Digital Critters

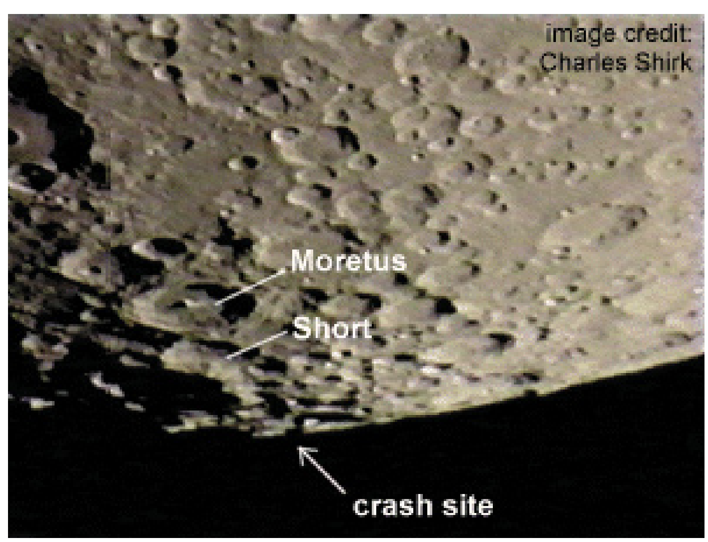
A team of researchers from Caltech and elsewhere have created "digital organisms"—computer programs that self-replicate, mutate, and adapt by a process analogous to natural selection, and whose response to mutations closely resembles the way real organisms evolve. Chris Adami, senior research fellow in computation and neural systems, and colleagues found that the overall effect of many mutations can actually result in a "better," more fit organism than one would predict from multiplying together the effect of the individual mutations—a result that matches experiments with real bacteria, fungi, and fruit flies. Adami says this is particularly exciting because it shows that digital organisms can be used by researchers to answer important biological questions—"The advantages are that it's very simple, and that it abstracts the system as much as possible. Living systems on Earth are very complex after four billion years of evolution, so it's very difficult to ask the most fundamental questions of them. For example, we can reconstruct a genetic tree, then change the origin of the tree slightly and rerun the entire tape of evolutionary history. If we change just one molecule way back, we discovered it can change everything."

The work has implications for searches for life beyond Earth, because no one really knows exactly how life got started and how it proceeded to grow in complexity. Therefore, no one really knows all the ground rules of life. "If we go somewhere else, are we going to find life that is similar or totally different? If it's similar but unrelated, then life is perhaps constrained narrowly. But if it's totally different, then maybe life is constrained very loosely."

The digital organisms are based on principles that are known about life here and assumed likely to be true of life elsewhere: living systems replicate, they conserve information, and they have dynamic properties that differ from other living systems and allow adaptations. By building a digital petri dish—an ecosystem, really—in which the programs "live," the researchers can allow the programs to fill a niche, interact with each other, mutate and adapt to local conditions, die out, provide opportunities for other organisms to fill the niche—all the things that organisms on Earth really do, but over many eons.

Adami hopes the work, which appeared in the August 12 issue of *Nature*, will help settle the debate about whether running experiments with digital organisms in a computer is really biology, as biologists understand it. It doesn't hurt that his collaborator is a respected biologist with many years of outstanding accomplishments using real petri dishes. "Richard Lenski is the world's expert at doing experimental evolution with *E. coli*," Adami says.

On July 31, 1999, the late Eugene Shoemaker (BS '47, MS '48) became the first human to be buried on the moon (or on any other nonterrestrial object, for that matter) when the Lunar Prospector, which carried a lipstick-sized vial of his ashes, crashed into a crater near the lunar south pole. The spacecraft, which had been orbiting the moon since January 11, 1998, was searching for signs that water ice might lurk in the moon's subsurface. This kamikaze finale was the culmination of that effort. It has been hypothesized that polar craters might hold frozen lakes, their water protected from evaporation by the everlasting night in which they lie, and it was hoped that the spacecraft's impact would send aloft a plume of ice particles that would be detectable from Earth. (No plume was visible, but the astronomers are still analyzing their data.) Shoemaker, one of the Caltech geologists who trained the Apollo astronauts to be scientists as well as fliers, had a lifelong dream to go to the moon himself.



"This paper is the first result of the collaboration, in which we repeated an experiment he has already done with *E. coli*. So I think this is the first time we have convinced biologists that artificial life is not just a pipe dream, but is answering some fundamental questions about biology."

Lenski is with the Center for Microbial Ecology at Michigan State University. The other collaborators are Charles Ofria (PhD '99), who is now a postdoc in Lenski's lab; and Travis C. Collier (BS '97) of the UCLA Deparment of Organismic Biology, Ecology and Evolution. □—*RT*

In preparation for its voyage to Chile, the Cosmic Background Imager—a 34-ton array of 13 one-meter radio telescopes—was hoisted onto an intermodal cargo platform called a "flat rack" (upper left) on July 8, and battened down against the elements by principal investigator Tony Readhead (upper right). The crane returned on August 2 to lift the now-crated CBI onto a flatbed truck for the trip to Long Beach Harbor. The CBI and its 10 shipping containers of support equipment arrived in Antofagasta, Chile on August 22, and reached the observatory site high in the Andes on the 28th. The telescope is now in its dome, and the shipping containers, which will double as offices, have been unpacked. The astronomers are now reinstalling the telescope's delicate components, and hope to soon begin looking for the seeds of the very first galaxies.

