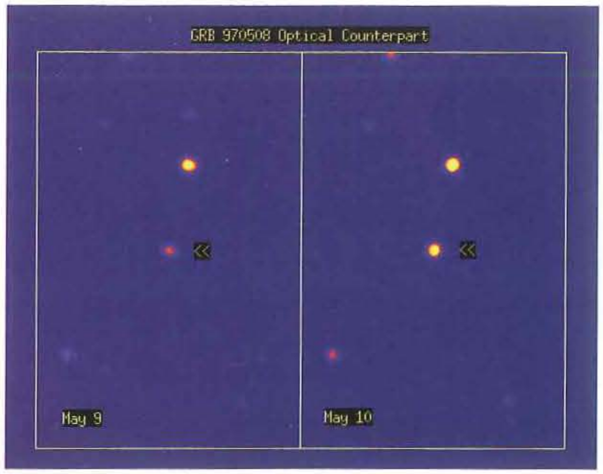


Images of the gamma-ray burst field obtained at the 200-inch Hale Telescope at Palomar Observatory on May 9 (left) and 10 (right) show the visible-light brightness of the optical counterpart (arrow) still rising. The gamma-ray burst was first detected May 8.

Gamma-Ray Bursts Demystified

"When I finished analyzing the spectrum and saw features, I knew we had finally caught it. It was a stunning moment of revelation."

In May a team of Caltech astronomers solved one of astronomy's most intriguing mysteries, pinpointing for a gamma-ray burst an optical counterpart several billion light-years away from the Milky Way. The results demonstrate for the first time that at least some of the enigmatic gamma-ray bursts that have puzzled astronomers for decades occur at very great distances and not, as some have thought, inside our own galaxy.

The bursts of high-energy radiation were first discovered by military satellites almost 30 years ago, but so far their origin has remained a mystery. New information came in recent years from NASA's Compton Gamma-Ray Observatory satellite, which has so far detected several thousand bursts (see *E&S*, Winter 1992). Nonetheless, the fundamental question of where the bursts came from remained unanswered.

Competing theories on gamma-ray bursts have generally fallen into two categories: one that suggests that the bursts to originate from some as-yet unknown population of objects within our own Milky Way galaxy; and another that proposes that the bursts originate in distant galaxies, several billion light-years away. If the latter is true (as was indirectly supported by the Compton Observatory's earlier observations), then the bursts are among the most violent and brilliant events in the universe.

Gamma-ray bursts occur a couple of times a day, says Shri Kulkarni, professor of astronomy and planetary science and one of the team members. These brilliant flashes seem to appear from random directions in space and typically last a few seconds. "After hunting clues to these bursts for so many years, we now know that the bursts are in fact incredibly energetic events," said Kulkarni.

Progress in understanding the nature of the bursts was stymied by the fact that until recently the bursts were detected as very high-energy gamma rays. It is difficult to focus gamma rays, and thus the positional accuracy of the bursts was quite crude, leaving astronomers with thousands of faint stars and galaxies as potential "hosts." An important recent development was the deployment of BeppoSAX, a joint Italian/Dutch satellite launched in late 1996 by the Italian space agency. This satellite, for the first time, provided a rapid and accurate position in the sky for strong gamma-ray bursts. This enabled astronomers to search for possible visible and radio counterparts, using telescopes on the ground. The first such counterpart was detected at the beginning of May, but faded away before its nature could be established.

The satellite detected another burst on May 8, and Caltech astronomers were able to bring telescopes at Palomar Observatory to bear within a few hours. The Caltech team noticed a star-like object that was changing brightness in an unusual fashion at the position of the burst. (Dr. Howard Bond of the Space Telescope Science Institute initially reported the object based on his measurements at Kitt Peak National Observatory.)

The crucial piece to the puzzle was finally found by the Caltech team on May 11 using one of the two W. M.

Keck 10-meter telescopes, the world's largest, on Mauna Kea, Hawaii. The starlike object showed features known to originate in intergalactic clouds in its spectrum. By measuring the wavelengths of these features, the Caltech astronomers were able to measure the distance to a gamma-ray burst for the first time. Their measurements place the burst at a distance of several billion light-years, over one-half the size of the observable universe.

Mark Metzger, assistant professor of astronomy, said he was thrilled by the result. "When I finished analyzing the spectrum and saw features, I knew we had finally caught it. It was a stunning moment of revelation. Such events happen only a few times in the life of a scientist."

Recent observations from the telescopes at Palomar show that this starlike object is fading away. Because such rapid fading had been seen with the burst in March, the Caltech astronomers had to make an extra effort to identify this counterpart quickly so that the Keck observations could be carried out when the object was bright.

