MEETING ASTROBIOLOGY SCIENCE CONFERENCE

The Science of Astrobiology Takes Shape

MOUNTAIN VIEW, CALIFORNIA—About 600 researchers from 30 countries came to NASA's Ames Research Center on 3 to 5 April, eager to help mold a new field. At the First Astrobiology Science Conference* every talk, it seemed, touched on a new discipline. Topics ranged from prebiotic chemicals to icy life, but the conference was a story unto itself.

Something Old, Something New

The night before the meeting began, Air Force One brought President Clinton to Ames for a Silicon Valley fund-raiser with the dot-com crowd. Signs and badges for the conference caught the eyes of a vigilant Secret Service agent, whose question Ames director Henry McDonald overheard crackling over a private radio: "What the hell is astrobiology?"

Answers varied. To atmospheric chemist James Kasting of Pennsylvania State University, University Park, it's an exercise in rebranding. "Astrobiology is not a new field," he says. "It's a new name for an old field." Indeed, NASA Administrator Daniel Goldin invoked the term 5 years ago while attempting to broaden NASA's program in "exobiology," the study of possible life beyond Earth. With the new name in place, NASA invited a wide slice of the scientific community—including earth scientists, chemists, oceanographers, planetary scientists, molecular biologists, zoologists, and paleontologists—to work out the content. A series of workshops led to an official astrobiology "roadmap," complete with three fundamental questions, four operating principles, 10 goals, and 17 objectives. They boil down to investigating how life arose and survived on Earth, how it might have done so on other worlds, and how we might go about finding it and recognizing it. That's the formula Goldin is banking on to unite the best minds of today and excite the laureates of tomorrow.

Judging from the response to the meeting, the old-new field is off to a golden start. Organizer Lynn Rothschild, an evolutionary biologist at Ames, was swamped by 370 submitted abstracts with a mere month's notice, and more than twice as many people showed up as she initially expected. Diverse talks kept the audience in place until the end. Disciplinary walls teetered at the egalitarian poster sessions, where members of the National Academy of Sciences presented alongside graduate students. "I felt a visceral sense of excitement," says geologist Peter Ward of the University of Washington, Seattle. "I think that was an almost universal reaction."

Participants aren't yet rushing to call themselves astrobiologists; rather, the title is becoming a "second identity," says planetary geologist Bruce Jakosky of the University of Colorado, Boulder. "I'm retooling to be an astrobiologist. I now talk to microbiologists on a regular basis. That's something new."

Jakosky attributes much of that new focus to the Astrobiology Institute, a virtual center that NASA established in 1998 at Ames. The institute now has about 420 contributing scientists and students at 11 member universities and research centers. It also has a director with cachet: biochemist Baruch Blumberg, winner of the 1976 Nobel Prize in physiology or medicine for his work on the hepatitis B vaccine.

The institute has a modest budget by the standards of national science: $13 million in this fiscal year and a projected $16 million to $17 million next year. That means most of the institute's investigators have received just $10,000 to $20,000 annually for each person on their peer-reviewed projects. "We're trying to shovel more money to the teams," Blumberg acknowledges. Even so, the institute's ranks will expand by another three to four member institutions this year.

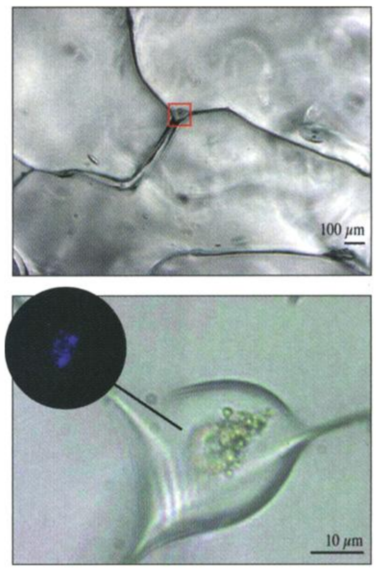
The fiscal situation makes some scientists wary. "Astrobiology has arrived, but it's fragile," says biochemist David Deamer of the University of California, Santa Cruz. "It all depends on the continued interest from NASA headquarters. Some new blood has come into the field, but the money got spread out too thinly, and everyone is complaining that it's not enough."