Number One

Caltech came out on top in this year's ranking of national universities by *U. S. News and World Report*, followed, in order, by Harvard, MIT, Princeton, Yale, and Stanford. The magazine bases its rankings on academic reputation (25 percent), graduation and retention rates (20 percent), faculty resources (20 pecent), student selectivity (15 percent), financial resources (spending per student; 10 percent), alumni giving (5 percent), and graduation-rate performance (the difference between actual and predicted graduation rates; 5 percent).

Although Caltech has always placed in the top 10 (last year it was ninth), it was a change in the magazine's statistical procedures, which formerly had flattened out the actual differences but now weighted them, that vaulted Caltech into first place. *U.S. News* admitted that these changes "boosted the rankings of a number of universities with strong science and engineering programs." The magazine pointed out that "[w]ith few students and many pricey scientific facilities, Caltech's average per-student spending is a whopping $192,000." But the Institute also placed first in faculty resources, freshmen in the top 10 percent of their high school classes (100 percent), SAT scores, and student/faculty ratio (3 to 1).

According to an accompanying article in the August 23 issue of the magazine: "At Caltech, would-be engineers and scientists can have it all: plentiful opportunities to learn at the feet of award-winning professors . . . and the sense of community that one finds at small schools." Amidst all the praise, however, the article did note that the racial and gender balance left something to be desired, not to mention the social life, as the *Princeton Review* observed in ranking Caltech among the worst party schools.

In yet another ranking, the September issue of *Kiplinger's Personal Finance Magazine* rated Caltech number 2 among the "Top 100 Values in Private Colleges." □

The Athenaeum dining-room ceiling was restored this summer to its former splendor. Originally designed by John Smeraldi in the Italian Renaissance style popular when the Ath was built, the ceiling had suffered over nearly 70 years of smoke and grime. Under the supervision of Tony Heinsbergen, son of Smeraldi's biggest local competitor, it was cleaned, in some places repainted, and varnished. Perhaps the most satisfying step of the restoration was the removal of acoustic tile (glued on during a '60s renovation to dampen the clatter of silverware) to reveal the original teal-blue panels beneath, bordered by patterned red and gold moldings. Romy Wyllie, the Athenaeum's interior designer, instigated the restoration project. Her book on Caltech's architecture will appear in December.

Lost in Space?

Long, long ago in a solar system not at all far away, five to ten Earth-like planets could have occupied Jupiter-crossing orbits. Warmed in the blanket of molecular hydrogen they accreted when the solar system formed, these planets could today be harboring life somewhere in interstellar space, said David Stevenson, Van Osdol Professor of Planetary Science, in a paper in the July 1 issue of *Nature*.

Called "interstellar planets" because they no longer orbit their parent star but instead drift through the void between the stars, such objects have never been directly observed, or even proved to exist. But based on what scientists know about the way matter should fall together to create a solar system, such planets could definitely have been formed. Then, over several million years, one of two things would have happened to them: either they slammed into Jupiter and were swallowed up, or they came close enough to Jupiter to be catapulted by its gravity completely out of the solar system, never to return.

Because these bodies formed when the solar system was permeated with hydrogen gas, they would have retained a dense atmosphere of hydrogen. Without sunlight, the natural radioactivity inside an Earth-like planet would only be sufficient to raise the radiating temperature of the body to 30 degrees above absolute zero (that's about minus 400 Fahrenheit), but a dense hydrogen atmosphere would trap that heat—just like the greenhouse effect on Earth, but more so. Over the eons, the planet's surface could attain Earth-like surface temperatures, allowing oceans of liquid water to form. (The dense atmosphere would also create a surface pressure similar to that at the bottom of Earth's oceans.) For this to happen, the interstellar planet would probably need to be at least half Earth's mass.

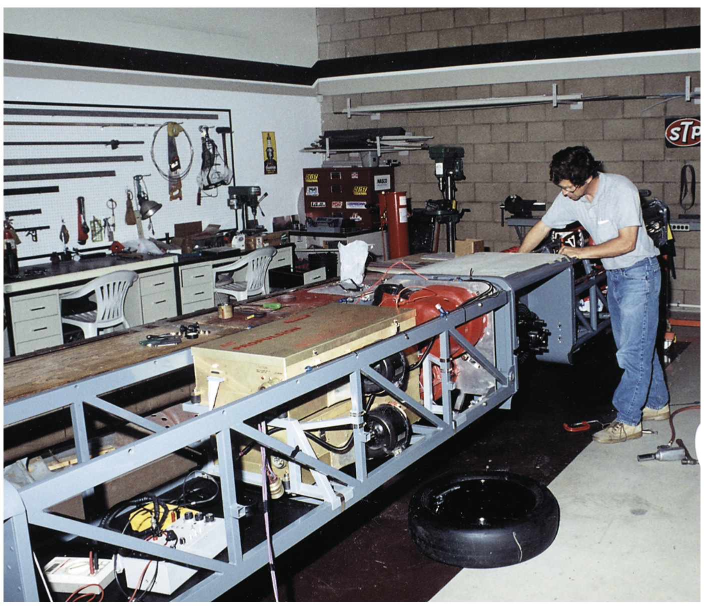
It is not known whether geothermal heat alone is sufficient to allow life to originate, and the amount of energy would be small compared to sunlight, suggesting that the amount of biological activity would also be small. But the existence of life in