The discovery is a major step toward helping scientists understand the nature of the burst's origin. We now know that for a few seconds the burst was more than a million times brighter than an entire galaxy. No other phenomena are known that produce this much energy in such a short time. Thus, while the observations have settled the question of whether the bursts come from cosmological distances, their physical mechanism remains shrouded in mystery.

In addition to Kulkarni and Metzger, the Caltech team consists of Associate Professor of Astronomy George Djorgovski; Assistant Professor of Astronomy Charles Steidel (PhD '90); postdoctoral scholars Steven Odewahn and Debra Shepherd; and graduate students Kurt Adelberger, Roy Gal, and Michael Pahre. The team also includes Dale Frail of the National Radio Astronomy Observatory in Socorro, New Mexico.

"Gamma-ray bursts are one of the great mysteries of science," said Djorgovski. "It is wonderful to contribute to its unraveling." □

626

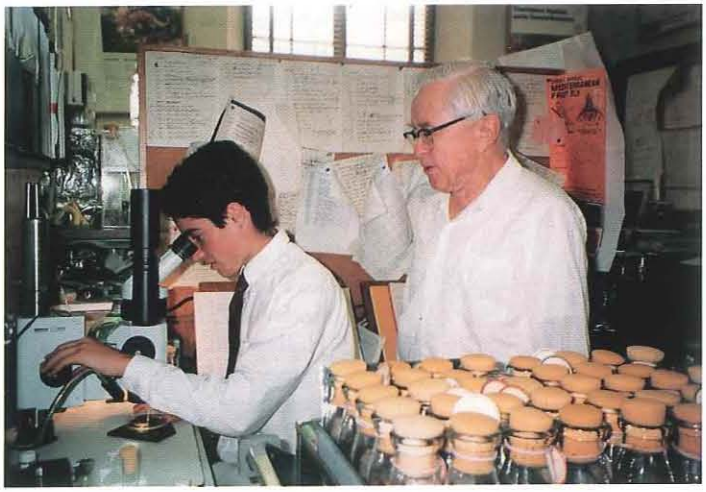
Longtime residents complain that the San Gabriel Valley doesn't have an identity of its own. Not any more—on June 14, 1997, the area code for the San Gabriel Valley, and with it Caltech, changed to 626. The old 818 area code will still work through February 21, 1998, however. And the telephone company in its infinite wisdom has decided that Burbank, Glendale, and La Cañada Flintridge belong to the San Fernando Valley, which retains the 818 area code. Thus the Jet Propulsion Laboratory's area code remains 818, because although JPL's mailing address is in Pasadena, the vast majority of the facility lies in La Cañada Flintridge.

In other telecommunications news, Caltech's Office of Public Events has changed its toll-free number from (800) 423-8849 to (888) 2-CALTECH.

Fly By

When Ari Hoffman, a sophomore at Tamalpais High School in Mill Valley, California, entered his *Drosophila* project in the Marin County science fair, he never dreamed he would run afoul of animal rights. Hoffman, whose study involved the effects of radiation on the fruit flies' reproduction patterns (number of offspring and percentage of mutations), won first prize in the science fair, only to see it withdrawn because of alleged "cruelty to animals." About 35 of his 200 flies had died before reaching the end of their normal 10-day life span.

Hoffman's prize was eventually reinstated, but not before a story in the *San Francisco Examiner* attracted the notice of Nobel laureate Ed Lewis (PhD '42), Caltech's Thomas Hunt Morgan Professor of Biology, Emeritus. Lewis, probably the most noted living fly geneticist, whose work on fruit flies won him the 1995 Nobel Prize, sent Hoffman a check "as a token award for your accomplishments." Lewis had also begun working with *Drosophila* when he was in high school back in 1934, the beginning of a long and fruitful career studying genetics with this tiny organism. That was before the days of science fairs, Lewis noted in his letter to the student.



Ed Lewis shows Ari Hoffman the view from his lab.

Lewis also invited Hoffman to visit Caltech when he and his father came to Southern California for yet another science fair. On May 20 the two stopped by for lunch at the Athenaeum and a look through Lewis's microscopes at *Drosophila* chromosomes. "Cool," Hoffman said. Lewis also gave him a few samples of his famous mutant, four-winged fly, the creature that had enabled Lewis to show how genes control the body's arrangement. The flies were dead, of course, but had served science well. □—*JD*

Sonoluminescence, Camera, Action!

It wasn't nominated for an Oscar (and no one is saying it should have been), but last fall's movie Chain Reaction *had hidden links to Caltech. Former Lloyd House president Ken Suslick (BS '74), now the William H. & Janet Lycan Professor of Chemistry at the University of Illinois at Urbana-Champaign, became a big noise in the study of ultrasound—ultra-high-frequency sound waves—in the early 1980s (see* E&S, *Spring 1994). Here he recounts how his research led Hollywood to come calling in central Illinois. (This article is reprinted courtesy of* Inside Illinois, *the faculty/staff newspaper of the University of Illinois at Urbana-Champaign.)*

Minor technical errors—such as violations of the laws of thermodynamics—are obviously no problem for Hollywood.

