Its Mars mission may be over, but JPL's rover still gets around. "The American Space Experience" at Disneyland's freshly updated Tomorrowland includes a full-scale model of the lander and rover as well as models and interactive displays about other JPL missions. At the opening ceremony, JPL Director Ed Stone cuts a rover-shaped cake while Mickey Mouse, park president Paul Pressler, and Pathfinder project scientist Matt Golombek look on.

Next on the rover's itinerary is a New Year's Day appearance on "Martian Mischief"—the 1999 Rose Parade float to be built by the city of La Cañada Flintridge, where the bulk of JPL is located. As the rover trundles across a floral Mars-scape, Martians will pop up out of hollow rocks to wave at it, but whenever it turns to look toward them, they will hide. The computer-animated float's mechanical, electrical, and hydraulic systems are being built by a group of volunteers that includes about 50 JPLers, and lots more help will be needed, especially come decorating time in December. Any member of the Caltech/JPL community with an urge to get a little bit of Mars (or at least some marigolds, carnations, lentils, carrot flakes, and potatoes) under their fingernails should call Bob Ferber at (818) 790-2013.

In other way-cool toy news, Mattel and JPL will reprise the tremendously popular Hot Wheels set based on the Pathfinder mission with a Hot Wheels Jupiter/Europa Encounter Action Pack. The set, due out in early 1999, will include replicas of the Galileo spacecraft, the descent probe, and a Deep Space Network antenna dish.

Biology Campaign Announced

Caltech has formally announced the goal of raising $100 million in a campaign to support new initiatives in the biological sciences. The Biological Sciences Initiative (BSI) will allow the Institute to create approximately a dozen new faculty positions in biology and related disciplines, construct a new biology building, develop new joint training programs with medical schools, and address several major biological questions that can be answered only through sustained research in state-of-the-art facilities.

"Our campaign is ultimately aimed at complex questions like the nature of consciousness, how memory and learning operate at the molecular level, how cells grow and die, and how genetic networks function," says David Baltimore, president of Caltech and a Nobel Prize–winning biologist himself. Adds Mel Simon, Biaggini Professor of Biological Sciences and chair of the Division of Biology, "We will go beyond the traditional disciplines and integrate our approaches with those of our colleagues in chemistry, physics, and engineering to achieve a more intimate understanding of how biology works." □

Pauling Exhibition to Tour Country

The life and legacy of the late Linus Pauling (PhD '25) will be celebrated in a free exhibition opening on September 20 at the Herbst International Exhibition Hall at the Presidio in San Francisco. *Linus Pauling and the Twentieth Century* will run in San Francisco through November 7, and will then tour the country. The itinerary is not yet final, but will include a visit to the Los Angeles area in 1999.

Pauling's groundbreaking discoveries in chemistry and his tireless campaigning to limit the spread of nuclear weapons led to his being the only person ever to win two unshared Nobel Prizes—chemistry in 1954 and peace in 1962. "The exhibition demonstrates how scientific pursuits and efforts to minimize human suffering need not be mutually exclusive," says Linus Pauling, Jr., chair of the exhibit's advisory committee. "We hope [it] will serve as inspiration for new generations to meet humanity's challenges in the 21st century."

The exhibit is cosponsored by the Pauling family; Oregon State University, which houses Pauling's papers; and Soka Gakkai International, a lay Buddhist organiztion dedicted to world peace with which Pauling had close ties.

For further information, visit http://www.paulingexhibit.org.

Astrophysics Thesis Makes (Gravity) Waves

When you're beginning a career in cosmology, it's only fitting to start with a big bang. That's what Ben Owen (PhD '98) is doing—not only did he win the Clauser Prize for best dissertation, but his work has already been the subject of an international symposium. His dissertation answers a nagging, decades-old astrophysical question: Why do young neutron stars have such slow spins? The research, done with Visiting Associate in Theoretical Astrophysics Lee Lindblom and Sharon Morsink (a postdoc at the University of Wisconsin–Milwaukee), predicts that newborn, rapidly spinning neutron stars will pulsate wildly, throwing off their spin energy as gravitational waves.