Nonetheless, Deamer and his colleagues say they were inspired by the conference and by visions of a web of new collaborations weaving among the attendees. As planetary scientist David Morrison, director of astrobiology and space at Ames, proclaimed in the aisle of the overflowing lecture hall: "I'm beginning to think astrobiology is real."

Shades of Europa in Arctic Sea Ice

Planetary scientists who dream of probing for microbes on Jupiter's icy moon Europa would love to explore similar settings on Earth. One popular choice is Lake Vostok, a freshwater lake buried under 4 kilometers of ice in the heart of Antarctica. A primitive ecosystem may eke out life in Vostok's dark waters (*Science*, 10 December 1999, p. 2094). However, new research points to a better and more accessible match: microscopic pockets of salt water frozen inside the Arctic Ocean's winter ice.

Bacteria make happy homes within those pockets at temperatures of –15°C and below, a team reported at the meeting—the most frigid climes yet seen for living microbes. Researchers had thought that in such extreme cold, organisms trapped inside isolated microscopic pores would freeze or starve. But scans using magnetic resonance imaging (MRI) and microscopy show that watery microveins lace the ice and connect the briny abodes to a surprising degree.



Cold comfort. Veins of salty water *(top)* riddle the Arctic Ocean's ice cover at –15°C and colder. New techniques reveal tiny pockets of brine *(above)* and their resident particles, including bacteria *(inset)* without melting the ice.

CREDITS: KAREN JUNGE/UNIVERSITY OF WASHINGTON

The developments are "exciting and encouraging" for the prospects of microbial habitats on Europa, says planetary geologist Robert Pappalardo of Brown University in Providence, Rhode Island. Slushy upwellings heated by the moon's tidal flexings should warm the ice near Europa's surface to –10°C or –20°C, he says. Further, the Galileo spacecraft apparently has spotted salty deposits on the moon, suggesting that its ocean and overlying ice are anything but fresh. "You'll get these brine pockets everywhere," Pappalardo says.

When seawater freezes on Earth, it leaves behind liquid-filled pores like the air bubbles in a sponge. Salts and other impurities concentrate within the pores, keeping

* www.astrobiology.com/asc2000

them fluid even as the ice grows colder and harder. Bacteria, diatoms, and other organisms spend their winters there, presumably subsisting on a bare minimum of nutrients.

No one had ever studied the physics and biology of this seasonal ecosystem without melting the ice, until a team led by marine microbiologist Jody Deming of the University of Washington, Seattle, and geophysicist Hajo Eicken of the University of Alaska, Fairbanks, devised a way to spot bacteria within ice at temperatures well below freezing. The researchers collected sea ice near Barrow, Alaska, in March 1999 and again last month—the coldest part of the winter there. Then, in a cold room in Fairbanks, graduate students Karen Junge and Aaron Stierle and postdoctoral researcher Christopher Krembs applied salty solutions of a bacterial stain to specially prepared ice sections. The stain attached to the DNA of the bacteria, making the cells fluoresce when exposed to ultraviolet light.

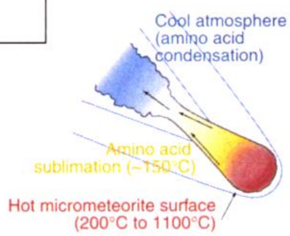
The team found dozens of intact bacteria dotting the ice samples from 1999 at temperatures ranging from −2°C to −15°C. Early results from last month's ice show similar concentrations of bacteria down to −20°C. Another stain, on melted samples, showed that the bacteria are respiring, not just dormantly waiting out the winter.

Of course, the organisms must also eat. For that, they need fluid moving through the ice and transporting nutrients. To determine whether the brine can flow, Eicken and his colleagues at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany, used a cold-adapted MRI probe to detect liquids within intact samples of ice. They found that a network of narrow veins among the pores persisted down to −30°C—within 5 degrees of the coldest temperatures that marine ice reaches naturally on Earth. "Even very cold, hard ice contains small wet areas that can and do support life on this planet," Deming says.

Such refuges may be the first place to look for life on Europa if a lander ever visits the moon. "The environments may have tremendous similarities," says planetary scientist Richard Greenberg of the University of Arizona in Tucson. Greenberg thinks Europa's icy crust may be thin enough for tidally induced cracks to penetrate to the ocean beneath. If that's true, he says, "the arctic ice is probably a closer analog to Europa than Lake Vostok."