Some of you may have seen a movie last fall called *Chain Reaction*. If so, you have my condolences. Nonetheless, it isn't too often that a chemist finds himself involved with Hollywood, much less gets money for his school off a bad movie.

One pleasant fall day in 1994, I found on my chair—the only safe place to leave a slip of paper in my office—a phone message from someone claiming to be a Hollywood director. "Yeah, right!" I remember thinking as I dialed the number. It turned out that the caller, Gene Serdena, was the set director of a Twentieth Century Fox movie tentatively titled *Dead Drop*, then in preproduction.

The movie was to be about a Nobel-laureate professor and his graduate student, who discover the use of sonoluminescence—the incandescent glow generated when liquids are irradiated with ultrasound—to catalytically produce unlimited quantities of hydrogen (the ultimate clean fuel) from water. (Minor technical errors—such as violations of the laws of thermodynamics—are obviously no problem for Hollywood.) The professor is killed when the bad guys try to steal the discovery, and the intrepid graduate student runs through chase scene after chase scene to expose the evildoers. This is no surprise, since the director is Andrew (*The Fugitive*) Davis. Serdena told me that the grad student would be played by Keanu Reeves, the love interest by Nicole Kidman, and the prof probably by Alan Arkin (or maybe—I kid you not—Marlon Brando). By the time the movie actually got made, Kidman had been traded for a starlet and Brando had been downsized to Morgan Freeman.

Gene called me because of my work on sonoluminescence and other chemical effects of high-intensity ultrasound. He wanted to visit our labs to see what a chemistry lab actually looks like. So Gene and his assistant drove in from Chicago for a visit. With video and still cameras, they shot everything that didn't move. It was fun showing him around and trying to explain why things were set up the way they were. They even gave disposable cameras to my graduate students and myself to see how we live. Cinema verité, at least for the set design!

A week later, Gene called again. Now he wanted to rent equipment from the lab for the set. I explained to him that we do actually use this stuff and that it's very expensive equipment. He sounded disappointed, and then it hit me—he doesn't want equipment that works, only that looks like it works. And I knew about this cavernous storage area in the basement of Roger Adams Lab that was full of old equipment—ancient Infracord spectrophotometers, several dozen old black-and-white monitors, prewar lathes (not sure which war), and so on—all stuff too good to throw away at the time it was hauled down there, but of no use now. I suggested that maybe they'd like to see the "scientific equipment" in our storage area. His assistant returned to Champaign and, with flashlights in hand, we went spelunking into the depths of RAL. She photographed everything (again)

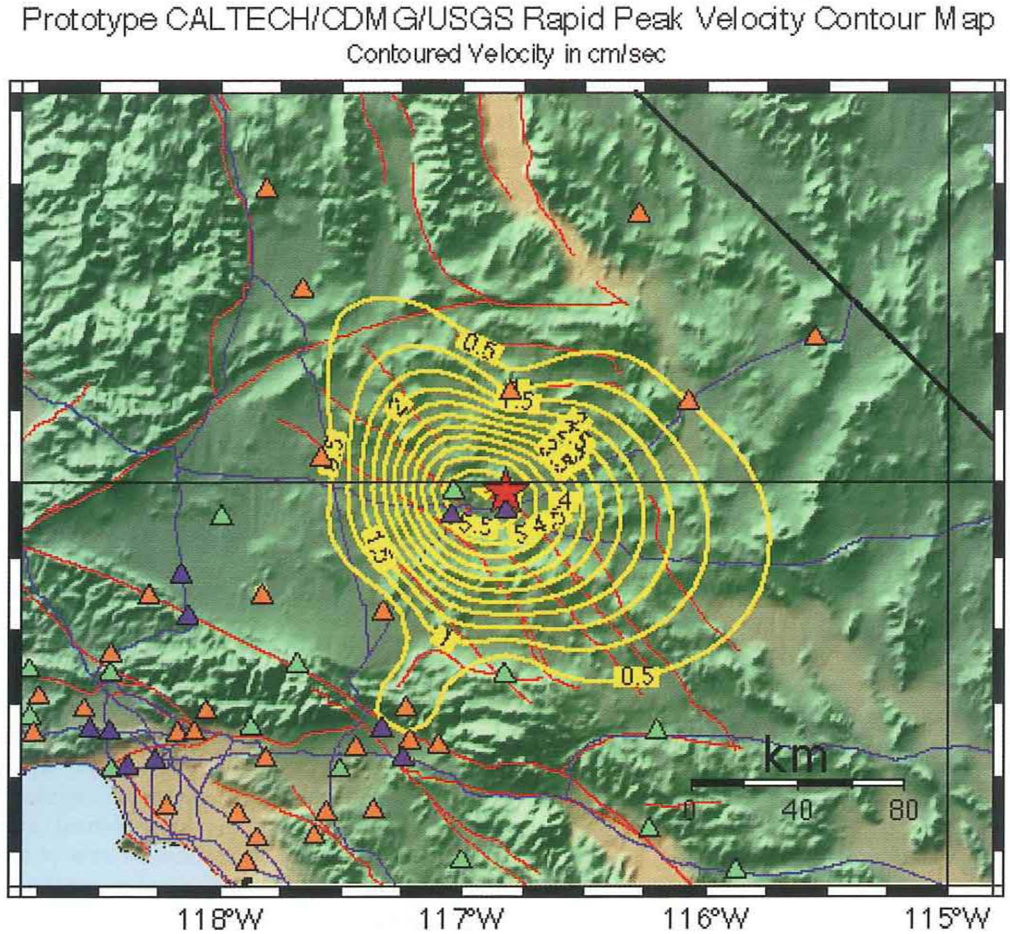
It's a nail-biting moment for Keanu Reeves (left), Morgan Freeman (to his right), and other "scientists" on a set that probably came from the collection of pre-owned lab equipment in Suslick's basement storage. ("Who uses dials anymore?" says Suslick. "Not even the Russians.")

