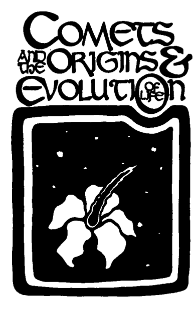
Did a Rain of Comets Nurture Life?

In recent years origin-of-life researchers have buzzed over a provocative notion: that comets could have supplied Earth with all the building blocks for primordial living molecules. From 30 September to 2 October, 55 specialists gathered at the University of Wisconsin at Eau Claire to discuss "Comets and the Origins and Evolution of Life," debating some intriguing proposals about how comets might have contributed to those origins—and how their signature might still be discerned.

Bringing a Comet in for Landing



PATRICIA PIERCE

A comet, so the phrase goes, is a dirty snowball, and much of that dirt is organic materials—formaldehyde, hydrogen cyanide, and more complex substances. But those materials are also fragile. What a waste it would have been, some researchers studying the origins of life say, if that organic cargo had been destroyed by the heat of impact as comets bombarded the early Earth. If those fragile compounds had somehow survived, these researchers think, they could have provided the starting point for the chemical evolution that led to more complex molecules like amino acids, nucleic acids, and, ultimately, the giant molecules of living things.

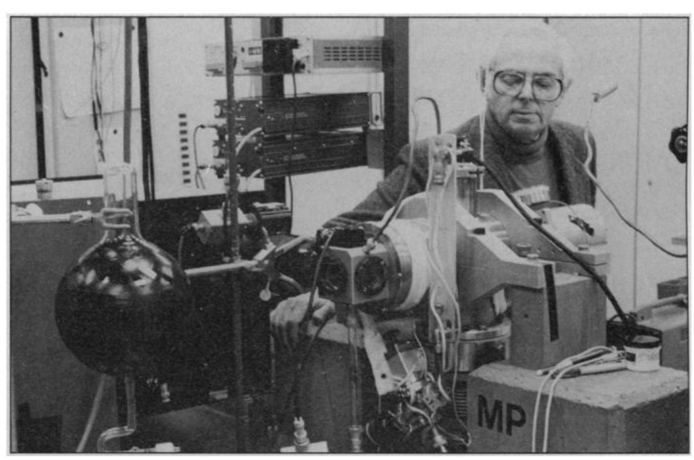
That's where astrophysicist J. Mayo Greenberg of the University of Leiden comes in: He thinks he knows how to get the organic building blocks safely to Earth. Key to that happy landing, he told his audience at the meeting, are his recent studies of the insulating properties of cometary ice, which he thinks could protect organic molecules from the heat of impact.

Not everyone agrees with the assumption implicit in Greenberg's proposal—that there's a need for an extraterrestrial source of organic compounds. At the Eau Claire meeting, chemist Stanley Miller of the University of California, San Diego, famous for the 1950s experiments in which he sparked the formation of amino acids and hydrogen cyanide in a mixture of simple precursors, defended the traditional view that the compounds were homegrown. Reactions driven by lightning and ultraviolet light in a methane- and ammonia-containing primordial atmosphere, he said, could have produced the same building-block compounds found in comets. But under different assumptions about the composition of the ancient atmosphere, Carl Sagan of Cornell University points out, "endogenous synthesis would be difficult, and you would have to import organics."

As Sagan and his colleagues Christopher Chyba and Paul Thomas of Cornell and Leigh Brookshaw of Yale University showed in a paper last year in *Science* (27 July 1990, p. 366), that's no mean feat. According to their computer simulation, only small parts of a comet plowing into the atmosphere would stay cool enough to preserve organic chemicals. The group did hold out the hope that if small fragments broke off the comet and wafted gently to Earth, the organic materials they harbored might survive. But Greenberg told the conference that he now has reason to think much more of the cometary cargo could survive the collision.

