C'est la Vie

Searching for life in the solar system

By RON COWEN

"What do they call it . . . the primordial soup? the glop? That heartbreaking second when it all got together, the sugars and the acids and the ultraviolets, and the next thing you knew there were tangerines and string quartets."
—*Seascape*, Edward Albee

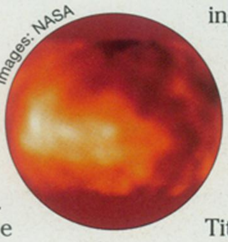
In the play *Seascape*, two creatures emerge from the sea, climb onto dry land, and come face to face with a strange new landscape. Planetary scientists are struck with a similar sense of awe as they ponder images of faraway vistas—a moon shrouded in an organic smog, an icy body whose fractured surface may hide a vast ocean, and a reddish terrain crisscrossed by channels that may once have carried water.

The notion that organic compounds might have come together and formed a biological brew on other planets and other moons is hardly new. Yet recent discoveries of primitive organisms on Earth that flourish in harsh habitats have sparked a revolution in the search for life throughout the solar system.

Researchers generally cite three ingredients necessary for life: organic compounds, liquid water, and a source of energy. With this in mind, planetary scientists have zeroed in on two places in the solar system: the planet Mars and Jupiter's moon Europa. A third locale, Saturn's largest moon, Titan, does not meet all three requirements, but it may offer a laboratory for scientists studying the chemical processes that led to life.

It would be thrilling, of course, to find life on Mars or Europa, but even if these bodies never harbored a single living thing, they "may tell us something about the very interesting intermediate steps" by which life gained a foothold on Earth, says Jonathan I. Lunine of the University of Arizona in Tucson.

Chilly enough that both water and carbon dioxide remain frozen on its surface, Titan isn't likely to harbor past or present life. However, of all the bodies in the solar system today, Titan has the atmosphere "closest to [that of] the early Earth," notes Lunine. For instance, both Titan's dense atmosphere of nitrogen and methane gas and Earth's early atmosphere of carbon dioxide and nitrogen insulate the surface and protect it from the sun's ultraviolet radiation.


Images: NASA

Titan

Obscured by this haze of organic compounds, Titan's surface has yet to be glimpsed. Lunine has long speculated, however, that it contains pools of liquid ethane and methane that replenish the moon's atmosphere as solar radiation destroys these molecules. This theory is expected to be put to the test 7 years from now when the Huygens probe, part of the Saturn-bound Cassini mission, parachutes onto Titan.

Tiny amounts of liquid water, formed when volcanic activity or the impact of comets or meteorites heat the moon's surface, could exist temporarily on Titan but probably not long enough to support life, Lunine says.

Titan's atmosphere, along with its possible hydrocarbon pools and occasional surface water, might provide a venue where solar energy, cosmic rays, and energetic particles accelerated by Saturn's magnetic field could trigger some of the simple chemical reactions that predate life, Lunine says. Some researchers speculate that such an environment, rich in energy and organic compounds, would enable material to organize spontaneously and become increasingly complex, thus making the transition from random to systematic organic structures.

For some 15 years, James P. Ferris and his colleagues at the Rensselaer Polytechnic Institute in Troy, N.Y., have simulated conditions on Titan in the laboratory. Flow tubes containing simple hydrocarbons, such as methane and ethane, are exposed to an ultraviolet lamp, a stand-in for the sun. "What we find most intriguing is that, starting with exceedingly low concentrations of [simple hydrocarbons], you can make quite complex molecules" similar to those that have been detected in Titan's atmosphere, Ferris says.

"The basic reason for studying Titan is that it may provide a way of understanding what might have happened on the early Earth—not so much understanding the origin of life on Earth, but at least how to build up complexity from simplicity," he adds.

In contrast to Titan, Jupiter's moon Europa may hide a vast water world beneath its icy surface. Recent images taken by the Galileo spacecraft show fractures that could be caused by water welling up from below. Other regions show signs that sections of the surface appear to have been pulled apart and rotated as if they were icebergs floating atop water or slushy ice (SN: 8/9/97, p. 90). More photos are in the offing: Galileo is scheduled to fly past Europa eight more times during the next 2 years.