and went away.

When Gene called next, about 48 hours later, I could practically hear him salivating over the phone. This room full of useless equipment turned out to be just the sort of place a set director dreams about (apparently set directors have very weird dreams). But how do we sell this detritus of dead equipment to them? We found that the university cannot sell equipment—no matter how useless—without rampant rivers of red tape. We could, however, declare old stuff surplus once it was of no further use, and simply take it off the books. Whether the junk then went into a dumpster or into a truck made no difference.

So, with help from our business-office manager, I arranged for a donation of $10,000 from Twentieth Century Fox to the school. I didn't even ask a finder's fee. Fox then sent down a crew of four humongous guys and a moving van to match, and they spent a full day hauling away junk that we'd been wondering how to get rid of for years!

Two years later the movie came out, now called *Chain Reaction*. On opening day, we shut down our lab, and I took the whole crew out to the first matinee. I bought the tickets, but my students had to get their own popcorn. Afterward, we agreed that the best part of the film was the labs, which were only slightly hokey. In fact, that was just about the only good thing in the entire movie. Even Siskel and Ebert gave it thumbs down. Fortunately, the UI's School of Chemical Sciences was not listed in the credits, so our anonymity remains preserved for posterity. Until now... □



On March 18, a magnitude 5.4 aftershock of the Landers earthquake rattled much of Southern California. What was really earthshaking, however, was the debut this provided for TriNet, a new seismic network operated jointly by Caltech, the U.S. Geological Survey, and the California Department of Conservation's Division of Mines and Geology. Seismologists were able to determine the quake's magnitude within five minutes—a tremendous improvement over the time it once took to confirm data—and in another five (practically before the TV crews could arrive!) they had created this contour map (above) of peak ground velocities. The red star marks the epicenter, the red lines are faults, the blue lines are freeways, and the yellow contours are in centimeters per second. The triangles are seismographic stations—blue for the Division of Mines and Geology, orange for Caltech/USGS digital stations, and green for analog stations. The maps show at a glance what areas might and might not have suffered damage, in a way that merely quoting magnitudes and epicenters cannot. The maps also go up on the World Wide Web (http://www-socal.wr.usgs.gov/pga.html) the moment they're made.

Oops!

The portrait of turbulence that *Engineering & Science* ran on the cover of Issue No. 3 for 1996 was unattributed, due to an editorial error. Our apologies to postdoc David Laidlaw, who generated the image and was kind enough to provide a copy for us.

DNA Repair Kit

Caltech chemists have found a way to repair DNA molecules that have been damaged by ultraviolet radiation. Professor of Chemistry Jacqueline K. Barton, postdoc Peter J. Dandliker, and grad student R. Erik Holmlin reported in the March 7 issue of *Science* that the new procedure reverses thymine dimers, a well-known type of DNA abnormality caused by exposure to ultraviolet light. By designing a synthetic molecule containing rhodium, the researchers have succeeded in repairing the damage and returning the DNA to its normal state. The research is also significant in that the rhodium complex can be attached to the end of the DNA strand and repair the damaged site even when it is much farther up the helix.