In a tangentially related story, grad student Adam Burgasser has found four brown dwarves—stellar wannabes bigger than Jupiter but too small to ignite their hydrogen-fusion reactors—while sorting through data from the Two-Micron All Sky Survey, for which Caltech's Infrared Processing and Analysis Center (IPAC) is doing the data reduction. Assistant Professor of Planetary Astronomy Michael Brown then trained the 10-meter Keck Telescope on Burgasser's sets of coordinates (in the Big Dipper, Leo, Virgo, and Corvus the crow) and found the spectral signature of methane, which dissociates at temperatures above 1200 kelvins—only twice as hot as your oven when you're trying to cook a roast in a hurry. "I was specifically looking for brown dwarves in the latter stages of their evolution," says Burgasser. "And that's what these have to be—no other substellar object could cool to temperatures where methane can form." Brown dwarves are so dim that only about a dozen have been discovered so far, and methane-rich brown dwarves are the rarest of the rare—grad student Ben Oppenheimer (PhD '99) and astronomy professor Shri Kulkarni found the first one in 1995. Until now, it was the only one known. This new batch, plus one discovered by the Sloan Digital Sky Survey, will help theorists flesh out the models of a brown dwarf's life cycle, giving us a better understanding of these odd creatures that are neither planet nor star.

But although very few of them have been found so far, they are probably as common as the stars we see. Davy Kirkpatrick, an IPAC senior staff scientist who is looking for slightly hotter brown dwarves, estimates that the new crop is only about 30 light years away—right in our own back yard, in galactic terms. The fact that we can just barely make them out at such close range implies that the Milky Way, like L.A., is full of wandering stars that never made it.

such an environment would be of great interest, even if the mass of living matter were small. The heat energy, and especially variations in temperature, could potentially allow life to get going, Stevenson says. "I'm not saying that these objects have life, but everyone agrees that life requires disequilibrium. So there has to be a way to get free energy, because that's what drives biochemical processes. These objects could have weather, variations in clouds, oceans… even lightning." If life exists on such objects, how complex that life could be is an open question, he says. "I don't think anyone knows what is required to drive biological evolution from simple to very complex systems."

These interstellar wanderers could be a common byproduct of star formation, but even if such a planet formed in our own solar system and is still hanging around the neighborhood, it would be very difficult to see with present technology. Although these bodies may have warm surfaces, not much heat would escape into space and they would appear dark and cold to us—at best, as very weak emitters of long-wavelength infrared radiation, far below current detection limits. The best bet for demonstrating that interstellar planets exist would be a programmed search for occultations, Stevenson says. The object might occasionally pass through the line of sight from Earth to a star, and if instruments were watching, the starlight might dim or even flicker out for a moment. Such programs have already been advocated to look for planets in orbit around other stars. Looking for interstellar planets would be much harder, he says, but it could be very rewarding. "All I'm saying is that, among the places you might want to consider for sustainable life, you might eventually want to look at these objects. They could be the most common location for life in the universe." □—*RT*

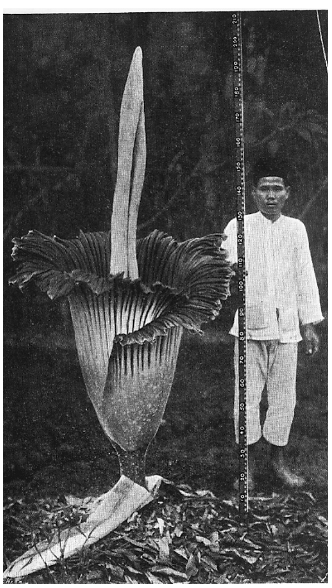


Left: Alan Cocconni (BS '80) checks some connections in the cockpit wiring of the *White Lightning* (below), an electric vehicle that set a land-speed record of 239.533 miles per hour at the Bonneville Salt Flats on August 20. The car was powered by 6,210 rechargeable nickel-cadmium "sub-C" batteries—a lighter-weight variant of the kind sold in hobby stores for radio-controlled models. "They discharge fully in 90 seconds—the fastest battery on the market at the time" says Cocconni, whose company, AC Propulsion, provided the power inverters (gold boxes) and 200-horsepower electric AC motors (red). "It's a standard drive system we've been selling to electric-vehicle builders and researchers for eight years," he says. "But not with that kind of battery, of course." Designed and built by the Arivett brothers of San Bernardino, the car's body shape was tested in Caltech's 10-foot wind tunnel. *White Lightning* is owned by Ed Dempsey, a well-known exponent of electric vehicles who says he is "trying to bring people a new and exciting image of the electric car, one that shows electric power is practical." With the car newly outfitted with special nickel-hydride batteries, Dempsey plans to break his own record.