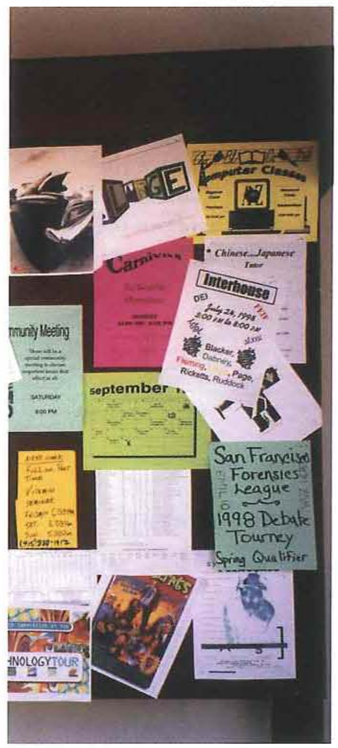
Neutron stars contain roughly the mass of the sun, packed into a sphere about 15 miles in diameter. They are typically formed in the supernova explosions of massive stars. They also tend to spin like crazy. Astronomers infer this spin from a telltale "blinking" in radio signals or sometimes even a strobelike blinking in visible light. Based on the rate of blinking, we know that these particular neutron stars—known as pulsars—can spin as rapidly as 600 times per second. And, based on the laws of Newtonian physics, there's no compelling reason why a normal star shouldn't speed up to the fastest rotation rate possible once it goes supernova and collapses into a neutron star, just like ice skaters who pull in their arms to spin faster.

But all of the young neutron stars observed to date spin at 120 revolutions per second or less—a factor of five slower than the fastest known pulsar, which is very old and is thought to have been spun up long after the supernova event by other mechanisms.

Owen, Lindblom, and Morsink theorize that circulation patterns on the neutron stars create a sort of drag in space-time. Called "r-modes" because they owe their existence to rotation, these circulation patterns look much like the eddies that move oceanic currents in circular motions on Earth. Owen's dissertation shows that the r-modes emit gravitational waves that cause drag as they leave the star, slowing down its spin. The drag, in turn, causes the r-modes to grow when they would normally die away due to internal friction. If an r-mode sloshed material nearly from pole to pole, the neutron star should slow down to one-tenth its original rate of rotation within a year—to rates typical of those seen in the fastest young pulsars.

But the effect is a self-defeating one, Owen says. The r-modes are kept going by gravitational waves, which are stronger when emitted by rapidly rotating stars. But the gravitational waves leaving the star cause it to spin down, which makes the waves weaker, which in turn means there is less power to keep the r-modes going. So the neutron star eventually reaches an equilibrium. "If the r-modes get very large, they'll start radiating a lot of energy as gravitational waves," Owen says. "But they can't do that forever, because the rotational energy they're radiating is what keeps them alive in the first place."

Owen's work is purely theoretical at this point, but could be tested when LIGO is operational. (See page 8.) If a supernova goes off in our cosmic neighborhood—say, within 60 million light-years—LIGO should be able to detect the gravitational waves thrown toward Earth. If Owen is correct, "When a supernova occurs, we should first see the waves start very abruptly at up to 1,000 cycles per second, and then chirp down to about 100 or 200 cycles per second over the course of a year." □—*RT*



Caltech's Avery House became Stanford's bookstore recently for an episode of *Party of Five*, the Fox-TV teen drama. Some house residents added a few Caltech touches—a *California Tech* newspaper rack and, on the Stanford-crimson bulletin board, nestled among the San Francisco Forensics League flyers and the jobs-wanted ads with 415 area codes, an Interhouse poster.

JPL Lends Students an Ear

A decommissioned antenna that used to talk to spacecraft is now talking to middle and high school students. The 34-meter dish, part of JPL's Deep Space Network (DSN) complex at Goldstone in the Mojave desert, has been converted into a radio telescope to be operated by the Apple Valley Unified School District's Lewis Center for Educational Research. (JPL will continue to maintain and upgrade the telescope.) The telescope can be controlled over the Internet, making it available to classes all over the country.