"What I think is exciting is that we can use the DNA to carry out chemistry at a distance," says Barton. "What we're really doing is transferring information along the helix."

A healthy DNA molecule appears something like a twisted ladder. The two "rails" of the ladder, the DNA backbone, are connected with "rungs," the DNA bases adenine, thymine, cytosine and guanine, which are paired together in units called base pairs to form the helical stack. Thymine dimers occur when two neighboring thymines on the same strand become linked together. The dimer, once formed, leads to mutations because of mispairings when new DNA is made. If the thymine dimers are not repaired, mutations and cancer can result.

The new method repairs the thymine dimers at the very first stage, before mutations can develop. The rhodium complex is exposed to normal visible light, which triggers an electron transfer reaction to repair the thymine dimer. The rhodium complex can either act locally on a thymine dimer lesion on the DNA strand, or can be tethered to the end of the DNA helix to work at a distance. In the latter case, the electron works its way through the stack of base pairs. The repair efficiency doesn't decrease as the tether point is moved away from the site of damage, the researchers have found. However, the efficiency of the reaction is diminished when the base-pair stack—the pathway for electron transfer—is disrupted.

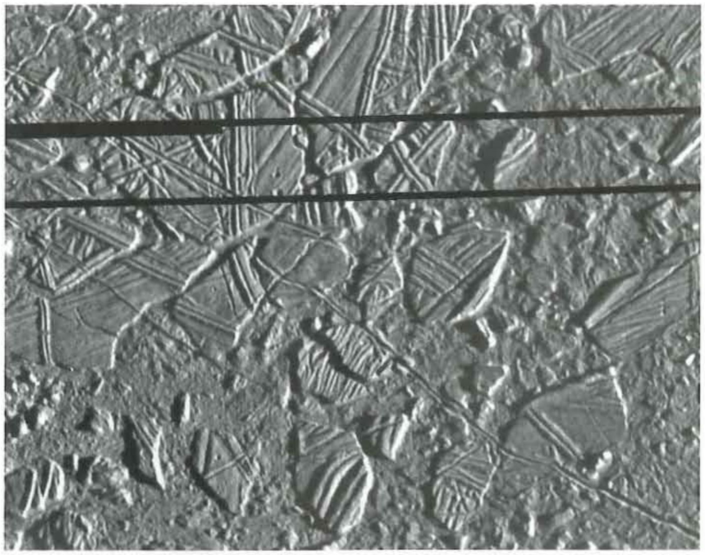
"This argues that the radical, or electron hole, is migrating through the base pairs," Barton says. "Whether electron transfer reactions on DNA also occur in nature is something we need to find out. We have found that this feature of DNA allows one to carry out chemical reactions from a distance." Barton cautions that the discovery does not represent a new form of chemotherapy. However, the research could point to new protocols for dealing with the molecular changes that precede mutations and cancer. "This could give us a framework to consider new strategies," she says.

This research was funded by the National Institutes of Health. Dandliker is a fellow of the Cancer Research Fund of the Damon Runyon-Walter Winchell Foundation, and Holmlin is a National Science Foundation predoctoral fellow. □—*RT*

Waiting to Exhale

In less earthshaking developments at Caltech and the USGS, Ken Hudnut and his colleagues have been monitoring the gradual squishing shut of the Los Angeles basin for the last year and a half now, using a network of Global Positioning System (GPS) receivers. One of these receivers is located atop the Pacoima Dam, where, says Hudnut, "we've seen the center of the arch of the dam deflect downstream, then back up again, and then down again." The movement is about two centimeters (about three-quarters of an inch), and it takes roughly a year per oscillation. "We think this is due to the warming and cooling of the whole structure with seasonal climate changes," Hudnut explains. "It's pretty cool that such a large structure 'breathes,' and that we can measure it. It's not like the dam is about to fail or anything. For all we know, it's been flexing like this ever since it was built in the late 1920s—it's just never been observed before now." If you'd like to see for yourself, there's a World Wide Web page at http://www-socal.wr.usgs.gov/scign/hudnut/dam.html.

But failure is ultimately what it's all about. Ever since Northridge, Caltech's civil engineers have been realizing that ground displacement and velocity contribute more to earthquake damage than does acceleration (see *E&S*, Summer 1995). But old-fashioned seismographs measured acceleration best, so the building codes have been based on that data. Combining digital seismological and GPS data should lead to a much better understanding of what happens to a structure when you shake it, and eventually to more earthquake-resistant buildings, overpasses, and dams. □
—*DS*



If this looks like a close-up of a shattered plate to you, you're not far wrong. The plate, however, is the icy crust of Jupiter's moon Europa as seen by the Galileo spacecraft. The individual fragments are up to 13 kilometers (8 miles) across, and you can see how they have drifted apart from one another, rotating slightly in the process. The scene looks remarkably like aerial views of the spring break-up of oceanic pack ice on Earth, fueling speculation that an ocean of slush or even liquid water lurks just beneath Europa's frozen surface. This high-resolution image (the smallest visible detail is 54 meters, or 59 yards, across) was shot on February 20, 1997, from a distance of 5,340 kilometers (3,320 miles), during Galileo's sixth orbit of Jupiter. For more Galileo images, check out their World Wide Web site at http://www.jpl.nasa.gov/galileo.

