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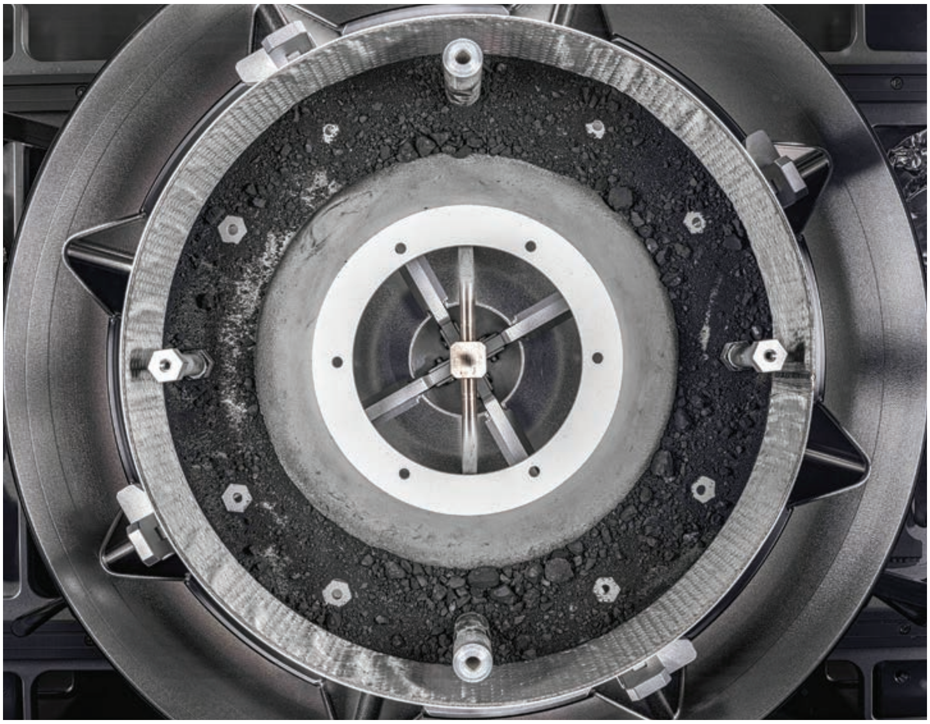
Life's Building Blocks Found in Bennu Samples



OSIRIS-REx's Touch-and-Go-Sample-Acquisition-Mechanism collected more than 120 grams of regolith from asteroid Bennu. Credit: NASA/Goddard/Erika Blumenfeld & Joseph Aebersold, Public Domain

Regolith samples from asteroid Bennu contain many of the essential building blocks of life. These molecules include 14 of the 20 protein-building amino acids found in Earth life, all five of the nucleotide bases found in DNA and RNA, and ammonia. The samples also contain sodium-rich salts, suggesting that Bennu's parent body contained enough water to produce brines.

"Bennu contains many precursor building blocks of life, along with the evidence that it comes from an ancient wet world and contains materials that point to Bennu having traveled from the coldest regions of the solar system," Nicky Fox, associate administrator of NASA's Science Mission Directorate, told reporters during a media call in January.

"I do want to emphasize that their findings do not show evidence of life itself," Fox cautioned, "but they do suggest that the conditions necessary for the emergence of life were likely widespread across the early solar system. This, of course, increases the odds that life could have formed on other planets."

Brewing Bennu Tea

Bennu is a carbon-rich asteroid about 500 meters wide that orbits about 168 million kilometers from Earth. It's a pile of rubble loosely held together by gravity rather than a solid hunk of rock and is thought to have started out as part of a larger asteroid that originated in the outer solar system.

> **"We found a really complex soup of organic molecules."**

NASA's Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission visited Bennu in 2020.

The spacecraft collected 121.6 grams of regolith from the asteroid's surface and returned to Earth in September 2023. The NASA mission team has been carefully curating the returned samples and doling out small portions for scientific analysis. At every stage of the process, scientists exercised extreme care not to expose the samples to Earth's atmosphere or other terrestrial contaminants, lest any potential discoveries be tainted.

Research teams received four small samples for analysis: two of fine- and medium-grained regolith from the main sample collection chambers and two of a fine-grained material that hitched a ride outside the main chambers after it was accidentally scooped up.

"We first made what we call a 'Bennu tea,'" said Danny Glavin, an astrobiologist and senior scientist for sample return at NASA's Goddard Space Flight Center in Greenbelt, Md. "We took samples, we boiled them in water and acids to extract the organic compounds to make this 'tea,' which we then analyzed using several different mass spectrometry techniques to identify the organic molecules."

The analyses revealed that the Bennu samples contained 33 known amino acids, including 14 of the 20 protein-building amino acids used by Earth's life and 19 nonprotein amino acids. The samples also contained high concentrations of ammonia, formaldehyde, carboxylic acids, and polycyclic aromatic hydrocarbons, all of which contribute to biological processes. What's more, the samples also contained all five nucleobases found in DNA and RNA—adenine, guanine, cytosine, thymine, and uracil—along with around 10,000 nitrogen-bearing chemical species.