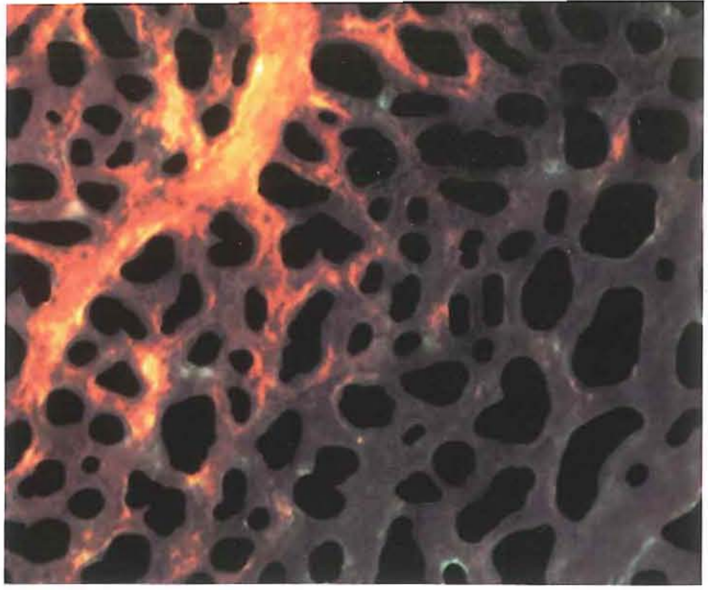
JPL is collaborating with the Lewis Center to develop science and technology curricula to go with the telescope. The first element, "Jupiter Quest," involves long-term studies of Jupiter's temperature, atmosphere, and radiation belts—a particularly appropriate assignment because during its 30-year DSN stint, the antenna kept tabs on Pioneers 10 and 11 and the Voyagers during their Jovian flybys. (It tracked Voyager 2 well past Neptune.) The students' observations are real science, complementing those being done elsewhere, and will eventually be published in journals. □

Starting Arteries

When do arteries and veins become different from one another? According to Professor of Biology and Howard Hughes Medical Institute Investigator David Anderson, it has been assumed that these identities develop only after the circulatory system forms, presumably as a consequence of differences in such things as blood pressure and dissolved oxygen levels. But new work in his lab shows that this is not the case.

Anderson, postdoc Zhoufeng Chen, and grad student Hai Wang have discovered that the cells destined to form arteries and veins are already genetically distinct at the earliest stages of blood vessel formation in the embryo. Moreover, these budding arteries and veins "have to 'talk' to each other to develop properly," says Anderson. By "talking," he means that complementary molecules found on surfaces of primitive arteries and veins must interact with each other for proper blood vessel formation to occur. The findings may help explain how an intact circulatory system can be put into place before the heart even begins to beat.

Specifically, the Anderson team found that a molecule



Blood vessels in the yolk sac of a mouse embryo form a network of arteries and veins. The vessels link up with each other through molecular signals. The red-gold tones in this photo are from an antibody that binds to ephrin-B2, a cell-surface molecule found only in developing arteries; its receptor molecule, Eph-B4, is found only in developing veins.

known as ephrin-B2, present on developing arteries, must communicate with its receptor, Eph-B4, present on developing veins. These proteins are made by endothelial cells, the cells that first form primitive vessel-like tubules in the embryo and then go on to form the inner lining of arteries or veins. This process appears to be fundamental—if it fails to occur, embryonic development ends almost as soon as the heart begins to beat.

The discovery occurred when Wang and Chen were performing a "knockout" experiment to see if the ephrin-B2 gene is essential for the development of the nervous system. When they eliminated the gene that codes for ephrin-B2 in mouse embryos, they found no nervous system defects, but did notice that there were defects in the developing vascular system and heart.

Fortunately, Chen and Wang had inserted a "marker" gene that makes cells turn blue where the ephrin-B2 gene would normally be turned on. They found, surprisingly, that the gene was active in arteries but not in veins. They then showed that the receptor gene, Eph-B4, was active in veins but not arteries. Eph-B4 and ephrin-B2 fit together like a lock and key, signaling each cell that the other has been engaged. This complementarity was seen on vessels throughout the developing embryo. The fact that elimination of the ephrin-B2 gene caused defects in both arteries and veins suggests that not only do arteries send a signal to veins via ephrin-B2, but that veins must also signal back to arteries. The fact that both ephrin-B2 and Eph-B4 span the cell membrane suggests that each protein may be involved in both sending and receiving a signal.

The findings may have broad implications, Anderson suggests. "One should reconsider the molecular biology, pathology, and drug therapies of the vascular system in terms of the molecular differences between arteries and veins." It is likely, says Anderson, that arteries and veins will differ in their expression of many other genes that have yet to be discovered. Such genes may lead to the development of new artery- or vein-specific drugs, or may help to target known drugs specifically to either arteries or veins. The research appeared in the May 29 issue of the journal *Cell*. □—*RT*

Maybe They'll Make a Movie About This One, Too

You've seen *Armageddon*. You've seen *Deep Impact*. Now read the paper in the May 22 issue of *Science* that describes geochemical evidence from a rock quarry in northern Italy that indicates that a shower of comets hit Earth about 36 million years ago.

The findings not only account for the huge craters at Popagai in Siberia and at Chesapeake Bay in Maryland, but posit that they were but a tiny fraction of the comets active during a span of two or three million years during the late Eocene period. The work provides indirect evidence that a gravitational perturbation of a cloud of comets beyond Pluto's orbit, called the Oort cloud, was responsible for sending a wave of comets swarming toward the center of the solar system.