He bases his proposal on laboratory simulations of the icy particles that make up comets. To create them he condenses mixtures of water vapor, methane, carbon monoxide, and other gases present in interstellar space onto a glass plate cooled to 10°K. Earlier experiments had shown that the ice deposited at these low temperatures is amorphous, having a disorderly molecular structure rather than the usual crystalline one.

Amorphous ice conducts heat more slowly than crystalline ice. Now Greenberg has found that when the ice is deposited very slowly, as it would be on interstellar grains, its thermal conductivity is lower still, by a factor of 10,000 to 100,000. The reason, he speculates, may be the "lesser connectedness" of water molecules that have accumulated slowly. And the effect of this extraordinarily low thermal conductivity might have been to insulate organic materials against the heat of a cometary impact. While the outer layers of the grains were vaporized during the comet's collision with the atmosphere, the inner parts might survive unscathed and float gently to Earth.


JOSEPH MARCUS

The ice man. *Mayo Greenberg in his laboratory at Leiden.*

Chyba is skeptical. "You must still remove from the comet the millions of megatons of TNT worth of heating that would occur with a large impactor"—enough to destroy organic material throughout the comet. "It just seems too hopeful." Still, says Thomas, he and Chyba would be interested in seeing a computer model of a comet impact incorporating Greenberg's notion, to see if it gives a more hopeful prognosis for the survival of cometary organics.

The discovery also has a practical implication, Greenberg points out. In 2002, the European Space Agency plans to launch its Rosetta mission to drill a 3-meter core sample from a comet and return it to Earth. Thanks to the powerful insulating properties of cometary ice, Greenberg says, drilling so deep may not be necessary. "Even periodic comets heated by the sun preserve pristine interstellar matter in cold storage at relatively shallow depths" of just tens of centimeters, he estimates. But the deep cold just under the comet's skin also means, he says, that getting the comet-stuff back to Earth in its native state may require "a greater effort to provide the lowest possible return temperature—preferably less than 20°K"—to match the cometary deep-freeze.

A Cometary Source for Cockeyed Molecules?

Stanford University chemist William Bonner has a special reason to root for J. Mayo Greenberg: If comet-stuff could have landed intact on the early Earth, he explained to meeting attendees, he and his fellow chemists who have been puzzling over molecular handedness could get on with their lives.

One of the most mysterious features of present-day biomolecules is the fact that the ribose and deoxyribose sugars in DNA and

RNA are all righties while the amino acids that make up proteins are all southpaws. That's a puzzle because both the sugars and amino acids are chiral molecules—that is, they can exist in two different, mirror-image forms. But not on Earth they don't. No one can satisfactorily explain how this "enantiomeric excess" came about on Earth. But Bonner can in space, he told his audience.

Bonner's scenario, developed with his Stanford colleague Edward Rubenstein, relies on the intense ultraviolet light that would emanate from electrons accelerated by the powerful magnetic field of a rapidly rotating neutron star. This synchrotron radiation would have strong circular polarization—that is, the plane of the waves would rotate continuously, in one direction for light coming from the star's northern hemisphere and in the other for light from the southern. If any interstellar grains bearing organic materials strayed into range, Bonner contends, the circularly polarized light would selectively destroy molecules of one handedness while sparing the other.

Biased by their encounter with the neutron star, the compounds could have reached Earth millions of years later, either in comets or in dust swept up as the solar system passed through an interstellar cloud. Such an extraterrestrial infusion could have sowed the seeds of today's curious asymmetry.

Chiral-molecule expert J.P. Ferris of the Rennselaer Polytechnic Institute is intrigued, but he points out uncertainties—among them the fact that no one has yet observed a neutron star giving off circularly polarized ultraviolet light. "It's a hypothesis, is what it really comes down to," says Ferris, but one he thinks is worth exploring. Interstellar-grain expert Greenberg is preparing to do just that in his laboratory at the University of Leiden. He plans to shine circularly polarized ultraviolet light on chiral compounds containing opposite-handed forms in equal amounts, trapped in simulated interstellar grains. He'll then analyze the grains to see if molecules of a particular handedness were destroyed preferentially.

