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Nucleobases and other N-heterocycles in samples returned from asteroid (101955) Bennu

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Samples collected at the B-type asteroid (101955) Bennu by NASA's OSIRIS-REx spacecraft [1] were delivered to Earth on 24 September 2023. Because the samples returned by OSIRIS-REx are among the most primitive and least contaminated extraterrestrial samples available for laboratory analyses [2], they should provide information on the chemical processes that occurred before and during early solar system formation. Various organic molecules have been identified in meteorites and samples of asteroid (162173) Ryugu, which have pointed to their possible role in prebiotic chemistry on the early Earth. We hypothesized [3] that Bennu contains prebiotic organic molecules, such as nucleobases, that could have contributed to the emergence of life on Earth. To test this, we searched for nitrogen (N)–heterocyclic molecules, including nucleobases, as a part of coordinated analyses of samples from Bennu [3].

We used high-performance liquid chromatography with high-resolution Orbitrap mass spectrometry (HPLC-HRMS) [4,5] to analyze the HCl extract from 17.75 mg of fine- to intermediate-sized particles of the Bennu sample OREX-800044-101.

We identified all five canonical nucleobases in the Bennu sample—cytosine, uracil, thymine, guanine, and adenine—and some of their structural isomers, with a wider diversity of N-heterocycles than previously observed in Ryugu samples and the Murchison meteorite [2,4,5]. We also identified other N-heterocyclic molecules such as xanthine, hypoxanthine, and nicotinic acid (B_3 vitamer). The concentration of the pyrimidine nucleobases (cytosine, uracil, and thymine) was 50–100 ng/g, which was a few times higher than that of the purine nucleobases (guanine and adenine). The diversity of structural isomers of these nucleobases supports an extraterrestrial origin. These results demonstrate that asteroids like Bennu may have delivered a wide variety of nucleobases that could have served as the building blocks of nucleic acids on the early Earth.

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