The authors, from Caltech, the U.S. Geological Survey's Flagstaff office, and the Coldigioco Geological Observatory in Italy, say their evidence points to a very large increase in the amount of extraterrestrial dust hitting Earth in the late Eocene period. The team included Gene (BS '47, MS '48) and Carolyn Shoemaker; Gene died in a car crash last year while the research was in progress. (See *E&S*, 1997, No. 3.)

According to Associate Professor of Geochemistry Ken Farley, the lead author of the paper, Shoemaker's contribution was crucial. "Basi-

A 65-million-year-old dusting of iridium—rare on Earth but common in asteroids—was first discovered in samples taken from this road cut near Gubbio, Italy. This iridium layer has since been found worldwde—strong evidence that one or more asteroid hits nuked the dinosaurs. From right: Gene Shoemaker takes samples to look for ³He, while Alessandro Montanari looks on and Carolyn Shoemaker keeps the sample log.

cally, Gene saw my earlier work (see *E&S*, Summer 1995) and recognized it as a new way to test an important question: Are large impact craters on Earth produced by collisions with comets or asteroids? He suggested we study a quarry near Massignano, Italy, where seafloor deposits record debris related to the large impact events 36 million years ago. He said that if there had been a comet shower, the technique I've been working on might show it clearly in these sediments." Carolyn Shoemaker adds that she and her husband went to Italy last year to perform field work in support of the paper.

The technique measures the helium isotope known as ^{3}He, which is rare on Earth but common in extraterrestrial materials. ^{3}He is very abundant in the sun, and some of it is ejected as part of the solar wind. The helium is easily implanted into and carried along by such extraterrestrial objects as asteroids, comets, and their associated dust particles. Thus, arrival of extraterrestrial matter on Earth's surface can be detected by measuring the matter's associated ^{3}He.

The ^{3}He-bearing material is unlikely to include large objects like asteroids and comets. Because these heavy, solid objects fall into the atmosphere with a high velocity, they melt or even vaporize. The liberated ^{3}He mixes with the atmosphere and is ultimately lost to space—it never gets trapped in sediment.

But tiny particles are another story. They can slowly pass through the atmosphere at low temperatures, retaining their helium. These particles accumulate on the seafloor as part of the sediment, providing an archive going back hundreds of millions of years.

Elevated levels of ^{3}He would suggest an unusually dusty inner solar system, possibly because of an enhanced abundance of active comets. Such an elevated abundance might arise when a passing star or other gravitational anomaly kicks a huge number of comets from the Oort cloud into elliptical, sun-approaching orbits.

And indeed, samples from the Italian quarry showed an elevated flux of ^{3}He-laced materials in a sedimentary layer some 50 feet beneath the surface—a depth that suggested that the ^{3}He had been deposited about 36 million years ago. This corresponds to the dating of the craters at Popagai and Chesapeake Bay.

More precisely, the ^{3}He measurements show enhanced solar system dustiness associated with the impacts 36 million years ago, but with the dustiness beginning 0.5 million years before the impacts and continuing for about 1.5 million years after. Thus it appears that there were a large number of Earth-crossing comets, and much dust from their tails, for a period of about 2.5 million years.

In addition to the Shoemakers and Farley, the paper was cowritten by Alessandro Montanari, who holds joint appointments at the Coldigioco Geological Observatory in Apiro, Italy, and the School of Mines in Paris. □—*RT*

Some Day My Prints Will Come

The punk rats on the cover of the last issue were a big hit—several people have asked if reprints were available. Artist Erika Oller has graciously given us permission to sell prints at cost—approximately $25.00 each. Call us at (626) 395-6730 for details.

Making Memories Stick in Your Head

A sticky molecule found at the junctions of brain cells may be a crucial chemical ingredient in learning and memory, according to Assistant Professor of Biology and Howard Hughes Medical Institute Investigator Erin Schuman. In the June issue of *Neuron*, she, grad student Lixin Tang, and Chou Hung (BS '96) report that a calcium-dependent family of molecules known as cadherins plays a significant role in chemically joining the synapses—the junctions of nerves. Neuroscientists believe that the environment of the synapses is where memories are stored.

Cadherin molecules span the cell membrane, with protrusions, or domains, that stick out into the synapse, which is actually a gap 10–20 nanometers wide—an easy reach for a protein molecule—between adjoining cells in a neural circuit. Since cadherins are found on both sides of the synapse, they "may form a sort of zipper-like structure at the junction of the presynaptic cell and the postsynaptic cell," says Schuman. "We show in this study that these molecules participate in making the synapses bigger and stronger, a process called 'long-term potentiation' that may be involved in memory storage."