Little Library of Horrors

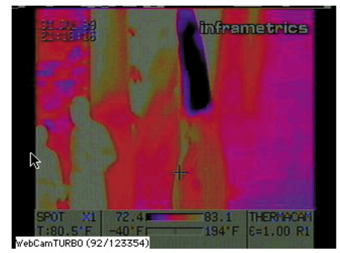
The total eclipse of the sun didn't happen until nine days later and on the other side of the planet, but a strange and interesting plant caused a sensation at the Huntington Library, Art Collections, and Botanical Gardens anyway. Bearing a more than passing resemblance to Audrey II, the bloodthirsty plant from the hit musical *Little Shop of Horrors*, a rare Sumatran species named *Amorphophallus titanum* (Latin for "large, shapeless… well, you know") bloomed briefly on Monday, August 2, sparking a media blitz not unlike the fictional Audrey's. Specimens have bloomed only eleven times in the United States, and this is the first in California, so the saturation coverage drew tourists like flies—entirely appropriate as the plant is known in Indonesia as the Bunga Bangkai, or "corpse flower," because of the reek it emits to lure its pollinators: dung beetles, sweat bees, and other feasters on the fetid. The line of human lovers of the pestilent was two hours long that day. Smelling the miasma, chiefly compounded of dimethyl disulfide and dimethyl trisulfide, was like sticking your head in a dumpster behind a Chinese restaurant—rotting bok choy, in other words, with a hint of exotic spices. (Odor is subjective, of course—other descriptions range from "dead possum" to "old sweat socks.") And the plant itself was a sight to behold: nearly six feet tall from the bottom of its stem to the tip of its fleshy, maroon spadix, which looked like a giant lipstick and at whose base thousands of flowers proper lay, protected within a green, cabbage-leafy sheath called a spathe. When the flowers bloomed, the spathe opened out away from the spadix like an inverted umbrella or a radiotelescope trained on the zenith.

The Araceae family, to which this nosesore belongs, has a curious property—the spadix can heat itself up to as much as 40° C, or 104° F, to help diffuse the noisome seduction. (Araceae are diverse and widely distributed, and include philodendrons, calla lilies, the jack-in-the-pulpit, and, perhaps most tellingly, the skunk cabbage.) The hot spadix acts like a chimney, creating a convection current that entrains the scent molecules and lofts them far and wide. On the day it bloomed, one observer (olfactor?) got a momentary whiff on Lombardy Road, a good half-mile from the plant. "According to anec-

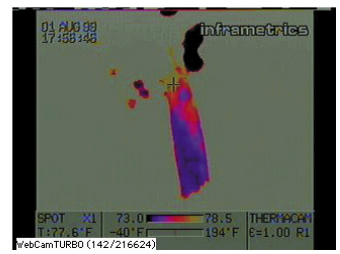


Above: Caltech astronomer Michelle Thaller (left) and Huntington botanist Kathy Musial (right) with the *Amorphophallus titanum* behind them in full bloom. Thaller appears to have gotten a fresh whiff of its stench. This specimen was donated to the Huntington by Mark Dimmitt of Tucson, Arizona, who raised it from a seed in his greenhouse. Left: A 1924 bloom in the Botanic Gardens in Buitenzorg, Java. The central spadix can grow up to 10 feet tall. The species was discovered in the Sumatran rain forest by Italian botanist Odoardo Beccari in 1878, who sent seeds to the Royal Botanic Gardens in Kew, England. When it first bloomed there in 1889, at least one lady allegedly swooned from the odor.

Above: A few of the more than 76,000 people that saw the plant in the 19 days it was on display. Left: Thaller and the video camera on Friday, three days before the bloom. The black thing behind her is the video monitor that displayed the infrared image to the crowd. Right: The image was also broadcast live over the internet. The color bar in the bottom center of the image shows the temperature scale; the "T:" in the lower left corner shows the temperature at the +-shaped cursor. On Saturday (top), the spadix was still relatively cool, but the spathe was heating up. By Sunday (bottom), the spadix was beginning to show heat variations. On Monday, the site overloaded.



LIVE: "corpse" flower in infrared light



LIVE: "corpse" flower in infrared light

dotal information I've received from colleagues, waves of heat have been seen in other *Amorphophallus* species, but not in *titanum*," says Kathy Musial, the Huntington's curator of plant collections. "*Titanum's* odor is well known to come out in waves, so it makes sense that the heat would as well." (In fact, one teenager christened the stinker "the plant that farts," and the crowd's reaction when a fresh pulse hit the air was quite amusing to see.) In order to find out if *titanum* pulsated heat as well, Gail Shair, special projects coordinator for the botanical gardens, asked her father, Fred Shair, who had been at Caltech and JPL since 1965, if he knew anyone who had an infrared camera. He put her in touch with Caltech infrared astronomers Michelle Thaller, staff scientist on SIRTF (Space Infrared Telescope Facility), and Michael Bicay. Thaller, who studies massive binary star systems and is also in charge of educational outreach, has a portable 8-14 micron mid-infrared video camera that she uses for public demonstrations. "It's a very popular trade-show kind of thing," Thaller says. "Kids love it—we give them ice cubes, and they draw on themselves, and it shows up blue. Then I might as well leave, because they don't pay any more attention to me!"

The infrared camera was set up on Wednesday, July 28, and the video feed, which was displayed on a monitor next to the plant and broadcast live on JPL's Web site, became part of the attraction. (The Huntington's Web site, which linked to the JPL feed, had 205,228 hits on August 2.) Thaller, who had to babysit the equipment anyway ("This is not how I planned on spending the end of my week," she said bemusedly), did her outreach thing, explaining to the crowd what infrared light is, and plugging JPL, NASA, and SIRTF, whose logos were prominently displayed. By mid-afternoon Sunday, a few hours before the bloom began to open, there was already a five-degree temperature difference between the tip of the spadix and the place where it emerged from the still-furled spathe. What happened the next day is still a mystery, however—some bystander apparently pushed a button he shouldn't have, and the video recorder, which had worked fine on Sunday, taped two hours of random TV channels on Monday.

