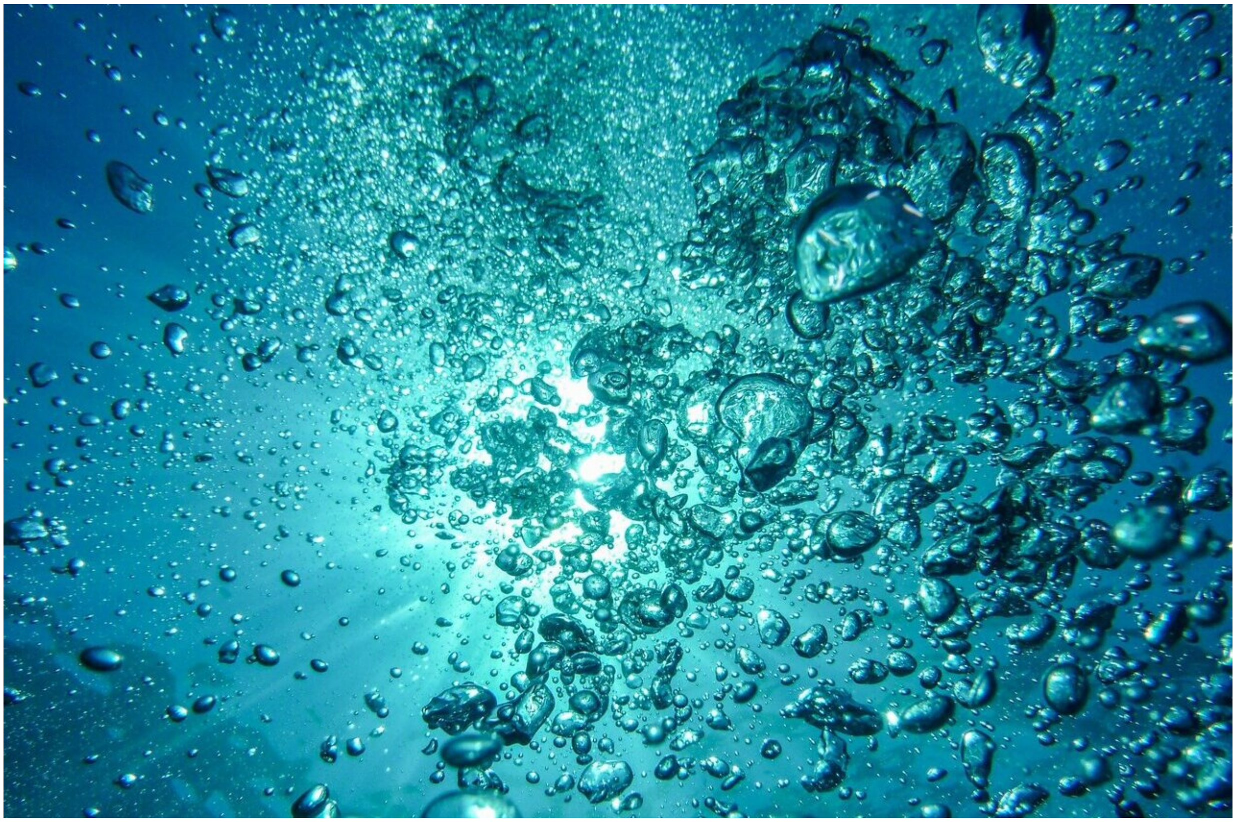

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Tiny gas-filled bubbles in the porous rock found around hot springs are thought to have played an important role in the origin of life. Temperature differences at the interface between liquid phases could therefore have initiated prebiotic chemical evolution.

A plethora of physicochemical processes must have created the conditions that enabled living systems to emerge on the early Earth. In other words, the era of biological evolution must have been preceded by a—presumably protracted—phase of 'prebiotic' chemical evolution, during which the first informational molecules capable of replicating themselves were assembled and selected. This scenario immediately raises another question: Under what environmental conditions could prebiotic evolution have taken place? One possible setting has long been discussed and explored—tiny pores in volcanic rocks. An international team of researchers led by Dieter Braun (Professor of Systems Biophysics at Ludwig-Maximilians-Universitaet (LMU) in Munich) has now taken a closer look at the water-air interfaces in these pores. They form spontaneously at gas-filled bubbles and show an interesting combination of effects.

They found that they could have played an important part in facilitating the physicochemical interactions that contributed to the origin of life. Specifically, Braun and his colleagues asked whether such interfaces could have stimulated the kinds of chemical reactions that triggered the initial stages of prebiotic chemical evolution. Their findings appear in the leading journal *Nature Chemistry*.

The study strongly supports the notion that tiny gas-filled bubbles that were trapped in, and reacted with, the surfaces of pores in volcanic rocks could indeed have accelerated the formation of the chemical networks that ultimately gave rise to the first cells. Thus, the authors were able to experimentally verify and characterize the facilitating effects of air-water interfaces on the relevant chemical reactions. If there is a difference in temperature along the surface of such a bubble, water will tend to evaporate on the warmer side and condense on the cooler side, just as a raindrop that lands on a window runs down the flat surface of the glass and eventually evaporates. "In principle, this process can be repeated ad infinitum, since the water continuously cycles between the gaseous and the liquid phase," says Braun, who has characterized the mechanism and the underlying physical processes in detail, together with his doctoral student Matthias Morasch and other members of his research group. The upshot of this cyclical phenomenon is that molecules accumulate to very high concentrations on the warmer side of the bubble.

"We began by making a series of measurements of reaction rates under various conditions, in order to characterize the nature of the underlying mechanism," says Morasch. The phenomenon turned out to be surprisingly effect and robust. Even small molecules could be concentrated to high levels. "We then tested a whole range of physical and chemical processes, which must have played a central role in the origin of life—and all of them were markedly accelerated or made possible at all under the conditions prevailing at the air-water interface." The study benefitted from interactions between Braun's group of biophysicists and the specialists in disciplines such as chemistry and geology who work together with him in the Collaborative Research Centre (SFB/TRR) on the Origin of Life (which is funded by the DFG), and from cooperations with members of international teams.

For example, the LMU researchers show that physicochemical processes which promote the formation of polymers are either stimulated—or made possible in the first place—by the availability of an interface between the aqueous environment and the gas phase, which markedly enhances rates of chemical reactions and catalytic mechanisms. In fact, in such experiments, molecules could be accumulated to high concentrations within lipid membranes when the researchers added the appropriate chemical constituents. "The vesicles produced in this way are not perfect. But the finding nevertheless suggests how the first rudimentary protocells and their outer membranes might have been formed," says Morasch.

Whether or not this sort of process can take place in such vesicles "does not depend on the nature of the gas within the bubble. What is important is that, owing to differences in temperature, the water can evaporate in one location and condense in another," Braun explains. In earlier work, his group has already described a different mechanism by which temperature differences in water bodies can serve to concentrate molecules. "Our explanatory model enables both effects to be combined, which would enhance the concentrating effect and thus increase the efficiency of prebiotic processes," he adds.

More information: Matthias Morasch et al. Heated gas bubbles enrich, crystallize, dry, phosphorylate and encapsulate prebiotic molecules. *Nature Chemistry* (2019) DOI: 10.1038/s41557-019-0299-5

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