Surface images don't constitute proof of what's underneath, cautions Steven W. Squyres of Cornell University. "You're asking a lot to say, 'Yeah, a kilometer down below this bizarre surface there's liquid water,' merely on the basis of photographs of the surface."


Europa

The same source of energy that might keep water from freezing—the flexing of Europa caused by the gravitational tug-of-war between the moon's siblings and Jupiter—could also drive volcanic activity.

"It's almost inescapable that at some time in Europa's history, back 3 to 4 billion years ago . . . there was liquid water and volcanism," Squyres says. "If one believes that life arises at hydrothermal systems . . . then you've got a credible scenario for life arising on Europa.

"Now maybe it doesn't persist to the present, maybe Europa gets too cold and everything freezes and it's all over after a couple of billion years, but it's still an interesting story," he says.

As for organic compounds, Galileo has yet to find any on Europa. However, the craft's near-infrared spectrometer has detected some organic compounds on two of Europa's colder sister moons, Ganymede and Callisto. The compounds lie trapped within water ice on the surface, Thomas B. McCord of the University of Hawaii in Honolulu and his colleagues report in the Oct. 10 SCIENCE.

Says Christopher F. Chyba of the University of Arizona, "If life doesn't require direct sunlight to make the chemistry go . . . then Europa is potentially the most interesting place in the solar system to look for life."

Shoot the rapids in Maja Canyon, dive into western Chryse Planitia. Spend a lazy afternoon on the lakes of Lunae Planum and Xanthe Terra. Four billion years ago, a visitor to Mars might have reveled in such aquatic activities.

Although the surface of the Red Planet today is as frigid and dry as Antarctica, images taken by the Viking spacecraft in 1976 show that the oldest terrain on the planet bears a network of channels most likely carved by flowing water. More recently, rocks examined by Sojourner, the tiny rover that landed on Mars last summer, have provided further evidence of a warmer, wetter climate on Mars sometime in the past (SN: 10/25/97, p. 264). Conditions that would have sustained water on the Martian surface might have lasted for 1 billion years.


Mars

Early volcanic activity on Mars could have provided a source of energy for life, and ancient carbonate deposits found in the now-famous Martian meteorite ALH84001 indicate that the planet had a substantial supply of organic compounds (SN: 3/29/97, p. 190). As Mars' atmosphere thinned and the temperature fell, some of the water that disappeared from the surface could have gone underground, several scientists speculate. At a depth of 1 to 3 kilometers, the planet's store of residual heat should keep temperatures high enough for water, if it exists there, to remain liquid.

Given what scientists have learned recently about life on Earth's seafloor, where hot water percolates through rock and a bizarre group of organisms thrives, underground reservoirs of water on Mars "would be an excellent place to look for life," says Chyba. "Life that evolved at the [Martian] surface could have retreated to these deep niches."

Or life could have begun there. Recent calculations by Everett L. Shock of Washington University in St. Louis and his colleagues suggest that in underground regions where warm water mixes with cooler water, the temperature difference generates organic compounds from dissolved carbon dioxide or bicarbonate ions, thus helping to sustain life.

It would be no mean feat for a robotic craft to drill a kilometer into Martian rock in search of life, but such an undertaking may not be necessary. David J. Des Marais of NASA's Ames Research Center in Mountain View, Calif., speculates that if some organisms lived at the surface 3.5 to 4 billion years ago, they may have been preserved there. He envisions an ancient community nourished by hot pools or springs, some similar to Yellowstone's Old Faithful geyser. When the Martian springs dried up, the organisms could have become trapped in mineral deposits.

Dried-up lake beds are another place where ancient fossils might exist above ground, Des Marais adds.