But there will be other chances. John Trager, the Huntington's curator of desert collections, attempted to hand-pollinate the plant. The fruit is now setting, but the greenhouse staff will have to wait several more weeks to find out if there are seeds within. And if not, says Musial, there are fifteen or so smaller specimens in pots, awaiting their turn in the limelight. □—*DS*

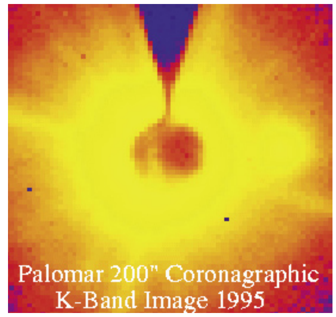
Below: A peek down the spathe at the flowers within. Each plant has a few thousand male flowers and several hundred female flowers, but the female ones bloom first to prevent self-pollination. As this *Amorphophallus* stood alone, the curators attempted to self-pollinate it by hand. The loop of string marks the pollinated region.

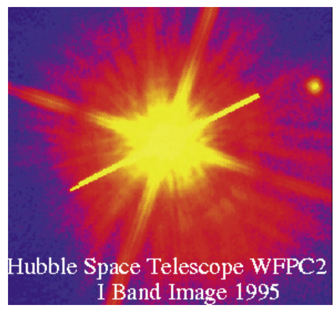
CALTECH JOINS EFFORT TO PUT ASTRONOMY IN FOCUS

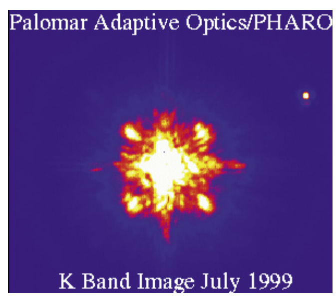
The Institute has signed up to participate in a multi-institutional effort—funded by the National Science Foundation's National Science Board—to advance the burgeoning field of adaptive optics. The project involves establishing a Center for Adaptive Optics at the University of California, Santa Cruz, to conduct research, educate students, develop new instruments, and disseminate knowledge about adaptive optics to the broader scientific community.

The use of adaptive optics compensates for changing distortions that cause blurring of images—turbulence in the earth's atmosphere, in the case of astronomy—and can give ground-based telescopes the same clarity of vision that space telescopes achieve by orbiting above the earth's atmosphere. Depending on the size of the telescope, adaptive optics technology will make images 10 to 20 times sharper, giving scientists a much better view of objects in space.

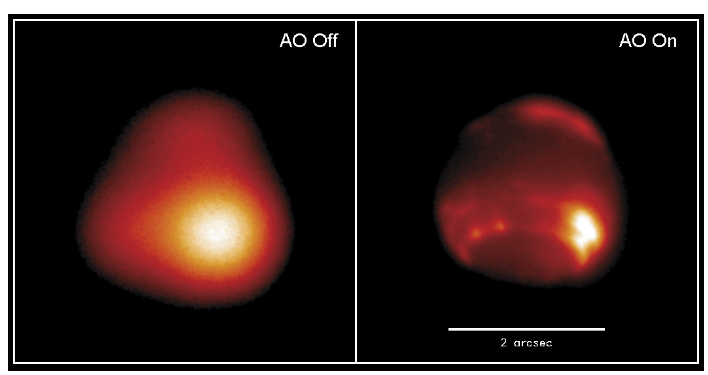
As one of 27 partner institutions, Caltech will bring together faculty from astronomy, planetary science, and physics in an effort to advance the use of working adaptive optics technology at the 200-inch Hale Telescope at Palomar and the two 10-meter Keck Telescopes. As these telescopes are among the largest in the world to begin with, the returns gained by fitting them with adaptive optics are proportionately large. The Caltech team will be led by Michael Brown, assistant professor of planetary astronomy, and will include Shri Kulkarni, Chuck Steidel, Mark Metzger, and Keith Matthews from astronomy, and Christopher Martin from physics. "This effort will breathe new life into ground-based observing by giving us more sophisticated tools to view distant planetary systems," says Brown. "We can learn and experiment at Palomar, then utilize Keck for the really big discoveries." □—*SMcH*







Left: Three shots of a bright star named Gliese 105 A and its faint, low-mass companion star, Gliese 105 C (to its right). The two stars are three arc seconds ($^{3}/_{3,600}$ of a degree) apart. The top shot is a near-infrared (2.2 micron) image made with the Hale Telescope without using the adaptive-optics system. A coronagraphic mask covers the bright star, blocking most of its glare and allowing the dimmer star to be seen. The middle picture was taken at visible wavelengths from the Hubble Space Telescope and did not need a mask, as there was no atmosphere to scatter the bright star's light and obscure the companion, which is now clearly visible. The bottom picture is another infrared from the Hale Telescope, using the adaptive-optics system. No mask is needed, and the companion is sharp and clear—clear enough, in fact, that its near-infrared spectrum could be taken, a hitherto impossible feat. Images courtesy of Ben Oppenheimer (PhD '99).



