Did comets kick-start life on Earth? Chemists find missing piece of puzzle

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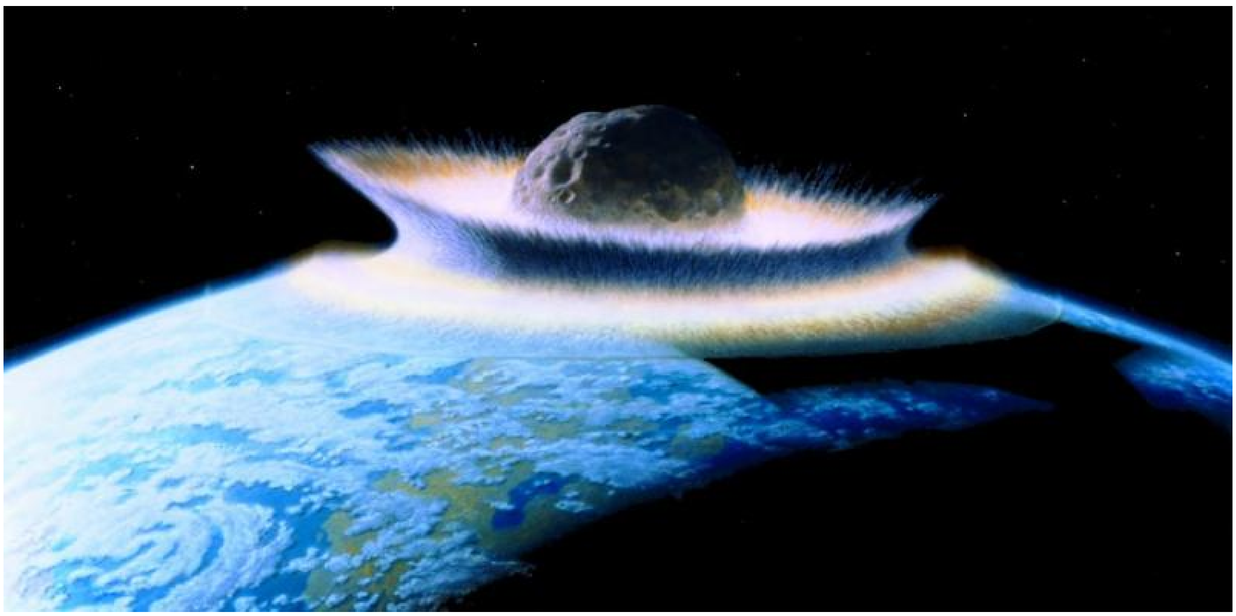

Artist’s impression. Don Davis. Credit: NASA

The origin of life on Earth has been a matter of intense debate throughout human history. Even today, scientists don't know whether the molecular building blocks of life were created on Earth or whether they were brought here by comets and meteorites. This is obviously hugely important – if they were delivered to Earth then it seems plausible that they may have been transported to other planets, too.

The molecular building blocks of life are organic compounds that can be assembled into proteins, RNA and DNA in living cells. To date, scientists have found most of these compounds in meteorites, comets, and interstellar dust. But the sugar ribose, which forms the backbone of RNA, has never been detected in this context. Now experimental results, published in the journal *Science*, suggest that even ribose can form in comets – strengthening the idea that comets kick-started life on Earth.

Like DNA, RNA can encode information. However, it is a much simpler, single strand molecule. A popular hypothesis states that early life might have used RNA instead of DNA to pass on genetic information. Even today, RNA is used by cells to deliver information for protein assembly, and many viruses still carry an RNA genome.

The history of research investigating the chemistry that might have created the building blocks of life started with a famous experiment in the 1950s. Stanley Miller and Harold Urey managed to create amino acids when passing electric sparks (representing lightning) through a mixture of water, methane, ammonia and hydrogen, which they thought resembled the atmosphere on the young Earth.

The new experiment mimics the conditions of the "protoplanetary disk" that formed both comets and the planets in our solar system. The researchers cooled down a mix of water, methanol and ammonia to a temperature of -195°C inside a vacuum chamber. While the mixture condensed into ice it was irradiated with ultraviolet light. This is basically what happens when icy grains – the raw material of a comet – form in a protoplanetary disk. Eventually, the ice was heated back up to room temperature, representing what happens when a comet approaches the sun. The experiment resulted in the formation of a large variety of organic compounds, including ribose and other sugar molecules.

So how could these compounds have been delivered to Earth? Any sugars or other organic materials in the protoplanetary disk would have had to survive the pull drawing the icy grains together to create comets and asteroids. While recent observation hints that this was a gentle process, subsequent collisions between these objects may have destroyed some – but not all – of the organic molecules. But experiments involving shooting bullets into ices have shown that this process itself can also lead to the formation of compounds such as amino acids.

Earth formed through collisions of such comets and asteroids. The heat released in these processes eventually became so immense that a magma ocean formed on the surface, which we know would have destroyed all organic compounds. A second wave of asteroids and comets raining down on the young planet must therefore have delivered them, unless they were created all over Earth on their own.

Life beyond Earth?

As exciting as the results are, it is important to remember that they have to be verified by being replicated and observed in real comets. Even if they hold up to scrutiny, it is still possible for the building blocks of life to have formed on Earth – an extraterrestrial influx is not necessarily needed.

The latest finding adds to a growing body of evidence that the building blocks of life are common throughout the universe, which presents the tantalising possibility that other planets with suitable conditions could have also been seeded with life by comets. The big question now is what the likelihood of these building blocks assembling themselves into living beings is (let's be content with microorganisms here). The molecules have to reach concentrations that allow further reactions in the first instance – and so far we have only detected them in trace amounts in meteorites. The new experimental results suggest a higher concentration in comets, though.

The questions don't end there. Ribose was not the most abundant of the sugars that formed in the experiment. Could one of the other types of sugar have led to the creation of some kind of life form with a different coding mechanism to RNA? How much liquid water is required? And are specific mineral surfaces needed in this process? Tackling these questions is the exciting ongoing step in the quest to understand whether widespread occurrence of the building blocks of life in the universe means the existence of actual life beyond Earth.

More information: C. Meinert et al. Ribose and related sugars from ultraviolet irradiation of interstellar ice analogs, *Science* (2016). DOI: 10.1126/science.aad8137

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