The research involved turning off the cadherins in the brains of adult rats and mice to see what effect that had on long-term potentiation. "It has been known for some time that cadherins are important during early development," says Tang. "But they are also expressed well into adulthood. So we were interested in seeing what would happen when cadherin was disrupted in the adult brain."

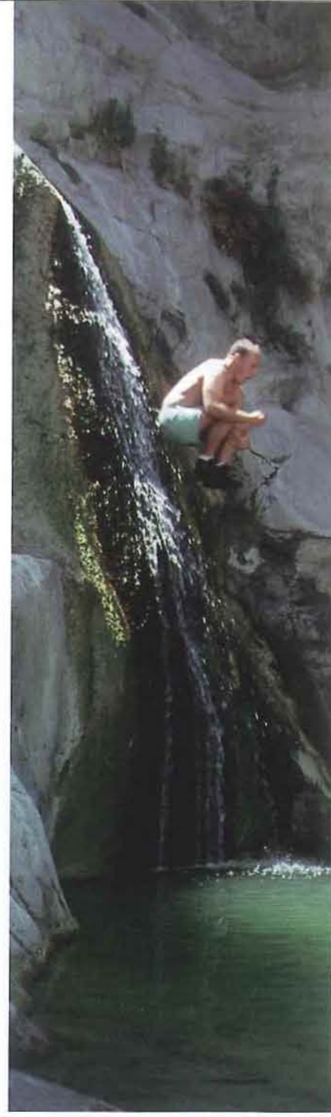
The researchers shut off the cadherins by either introducing antibodies that bound to the part of the cadherin molecule that sticks out into the synapse, or with an inhibitory peptide that mimicked the real cadherin's presumed binding site. Either way, the interloper got stuck between the zipper's teeth, as it were, and long-term potentiation was significantly reduced.

However, the synapses' overall signal transmission rate and their structural integrity were unchanged by the antibodies. This would indicate that the cadherins are used very specifically by the nerves for changing the strength of synapses, but not for the basic transmission of nerve impulses.

And the inhibitory peptides were only effective in shutting down long-term potentiation if they were introduced at the beginning of the process. When the peptides were introduced about 30 minutes afterward, they had no effect. This suggests that there may be factors other than the cadherins involved in long-term potentiation, and that these factors cannot be blocked by the peptides, Schuman explains. Like the antibodies, the peptides have no effect on baseline signal transmission or structural integrity when they disrupt the cadherins.

Cadherins require calcium ions in order to stick to one another, and it's known that calcium ions temporarily leave the synaptic junction during nerve impulses. So perhaps the calcium's departure momentarily destabilizes the cadherin-cadherin bonds, allowing the peptides to block long-term potentiation. Schuman and colleagues found that adding calcium ions to the solution bathing the nerve cells protects the cadherins from the inhibitory peptides. This suggests that cadherins might be able to work as "activity sensors" outside nerve cells, changing their binding behavior in response to changing calcium levels. □—*RT*

Astronaut candidate Reisman experiences weightlessness of another kind while hiking with Chris Brennen in the San Gabriel Mountains.



AND HE'S BUILDING A STAIRWAY TO HEAVEN

When Garrett Reisman (MS '92, PhD '97) was a grad student here, he was president of the Caltech Flying Club. Now he hopes to trade in his Cessna for a space shuttle—he is one of the latest crop of 25 astronaut candidates chosen from across the country to begin a yearlong training and evaluation program at the Johnson Space Center in August. Reisman will be training as a mission specialist. "We don't actually fly the shuttle; we're the guys who sit in the back and operate the payload. But we do get to do other cool stuff—we take spacewalks and run the robot arm. The shuttle drivers don't—they have to stay at the controls to keep the shuttle in the right relative position." Although it's far too early for him to have been assigned to a specific mission, he notes that his class of trainees will be the ones building and maintaining the International Space Station.

Reisman, who got his degrees under Professor of Mechanical Engineering Chris Brennen, credits Brennen with helping land him the appointment. "He wrote lots of letters of recommendation, and he told them about all the things we had to do to keep the water tunnel going. When you're an experimentalist, you have to do a lot of problem solving. I did plumbing, I changed out pumps, I did a lot of stuff besides just running my experiments. They were looking for mechanical and aeronautical engineers with hands-on experience, and the cavitation work I did at Caltech probably made the difference." □