Right: The Palomar Adaptive Optics Project, based on a bendable mirror with 241 computer-controlled actuators, is one of the strengths Caltech brings to the collaboration. Built by a JPL team headed by Richard Dekany (BS '89) and installed on the 200-inch Hale Telescope, the system takes 500 samples per second of the light from a bright star in the vicinity of the object of interest, and flexes the mirror as needed to remove atmospheric distortion and create images 10 times sharper than otherwise possible from the ground and twice as sharp (because of the Hale's larger mirror) as the Hubble Space Telescope. These views of Neptune were made with PHARO, a multi-purpose infrared camera built by Cornell University, but the system can be used with all kinds of cameras and spectrometers. Under most seeing conditions, the system gives diffraction-limited resolution, meaning the wavelength of the light itself is the limiting factor—as good as it gets, in other words. Images courtesy of Tom Hayward, Cornell.

Encore!

Caltech's answer to Tom Lehrer, Emeritus Professor of Literature J. Kent Clark, is poised to make a splash in the recording industry. The lyricist, librettist, director, and one of the founding members of the Caltech Stock Company—a musical-theater troupe and not, as one might expect in this day and age, an investment group—has finally gotten around to reissuing the Stock Company's 1975 LP, *Let's Advance on Science*, on CD. "People have been badgering me to do this for years," he confesses, "and when my wife finally started getting on me too, I knew the time had come." The CD, digitally remastered by Disk Masters (the same outfit that put out the Caltech-Occidental Concert Band CD *TECHnically Sound* last year), "has cleaned up the sound, but it can't improve my singing."

The best-known song on the album is "The Richter Scale," which has received national airplay on *The Doctor Demento Show*, and gets dragged out of the vaults every time there's a really good earthquake. (The song has held up well, but Clark has no plans to add a verse commemorating Northridge. "Everything since Anchorage is anti-climax.") Other classics include "I Never See Stars," a lilting lament about an astronomer who sings, "I never see stars, even when it's clear/I muck about with photographs and paper up to here/ I never see stars, any size or shape/ I only see computers and a million miles of tape"; "That's Not Gneiss," a rumination on disreputable rocks; and "Down at the Burbank," a tribute to the late Nobelist Richard Feynman's favorite strip joint, where he used to doodle quantum physics on the cocktail napkins while watching Newton's Laws in action.

The Caltech Stock Company, an ensemble of faculty, staff, students, spouses, and offspring, flourished from 1955 to 1975, producing, choreographing, and performing 10 full-length shows and innumerable skits commemorating all aspects of campus life. "In that 20 years," Clark chuckles, "only three important events happened. Beckman Auditorium was built, the Ath got a liquor license, and Caltech admitted women undergraduates. The last is the most important." One of those undergrads, Elizabeth McLeod (BS '76), Caltech's first female ASCIT president, can be heard singing "A Nice Girl Like You," which honors their arrival: "What's a nice girl like me doing in a place like this?/ A nice girl like me happens to be fond of physics/ A nice girl like me wants to be an engineer… Wild about a photon, gamma ray or proton/ No *ton* I want to miss, being in a place like this."

Let's Advance on Science is available at the Caltech Bookstore for $8.50, plus shipping and handling. You can reach the bookstore by phone: (626) 395-6161; fax: (626) 795-3156; email: citbook@caltech.edu; or campus mail code 1-51. ☐—*DS*

Heather Dean, senior in engineering, braves the tepid shallows of Throop Pond to test the reliability of a student-constructed bridge. Dean was one of four student instructors for the seventh annual YESS (Young Engineering and Science Scholars) program, which took place over four weeks in July and August. Sponsored by the Caltech Precollege Science Initiative and the Caltech Y, the program hosts 40 talented high school students from underrepresented socioeconomic and ethnic backgrounds to encourage them to pursue careers in science and engineering. As part of the program, students tackle creative problem-solving challenges, take field trips, listen to guest speakers, and attend sessions exploring college life, leadership, and group dynamics.

Employer of the Year

At a dinner at the Doubletree Hotel on July 16, Caltech was given one of two annual Pasadena Model Employer of the Year for Working Parents awards. Established this year by the city of Pasadena and the Pasadena Chamber of Commerce, the award honors employers that offer family-friendly policies and benefits. "The selection criteria include such items as the availability and quality of on-site child care, family leave, continuing education benefits, and other things to improve the quality of life for employees," said Chamber President Lynne Hess. The judges included community leaders, chamber members, and city officials. Two awards were given, with Caltech taking the non-profit organization award and Fannie Mae the for-profit one.