"We found a really complex soup of organic molecules," Glavin said.

Bennu's concentration of ammonia was about 75 times that found in samples from asteroid Ryugu, which were collected and returned to Earth by the Japan Aerospace Exploration Agency's Hayabusa2 mission in 2020. Bennu's high ammonia levels add to evidence that its parent body originated in the outer solar system, where ammonia ice is more stable, before it migrated closer to the Sun, where ammonia ice would have sublimated.

Bennu's regolith also contained a diverse array of salts, including sodium-rich salts, carbonates, phosphates, and sulfites, which only rarely have been seen in fallen meteorites. Some of the salts were clearly deposited on top of clay materials in veinlike streaks.

"On Earth, these [salt deposits] form in lakes on the surface," said Tim McCoy, a mineral scientist and curator of meteorites at the Smithsonian National Museum of Natural History in Washington, D.C. "That probably wasn't the case on Bennu's parent asteroid.... There [was] something like a muddy surface that had pockets of fluid or veins of fluid, perhaps only a few feet wide, under the surface, and it was within those cracks that the evaporation occurred. Water was lost to the surface, and these minerals were left behind."

These salt patterns, which the team did not expect to find, are consistent with other evidence that Bennu's parent asteroid had enough water for a long enough period in its past to alter its minerology.

Another unexpected find had to do with the way the amino acid structures were oriented, a property known as chirality.

Life on Earth builds proteins almost exclusively from amino acids that twist to the left. In a quirk of fate, most of the amino acids found in past meteorite falls also twist to the left, which led planetary scientists to theorize that meteorites brought at least some of life's building blocks to Earth.

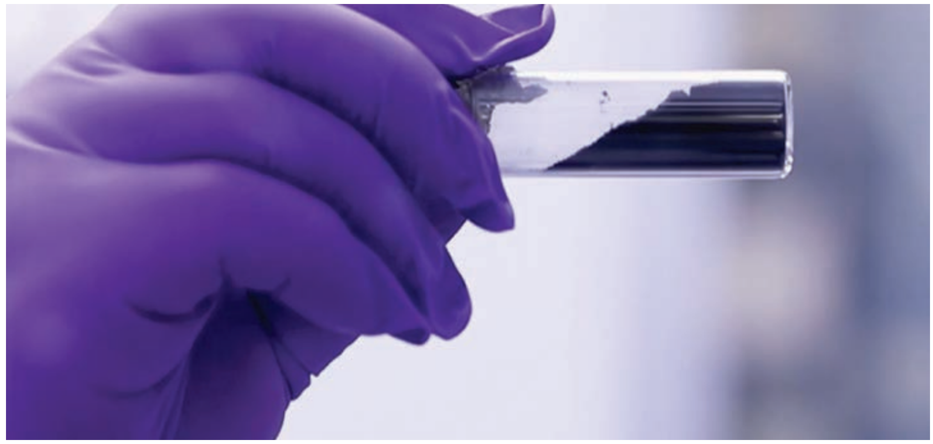
But in the Bennu samples, the amino acids twist to the left and to the right in almost equal abundance.

"I have to admit, I was a little disillusioned or disappointed," Glavin said. "I felt like this had invalidated 20 years of research in our lab and my career. But this is exactly why we explore. This is why we do these missions, right?"

Glavin and his colleagues plan to look at more Bennu samples to see whether more of the asteroid's amino acids have evenly split chirality.

"But for now, the origin of molecular homochirality in life on Earth continues to remain a mystery," Glavin said.

These discoveries were published in *Nature* and *Nature Astronomy* (bit.ly/Bennu-brine, bit.ly/Bennu-organics).



NASA researchers extracted a small portion of their regolith sample to brew "Bennu tea." Credit: NASA Goddard/OSIRIS-REx, Public Domain