By hunting fossils, "we may not only be addressing the possibility of ancient life on Mars but the possibility of life being there today," says Des Marais. If aquifers containing organisms reside a few kilometers underground, a chance blow by a meteorite or comet could discharge some of the contents. "The material would then be strewn along the surface, and although the actual thing you pick up is dead, it's like a smoking gun for something [living] 2 kilometers beneath your feet," he observes.

Mars Global Surveyor, the craft that arrived at the Red Planet in September and will begin its main mission next March, may help to identify hot springs by searching for mineral deposits that appear to have been altered by the passage of warm or hot water.

"If you're in the right place, just by scratching the surface you can find stuff," says Squyres. NASA intends to do just that, using bigger, more advanced versions of Sojourner. Scheduled to land on Mars in 2001 and 2003, these rovers will probably tour the planet's rugged ancient highlands, scooping up rock and soil samples that another mission, scheduled for launch in 2005, will carry back to Earth.

Not all scientists agree on the optimum search strategy. For instance, Christopher P. McKay of Ames Research Center suggests that the best place to find life on Mars may be the south polar region. Beneath a 100-meter-thick ice cap, researchers may find the pristine, frozen remains of organisms that lived 3 billion years ago.

Suppose researchers do find fossils that provide convincing evidence of life. "That actually leaves us in a big quandary," McKay argues. "Is the fossil related to us, or is it really an independent, second genesis of life?"

Planets may not be biologically isolated. When an asteroid or comet strikes a planet, some of the fragments it gouges out could land on another planet—sometimes in only a few thousand years (SN: 9/28/96, p. 204). "We know that the planets throughout the solar system exchange material; they're swapping spit," McKay says.

Indeed, he adds, the exchange rate between planets was probably far greater 3.8 billion years ago, during the period known as the late heavy bombardment, when much more space debris pelted the inner planets than do so today. The earliest known fossils on Earth date from this era (SN: 11/9/96, p. 292).

"[S]earching for life is really a search for biochemistry," says McKay. "We have to actually get the guts of the organisms, the amino acids, the proteins, the genetic code if there is one, and compare it to ours. We want to know if these organisms are really our long-lost cousins, or if they're truly a second biochemistry.

"The first case is interesting; the second case, astounding." ☐

Comets and Asteroids

Whizzing about the solar system, both comets and asteroids smack into planets, potentially altering their chemical makeup and delivering key compounds necessary for life to begin. Comets are thought to have carried significant amounts of organic matter and water from the outer reaches of the solar system to Earth, Mars, and the other rocky planets. It's unlikely that life originated on comets, planetary scientists say, simply because water remains frozen on these icy bodies.

Asteroids—the rocky bodies left behind after planets formed—originated closer to the sun than comets did and were initially kept warm by the decay of radioactive elements within them. Radioactive heating in an asteroid roughly 100 kilometers in diameter could have kept water in its liquid form for perhaps 100 million years, notes Christopher F. Chyba of the University of Arizona in Tucson. It's unclear whether that is long enough for some primitive version of life to have formed, but it does appear long enough for organic compounds to have undergone transformations to orderly, more complex forms.

For instance, researchers have found amino acids in several of the meteorites that have fallen to Earth. Amino acids occur in left-handed and right-handed forms, and chemical processes ordinarily produce a roughly equal mixture of the two forms; however, all amino acids in living things on Earth are left-handed. Scientists recently showed that a famous meteorite, Murchison, contains a slight excess of left-handed amino acids (SN: 2/22/97, p. 118). Such an imbalance could have provided the initial asymmetry from which life on Earth developed an exclusive preference for the left-handed form.

Chyba notes that although meteorites contain amino acids, they do not possess the chains of amino acids that make up proteins. It appears, he says, that inside meteorites "you've got the initial stages in the origin of life, organic monomers [such as amino acids], and you didn't get any farther. That might mean that [inside] the parent bodies of meteorites—asteroids—you didn't get very far."

To the extent that asteroids are a stand-in for the rocky planets, determining whether the interior of an asteroid could have contained primitive life "may of course bear on how likely it is that life originated beneath planets rather than on the surface," Chyba notes. *—R.C.*