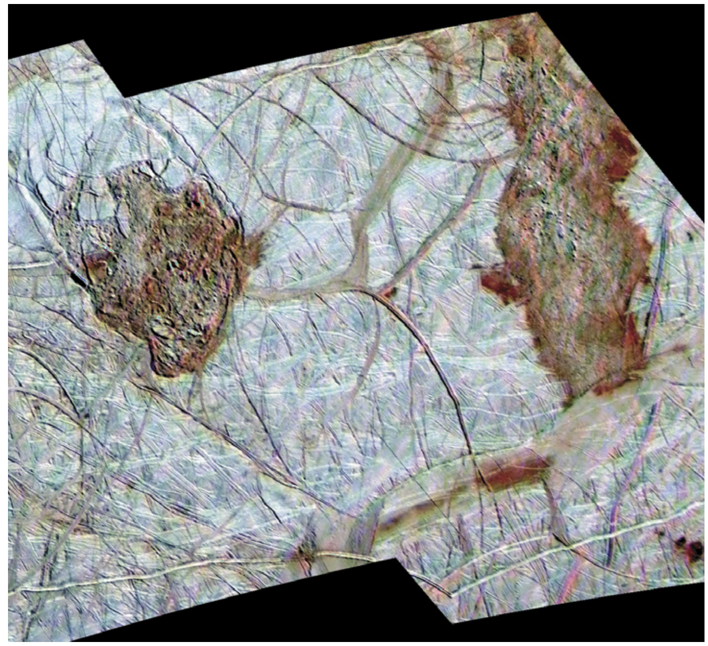
Erratum

In the last issue of *E&S*, the 1984 Caltech tomographic map on page 13 should have been credited to Don L. Anderson, Yu-Shen Zhang, and Toshiro Tanimoto instead of Nakanishi, Nataf, and Anderson.

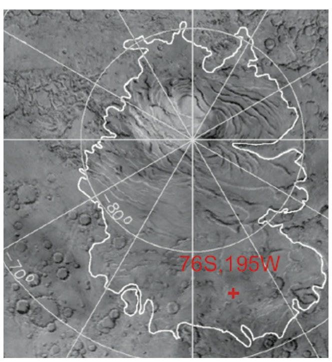
Pizza and Epsom Salts from Galileo

Despite the loss last month of the Mars Climate Orbiter (due to a mixup of metric and English units) the Jet Propulsion Laboratory has a lot going on. The Mars Polar Lander (below), which was going to use the orbiter to relay its data back to Earth, will instead use the Mars Global Surveyor, which has been observing Mars for a couple of years.

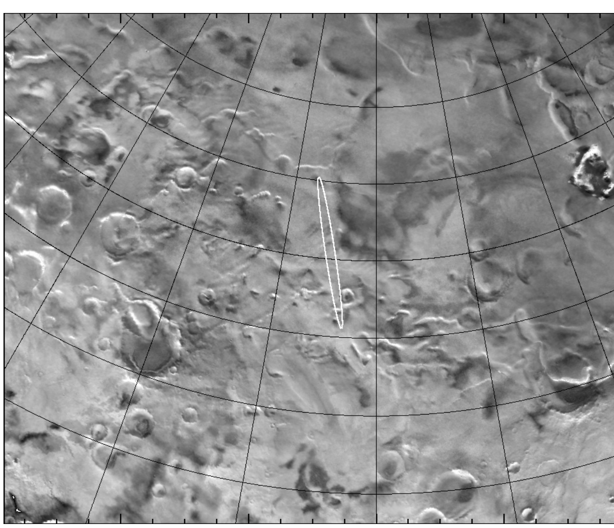
And sturdy Galileo, which also suffered some adversity when its main antenna failed to open after launch, has been orbiting Jupiter and its moons since December 1995, sending back remarkable pictures. Its primary mission ended nearly two years ago, but it's still going strong. Galileo flew by Io again in July and Europa in August, and as *E&S* went to press Galileo was en route to a daring close approach to Io, possibly flying through a volcanic plume.

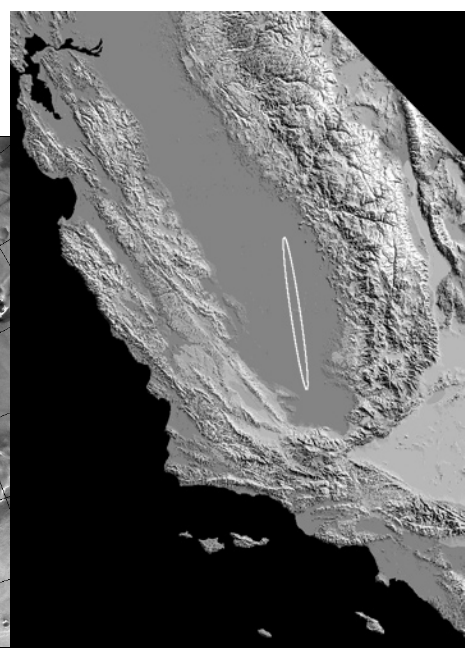


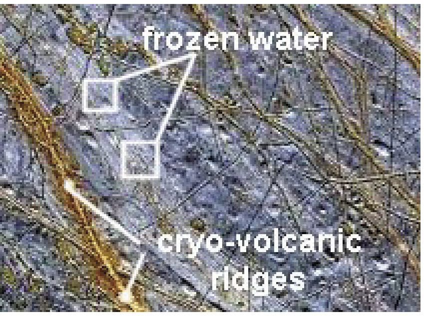
Thera (left) and Thrace (right), rust-colored, 50-mile-wide patches of jumbled terrain on Jupiter's moon Europa, may have come from a liquid ocean or warm ice welling up and cracking the moon's icy shell. Europa's surface is thought to be salty in places (the best spectral match is to magnesium sulfate, better known as Epsom salts), and when warm convecting ice rises up through one of these salty areas, the area will melt at a lower temperature than the surrounding plains. Curved cracks suggest the whole region collapsed at some time. Galileo took these images on August 27.



