sets of field lines can then splice into each other, allowing particles from the solar wind to leak into the magnetosphere. Poorly understood mechanisms roil the magnetosphere, and the spliced field lines are stretched downwind, where they can snap back, slinging lumps of plasma toward Earth.

Inside the magnetosphere, all of this action sends electrons scooting down the magnetic field lines that curl toward Earth at high latitudes. Bombarded by the electrons, oxygen and nitrogen atoms in the upper atmosphere glow, creating aurorae in oval-shaped regions ringing the magnetic poles. At the same time, the magnetic disturbances that accompany the huge electrical currents at the poles rattle the magnetic field all over the globe. Worldwide magnetometer data can thus provide a continuous, composite measure of auroral activity.

Deehr and Akasofu try to forecast this activity by searching the magnetometer data for disturbances that recur every 27 days—the time it takes the sun to rotate once, sweeping its sprinkler streams of particles past Earth. But because the coronal holes that ultimately drive the disturbances can shrink, vanish, or migrate from one solar rotation to the next, Deehr and Akasofu also keep an eye on reports from solar observatories. They then combine the observed periodicities with recent changes in the holes to predict magnetic activity 4 or 5 days in advance.

To translate the expected magnetic activity into an aurora forecast, the team searches archived satellite pictures of the auroral ovals, looking for an image that shows the brightness and extent of aurorae at a comparable level of magnetic activity. The method probably won't work well at solar maximum, when the sun's behavior is more fickle. And even now the drifting coronal holes can throw off the timing of the displays by a day or so, says Akasofu. But on the whole, he says, the agreement between the forecasts and the observations has been "quite a lovely thing."

Eugene Wescott, a UAF geophysicist who used the forecasts to help time a rocket launch on Saturday, 25 March, agrees. Without the forecast, he might have considered firing into the faint aurora that appeared earlier that week. "But the predictions were that it was going to get better for the weekend," he says. His reward for waiting? "We had a quite good aurora" for the experiment.

Deehr and Akasofu admit that their main motivation for going public with the forecasts wasn't scientific, however. They just hoped to cut down on the hundreds of phone calls they receive each year from American and Japanese tourists seeking the inside word on auroral displays. It seems the aurora hasn't lost all of its old magic.

–James Glanz

James Glanz is a science writer in Chicago.

MEETING BRIEFS

NASA's Space Biology Program Shows Signs of Life

HOUSTON—At the first Life Sciences and Space Medicine Conference, held here from 3 to 5 April, NASA Administrator Daniel Goldin made it clear that NASA's life sciences program is not exempt from his drive to reinvent the space agency. "We've got to do things differently to get to our goal" of making long-duration space travel a reality, he told the audience. He stressed "rigorous peer review," collaboration with investigators at the National Institutes of Health and in industry, and the development of commercial spin-offs. Once NASA's overhaul is complete, "life sciences will be the jewel in the crown," Goldin told *Science*. But as the meeting revealed, there are already some bright spots.

Unbalanced Rats

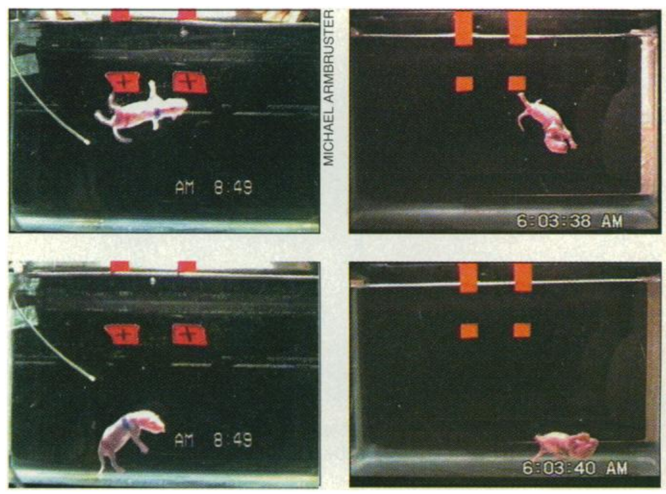
It's well known that for normal development of its sensory nervous system, an infant must experience the full clamor of changing sight, sound, taste, and touch stimuli available on Earth. Now it seems that a more constant stimulus—gravity—may also be crucial for sensory development.

