# The search for life on other planets could get a boost from biosignatures

January 28 2018, by Amina Khan, Los Angeles Times

This artist's concept depicts a planetary system. Credit: NASA/JPL-Caltech

By studying the atmospheric contents of ancient and present-day Earth, scientists say they've discovered specific chemical combinations that could reveal the presence of biological activity on other planets.

These biosignatures, described in the journal *Science Advances*, could offer a key tool in the search for extraterrestrial life.

"There's a direct path from the conclusions of our work to the possible discovery, which would be an historic one, of life elsewhere," said senior author David Catling, a planetary scientist and astrobiologist at the University of Washington in Seattle.

Thousands of planets beyond our solar system, known as exoplanets, have been discovered in the last several years, a small number of which appear to be rocky, Earth-sized planets at the right distance from their star to hold liquid water. Studying the ones with detectable atmospheres could provide crucial clues as to whether they host life.

As powerful new telescopes start to come online, researchers are trying to figure out exactly which atmospheric chemicals they should be looking for. After all, just because a planet looks like it has the right ingredients for life doesn't mean there's actually anything living there.

Scientists have focused on a few potentially telltale molecules, such as methane. Methane is produced in large quantities by microbes on Earth (including those in the bellies of cattle). But methane can also be produced by nonbiological sources, such as volcanoes.

Molecular oxygen (two oxygen atoms bonded together) is produced in massive amounts today by photosynthesizing algae, plants and microbes. But the photosynthetic mechanism is so complicated that scientists think it evolved only once on our own planet. That means there's no guarantee of finding oxygen-producing photosynthesis on other worlds, even if life does exist there.

Thus, relying on any individual chemical could produce false positives or false negatives, said study coauthor Stephanie Olson, an astrobiologist and graduate student at the University of California, Riverside. But living things alter their environments in complex ways. What if there was a particular mixture of molecules that would not exist without life?

To find out, Catling's graduate student Joshua Krissansen-Totton led a study that examined the Earth's atmosphere in three stages of its existence: The Archean (4 billion to 2.5 billion years ago), the Proterozoic (2.5 billion to 541 million years ago) and the Phanerozoic (541 million years ago to the present).

During each of these time periods, life (and the planet itself) looked very different. Place a snapshot of each Earthly period side-by-side, and they'd look like totally different planets.

"The phrase Earth-like does not refer to a planet that necessarily resembles modern-day Earth at all," Olson said. "It's actually a very broad term that encompasses a broad variety of worlds. It includes hazy worlds like the Archean; it includes icy worlds like the 'snowball Earth' intervals; it includes anoxic worlds with exclusively microbial ecosystems; it includes worlds with complex and intelligent life; and it includes worlds that we haven't even seen yet."

That's helpful for scientists, she added, who need several models for what life on other worlds might look like.

In spite of their differences, each of these periods in Earth's history share at least one characteristic: chemical imbalances in their atmosphere. That's because biological activity produces substances that otherwise have no business coexisting, Catling said.

Take methane and oxygen: Placed together, these gases quickly react and destroy each other. But there's plenty of both on Earth, because living things keep making them.

"If you find a system in equilibrium, you've found something that's dead. Or something that's not alive," Catling said. "When we see something unusual, that's out of whack, it can be a sign of life."

People have talked about this idea since the 1960s, Catling said, but hadn't really quantified it up until now. For this paper, the scientists ran simulations using the known chemical contents of each atmosphere to see whether any telltale chemical disequilibriums existed.

The researchers found that during the Archean, when there was little oxygen, the coexistence of methane, nitrogen and carbon dioxide in the atmosphere (together with liquid water) would have been a sign that living things were hard at work.

"Large fluxes of each gas in the absence of biology is really difficult to explain," Olson said of the coexistence of carbon dioxide and methane.

In the mid-Proterozoic, as oxygen-producing microbes rose, the giveaway would be a combo of oxygen, nitrogen and liquid water. Even if the levels of atmospheric oxygen are too low to be detectable, scientists could look for ozone instead, Olson said. That's because ozone (composed of three oxygen atoms) is made by reactions involving biologically produced oxygen and it produces a very strong signal that could be detectable even at low levels.

In the Phanerozoic, which includes the present day, the biosignatures would be oxygen with nitrogen and water. (Oxygen levels here would far higher and much easier to detect than in the mid-Proterozoic.)

A few of the chemical cocktails, such as the combination of methane and carbon dioxide, might be detectable by future observatories like NASA's James Webb Space Telescope, set for launch in 2019.

"It's really giving people a path forward on what to focus on in their observations," said Nikole Lewis, a project scientist for the James Webb who is based at the Space Telescope Science Institute in Baltimore.

James Webb will survey a broad range of planets, and having a wide variety of biosignatures and a range of planetary templates is a crucial tool, she added. That's because the more planets they're able to find that fit these criteria, the more likely they are to discover the few that might really host living things.

"We'll have a large enough sample that hopefully there'll be a few that will stick out like sore thumbs," Lewis said.

Until James Webb and other telescopes capable of finding these atmospheric contents come online, the hunt for possible biosignatures continues, scientists said.

"At the moment we're not yet prepared to recognize life on the full diversity of Earth-like exoplanets, and we can only imagine what life might look like on a planet that's not Earth-like," Olson said. "That's of course a huge area of research, and I don't think we've quite figured it out yet. But disequilibrium is potentially a particularly powerful path forward."

**More information:** J. Krissansen-Totton el al., "Disequilibrium biosignatures over Earth history and implications for detecting exoplanet life," *Science Advances* (2018).
advances.sciencemag.org/content/4/1/eaao5747 , DOI: 10.1126/sciadv.aao5747