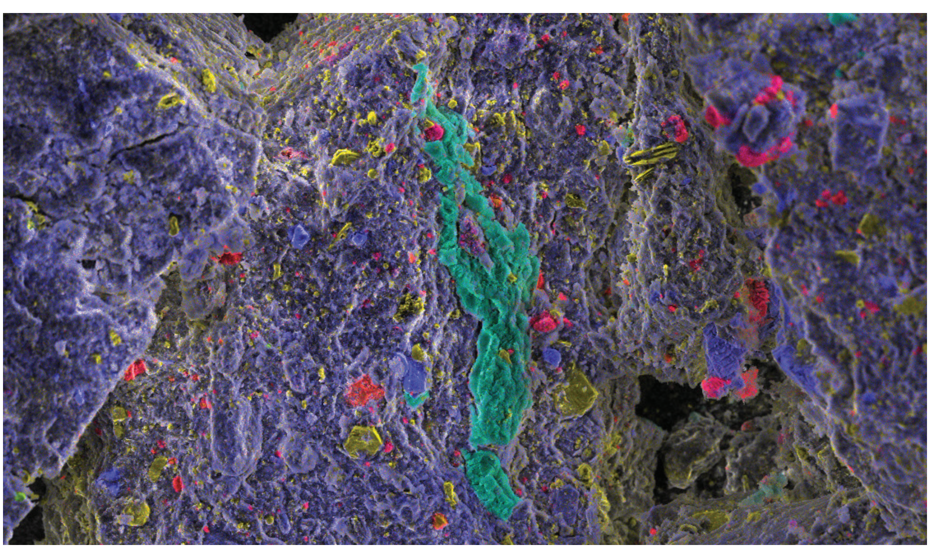
Life's Building Blocks Are Everywhere

"The discovery of brines is crucial for understanding the origin of life in the solar system," said Ahmed Mahjoub, a planetary scientist at the Jet Propulsion Laboratory in Pasadena, Calif. "Salt-rich evaporites create environments ideal for preserving and concentrating organic molecules, including life's building blocks like amino acids and nucleotides."

"I have to admit, I was a little disillusioned or disappointed. I felt like this had invalidated 20 years of research in our lab and my career."

Mahjoub has studied the chemical characteristics of organic material in our solar system but was not involved with these new studies of Bennu. "Similar brines have been detected on Ceres and Enceladus, highlighting their astrobiological significance across the solar system," he said.

Study authors noted that many of these biologically important compounds, including the amino acids and nucleobases, have been detected before in meteorites and comets or remotely detected on bodies in the outer solar system.



This energy dispersive spectrometry map of an unprepared grain of Bennu's regolith shows the placement of briny salt atop clay materials. Phosphorus is shown in green, calcium in red, iron in yellow, and magnesium in blue. A 0.1-millimeter vein of magnesium sodium phosphate (green cluster at center) was formed by evaporation. The phosphate may have played a role in the formation of organic molecules found within the samples. Credit: Natural History Museum, London/Tobias Salge and NASA's Goddard Space Flight Center, Public Domain

"What's so significant about the Bennu findings is that those samples are pristine," Glavin said. The samples were protected from heat damage during atmospheric reentry and from exposure to Earth's atmosphere and biosphere. "All meteorites are exposed to some level of contamination," he said. "The bottom line is, we have a higher confidence that the organic material we're seeing in these samples [is] extraterrestrial and not contamination. We can trust these results."

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That Bennu hosts bioessential material similar to that discovered elsewhere in the solar system confirms that life's building blocks are quite widespread, Mahjoub added.

"These molecules may have formed in molecular clouds through irradiation of simple compounds," Mahjoub said. "Collisions of comets and asteroids with planets and moons could have delivered these organics, potentially contributing to the origin of life. Such impacts may also release prebiotic molecules into space, allowing them to travel to other locations."

Many of the methods that can tease out the subtle signals of complex molecules found in asteroid samples fundamentally change or destroy the material in the process, rendering sample reanalysis impossible—you can't brew the same Bennu tea twice. Because of that, NASA and its partners are preserving around 70% of the returned Bennu samples for scientists to study in the future, as was done with the lunar samples returned by the Apollo missions.

"I cannot wait to see what our future explorers will find as they study these pristine materials in ways that we cannot even imagine today," Fox said.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer

How Much Did Climate Change Affect the Los Angeles Wildfires?

Climate change made the combination of heat, dry climate, and forceful winds that drove January's devastating Los Angeles wildfires about 35% more likely, according to a report published that month by World Weather Attribution (WWA) (bit.ly/WWA-LA-fires).

The study, conducted by nearly three dozen researchers at institutions in Europe and the United States, examined the Fire Weather Index, which incorporates meteorological factors such as temperature, relative humidity, wind speed, and precipitation to estimate fire danger. Researchers compared the index and resulting likelihood and intensity of fires in a 2025 climate to what they might have been under preindustrial conditions, in which the global mean surface temperature was approximately 1.3°C cooler.

The factors that led to the Los Angeles fires are expected to coincide, on average, every 17 years, whereas in preindustrial conditions they may have occurred together only every 23 years.

The Palisades and Eaton Fires in Los Angeles County burned nearly 40,000 acres, claiming at least 29 lives and more than 16,000 structures.

What ignited the first flames of these fires is not yet known, but they were fanned by what Chad Thackeray called "a recipe for disaster." Thackeray is a climate scientist at the University of California, Los Angeles (UCLA) who was not involved in the new study.

"The impact of these fires and the timing of these fires in the core of what should be the wet season differentiate this event as an extreme outlier."

Water years 2022–2024 brought Los Angeles to a 2-year rain total not seen since the highs of 1888–1890, leading to a buildup of vegetation. Then a record-breaking heat wave in summer 2024 dried out that vegetation, and Southern California's rainy sea-

A firefighter battles the Palisades Fire in Los Angeles. Credit: Cal Fire/Flickr, CC BY-NC 2.0 (bit.ly/ccbync2-0)