Snowball Earth

Those who think the winter of '97 was rough should be relieved that they weren't around 2.2 billion years ago. Scientists have discovered evidence for an ice age back then that was severe enough to partially freeze over the equator. Professor of Geobiology Joseph Kirschvink (BS, MS '75) and grad student Dave Evans have found evidence that glaciers came within a few degrees of the equator's latitude when the planet was about 2.4 billion years old. They base their conclusion on glacial deposits discovered in present-day South Africa, plus magnetic evidence showing where South Africa's crustal plate was located at that time.

Based on that evidence, the Caltech researchers think they have documented the extremely rare "Snowball Earth" phenomenon, in which virtually the entire planet may have been covered in ice and snow. According to Kirschvink, who originally proposed the Snowball Earth theory, there have probably been only two episodes in which glaciation of the planet reached such an extent—one less than a billion years ago during the Neoproterozoic Era, and the one that has now been discovered from the Paleoproterozoic Era 2.2 billion years ago.

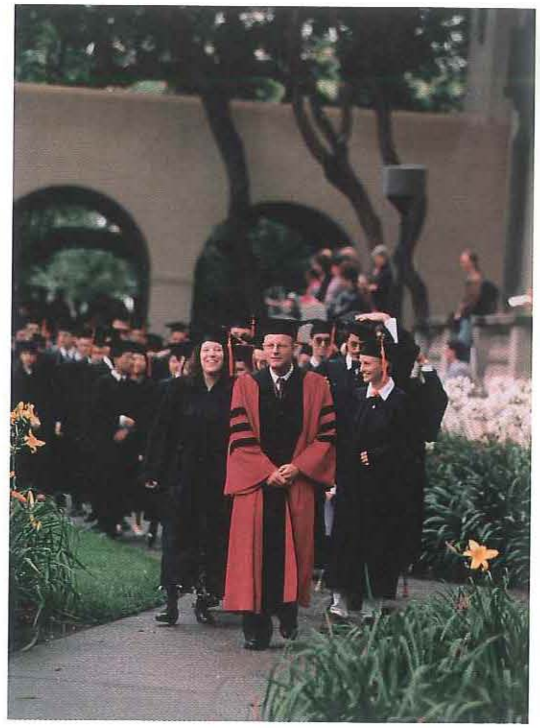
"The young Earth didn't catch a cold very often," says Evans, a graduate student in Kirschvink's lab. "But when it did, it seems to have been pretty severe."

The researchers collected their data by drilling rock specimens in South Africa and carefully recording the magnetic directions of the samples. From this information, the researchers then computed the direction and distance to the ancient north and south poles. The conclusion was that the place in which they were drilling was 11 degrees (plus or minus five degrees) from the equator when Earth was 2.4 billion years old. Plate tectonic motions since that time have caused South Africa to drift all over the planet, to its current position at about 30 degrees south latitude. Additional tests showed that the samples were from glacial deposits, and further, were characteristic of a widespread region.

Kirschvink and Evans say that the preliminary implications are that Earth can somehow manage to pull itself out of a period of severe glaciation. Because ice and snow tend to reflect sunlight much better than land and water, Earth would normally be expected to have a hard time reheating itself in order to leave an ice age. Thus, one would expect a Snowball Earth to remain forever. Yet, the planet obviously recovered both times from the severe glaciation.

"We think it is likely that the intricacies of global climate feedback are not yet completely understood, especially concerning major departures from today's climate," says Evans. "If the Snowball Earth model is correct, then our planet has a remarkable resilience to abrupt shifts in climate. Somehow, the planet recovered from these ice ages, probably as a result of increased carbon dioxide—the main greenhouse gas."

Evans says that an asteroid or comet impact could have caused carbon dioxide to pour into the atmosphere, allowing Earth to trap solar energy and reheat itself. But evidence of an impact during this age, such as a crater, is lacking. Large volcanic outpourings could also have released a lot of carbon dioxide, as well as other factors, such as sedimentary processes and biological factors. At any rate, the evidence for the robustness of the planet and the life that inhabits it is encouraging, the researchers say. Not only did Earth pull itself out of both periods of severe glaciation, but many of the single-celled organisms that existed at the time managed to persevere. □
—*RT*



David Wales, professor of mathematics and master of student houses, leads the academic procession of candidates for the BS degree in 1997.