And there's already some support for one of Bonner's assumptions: that an enantiomeric excess—however it originated—can survive for millions of years, protected by the deep cold of interstellar space. According to geophysicist Michael Engel of the University of Oklahoma and his colleagues, an organic-rich meteorite that landed in Australia in 1969 may contain a significant excess of one amino acid's left-handed form—perhaps a signature of an ancient encounter with a neutron star. ■ JOSEPH MARCUS

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A Layer by Layer Look at the Skin Blister Diseases

Discovery of the gene defects causing two types of hereditary blistering diseases is aiding understanding of skin structure


P. COULOMBE, M. HUTTON, AND E. FUCHS

All balled up. *A mutant keratin gene results in abnormal keratin filaments, with ball-like structures at the ends, in this mouse cell, which was taken from a trangenic animal.*

REAL EPIPHANIES ARE RARE IN SCIENCE. THE scene where a scientist solves a mystery and yells "Eureka" belongs more to the realm of science fiction than to fact. Less rare perhaps, but nevertheless breathtaking, are those discoveries that ripple out through a community of researchers, triggering a surge of new insights. Take the case of the rare hereditary skin diseases known as epidermolysis bullosa.

Called EB by the dermatology community, this family of diseases shares one aspect: They are all characterized by such an extreme skin fragility that even the slightest friction can cause painful blistering. Until very recently, no one understood the genetic basis of any form of EB. But within the past few months, three independent teams have identified the defects causing two forms of EB. And their discoveries are having the ripple effect: Not only are they pointing the way to potential new therapies for the blistering diseases, they may also have wider implications by producing a much better picture of skin structure, which has been as poorly understood as the EB diseases. Such information may, for example, provide new insights into normal skin aging.

Two of the teams, one led by Ervin Epstein Jr. of the University of California, San Francisco (UCSF), and the other by Elaine Fuchs of the Howard Hughes Medical Institute at the University of Chicago, are studying the commonest and least severe form of EB, known as EB simplex. While about 50,000 U.S. residents have some form of EB, how many suffer from EB simplex is unknown. Martin Carter, head of the National EB Registry's branch at Rockefeller University in New York, says, however, that roughly half of the 1700 tissue samples collected by the registry come from patients with EB simplex.

What these people experience stems from a defect residing in the outermost layer of the skin, known as the epidermis. Their epidermal cells, which are called keratinocytes, are unusually fragile and break apart when the skin is abraded. The cell breakdown leaves a gap in the epidermis, which can be filled with extracellular fluid to form blisters.

Fuchs and her colleagues hadn't initially set out to study EB. They were instead curious about the function of the keratins, a family of over twenty proteins that are found almost exclusively in the keratinocytes where they form networks of filaments. The structure of keratins has been studied for more than 20 years, Fuchs says, but little was known about their function back in the mid-1980s when her team began working on them.

One way to find out what the filaments do is to alter them by introducing mutations into one of the keratin genes, and then see what fails to occur, explains Pierre Coulombe, a postdoc in the Fuchs lab. And that's what led the group into the EB arena. The researchers discovered that the mutations caused the keratin networks in cells growing in culture to be disrupted, sometimes to such an extent that the keratin ended up clumped around the nucleus. To find out how the mutations might affect keratinocyte function in a living organism, graduate student Robert Vassar, Coulombe, Fuchs, and their colleagues then went on to insert mutant keratin genes into mouse embryos. The resulting transgenic mice developed a disease very much like EB. Says Coulombe: "The transgenic mice were missing significant portions of their skin. The skin was blistered either by the birth process or by trivial mechanical trauma."

Back at UCSF, meanwhile, the Epstein group had also gotten interested in the keratins, but for a different reason. They had noticed a resemblance between certain diseases of red blood cells and EB. Red blood