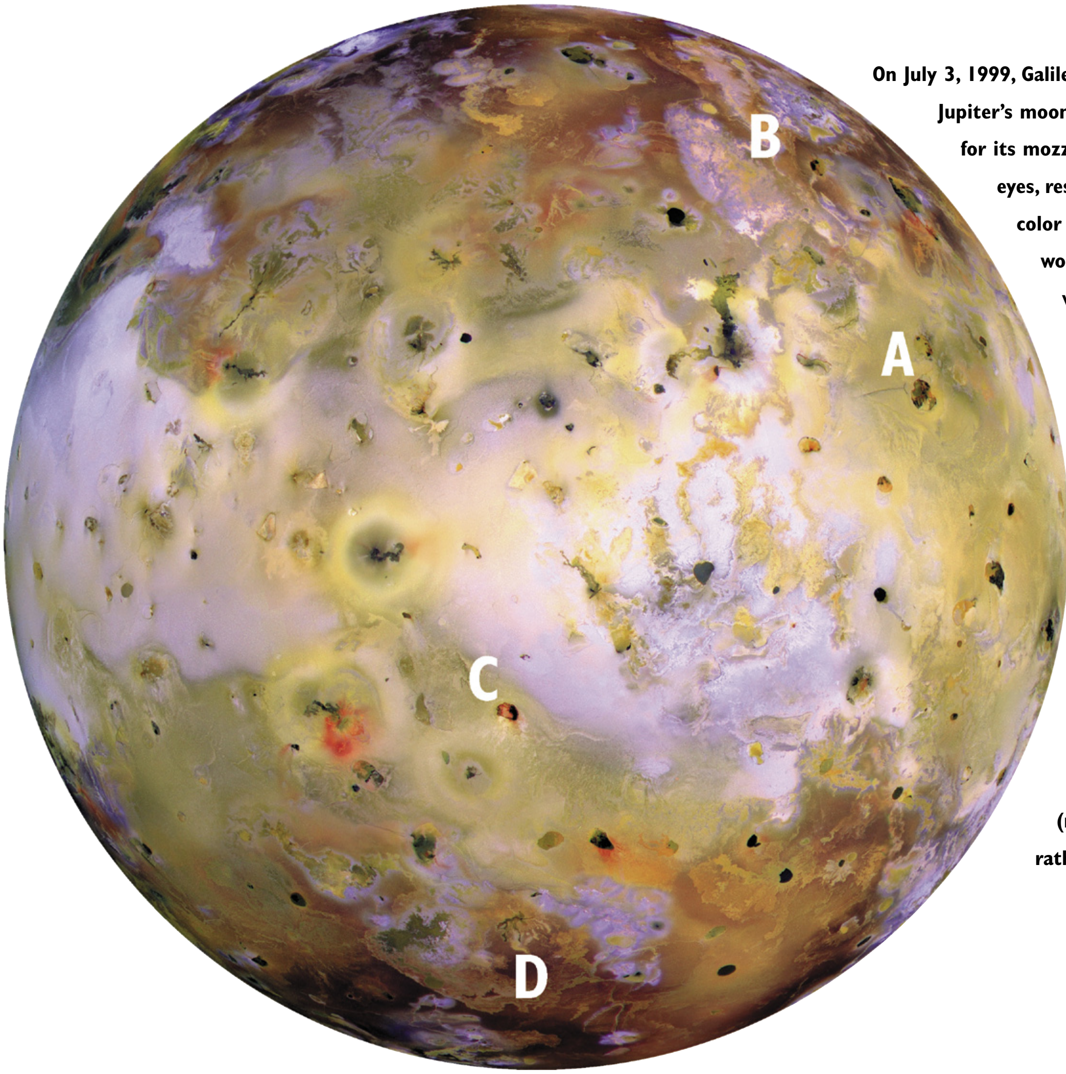
On December 3, JPL's Mars Polar Lander will set down on gentle, rolling plains near the Martian south pole, as marked by the red cross at left. The site, at 76° S latitude and 195° W longitude, is near the northern edge of the so-called layered terrain, outlined in white, whose alternating blankets of dust and ice may provide a readable record of Mars's climate. (A backup site at 75° S, 180° W has also been chosen.) At left below is a close-up of the landing area, showing the 240x20-kilometer landing ellipse, and the same ellipse superimposed on California's Central Valley (right).







The blue areas in this color-enhanced close-up of Europa's surface are thought to be pure water ice. The brown of the cryo-volcanic ridges may come from underground mineral-laden water percolating through cracks in the crust.



On July 3, 1999, Galileo passed within 81,000 miles of Jupiter's moon Io, known as the "pizza moon," for its mozzarella color and blotches of what, to some eyes, resemble pepperoni and olives. This false-color image, which approximates what it would actually look like to the human eye, revealed some previously unrecognized small-scale features in volcanic Io's constantly changing surface. One of the multicolored "olives" (A in close-up at far left below) suggests that Io's lava and sulfurous deposits are composed of complex mixtures. The bright, whitish deposits in B (second from left) and elsewhere in the high latitudes resemble transparent lids of frost. The red spot at C (third from left below) reveals sharp linear fissure-like features, and the colorful swirls at D (right) might be due to flows of sulfur, rather than silicate, lava.