Women at Caltech: Not 25 Years, But 53 or 42 or . . .

Hans Liepmann

In response to the notice in the last issue of E&S *on the 25th anniversary of women at Caltech, Hans Liepmann, the Theodore von Kármán Professor of Aeronautics, Emeritus, and former director of GALCIT, pointed out that we had written only about undergraduate women. He thought that the struggle to admit female graduate students also merited mention, and he provided some reminiscences of his own.*

I arrived at Caltech in September 1939 to work as an (unpaid) postdoc in the Guggenheim Aeronautical Laboratories. Due to the outbreak of the war in Europe and various visa problems, my wife arrived a few months later. When she inquired about the possibility of continuing her physics studies, we found that Caltech did not accept female students. I confess that this possibility had not occurred to me at all. I had seen many young women on the campus; I realized that in an institute of technology comparatively few women could be expected, but my middle-European experience did not prepare me for a non-coeducational university!

In the late '40s, I believe, when I was a relatively young member of the voting faculty, we had to vote on the proposed admission of female graduate students. I cannot remember whether this voting by the faculty was supposed to be a poll only or had more decision power. Of the pro and con arguments, I can remember only one, possibly because it was so silly: "If you flunk a girl in class she will cry on your shoulder!" was proclaimed by someone against. This was answered by a loud, but anonymous, voice from the back: "Now, what's wrong with that?"

In any case, after a rather heated debate in the Hall of the Associates of the Athenaeum, the motion was defeated by three votes. When we filed out of the room, Charlie De Prima, a then equally young professor of mathematics, slapped me on the back and said in a rather loud voice: "Don't worry, Hans; three of the old guys are likely to die soon!" This demonstrates the heat of the argument, but the remark was actually not quite fair, since the lineup of votes was by no means according to age.

In 1950, Richard Feynman was considering whether or not to accept a permanent professorship at Caltech. Paco Lagerstrom, who had known Feynman when they were both students at Princeton, and I had either lunch or dinner (I have forgotten which) with Feynman in the Athenaeum. Debating the pros and cons, we proposed that if Feynman should turn down the offer, he should help the cause by giving the failure to admit women as a reason. Fortunately for all of us, he accepted the offer, and so, unfortunately, nothing came of our proposition. But a little later, the faculty vote was reversed anyway.

In 1944 or thereabouts, a young female aeronautical engineer applied to complete a master's degree in aeronautics at Caltech. Her husband worked, I believe, at Lockheed. I don't know exactly how she was permitted to enter, but Gertrude Fila took classes and worked with me on a research project, keeping her one-year-old son in a playpen between two wind tunnels. We even published a paper together. Mrs. Fila's classwork was graded, but she did not get credit toward a degree; however, Clark Millikan had told her that whenever Caltech accepted female graduate students, she would get her MS degree.

When I became director of GALCIT, I discovered correspondence in the files indicating that Mrs. Fila, then teaching at Oklahoma A&M, had asked for her degree and been turned down because the requirements had changed. With a little noise from me, this decision was repealed, and Gertrude Fila, by then a gray-haired professor, marched up with the graduate students and finally got her degree in 1974.

The barriers finally fell, and they fell suddenly. When Jack Roberts, now Institute Professor of Chemistry, Emeritus, was recruited to the faculty from MIT in 1952, he had, according to his oral history in the Caltech Archives, four very, very good grad students who were interested in coming with him to Caltech. One was Dorothy Semenow. Linus Pauling told Roberts that although the faculty and trustees had voted against admitting women, they had never considered a specific case, and he urged her to apply. Pauling put his own considerable clout behind the case, and by June 1953 it was a done deal. Dorothy Semenow received her PhD from Caltech in 1955. Other women followed. The world did not end. □

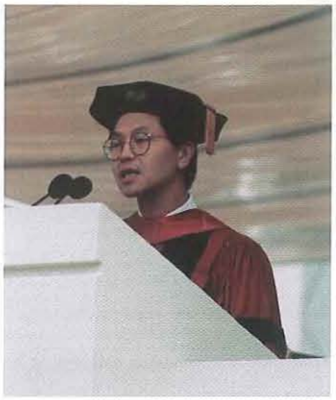
Hope and Glory

Unseasonable rain fell early on the morning of June 13, but by 10 a.m. the skies were clearing and Caltech's 103rd Commencement commenced. Some 202 students received their bachelor of science degrees; 104 master of science degrees, 6 engineer degrees, and 173 PhDs were awarded.

