viruses fuse under certain circumstances. In particular, he is interested in understanding the fusion mechanism of mitochondria—organelles important for energy production and cell death. He also studies how the human immunodeficiency virus (HIV), the agent of the disease AIDS, enters human cells by fusing with the cell membrane. And Dianne Newman, the Clare Boothe Luce Assistant Professor of Geobiology and Environmental Engineering Science, is leading a project to investigate how microorganisms and Earth's near-surface environments have interacted over billions of years. Her work integrates molecular microbiology with geochemistry and field geology to try to identify chemical signatures of early life in the geological record.

"The biological sciences today present an intellectual challenge that is changing the environment at Caltech," said Mel Simon, the former chair of the Division of Biology, who played a pivotal role in the BSI. "So the resources are here, the vision is here, and some of the people are here. Now all we have to do is great science." □—*RT*

UNDERGRADS RIDE THE "VOMIT COMET"

Though the nickname "Vomit Comet" would scare most people off, four Techers couldn't wait to board NASA's modified KC-135 jet tanker last summer in the name of science. (The plane allows Earthbound scientists fleeting access to zero gravity by flying a parabolic trajectory that produces about 30 seconds of weightlessness; some people handle this worse than others.) Twice a year, university students across the country are encouraged by NASA's Johnson Space Center in Houston to submit proposals to its Reduced Gravity Student Flight Opportunities Program. The winners get to fly the Comet to conduct their experiments.

One of 2001's 35 winning teams consisted of Serena Eley, Dirk Englund, and John Ferguson, all senior physics majors, and sophomore aeronautics major Joseph Jewell. They made tiny droplets of a type of glass called ZBLAN—named for the zirconium (Zr), barium (Ba), lanthanum (La), aluminum (Al), and sodium (Na) it contains—that for some years now has been touted as the fiber-optic material of the future. The optical fibers that are the backbone of today's high-speed data lines are based on silicon dioxide, as is ordinary window glass, and transmit a fairly narrow range of wavelengths. Ultraviolet light, for example, is blocked—you can't get a suntan though a picture window. Near-infrared light is transmitted reasonably well, but the glass quickly turns opaque at longer wavelengths. And even in the visible spectrum, ordinary glass is pretty absorptive—try looking through a piece of glass end-on some time.

ZBLAN is a radically different material that contains no silicon or oxygen. It is a complex mixture of the five previously mentioned metals and fluorine—one of a family of "heavy-metal fluoride" glasses that has been known for about 20 years. ZBLAN is nearly perfectly transparent from the near-ultraviolet to the near-infrared. It's a very tricky material to make here on Earth, however, as molten ZBLAN generally begins to crystallize as it cools. Presumably, the heavier molecules—the zirconium and lanthanum fluorides—have the slightest tendency to sink, while the lighter ones rise. This inadvertent sorting leads to crystallization as like molecules congregate. Each crystal acts somewhat like a tiny mirror, and there go your optical properties—the sample turns milky. But previous experiments on the Comet and elsewhere have shown that zero-G ZBLAN retains its amorphous character as it cools, remaining crystal-clear.

Jewell (left) and Ferguson with the experimental setup, which was kept under helium to prevent oxygen or moisture contamination.

When you hit the top of the parabola, even a harness won't stop you from floating, as Englund (left) and Eley (below) discover.

So if fibers are the name of the game, why were the Techers making droplets? Because ZBLAN microspheres some 300 to 400 microns (millionths of a meter) in diameter could act as "resonators" to store photons of light for long periods of time. These resonators could be married to silicon chips to make oscillators, switches, modulators, and even tiny lasers. Such components are essential to fiber-optic networks, advanced surgical devices, CD players, supermarket scanners, and what have you. And resonators are a staple of the cavity quantum-electrodynamics (QED) experiments that might one day lead to quantum communications networks, quantum cryptography, and even quantum computers, and are of keen interest to the experiment's sponsors—Hideo Mabuchi (PhD '98), associate professor of physics; and Lute Maleki, senior research scientist, and Vladimir Iltchenko, senior member of the technical staff of the Quantum Sciences and Technology Group at JPL. "There has been a lot of excitement about the possibility of using microspheres for cavity QED, but a lot of technical groundwork has to be laid for it to be practical," says Mabuchi. For one thing, making crystal-free ZBLAN microspheres on the ground is no easier than making clear ZBLAN fibers—in fact, it has only been done once, says Maleki.

The experiment's goal is to compare the optical properties of three sets of microspheres made beforehand at Caltech and JPL with three sets made using the same procedures in zero gravity. The microspheres were made with a fiber splicer, which employs a tiny high-voltage arc to melt the ends of two optical fibers and fuse them. In this case, the students melted the tip of a single fiber, allwing surface tension to cause the molten glass to bead up into a sphere. "The result is like a lollypop, a fiber stem with a small sphere on the end," says Eley. The samples' Q factors are now being measured in the lab. "The Q factor is a quality factor," explains Maleki. "If you think of the microsphere as a cavity, the Q factor measures its resonance. The narrower the resonance, the longer the energy-storage time." "In a sense, it's like tapping a wine glass with a fork and measuring how long it takes to stop ringing," says Englund. "The longer it rings, the larger the Q factor."