Rat pups that spend part of their fetal development in the microgravity of space are born with a "dramatic" impairment in their sense of balance, Jeffrey Alberts, a developmental psychobiologist at Indiana University in Bloomington, told attendees. Biologist Kenneth Souza of NASA's Ames Research Center in Moffett Field, California, calls the results "convincing," but he and Alberts say further experiments are needed to show that the impairment is a permanent developmental change rather than a temporary adaptation to microgravity.

In last November's experiment, 10 pregnant rats were flown aboard NASA's space shuttle Atlantis; two control groups of 10 pregnant rats each remained on Earth. After 11 days in space, Atlantis returned home; the 30 mother rats gave birth 2 days later. Alberts and April Ronca of Indiana University then ran at least one pup from each litter through tests of the vestibular system—sensors in the inner ear that keep track of gravity and body position, generating a sense of balance.

The space pups fared badly. For instance, the so-called "water-drop righting response," in which a rat placed on its back in a bath of water uses a coordinated sequence of movements to right itself, was far slower in pups that developed under microgravity than in either set of controls. "The flight rats are less responsive to the stimulus of being upside down," says Alberts.

One of the next steps will be to find out whether the absence of Earth's gravity triggers structural changes in the brain circuits that process information from the vestibular system. If it does, developmental neurobiologists won't be surprised. In the 1960s and '70s, David Hubel and Torsten Wiesel, then at Harvard Medical School, showed that if a kitten is deprived of light, the nerve cells in the brain cortex that process visual information do not make the highly organized pattern of connections that is seen in a normal cat. Since then, studies of hearing, touch, and smell have all confirmed that a sensory system needs input to develop normally. There's no reason to think balance is exempt, Alberts said, because when it comes to developmental processes, "it's a rule—almost a law—that input affects structure."



MICHAEL ARMBRUSTER
WILLIAM FARRELL

Out of kilter. Rat pups that spent part of their gestation in space *(right)* are slower to right themselves in a water bath than are controls *(left)*.

Swelled Heads in Space

Vomiting in space is both peculiarly messy and potentially dangerous because it can block the valves of a space suit. Arriving in orbit with an incapacitating headache isn't so wonderful either. Both are symptoms of the space sickness that commonly strikes astronauts during the first few days of flight. Drugs are available to treat the symptoms, but they cause side effects such as drowsiness.

Meanwhile, NASA scientists are at a loss to explain exactly what causes space sickness. But at the meeting, physiologist Alan Hargens of NASA's Ames Research Center described a device that his team is developing to test one hypothesis: that space sickness is the result of pressure buildup inside the skull. If the device—which uses ultrasound to measure fraction-of-a-millimeter changes in skull size—shows that space sickness is associated with surges in intracranial pressure, it could lead to better means of combating the condition.

The pressure hypothesis for space sickness is plausible because without Earth's gravity to pull blood toward the feet, blood volume in the head increases. That increase should boost pressure inside the skull, and increased intracranial pressure is known to trigger nausea, vomiting, and headache in Earthbound patients who have a defect in the drainage of cerebrospinal fluid.

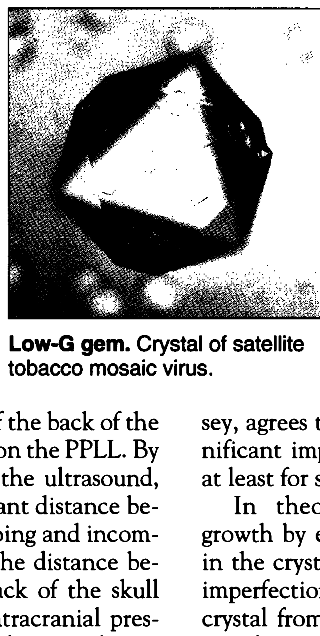
To test the idea, the Hargens team is now adapting a prototype device developed by NASA physicists for detecting stresses in metals used to build rockets. Referred to as the Variable Frequency Pulse Phase-Locked Loop (PPLL) measuring device, it sends a high-frequency sound wave through the head, where it is reflected off the back of the skull and returns to a sensor on the PPLL. By altering the wavelength of the ultrasound, the PPLL maintains a constant distance between the peaks of the outgoing and incoming sound waves. Thus, as the distance between the front and the back of the skull increases with increasing intracranial pressure, so does the wavelength, providing a marker for pressure.