Dr. David Ho, BS '74, director of the Aaron Diamond AIDS Research Center at Rockefeller University, and *Time* magazine's 1996 Man of the Year, gave the commencement address—"Science as a Candle of Hope." Ho touched briefly on his own Caltech experience: "As a young boy growing up in Southern California, this was my dream school. . . . It is the place where I first learned to tackle research with a multidisciplinary approach not limited by arbitrary boundaries that separate biomedical sciences from physics, chemistry, engineering, and mathematics."

He told the graduating class that they had chosen "a noble profession, one filled with excitement," and illustrated this claim with the story of his own recent discoveries. Ho described how he and his colleagues were working in 1991 "with structural biologists and medicinal chemists to test small chemicals that might intercalate into the catalytic site of the HIV protease, an enzyme essential for the production of infectious progeny virus." He spoke of the overwhelming excitement they felt when they realized that they could inhibit the protease enzyme, thereby blocking viral replication in the test tube.

Three years later, they were able to administer to HIV-infected patients one of the chemicals they had found. Ho described the "joy and amazement as we watched the level of HIV fall ever so dramatically. At first we did not know that we were sitting on top of a fundamental discovery in AIDS research." But then, when they asked the right questions, "it quickly dawned on us that HIV must be turning over rapidly, in a dynamic equilibrium with the host. Using data from our patients and working together with mathematicians, we proved that HIV replication in vivo was rapid and remorseless. In the course of only a few weeks, the old paradigm that HIV was largely a latent virus was completely shattered."



David Ho, BS '74, speaks to the graduating class of 1997.

Later in his talk, Ho, who came with his family to California from Taiwan when he was 12 years old, reflected on the contribution of his heritage to his career—the Asian respect for intellectual achievement and hard work. But, he remarked, "I have been an American for so long that I have nearly forgotten that I am also an immigrant. From time to time, I can still sense the desire that burns in the belly of a new immigrant, the desire to carve out a place in the new world, in the land of opportunities. . . . Throughout its history, America has continually benefited from the drive, labor, and creativity of immigrants, many in the field of science." □

With Gordon Moore (PhD '54), chair of the Board of Trustees, Tom Everhart brings up the rear of his last Commencement academic procession as president of Caltech.

Melting the Mantle

"We have replicated the melting that we think occurs in the deepest mantle of the Earth."

Earth's mantle reaches a maximum temperature of 4,300K, say a group of Caltech researchers.

According to Tom Ahrens (MS '58), the W. M. Keck Foundation Professor of Earth Sciences and Environmental Engineering, and graduate student Kathleen Holland, the results are important for setting very reliable bounds on the temperature of Earth's interior. Scientists need to know very precisely the temperature at various depths in order to better understand large-scale processes, such as plate tectonics and volcanic activity, which involve movement of molten rock from the deep interior of the Earth to the surface.

"This nails down the maximum temperature of the lowermost mantle, a rocky layer extending from a depth of 10 to 30 kilometers to a depth of 2,900 kilometers, where the molten iron core begins," Ahrens says. "We know from seismic data that the mantle is solid, so it has to be at a lower temperature than the melting temperature of the materials that make it up."

In effect, the research establishes the melting temperature of the high-pressure form of the crystal olivine. At normal pressures, olivine is known by the formula $(Mg,Fe)_2SiO_4$, and is a semiprecious translucent green gem. At very high pressures, olivine breaks down into magnesiowüstite and a mineral with the perovskite structure. Together these two minerals are thought to make up the bulk of the materials in the lower mantle.

The researchers achieved these ultra-high pressures in their samples by propagating a shock wave into them, using a high-powered cannon apparatus called a light-gas gun. This gun launches projectiles at speeds of up to 7 kilometers per second. Upon impact with the sample, a strong shock wave causes ultra-high pressures to be achieved for only about one-half a millionth of a second. The researchers have established the melting temperature at a pressure of 1.3 million atmospheres. This is the pressure at the boundary of the solid lower mantle and liquid outer core.

"We have replicated the melting which we think occurs in the deepest mantle of the Earth," says Holland. "This study shows that material in the deep mantle can melt at a much lower temperature than had been previously estimated. It is exciting that we can measure phase transitions at these ultra-high pressures."

The researchers further note that the temperature of 4,300K would allow partial melting in the lowest 40 kilometers or so of the lower mantle. This agrees well with seismic analysis of wave forms conducted in 1996 by Professor of Geophysics Donald Helmberger and Edward Garnero (PhD '94). Their research suggests that at the very lowest reaches of the mantle there is a partially molten layer, called the Ultra-Low-Velocity Zone.

"We're getting into explaining how such a thin layer of molten rock could exist at great depth," says Ahrens. "This layer may be the origin layer that feeds mantle plumes, the volcanic edifices such as the Hawaiian island chain and Iceland.

"We want to understand how Earth works." □—*RT*