Eley, Englund, Ferguson, and Jewell were at Johnson Space Center from August 22 to September 1. Several days of training led up to a "chamber flight" on August 28—a room the size of a school bus, says Ferguson, that simulates high-altitude conditions. "They make us breathe pure oxygen for half an hour to get the nitrogen out of our blood, and then they pump it down to 25,000 feet and see how we do. Some people don't feel much of an effect. But some people get really giddy, and some people can't do simple math problems, like 3 + 4, even with a pencil and paper. They do it partly to show us what it's going to be like if there's an emergency in flight and we lose cabin pressure, and partly to document our reactions."

The actual flights followed a couple of days later. Eley and Englund went first, on August 30, logging "about 26" parabolas before deteriorating weather forced them back to Earth. Ferguson and Jewell were slated to go the following day, on the last flight of the season. The weather did not let up, and the flight was very nearly scrubbed. But at the last minute, says Ferguson, "they got access to some airspace they don't normally have. And it turned out to be an absolutely perfect flight." Ferguson and Jewell did 32 parabolas—"close to an hour of total weightlessness. We were lucky enough to be on a very special flight. It was the fourth 'no kill' flight, out of hundreds of flights in the past seven years, where no one actually hurled." The first 30 parabolas were zero-G and strictly business, but the last two were reduced gravity and just for fun. "They did one to simulate lunar gravity and one for Martian gravity. So instead of floating weightless, you drifted very slowly toward the floor. Or you could do pushups, and feel like the strongest man in the world."

The program pays for the training and the cost of the Comet flight, but the team had to raise money for equipment, transportation to and from Houston, and accommodations. Says Englund, "We've been very fortunate with our funding. There are not many schools that would support a group of undergrads wanting to do some science experiment as readily, and as generously, as Caltech and JPL did. JPL put up about $6,000 for fibers and some other things such as shipping the equipment. And Thomas Tombrello, the chair of Physics, Math, and Astronomy, put up a similar amount from the physics department." Each team must also participate in a community project, so the students will be presenting their experiments at a number of Southern California elementary and high schools. □—*DS*

This Still Needs a Catchy Title

Though over 100 million Americans went to the polls on election day 2000, as many as 6 million might just have well have spent the day fishing. Researchers at Caltech and MIT call these "lost votes" and think the number of uncounted votes could easily be cut by more than half in the 2004 election with just three simple reforms. "This study shows that the voting problem is much worse than we expected," said Caltech president David Baltimore, who initiated the nonpartisan study after the November election debacle. "It is remarkable that we in America put up with a system where as many as six out of every hundred voters are unable to get their vote counted. Twenty-first-century technology should be able to do much better than this."

According to the comprehensive Caltech-MIT study, faulty and outdated voting technology together with registration problems were largely to blame for many of the 4-to-6 million votes lost during the 2000 election. With respect to the votes that simply weren't counted, the researchers found that punch-card methods and some direct recording electronic (DRE) voting machines were especially prone to error. Lever machines, optically scanned, and hand-counted paper ballots were somewhat less likely to result in spoiled or "residual" votes. Optical scanning, moreover, was better than lever machines. As for voter registration problems, lost votes resulted primarily from inadequate registration data available at the polling places, and the widespread absence of provisional ballot methods to allow people to vote when ambiguities could not be resolved at the voting precinct.

The three most immediate ways to reduce the number of residual votes would be to:

- replace punch cards, lever machines, and some underperforming electronic machines with optical scanning systems;
- make countywide or even statewide voter registration data available at polling places;
- make provisional ballots available.

The first method, it is estimated, would save up to 1.5 million votes in a presidential election, while the second and third would combine to rescue as many as 2 million votes.

"We could bring about these reforms by spending around $3 per registered voter, at a total cost of about $400 million," says Tom Palfrey, a professor of economics and political science who headed the Caltech effort. "We think the price of these reforms is a small price to pay for insurance against a reprise of November 2000." Approximately half the cost would go toward equipment upgrades, while the remainder would be used to implement improvements at the precinct level, in order to resolve registration problems on the spot. The $400 million would be a 40 percent increase over the money currently spent annually on election administration in the United States.

In addition to these quick fixes, the report identifies five long-run recommendations.

- First, institute a program of federal matching grants for equipment and registration system upgrades, and for polling-place improvement.
- Second, create an information clearinghouse and data-bank for election equipment and system performance, precinct-level election reporting, recounts, and election finance and administration.
- Third, develop a research grant program to field-test new equipment, develop better ballot designs, and analyze data on election system performance.
- Fourth, set more stringent and more uniform standards on performance and testing.
- Fifth, create an election administration agency, independent of the Federal Election Commission. The agency would be an expanded version of the current Office of Election Administration,