Can Amino Acids Beat The Heat?

Astrobiologists would love to divine the birthplaces of amino acids, the links in the protein chains of life. Some probably formed on the primitive Earth as lightning and ultraviolet light from the sun energized the atmosphere. An even richer source may have been space, where chemical reactions within the wombs of star-forming regions may forge amino acids in abundance. To help spark life, however, they had to withstand the fiery plunge to Earth's surface. New work presented at the meeting suggests that some amino acids survived that trip aboard two seemingly fragile hosts: comets and dust.



Hot dust. When researchers heated tiny grains of the Murchison meteorite, the amino acid glycine sublimed into a vapor. A similar process could help amino acids survive when micrometeorites plunge into Earth's atmosphere (*inset*).

CREDITS: (METEOR) MARTIN HOREJSI; (ILLUSTRATION) DANIEL GLAVIN/SCRIPPS INSTITUTION OF OCEANOGRAPHY

Planetary scientists have long known that organic compounds could make the passage aboard meteorites. For instance, fragments of the carbon-rich Murchison meteorite, which decelerated relatively gently in the atmosphere and fell onto Australia in 1969, contain amino acids (including a few not found on Earth) that stayed cool beneath a red-hot outer rind. "As long as some chunks remain, the surface heating seems to go only a few millimeters deep," says impact specialist H. Jay Melosh of the University of Arizona in Tucson.

In principle, comets—which carry more carbon-rich material than most meteorites—ought to be even better sources of the chemicals that assemble to make amino acids. Most comets, however, slam into Earth at tremendous speeds because of their distant orbits. Intense atmospheric shock pressures and high temperatures should prove fatal to amino acids, planetary scientists believed. Even so, some researchers held out hope that a fraction of the cometary bounty would survive.

Now, experiments led by geophysicists Jen Blank of the University of California, Berkeley, and Greg Miller of UC Davis have boosted that optimism. The team encased watery solutions of five amino acids inside steel disks and fired steel projectiles at them with a 12-meter-long gun. The impacts, at speeds up to 1.5 kilometers per second, pummeled the amino acids with up to 200,000 times Earth's atmospheric pressure and temperatures as high as 600°C. Such conditions might be felt by a comet slicing into Earth's atmosphere at a very low angle, Blank says: "This is the closest anyone has achieved in the lab to recreating the conditions of a cometary impact."

Blank and Miller found that 40% to 70% of the amino acids survived, perhaps because the pressure stabilized them and prevented the heat from breaking their chemical bonds. Moreover, some of them paired in a flash to form dipeptides, the first step toward amino acid chains. The experiments are encouraging, Melosh says, although he warns that time scales are vastly different in the atmosphere. "Extreme conditions in a real impact last up to a second," he notes—a million times longer than collisions in the lab. The extra time might let destructive reactions penetrate throughout an impactor.

On a far smaller scale are micrometeorites and dust particles, which add some 40,000 tons of extraterrestrial material to Earth each year. Some tiny particles decelerate and drift to the ground, but they can still roast at more than 1000°C for several seconds—enough to destroy amino acids. However, geochemists Daniel Glavin and Jeffrey Bada of the Scripps Institution of Oceanography in La Jolla, California, have now demonstrated a way for organic compounds to escape the mini-infernos.

Glavin and Bada extracted grains from part of the Murchison meteorite and heated them in a partial vacuum. Glycine, the simplest amino acid, sublimed into a vapor when the temperature reached 150°C and survived as the rest of the grains heated to 800°C. Such a vapor would recondense in a cold trail behind the micrometeorites, Glavin says, creating tiny rains of glycine seeding the surface. Because interplanetary dust was rampant in the young solar system, he says, "this may have been a good way to get some of the prebiotic molecules onto the early Earth." However, the news is not entirely rosy: Other amino acids in the Murchison sample did not sublime and were destroyed by the heat. This summer, the Scripps team will analyze antarctic micrometeorites—in which the researchers have detected extraterrestrial amino acids—to see whether they will sublime in the lab.

The experiments suggest that space delivery of amino acids billions of years ago was a "plausible" companion to organic synthesis in the atmosphere, says David Deamer of UC Santa Cruz: "There's just no doubt that some of the amino acids survive the impacts. It's become surprisingly convincing."

—ROBERT IRION