At the Houston conference, Hargens reported that his team had tested the PPLL on seven adults by slowly tilting their bodies so that their heads were just below the horizontal, a position that causes blood to rush to the head as it does in weightlessness. The device could easily measure the tiny increases in skull length, which totaled about 0.1 millimeter. "The more we tilted, the greater the increase in intracranial distance," says Hargens.

Next, the PPLL will be calibrated on cadaver skulls implanted with pressure transducers and infused with fluid to alter pressure. The ultimate aim, says Hargens, is to use the PPLL to monitor intracranial pressure in astronauts "during the launch and into early microgravity, because that is when we think you get the rapid increase in intracranial pressure" that triggers space sickness. The device could be useful on Earth too, says neurosurgeon Lawrence Shuer of Stanford University in Palo Alto, California, who will help test the PPLL. To identify which head-trauma patients need treatment to reduce brain swelling, surgeons now have to implant pressure transducers in their skulls. The PPLL, says Shuer, could provide a noninvasive alternative.

Unpredictable Crystals

There's a common perception that crystal growing in space has failed to live up to its promise of producing protein crystals that are bigger, better, and altogether more suitable for gleaning a protein's 3D structure than those grown on Earth. But that's not quite true, crystallographer Lawrence DeLucas of the University of Alabama, Birmingham, told the meeting. "Of the 100 proteins flown in space, 25 have produced crystals better than anything that can be produced on Earth," said DeLucas, who is also chief scientist for the international space station.


ALEX MCPHERSON

Low-G gem. Crystal of satellite tobacco mosaic virus.

Space provided the superior crystals that helped solve or sharpen the 3D structures of insulin, the HIV protease enzyme, satellite tobacco mosaic virus, and human serum albumin, DeLucas said. And crystallographer Eddy Arnold of Rutgers University in New Brunswick, New Jersey, agrees that space has brought "very significant improvements" in crystal growing, at least for some proteins.

In theory, low gravity aids crystal growth by eliminating convection currents in the crystal-growing fluid that can create imperfections and by keeping the growing crystal from crashing to the bottom of the vessel. But "it's been impossible to predict which proteins will grow better [in space]," says Arnold.

Gaining such foresight has become one of the hottest challenges in crystallization research, says Alex McPherson of the University of California, Riverside. In an upcoming issue of the *Journal of Crystal Growth*, McPherson and his colleagues describe using atomic force microscopy (AFM) to watch crystals grow one molecule at a time. The next step will be to use AFM to find out how crystal growth differs in microgravity. And that, says McPherson, may make it possible to pick out the proteins likely to benefit most from a ride in space.

–Rachel Nowak

COMPUTER SCIENCE

A Boom in Plans for DNA Computing

Five months ago, when Leonard Adleman reported building a "DNA computer," few of his peers in the computer science community thought it would ever be more than a toy. They were impressed by how cleverly the University of Southern California researcher had solved a variation of the "traveling salesman" problem, coaxing strands of DNA to link up in a way that identified a route through each of a series of destinations. But they suspected the technique would be a one-trick pony. Nature, it seemed, offered a tailor-made approach to attacking one specialized problem, but even Adleman himself was unsure of the next step—or whether there was one. "Wider applicability wasn't apparent," he says.

It is now. Early this month nearly 200 computer scientists, molecular biologists, and other researchers gathered at a hastily arranged meeting at Princeton University to discuss what has suddenly become the hottest field in computer science: computing with DNA. One speaker after another described schemes to apply the techniques of molecular biology to computational problems from cracking codes to building a "universal computer," a device that can carry out any combination of logical and arithmetic operations. And on page 542 of this issue of *Science*, Princeton computer scientist Richard Lipton details a scheme that helped spark the excitement: a way to use DNA to solve a problem that requires searching a universe of solutions so large it would defeat any conventional computer.

So far, no one but Adleman has actually built a DNA computer, and the practical difficulties may be formidable. "Nobody knows if any of this stuff works," says David Gifford, a computer scientist at the Massachusetts Institute of Technology, noting that Adleman's computer had to consider fewer than 100 possibilities and that errors may creep in as the size of the problems increases. Nevertheless, the excitement has a very real basis: Working with DNA offers the chance to perform billions of operations simultaneously, compared with only a few thousand parallel operations in even the most advanced electronic computers.

A single flask, Adleman says, might hold 10^{19} to 10^{20} strands of DNA, each encoding a string of data in its sequence of nucleotides. These data can be manipulated in various ways by the techniques of molecular biology: