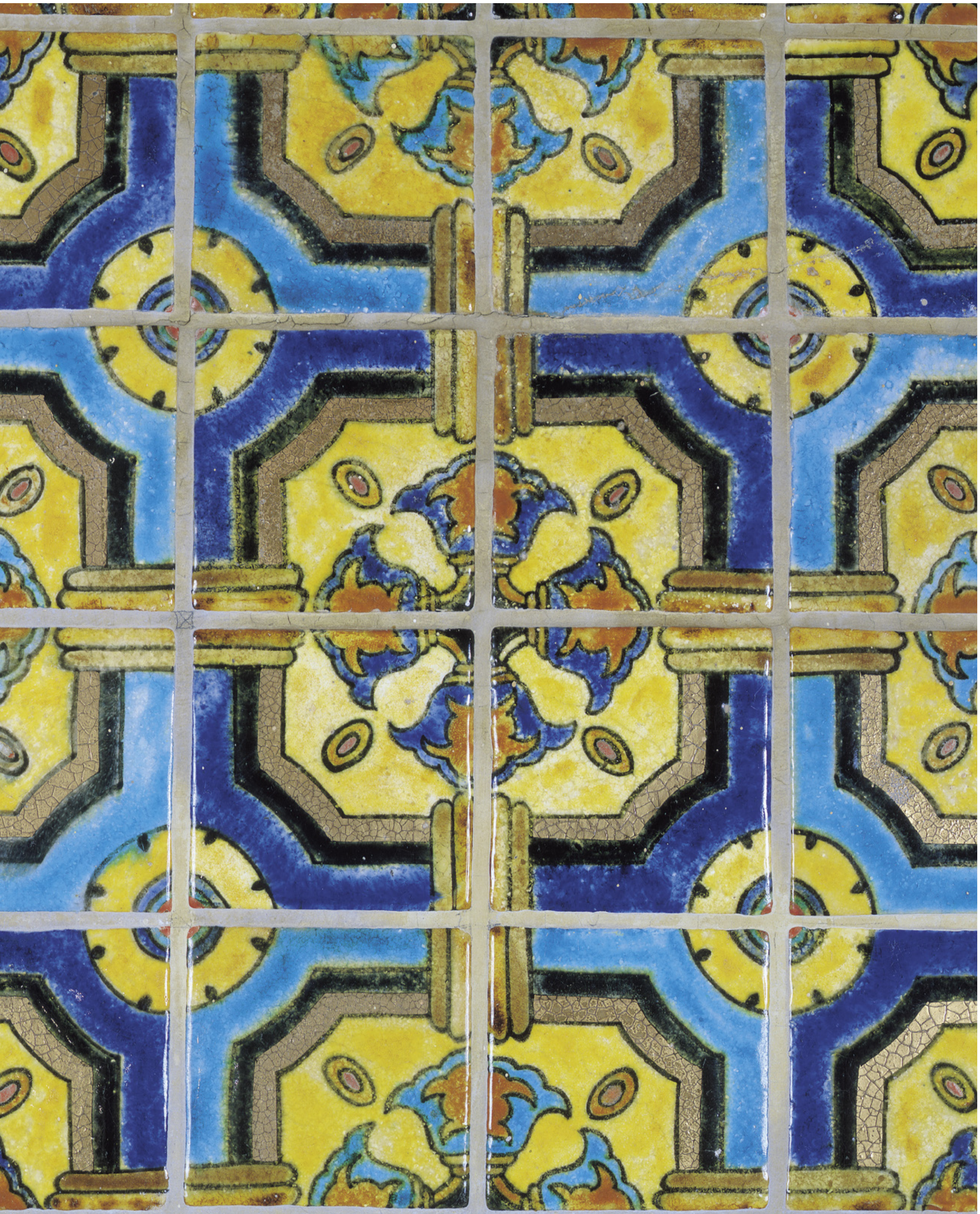
CALIFORNIA
INSTITUTE OF
TECHNOLOGY

ENGINEERING AND SCIENCE

Volume LXII,
Number 4,
1999

IN THIS ISSUE



These tiles in a Dabney Hall fountain are among the stunning, and often overlooked, campus details depicted in Romy Wyllie's recent book, *Caltech's Architectural Heritage: From Spanish Tile to Modern Stone.* A chapter on some other buildings from the Spanish-tile era begins on page 18.

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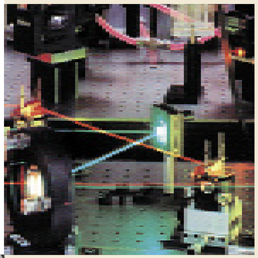

On the cover: Ahmed Zewail, the Pauling Professor of Chemical Physics and professor of physics, is awarded the 1999 Nobel Prize for chemistry by King Carl Gustaf of Sweden. Zewail was honored for his work in femtochemistry, which slices time so thinly that chemists can watch atoms react in slow motion. The story begins on page 6.

Engineering & Science (ISSN 0013-7812) is published quarterly at the California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91125. Annual subscription $10.00 domestic, $20.00 foreign air mail; single copies $3.00. Send subscriptions to Caltech 1-71, Pasadena, CA 91125. Third class postage paid at Pasadena, CA.

Published by Caltech and the Alumni Association. Telephone: 626-395-3630.

PICTURE CREDITS: Cover — Anders Wiklund/SCANPIX; Inside front cover, 18, 19, 22 — Douglas Hill Photography; 2, 17, 26, 28-30, 33 — Bob Paz; 5 — Phil Lindquist; 6, 9, 17 — Joe Umbro; 8, 9, 12, 13 — Dongping Zhong; 10, 14 — Spencer Baskin; 11, 38 — JPL; 17 — Vladimir Lobastov; 20, 21, 23, 25 — Caltech Archives; 22, 23 — Romy Wyllie; 24-25 Caltech Physical Plant; 34 — Aron Meltzner; 36, 37 — Dave Wald; 38 — Sally McGill

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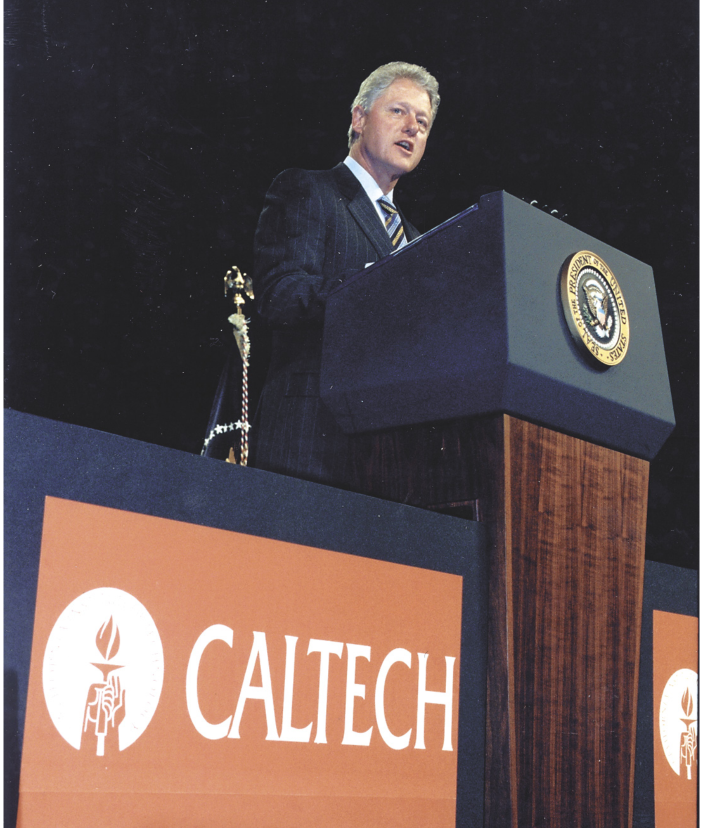

Bill Clinton speaks from the Beckman Auditorium stage.

THE PRESIDENT COMES TO TOWN

Above: Clinton tries out one of the set of Liquidmetal golf clubs presented to him by Caltech President David Baltimore. They're actually made of metallic glass, a stronger and more flexible noncrystalline metal developed by William Johnson, the Mettler Professor of Engineering and Applied Science.

Right: The President mingles with a crowd of students after his talk.

President Bill Clinton chose Caltech as the site to unveil his science and technology budget for the 2001 fiscal year and announced to a packed Beckman Auditorium on January 21 that he was proposing a $2.8 billion increase.

His proposed budget includes a $675 million increase for the National Science Foundation—double the largest increase in NSF's history—and $1 billion more for biomedical research at the National Institutes of Health. In addition, two specific fields were singled out for generous funding: information technology research, for which $600 million is earmarked, and a new $497 million National Nanotechnology Initiative. Clinton, standing in front of a backdrop of the western hemisphere drawn in gold atoms (enlarged for the occasion), noted in his speech that Richard Feynman had first prophesied the field of nanotechnology at Caltech ("There's Plenty of Room at the Bottom," *E&S*, February 1960).

Clinton praised a number of Caltech's accomplishments and said that the government has "not done a good job of explaining why we need large investments in science; we have to explain why science is important and how it affects people's lives." Research at universities is "a top priority," Clinton said, as is the next generation of scientists. He stressed the need to recruit more minority students into science and technology and to help them graduate, and he reiterated his support for student loans and tax deductions for college tuition, which he had announced the previous day. And the President received a round of applause when he noted the benefits we have gained from scientists born in other countries; "we should continue to welcome them to our shores."

In conclusion, Clinton told the members of the audience, "You have the power to put science and technology to work," but he urged them to "keep human values at the center."

Then, instead of being whisked away by the Secret Service, the President left the stage and, to the strains of Elton John's "Rocket Man," joined the delighted Caltech crowd, shaking hands and posing for pictures for more than half an hour. ☐

AGING AND MITOCHONDRIAL DNA

Certain effects of aging could be caused by mutations in the DNA molecules of the energy-producing engines of cells known as mitochondria, according to new research from Caltech and the University of Milan.

The study describes the results of skin-cell biopsies of about 30 individuals in a variety of age groups. The study concludes that damage to mitochondrial DNA dramatically increases around the age of 65.

"It's not a magic number, but we see a clear trend," says Giuseppe Attardi, the Grace C. Steele Professor of Molecular Biology and leader of the team authoring the paper.

Attardi and his colleagues focused their efforts on the small structures in mitochondria. Every cell can have tens to hundreds of these structures, which play an important metabolic role in the energy production that allows the cell to do its work.

Each of the mitochondria has about 10 to 20 molecules of DNA, which means that a single cell can have hundreds or thousands of mitochondrial DNA molecules.

But mitochondrial DNA is known to be susceptible to mutations over the course of a lifetime. These mutations can be due to oxidative damage, some enzyme malfunction, or even the cell's own efforts to repair itself. But prior to the new study, molecular biologists had difficulty detecting aging-related mutations.

Over a period of about five years, Attardi and his colleagues developed a technique for detecting aging-related mutations in the main control region of mitochondrial DNA. This provided a very reliable method for determining the percentage of mitochondrial DNA molecules in a cell that had actually undergone mutations.

With this technique, they then studied tissue samples provided by the National Institutes of Health (NIH) and the University of Milan from skin biopsies. These biopsies came from individuals ranging from a 20-week-old fetus to a 101-year-old subject, which allowed the researchers to determine the prevalence of mutations in different age groups.

The results showed virtually no aging-related mutations for any of the subjects under the age of 65. But a dozen or so individuals above the age of 65 showed a dramatic increase in mutations. And not only did the rate of mutations sharply increase with age, but individuals also showed a sharp increase in mutations if they passed the age of 65 between biopsies.

Overall, the researchers found that up to 50 percent of the mitochondrial DNA molecules had been mutated in subjects 65 or over.

Attardi says future study will be needed to ascertain the precise effects of the mutations and the relationship to the known characteristics of aging. In addition, the researchers would like to know how the original mutation "amplifies," or is established in thousands of other molecules.

Also, the precise mechanism of the mutations is not known at this time. And finally, the study was done only on skin cells, although Attardi says the effect may possibly be seen in other cells of the human body.

In addition to Attardi, the other authors are Yuichi Michikawa, a senior research fellow in biology at Caltech; and Franca Mazzucchelli, Nereo Bresolin, and Guglielmo Scarlato, all of the University of Milan. □ — *RT*

Overall, the researchers found that up to 50 percent of the mitochondrial DNA molecules had been mutated in subjects 65 or over.

HEART DRUG INHIBITS MELANOMA GROWTH

Professor of Biology Paul Patterson and researchers Ronit Lahav and Garrett Heffner have discovered that one type of drug used for human heart disease can inhibit the growth of skin cancer cells.

The drug, known as BQ788, is proving effective in suppressing skin cancer in mice, and drugs of this type could have potential for ovarian and prostate tumors as well. The Caltech team reports that the drug can stop melanoma tumor growth and even reduce tumors in some cases.

Further, the drug seems to be effective both as a direct treatment of the tumor and when injected systemically into the animal. The latter result is particularly promising as it has the potential for also suppressing metastasis, or the spread of tumors to other organs, says Patterson.

"If you went to the doctor with a tumor on the skin, he would take it out immediately," says Patterson. "So the first line of treatment is to surgically excise the tumor, and if it's a superficial tumor, you essentially have a complete cure.

"But the worry is when the

"We think this drug could turn out to be an effective way to stop cancer cells from spreading, or at least stop their growth if they have already spread."

tumor has penetrated more deeply and already metastasized," he says. "We think this drug could turn out to be an effective way to stop cancer cells from spreading, or at least stop their growth if they have already spread."

The strategy is based on the targeting of "growth factors," or proteins that cells use to stimulate their growth. The cancerous state represents a reversal of healthy, mature cells to a state similar to that of embryonic cells. In other words, cancerous cells tend to multiply rapidly, just as cells do in a developing embryo.

Lahav, the lead author on the paper, reasoned that melanoma cancer cells perhaps use a growth factor similar to that employed by their precursor cells in the embryo. She showed that such a growth factor, called endothelin, acts on the embryonic cells, and is also made by the cancer cells. By serendipity, the heart drug BQ788 is an antagonist for the endothelin receptor B. Thus, BQ788 is a substance that disrupts the receptor from performing its function in the cell.

Lahav found that this drug can stop human melanoma cell growth when introduced into cell cultures. In fact, the drug not only makes the cells stop dividing, but it can also kill such cells.

When the drug was given to mice with tumors, tumor growth slowed dramatically, and in some cases even regressed.

"It works whether you inject it into the tumor or into the body cavity," Patterson says. "In about half the mice, the tumors actually shrank."

Patterson says there is reason to think this type of drug could also work on certain other cancers (ovarian, prostate) where runaway cell growth may also be controlled by the same growth factor, endothelin.

Ronit Lahav is a postdoctoral scholar from Israel, and Garrett Heffner is a Caltech sophomore who participated in this research the summer after graduating from high school. □ —*RT*

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Log onto the new Web site @Caltech at http://atcaltech.caltech.edu for daily information about campus news and events. There's a campuswide calendar listing everything from public and academic events to student-club activities, and a Web theater will bring you broadcasts of campus events, such as President Clinton's recent speech. You can read articles from *Caltech News, On Campus,* and even *Engineering & Science*—if you'd rather read it on a screen than on paper.

WORM LOVE AND KIDNEY DISEASE

For a male nematode, the LOV-1 gene couldn't be more aptly named. The millimeter-long roundworm, if its LOV-1 gene is functioning properly, has the eagerness to mate and the instincts to perform successfully.

But if the LOV-1 gene is disabled, the male nematode is truly clueless. The fact that "LOV" is an acronym for "location of vulva" pretty much says it all.

While there is no such single gene controlling sexual interest and instinct in humans, Paul Sternberg, professor of biology and Howard Hughes Medical Institute investigator, and postdoc Maureen Barr, who recently identified the LOV-1 gene, say there is a similar human gene involved in a type of kidney disease. The LOV-1 gene has a sensory role in nematodes, but the human homolog (or counterpart) is PKD1, or polycystic kidney disease gene 1.

In other words, a male nematode that has this particular gene intact is able and willing to mate, while a human with the gene intact is disease-free. But if the genes are respectively knocked out, the nematode is sexually dysfunctional and the human is prone to autosomal dominant polycystic kidney disease, a serious disease that afflicts about one in 1,000 people and may ultimately result in renal failure.

"This is a surprise," says Sternberg. "We can only speculate on what the connection might be."

PKD1 and a second gene, PKD2, account for about 95 percent of all cases of autosomal dominant polycystic kidney disease. These genes cause the human body to produce polycystin 1 and polycystin 2, which are thought to work somehow in concert at the molecular level.

In an analogous manner, the LOV-1 gene also seems to work in concert with the PKD-2 gene, which in nematodes is the counterpart of the PKD2 gene in humans. The fact that the genes in both humans and nematodes seem to work in pairs actually strengthens the likelihood that there is some underlying molecular relationship, Sternberg says.

Much of the lab work leading to this discovery was done by Barr, who painstakingly watched in a microscope for male nematodes who were not successfully mating.

Barr then singled out the dysfunctional males and used standard genetic screening techniques and DNA sequencing analysis to identify the LOV-1 gene, which when mutated, is responsible for the lack of mating behavior.

While the researchers are not clear on why a gene involved in mating behavior in one species would be involved in disease in another, they say there could be a couple of possible explanations.

For one thing, the connection between the human gene and the worm gene might be very basic. Perhaps the gene is involved in setting up polarity of human kidney cells and polarity of worm neurons that govern sexual behavior.

In the case of the worm, the LOV-1 might actually act as part of a sensory signaling pathway responding to the presence of a mating partner by altering the electrical properties of the specific nerve cell that senses the mate.

Or perhaps the underlying relationship has to do with cell structure, Sternberg says. In this case, the LOV-1 protein might function as a molecular scaffold for other molecules, or promote the assembly of many molecules to create structures such as the sensory neuronal cilia.

Sternberg and Barr say the scientific goal of the study was to investigate ways in which genes influence behavior. But the findings could also serendipitously point to new avenues for research on autosomal dominant polycystic kidney disease.

"This is a mystery disease, so it could be that renal failure is just the first defect in a disease with broader manifestations," Sternberg says. In that case, improved knowledge at the molecular level could lead to different approaches in identifying treatments or even a cure.

"Here's a new way to study the basic mechanism," Sternberg says. ☐ —*RT*

Right: During the November 12 dedication ceremony of the Livingston, Louisiana, site of the Laser Interferometer Gravitational-Wave Observatory, Mark Coles (right), head of the Livingston observatory, explains what goes on in the laser/vacuum equipment area. Among the guests are Caltech President David Baltimore (next to Coles) and Rita Colwell (left, foreground), director of the National Science Foundation. The ceremony celebrated completion of construction. The two LIGO detectors (the other one is in Hanford, Washington) should be up and running together in 2001.

WATSON LECTURES - 2000

February 9: Sampling the Universe — *Edward Stone*, director of JPL, vice president, Morrisroe Professor of Physics

March 1: Caltech: An Entrepreneurial Leader — *Kenneth Pickar*, Johnson Visiting Professor of Mechanical Engineering

April 12: Acts of God, Acts of Man: How Humans Make Natural Hazards into Disasters — *Kerry Sieh*, professor of geology

May 3: Images of the Early Universe — *Andrew Lange*, professor of physics

May 17: A Different View of the DNA Double Helix: A Conduit for Charge Transport — *Jacqueline Barton*, Hanisch Memorial Professor and professor of chemistry

October 4: Combined Value Markets — *John Ledyard*, division chair, professor of economics and social sciences

October 18: The Evolution of Big Brains — *John Allman*, Hixon Professor of Psychobiology and professor of biology

November 1: The Keck Telescope at the Age of Five Years: The Early Childhood of a Scientific Giant — *Judith Cohen*, professor of astonomy

November 15: Memories of Caltech Past — *Judith Goodstein*, university archivist, registrar, faculty associate in history

Zewail, Caltech's Linus Pauling Professor of Chemical Physics and professor of physics, makes movies of molecular births, weddings, divorces, and deaths with what the citation calls the world's fastest camera… "But if it weren't for the ability to glue all of these molecules together with coherence, we'd never be able to synchronize their motion."

Coherent Thinking

by Douglas L. Smith

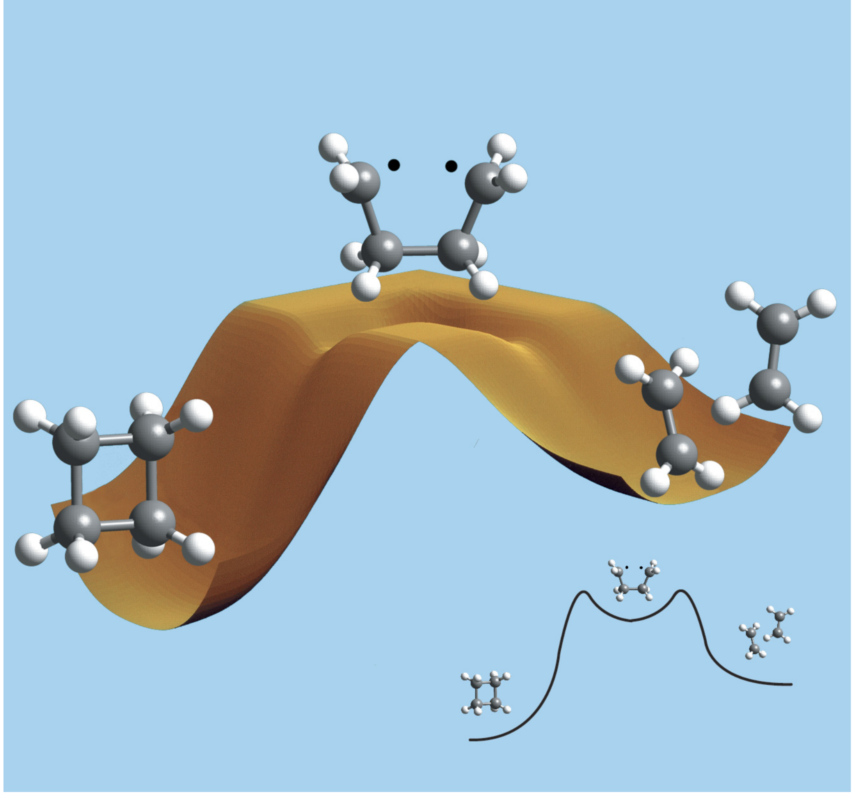
Ahmed Zewail, Caltech's latest Nobelist, has time on his mind as well as on his screen saver.

At 5:40 in the doggone morning on Tuesday, October 12, Ahmed Zewail got a phone call. But it wasn't a wrong number or a particularly ambitious aluminum-window salesman—it was the Royal Swedish Academy of Sciences informing him he had won the 1999 Nobel Prize in chemistry. The citation reads, in part, that Zewail "is being rewarded for his pioneering investigation of fundamental chemical reactions, using ultra-short laser flashes on the time scale on which the reactions actually occur. Professor Zewail's contributions have brought about a revolution in chemistry and adjacent sciences, since this type of investigation allows us to understand and predict important reactions." Or, as Zewail puts it, "Atoms and molecules have an enormously complex sociology, and for centuries chemists have been trying to understand why they sometimes like each other and sometimes hate each other. This love and hate is extremely important—it determines why substances can exist, and how they behave." And, like humans, the only way to find out how they behave is to watch them in action. So Zewail, Caltech's Linus Pauling Professor of Chemical Physics and professor of physics, makes movies of molecular births, weddings, divorces, and deaths with what the citation calls the world's fastest camera—one with a shutter speed measured in femtoseconds. A femtosecond is a millionth of a billionth of a second—10^{-15} seconds, or 0.000000000000001 seconds; a femtosecond is to a second as a second is to 32 million years. The citation continues, "The contribution for which Zewail is to receive the Nobel Prize means that we have reached the end of the road: no chemical reactions take place faster than this. With femtosecond spectroscopy we can for the first time observe in 'slow motion' what happens as the reaction barrier is crossed."

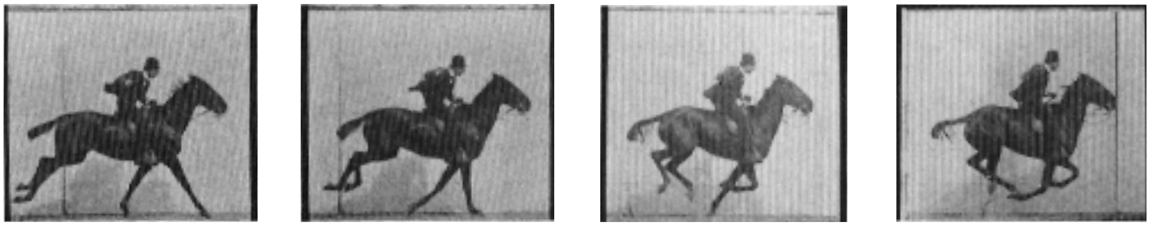
This reaction barrier is generally pictured as a mountain separating two valleys. In one valley, or state of minimum energy, lie the reactants; the products lie in the other. The reactants have to have enough energy to hike up the mountain before they can ski down the other side. These landscapes are called potential-energy surfaces, but unlike the latitude and longitude coordinates one uses to navigate cross-country, the axes of a potential-energy surface are the distances between the atoms involved in the reaction. When only two atoms are involved, the potential-energy surface becomes a curved line on a piece of paper: a two-dimensional plot of energy versus bond length. When one bond breaks and a different bond forms, the surface is three-dimensional, like a relief map, and as additional atoms get involved, the surface can occupy still more dimensions. And complex reactions may have several intermediate products in Alpine valleys scattered through a whole canton's worth of peaks and passes.

Each summit (in two dimensions) or saddleback (in three or more dimensions) in the potential-energy surface is what chemists call a transition state—that point when the molecule is betwixt and between, no longer reactants and not yet products, its bonds, like Richard III's physique, scarce half made up. The transition state is a razorback ridge, not a broad plateau, and molecules don't dally there. In fact, transition states are so fleeting that before Zewail's work they had never been observed directly, even though they had been postulated to exist since the 1930s. The best efforts to view them produced the spectroscopic equivalent of a blurry daguerreotype of a busy street.

In order to shoot bonds in sharp focus, you need a shutter speed faster than the fastest atomic motion. Explains Zewail, "A femtosecond is shorter than the period of any nuclear vibration or rotation in the molecule, so we are able to freeze the system in time. The atoms in the molecules inside you are vibrating at about a kilometer per second, and they're so tiny that we measure their relative positions in a unit called the angstrom,

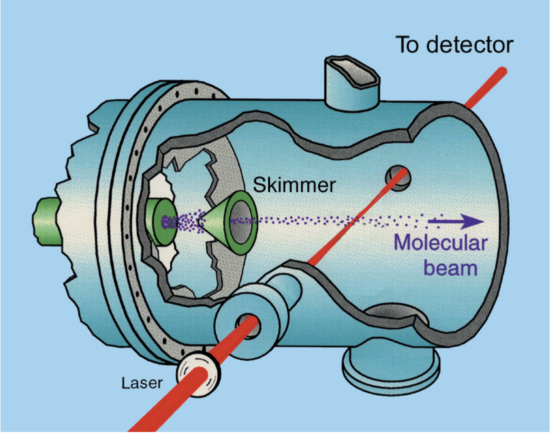


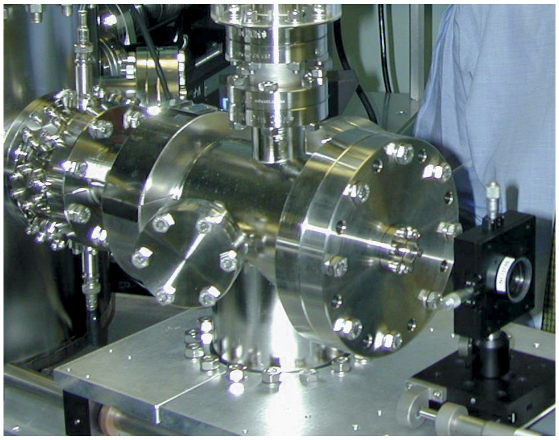
Above: The potential-energy surface for cyclobutane (the square molecule at left) splitting into two molecules of ethylene (right). The intermediate product (middle) lasts for a few hundred femtoseconds and is higher in energy because two of the carbon atoms each now have a highly reactive electron (black dot) that used to be half of a bond. The system follows the crease of minimum energy that runs along the center of the potential-energy surface—a crease that deepens ever so slightly under the intermediate, as shown in exaggerated form in the inset. Below: One hundred years, or 3,100,000,000,000,000,000,000,000 femtoseconds ago, Eadweard Muybridge developed a camera with a shutter speed of two-thousandths of a second, sufficient to freeze a horse in mid-stride. Muybridge had been hired by Leland Stanford, president of the Central Pacific Railroad, to settle a $25,000 bet that a galloping horse has all four legs off the ground at some point. That's about $450,000 in today's dollars—roughly the price of a femtosecond camera system.



which is 10^{-10} meters—one ten-billionth of a meter. A typical chemical bond is a few angstroms long. If you combine these numbers, you see it takes about 100 femtoseconds for an atom to move an angstrom. So we have to be substantially faster than that to catch them in the act." And then there's the daunting task of getting all the molecules in step. When Eadweard Muybridge took his groundbreaking stop-motion photos of a galloping horse in 1887, one horse was ridden past a row of a dozen cameras. But each of Zewail's photographs contains millions of molecules, as if Muybridge had run a whole herd of horses in lock step past one camera. Even when they are undergoing the same reaction, molecules don't run in lock step, so how do you synchronize their gaits?

That's where matters stood when Zewail arrived at Caltech in 1976 as a brand-new, untenured professor. Born near Alexandria, Egypt, he had graduated from Alexandria University in 1967 with a degree in chemistry and first-class honors. He earned his PhD at the University of Pennsylvania in 1974, where he specialized in solid-state spectroscopy and nuclear magnetic resonance, and had continued in this vein during a two-year stint as a postdoc at UC Berkeley. Lasers were pretty hot stuff back then, so he "proposed for my assistant professorship to apply some of the concepts I had learned from my other fields into lasers, and use them to probe molecules at the fundamental level." The initial experiments, done with grad students Tom Orlowski (MS '76, PhD '79) and





Above: A look inside a molecular beam's vacuum chamber. The carrier gas shoots out of a pinhole in the end of the green pipe at left, and immediately expands in all directions. After traveling a couple of centimeters, the gas cloud hits a skimmer, which is essentially a funnel with a pinhole at its point that shoves aside all the straying molecules. The molecules that survive the skimmer have very little sideways velocity, so when the molecular and laser beams cross in another few tens of centimeters, all the molecules are on essentially parallel paths. Above, right: The hardware.

Dan Dawson (MS '78) and undergrad Kevin Jones (BS '77), proved that short laser pulses (and in those days, short laser pulses were measured in nanoseconds, or billionths of a second—an eternity in his lab today!) could excite simple or even complex molecules into so-called coherent states, and that such coherence could be detected during their spontaneous decay. In other words, even though each individual molecule in the sample was zipping around on its own course, banging into its fellows and tumbling like an X-wing fighter that's taken a hit, there were some spectroscopic phenomena in which a huge percentage of them acted together. If shot with a sufficiently brief laser pulse, they would shed the excess energy in a coordinated fashion. The chemistry faculty was sufficiently impressed to give Zewail tenure in less than two years—an ultrafast reaction in its own right.

"After doing that," Zewail recounts, "I was interested to see whether we could look, not at perturbations between molecules, which is what we had done with these experiments, but at what coherence goes on *inside* complex molecules. Why not try to isolate these molecules from the rest of the world by doing what's called molecular beams? So we built our first molecular beam in '79." A molecular beam is just what its name implies—a beam of molecules enclosed in a vacuum chamber that looks like a capped-off segment of stainless steel sewer pipe. You vaporize your sample and suck it up into a stream of an inert "carrier" gas such as argon, and squirt the gas through a pinhole into the vacuum chamber at right angles to the laser's path. The carrier gas dilutes the sample so that, although the laser is exciting millions of molecules at a time, the molecules don't collide with one another. The gas also expands when it enters the vacuum, accelerating the molecules to supersonic speeds, and, paradoxically, cooling them. An isolated molecule has a fixed kinetic-energy budget, so the extra energy invested in speed has to come from the molecule's rotational- and vibrational-energy accounts. The energy overdraft protection plan kicks in automatically, leaving the fast-flying molecules flat broke and plunging their temperatures to within a few tens of degrees of absolute zero. This is a vital first step to establishing coherence, because the bankrupt molecules can afford to live in only the lowest-energy rotational and vibrational states, imposing a significant degree of order on them already.

"I knew *nothing* about this technology," Zewail confesses. "But I had two *wonderful* students, Bill Lambert [PhD '83] and Peter Felker [PhD '85], who were willing to take on this new vision. They really started from scratch." Molecular-beam technology is pretty standard nowadays, but back then trying to meld a molecular beam and an ultrafast laser into a workable apparatus posed huge technical challenges. But though the Techers were molecular-beam neophytes, Lambert explains, they had "a significant advantage in having a close relationship with Spectra Physics [the leading manufacturer of high-speed lasers], which provided equipment in the initial stages of production and development to our group at a substantial discount. This enabled us to perform experiments everyone in the field wanted to perform before anyone else reasonably could."

This experiment called for a large but well-chosen molecule, says Zewail. "We chose anthracene as our molecular guinea pig because its

spectroscopy gave us a hint that energy redistribution might be happening in the molecule. Also, the frequencies of all its vibrational modes were well known." A laser pulse tuned to one of those frequencies excited the molecules into that vibrational mode. Then the researchers counted the picoseconds—we're down to trillionths of a second, now—until the molecule got rid of that extra energy by fluorescing. Anthracene is a big, flat molecule consisting of three hexagons fused edge-to-edge, so there are hundreds of ways it can vibrate. For example, if you picture it as a bat in flight, it could stretch out its wingtips, or flap them, or scull them forward and backward, or curl the edges up and down, and it can do all these things with the wings either alternating or coordinating their motions. And then there's the body, which can move, too. These states require roughly the same energy, so, says Zewail, "if, on a short time scale, we deposited energy into a big molecule isolated from the rest of the world, could we see how the energy will go around within the molecule? This was a hot area—lots of conjectures, inferences, and claims."

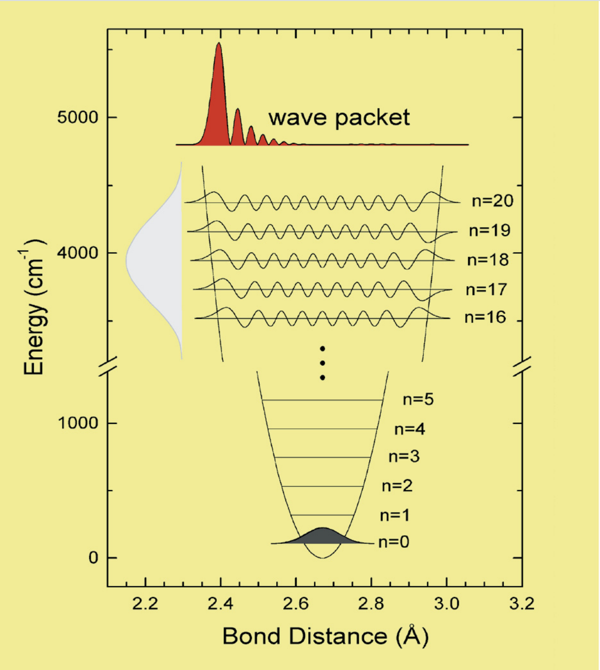
Everyone expected to watch the fluorescence decay smoothly as the energy leaked away, with each molecule dumping its energy into a randomly chosen state—a little here, a little there, but not a whole awful lot to any one state. And that's exactly what happened, except that suddenly, some picoseconds later, the fluorescence came back! It spiked and then disappeared again… and again… and again… as many as nine times. Says Zewail, "Everybody knows we are born, we die, and that's it. But if all of a sudden somebody is coming back from the dead, reincarnated like Shirley MacLaine says, it would be an incredible result. And, of course, some people would be skeptical."

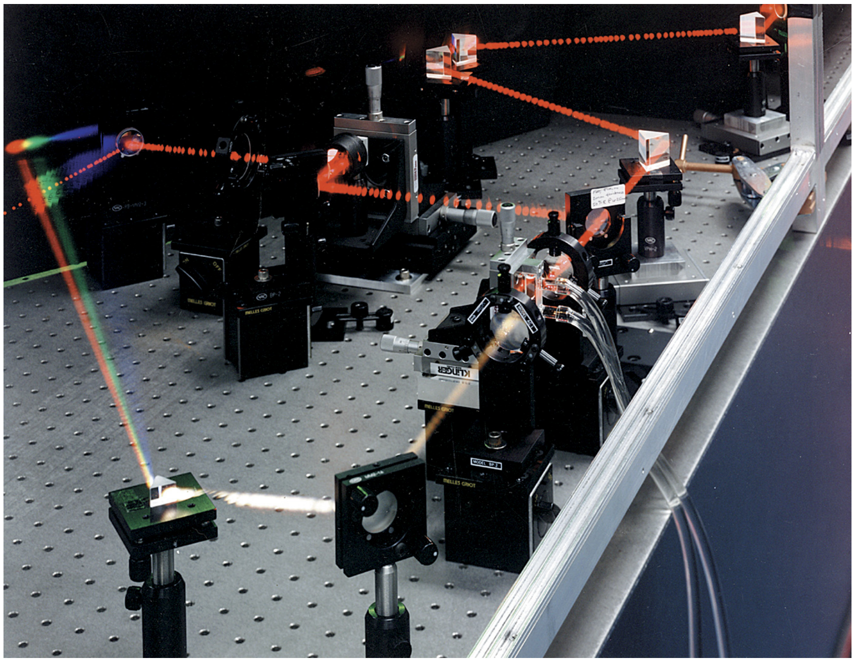
"I was in Paris or somewhere to give a talk, and I called Peter and Bill in the lab, and I said, 'What's new? How's the experiment going?' because we had been trying really hard to get this experiment to work, and they told me, 'Well, we're seeing something that's really *something*. It's not decaying—it's *oscillating*.' And this was incredible. This was indeed the door-opening observation." What this meant was that all the energy was moving into just one other state, and from there back to the original state. Such oscillations were known in atoms and small molecules with a handful of states, but unexpected in large molecules with a profusion of states. Proving it meant finding the other state into which the energy was going. Sure enough, when the other frequency was found, it was dark at first, but picoseconds later it lit briefly, faded, then returned. Comparing the signals verified that one rose as the other fell. It's like that toy with the two magnetic propellers—you set one spinning, and the magnets in its propeller tips tug on the magnets in the other one's tips. The second one starts twitching as the rotational energy trickles

In the quantum world, waves can be particles and particles—even molecules!—can be waves as the occasion demands or the whim takes them. The wave's amplitude at any point is a measure of the likelihood of finding the molecule there. Each vibrational state has a different wave function (here labeled n = 0 to 20) that reflects the probability of finding the molecule in that state at that location; in this example of a two-atom molecule, it's the probability of finding the two atoms separated by a given bond distance. Each state's probability wave extends from wall to wall of the potential-energy surface (the parabola), meaning that, in the case of state 20, there are 21 bond distances one would expect to see—count the crests and troughs (yes, the troughs matter, too; they have a nonzero amplitude). So any quantum mechanic could tell you that a photo of the molecule in that state would be blurry, because the atom would show up equally at all 21 of those bond lengths—it would be naive to expect the atom to be a ball on a spring that moves through one bond distance at a time as it bounces back and forth between the walls. But if you want to make a movie of a bond breaking, a ball on a spring is exactly what you need to be able to see.

The sum of all these wave functions is the overall probability wave for the molecule in all of its states. Normally, the component waves are out of step, but when they're coherent, they interfere with each other. Where crest matches crest or trough matches trough, you get a big amplitude; where crest matches trough, you get zip. It's like striking two adjacent keys on a piano—the sound comes and goes in "beats" as the waves alternately add to and cancel each other. (These oscillations, known as quantum beats, are what Lambert and Felker were seeing.) When all the molecules are coherently excited into just a few states, as shown by the gray bell curve, something truly remarkable happens—the sum of these states, called a wave packet, is now "localized." It has a nonzero amplitude in only a very small region, and the molecules—all of them—have to be there. And if you watch this wave packet over time, you'll see it travel back and forth from wall to wall, just like that ball on a spring that quantum mechanics says you can't see! (This would do you no good if each molecule's wave packet had begun moving at a slightly different time, as you'd *still* get a blur. But the laser pulse synchronizes all the molecules, lining up their toes in the blocks and firing the starter's pistol.)

The same story holds true for the molecule's rotational states.





Above: Femtosecond laser pulses on parade.

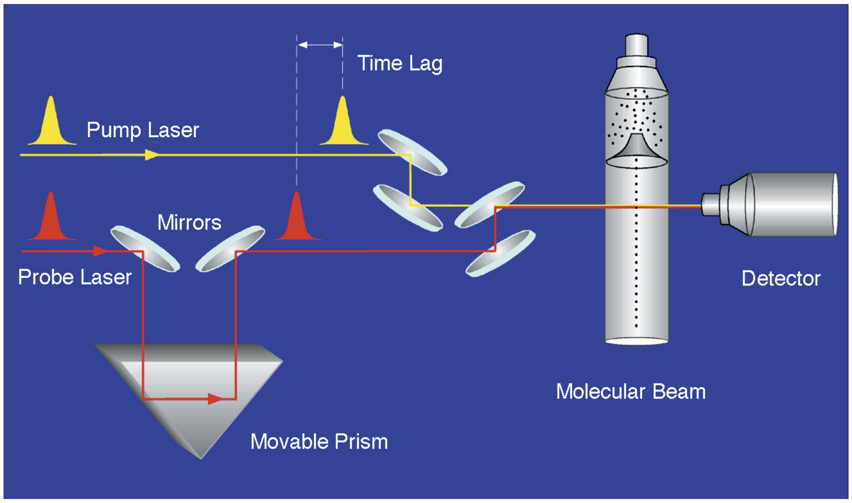
over, and soon both are spinning, until all the energy has been sucked out of the first one and it stops. But not for long—as the second propeller's tips tug on it, the energy starts to slosh back. (A somewhat more rigorous description of molecular coherence is given in the box on the previous page.) Zewail explains, "We saw a coherent cycle, with energy going back and forth between a very select number of vibrations. And even though we had a million molecules, we were observing their behavior as if they were one molecule because we were using such short pulses." So all the molecules would choose to, say, flap their wings, then curl their wingtips up, and then flap them again—a regular chorus line of molecular bats!

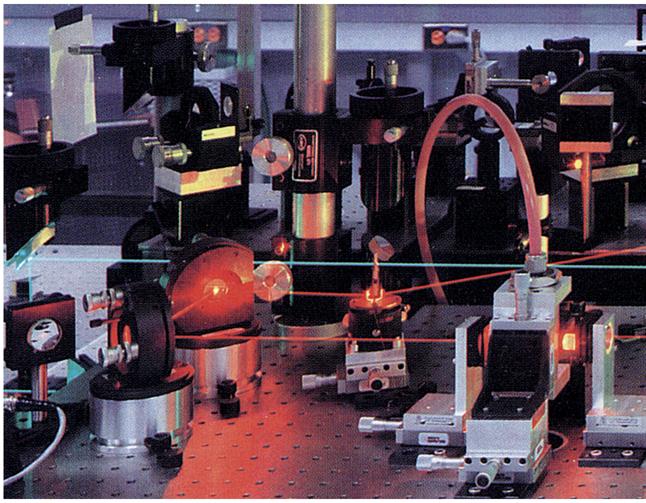
> "Everybody knows we are born, we die, and that's it. But if all of a sudden somebody is coming back from the dead, reincarnated like Shirley MacLaine says, it would be an incredible result. And, of course, some people would be skeptical."

Nobody knew it then, but this demonstration of intramolecular coherence was the key to making femtochemical movies. It implied that, under the right conditions, a horde of complex molecules could march in lockstep from a common starting point for a considerable length of time. Thus, a snapshot of any one of those molecules represented them all, and a series of pictures of different molecules taken at different times, when arranged in order, truly was equivalent to a time-lapse movie of a single Joe Average molecule. The inverse-Muybridge problem of synchronizing the gaits of a herd of horses running past a single camera had been solved.

"So then," Zewail continues, "we said, well, if we can see the vibration, would it be possible to observe the molecule's rotational motion in real time? I had another brilliant experimentalist by the name of [John] Spencer Baskin [PhD '90], who is now a senior research fellow in my lab. And, in 1986, Spencer and Peter published the first experimental observations of coherent rotational phenomena in isolated molecules, using a molecule called stilbene." When the molecules go supersonic and lose their excess rotational energy, they don't all wind up in the same state. Some will be tumbling end-over-end; some will be rolling around their long axis, like a barrel going down a hillside; some will be spinning like tops. Most will be doing all three of these things, but at different speeds, and, of course, no two of them will be in step. When you hit them with the laser, it punts them into an excited state where they will fluoresce, but it doesn't change the way they're rotating—that is, if they're tumbling it won't set them spinning, nor will it make them tumble faster. But if the laser is vertically polarized, it will only excite molecules that happen to be vertically aligned at the moment the laser is fired. The molecules rotate out of alignment immediately, of course, and an ordinary fluorescence spectrum is featureless. But slap a vertically polarized filter on the detector, and behold! oscillations. "Every time the faster-rotating molecules caught up with the slower ones, they all came back into phase, and we saw a peak," Baskin explains. "The peak could go up to almost its original height, and the coherence was maintained for nanoseconds." Repeating the experiment with horizontal polarization gave the same result, only 90 degrees out of phase. And with the establishment of rotational coherence on top of vibrational coherence, the creation of a composite molecule was complete. "I was so thrilled, so excited," Zewail recalls. "When we started this work, most people did not appreciate the importance of molecular coherence. The chemists thought it was just physics, and some even suggested that I should be doing chemistry! But if it weren't for the ability to glue all of these molecules together with coherence, we'd never be able to synchronize their motions—one guy would want to start earlier, one later, and so forth. So it immediately became clear that we had to push the time scale further."

Fortunately, lasers were getting faster too—Spectra Physics had just developed a pulse compressor that would deliver a 400-femtosecond burst. But the pulses were getting so truncated that they didn't have many photons in them, so every last one was precious. A couple of decent dust motes could scatter the beam, which was





Above: The pump-probe concept. The pump pulse takes a more direct route to the detector, while the probe pulse takes a roundabout path and arrives later. Moving the prism toward or away from the mirrors adjusts the lag time.

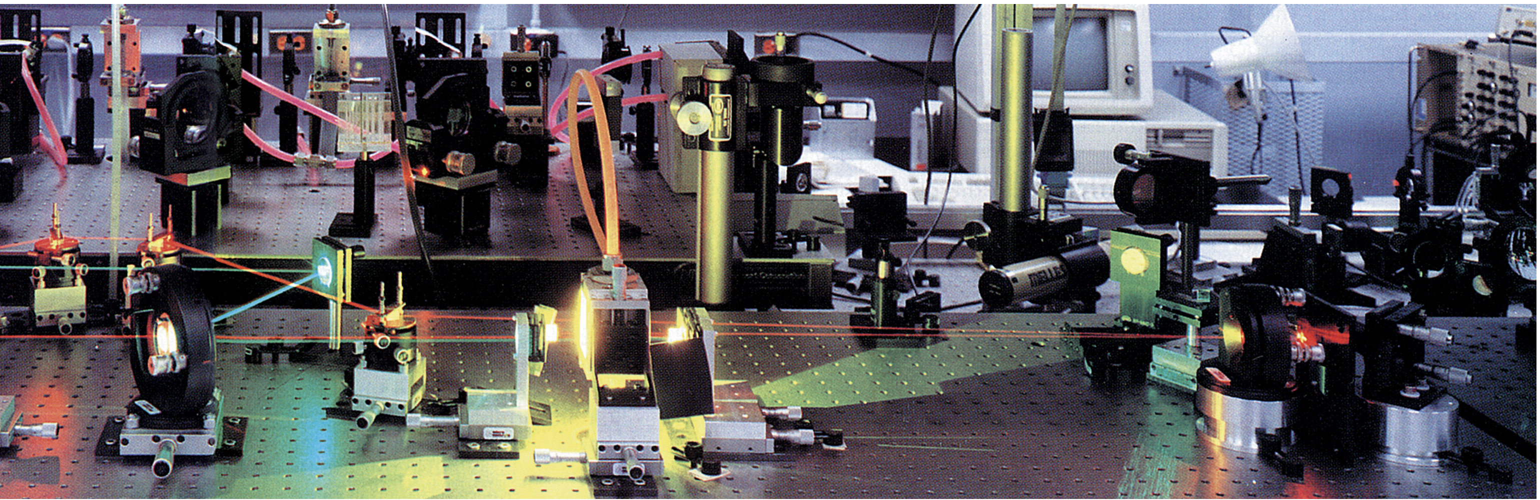
Above, right: The reality, of course, is somewhat more complex—and this is only a portion of the optical apparatus.

about the diameter of paper-clip wire. And an air current—from something as innocuous as a grad student crossing the room to turn off the lights—could cause the laser to twinkle like a distant star. So sliding plastic panels, not unlike patio doors, were hung around the optics, and anyone entering the lab has to don stylish blue paper booties before crossing the threshold, while the lab is further protected from dust by sticky white plastic welcome mats—flypaper for your feet.

The lasers had also outpaced the electronics—before a time signal could travel by wire to the detector, the experiment would be over. So while Baskin and Felker were nailing down coherence, postdoc Joe Knee and grad student Norbert Scherer (PhD ’89) were pushing forward with another technique the lab had been developing that harked back to Zewail’s early nuclear magnetic resonance training. NMR uses one radio pulse to put a molecule into a desired state and then a second one (sometimes more) to monitor the response. The new method used two laser pulses, or, rather, one pulse split in two by shining it through a partially silvered mirror. The first part, called the pump pulse, started the clock: it triggered the reaction by twanging the molecule at the frequency of the bond to be broken, pumping it to bursting. The second part, called the probe pulse, was tuned to the frequency of the bond to be observed and was detoured through a forest of lenses and prisms to arrive a predetermined number of femtoseconds later, photographing the reaction in progress. Says Zewail, “The beautiful thing is that the speed of light is so huge —3×10^8 meters per second—that if we move a distance of one micron [a millionth of a meter], we can create a delay of 3.3 femtoseconds.”

In most places, time is money, but in the Zewail lab, time became distance. An experiment started by adjusting the second path until both pulses arrived at the sample simultaneously (in other words, making the paths exactly equal in length), setting time-zero very accurately and recording the molecules’ initial configuration. Then, a precision-driven worm gear eased a mirrored prism just a skosh farther away on the second path. Thirty microns equals 100 femtoseconds, which was about the resolution of that first experiment, done in 1985. This wasn’t yet fast enough to salami-slice the transition state, but sufficed for watching the product appear. For cyanogen iodide (ICN) breaking into an iodine atom (I) and a cyanide radical (CN), the very first snapshot revealed significant cyanide buildup, and the show was over in six frames. (As a side note, Spectra Physics’ first 400-femtosecond pulse compressor was actually delivered to former Zewail grad student Duane Smith (PhD ’81), who was by then a professor at Purdue University. The company told Zewail it would take months to build another one, so he got on the phone with his protégé and talked such an exciting game that Smith loaned him the compressor and came out to Pasadena for two weeks to join the fun.)

How fine you can slice time also depends on how narrow you can make your pulse. By 1987, the next-generation compressor could deliver 50-femtosecond pulses. The way the math works, you can see time differences of about one-fifth the pulse width, making 10-femtosecond resolution a reality. The race against time was over, and the experimentalists had won. (The subbasement room in which the apparatus lives, 047 Noyes, housed Linus Pauling’s X-ray diffraction lab in the late ’60s—a coincidence that Zewail, who holds the Pauling Professorship, finds satisfying.) Grad student Marcos Dantus (PhD ’91) and postdoc Mark Rosker (BS ’81—he went to Cornell for his PhD, but just couldn’t stay away) went back to the ICN dissociation reaction, snapping away at 10-femtosecond intervals, fast enough to record a dozen or so frames of the I—C bond breaking, little by little: the first time such a thing had ever been witnessed in real time. “Those



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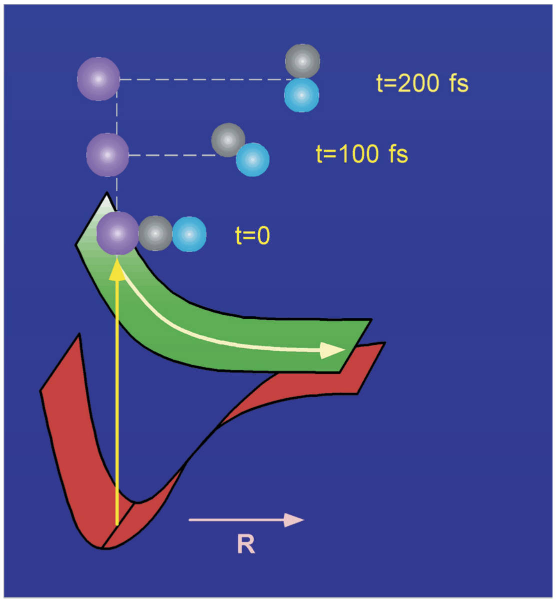
were thrilling moments," Zewail recalls fondly. "Marcos threw himself into everything he did, no matter what it took. And Mark was a gifted experimentalist who brought the Techer tradition back to our lab." And again, the faculty took notice—upon graduation, Dantus won the Clauser Prize, which is awarded annually "to the PhD candidate whose research is judged to exhibit the greatest degree of originality as evidenced by its potential for opening up new avenues of human thought and endeavor as well as by the ingenuity with which it has been carried out."

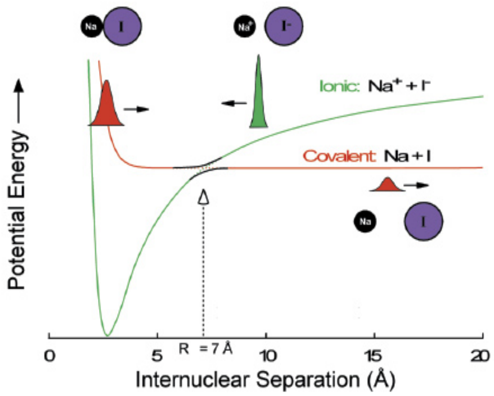
These slow-motion movies are composite pictures in more ways than one. The exact frequency that a bond absorbs depends (among other things) on the distance between the atoms. So you set the probe laser to a frequency that corresponds to some distance, and then march through a complete set of, say, 150 delay times to see when that particular bond distance shows up. Then you reset the probe to a slightly different frequency and do it all again. Once you compile all the appearance and disappearance times for all the bond lengths into a single data set, you can see the bond stretch till it snaps. And snap it does—ICN falls apart in a mere 200 femtoseconds. (See *E&S*, Spring 1988.) There's an additional subtlety to the ICN experiment: the frequency a bond absorbs also depends on the mass hanging from each end of the bond, so Dantus and Rosker tuned in on the free CN fragment, whose spectroscopy is a well-read book. The iodine atom's mass drags the CN vibration to a slightly lower frequency, which rises to the free fragment's frequency as the iodine atom loses its grip.

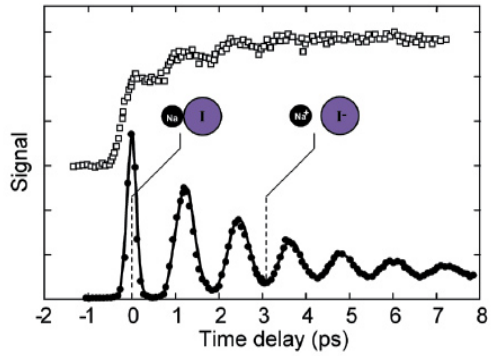


Left: The ICN breakup reaction's potential-energy surface (red) bottoms out at the normal I—C bond distance. The pump laser kicks the molecule onto a higher-energy surface (green), down which it slides as it breaks up.

Not every dissociation is so fast. Postdoc Todd Rose and Rosker next assaulted molecules of sodium iodide, a simple molecule that Zewail calls "the drosophila of our field." Sodium iodide, an experimental system that was a favorite of Pauling's, exists in ionic form when left unmolested. When neutral sodium and iodine atoms approach one another to within 6.9 angstroms, the greedy iodine steals an electron from the sodium and becomes negatively charged, leaving the sodium ion with a positive charge. The two ions cling together electrostatically in a deep, steep energy valley at a bond length of 2.8 angstroms. But it's also possible for the two atoms to share the electron in what chemists call a covalent bond, whose potential-energy surface lies at a higher elevation and has only one sidewall, like a ledge on the mountain's face. At distances of greater than 6.9 angstroms, the covalent potential-energy surface is actually lower in energy. In other words, the ionic and covalent potential-energy surfaces—parallel universes, if you will, that occupy the same space—intersect at that distance. And, as any viewer of any incarnation of *Star Trek* will tell you, where parallel universes cross, there's a portal from one to the other. In other words, the *real* potential-energy surface—the solid ground on

As any viewer of any incarnation of *Star Trek* will tell you, where parallel universes cross, there's a portal from one to the other. In other words, the *real* potential-energy surface—the solid ground on which the system hikes—is ionic at short range and covalent farther out.





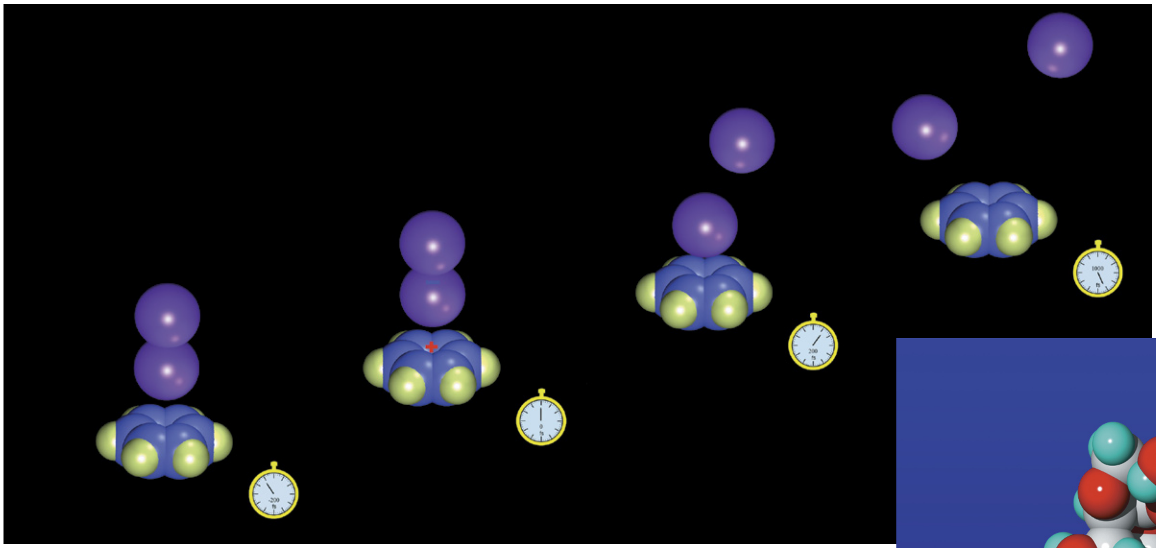
Above: Sodium iodide's ionic potential-energy surface (green) and covalent potential-energy surface (red) intersect, forming low- and high-energy surfaces. The pump laser excites the system onto the high-energy surface and kicks the atoms apart. With every outbound crossing, the excited wave packet risks missing its turn and remaining covalent, in which case the two atoms will fly apart. Right: The pump laser blasts a fair number of atoms apart at time zero, as the data plotted in open squares shows, and their number increases with each cycle. The solid circles are the number of covalently bound molecules whose bond length is 2.8 angstroms.

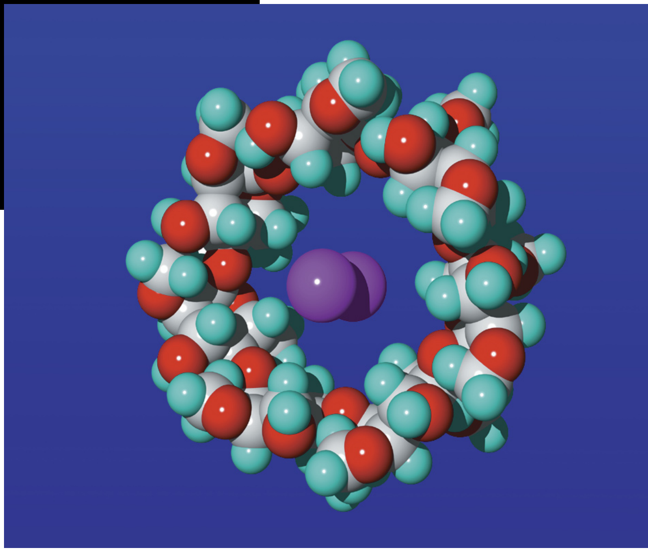
which the system hikes—is ionic at short range and covalent farther out. The pump laser punts the bond onto the unused, high-energy portions—covalent close up and ionic afar—that float above the low-energy landscape where the system normally lives. The laser also sets the atoms flying away from each other, and as they pass the magic 6.9 angstrom mark, the iodine snatches the electron, reverting to ionic form. As anyone who has ever pulled polyester socks out of the dryer knows, charges don't like to be separated, and the femtoscale version of static cling starts pulling the atoms back inward. They whoosh together again, and at 6.9 angstroms the iodine coughs up the electron. Says Zewail, "For the first time, we could see a chemical bond transforming in real time from covalent to ionic, covalent, ionic, covalent, ionic, covalent, ionic, covalent, ionic—in this case, by the way, they were in love for about nine or ten cycles before they divorced each other at the end." With each cycle comes a chance that the outbound system would stay on the covalent potential-energy surface beyond the crossover point, in which case the two electrically neutral atoms would part company forever. The sodium-iodide marriage took about 8 picoseconds to fall apart—a long-term commitment on the atomic scale, if not the human one.

Meanwhile, across the hall, Scherer, grad student Lutfur Khundkar (PhD '88), and the late Richard Bernstein of UCLA were shooting an even tougher assignment: an atom of hydrogen and a molecule of carbon dioxide going to a hydroxyl radical and a carbon dioxide molecule ($H + CO_2 \rightarrow OH + CO$). (Bernstein was a longtime collaborator of Zewail's and a familiar face at Caltech, having once been a Sherman Fairchild Scholar. His important contributions to femtochemistry were cut short by his untimely death in 1990.) Watching a molecule fall apart is all well and good, and a lot of important chemistry happens that way. But how do you bang two molecules together so that they will react? Most collisions are fruitless—the atoms just ricochet off each other. To react, they need to be in just the right orientation, and have to hit each other hard enough to stick. And how do you start the clock consistently with each fresh pair of molecules? Unlike Muybridge's camera, there are no trip wires for the inbound molecules to cross. Fortunately, as Curt Wittig showed at USC, if you shoot a mixture of carbon dioxide and hydrogen iodide (HI) into the vacuum chamber, when the two gases go supersonic and lose energy, some of the molecules will pair up into loosely bound clusters that put the atoms in the proper relative positions at a fixed separation, ready to be zapped with the pump laser.

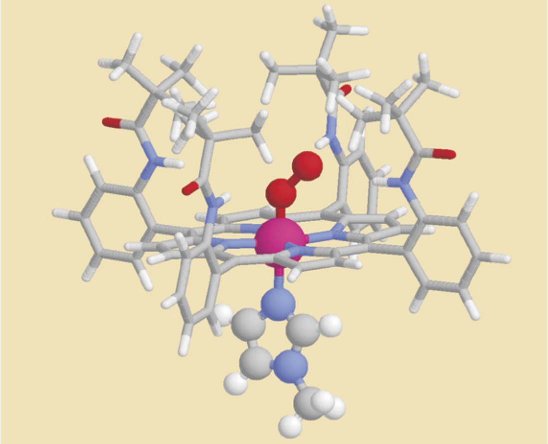
Now that one bond (in this case, the H—O) is forming while another (C—O) is breaking, we get into questions of sequence and timing. Do both happen at once? Are there intermediate products? The researchers discovered that once the H had collided with the O, the atoms clung together for a few picoseconds as they climbed the energy mountain leading to the H—O bond. Then the intermediate HOCO hung around, quivering like a Jell-O mold, for another picosecond or so as the excess collisional energy worked its way into the C—O bond in order to blow it apart. The exact timing could then be compared to the detailed quantum-mechanical predictions numerous researchers were making from first principles—a rigorous test of the theory.

Femtochemistry took off in the 1990s. Zewail's group immediately moved to the next level of complexity—organic chemistry, the chemistry of carbon atoms and therefore of life. The group started with simple organic molecules—the cyclo-





Some of the worlds of femtochemistry. Organic, above: When you hit a benzene-iodine complex with the pump laser, an electron jumps from the benzene molecule (+) to the iodine molecule (-). The iodine molecule promptly falls apart, even if the electron has already leapt back to the benzene. Supramolecular, right: This Christmas wreath—the holly berries are oxygen atoms—is a nanocavity made of sugar molecules in which an iodine molecule nestles all snug, and in which reactions can be catalyzed. Electro, lower right: A simple stand-in for hemoglobin, a big, complex protein that carries oxygen in your blood. This version is used to study how oxygen binds, which is also relevant for generating electricity in fuel cells. Theoretical, below: Pyridine's six-membered ring can crumple in many ways that can be predicted by quantum mechanics and tested and observed by femtochemists. The excited wave packet can follow the green arrow into a box canyon and shed its excess energy by fluorescence, or it can fall through the conical intersection back to the lower potential-energy surface and follow any number of reaction routes, two of which are shown by the red and yellow arrows.



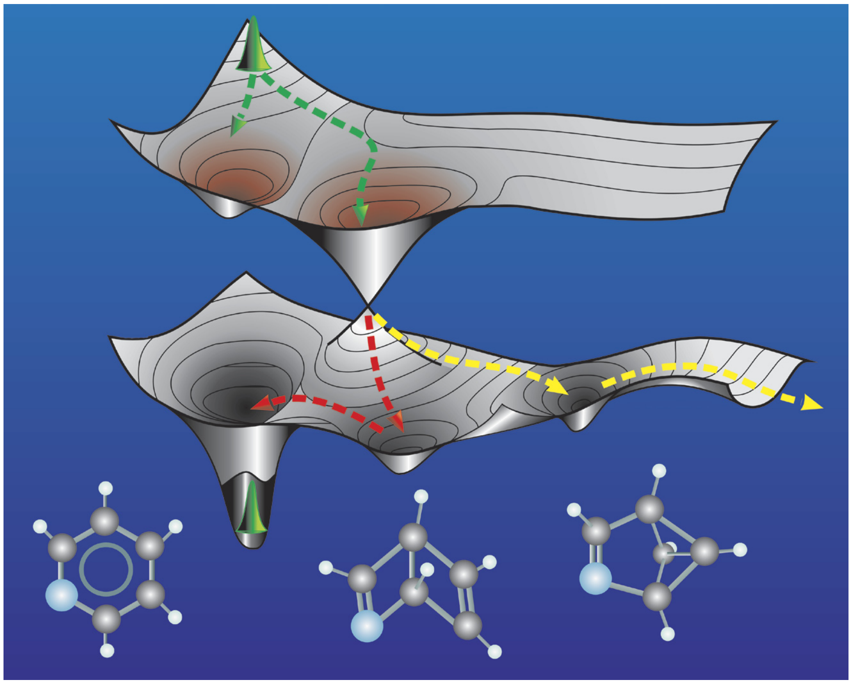


Illustration credits, clockwise from top: Dongping Zhong, Mirianas Chachisvilis, Spencer Baskin, Dongping Zhong.

Zewail takes great pride that his entire professorial life has been spent here, so the prize is truly a Caltech one.... He takes even greater pride in being at the same institution where his hero, Linus Pauling (PhD '25), did his own Nobel Prize–winning work on the nature of the chemical bond.

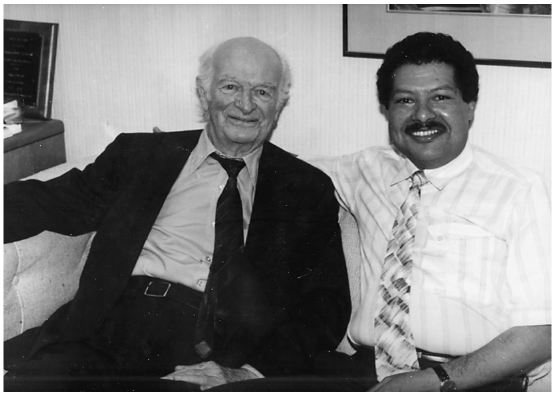
butane reaction pictured earlier—and soon worked their way all the way up to DNA. (Jacqueline Barton, the Hanisch Memorial Professor and professor of chemistry, and Zewail are watching electrons fly down a DNA strand. DNA is a potentially good conductor of electricity, and this attribute may be important biologically.)

And the Zewail lab continues its tradition of figuring out how to apply instrumental methods from other fields, bringing in such techniques as mass spectrometry. Organic molecules are complex enough that a reaction starting with a given molecule will often proceed by several routes at once, giving you a family of similar looking products that absorb and emit similar frequencies of light. But mass spec, as it's called, separates molecular fragments by their mass-to-charge ratio, allowing you to discriminate between two variants that differ by as little as one hydrogen atom. A fancier version measures the arrival time, energy, and spatial orientation of each piece—vital clues for reconstructing the molecule's history. Dongping Zhong (PhD '99), who also won the Clauser Prize upon graduation and is staying on as a postdoc, developed these applications.

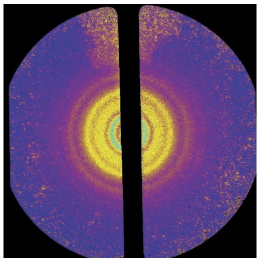
Chemical theory comes in for its fair share of scrutiny as well, because femtochemists can make very stringent tests of theoretical predictions by using one of those complex molecules that can follow many reaction paths, and comparing what actually happens to what the theory says should occur. Says Zewail, "In the world of complex reactions, the initial efforts of Jennifer Herek [PhD '96], Soren Pederson [MS '94, PhD '96], and postdoc Luis Bañares, culminating in the work of postdoc Eric Diau, have taken the work to a whole new level."

There are now six Femtolands, as Zewail's laboratories are affectionately called, in which, over the years, a gross of grad students, undergrads, and postdocs have studied a hundred or so reactions from all branches of chemistry. And the outside world followed right behind. As the Nobel citation said, "Scientists the world over are studying processes with femtosecond spectroscopy in gases, in fluids and in solids, on surfaces and in polymers. Applications range from how catalysts function and how molecular electronic components must be designed, to the most delicate mechanisms in life processes and how the medicines of the future should be produced." Following the announcement of the Nobel Prize, the Institute for Scientific Information, which uses how often a researcher's papers are cited in their peer's publications as a proxy for how influential the cited work is, announced that femtochemistry had been footnoted 50,000 times since its birth.

One of the projects the Nobel committee singled out had to do with stilbene, which has two benzene rings at opposite ends of a double bond. Double bonds don't spin freely, so the rings are locked into position—if you think of your shoulders as being the double bond and a tennis racquet in each hand as the benzene rings, you can hold both racquets up (what chemists call the *cis* configuration), or hold one up and one down (the *trans* configuration). However, zinging the right laser pulse at the bond unlocks it and flips the rings. Pederson and Bañares were studying *cis*-stilbene in 1992, and found that not only do the shoulders move, but the wrists turn at the same time, and the entire process is coherently complete in 300 femtoseconds. Work at UC Berkeley by Richard Mathies and Charles Shank on biological molecules with a similar double-bonded structure showed that retinal, a light-sensitive pigment in the eye, undergoes a similar reaction with 70 percent efficiency in 200 femtoseconds as the first step in transforming a photon of light into a nerve impulse. The fact that the reaction happens so quickly and so efficiently (a vital attribute for good night vision!) indicates that the incoming light goes straight to the double bond rather than being spread throughout the molecule—a theme that runs straight back to those early coherence experiments. It's identical in concept to sodium



Above: Professor Linus Pauling and the Linus Pauling Professor.



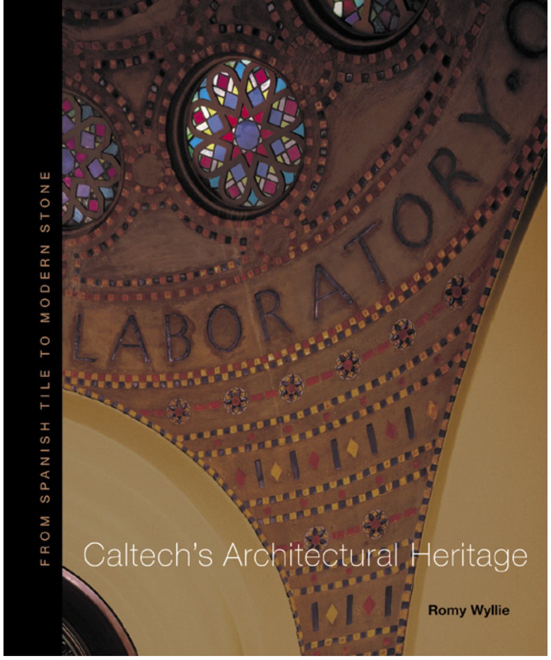
Below: A picosecond electron diffraction image. When the electron beam hits the atoms in a molecule, the electrons scatter in all directions. The bullseye pattern shows the electron density at different angles, from which you can back-calculate where the atoms must have been to produce that distribution.

iodide—the wave packet that represents the twisting motion of the double bond is going back and forth between two states. Other researchers tell the same story about photosynthesis, the process by which plants harvest energy from sunlight. And there's even talk about using lasers to steer chemical reactions—for example, coaxing a drug precursor to fall apart in just the right way to give a 100 percent yield of the drug. Laser-selective chemistry has become a hot field in many labs, and Zewail, who anticipated the field in a paper written in 1980, expects to see substantial progress within a decade or so.

But Zewail has his eye on The Next Big Thing: "Can we actually take a direct structural image of a molecule as it undergoes these transitions, using femtosecond electron diffraction? Once we break a bond here or a bond there, how does the architecture of this molecule change with time? This is a dream I have shared with some members of my group since 1991, and it has become a major effort lately. Just this year, postdoc Jianming Cao and grad student Hyotcherl Ihee showed for the first time that we can actually see the chemical structure of the entire molecule in a simple model system on a picosecond time scale, and postdocs Boyd Gibson and Vladimir Lobastov and grad student Ramesh Srinivasan are also involved in developing the methods and apparatus." Spectroscopic techniques focus on one bond at a time, and even the most patient grad student would balk at the prospect of looking at every blessed bond between the several thousand atoms of your average small protein. But a diffraction pattern, in principle, gives you the three-dimensional location of all the atoms in the molecule, regardless of its size, and it gives them to you all at once—a true snapshot! The setup uses the usual femtosecond pump laser to start the clock. However, the probe, after going down its variable-length path, is focused on a photocathode, which emits electrons when hit by light. This adds a mutually perpendicular electron beam to the intersection of the pump beam and the molecular beam. "Just like a chest X ray," Zewail says. "When we look at a molecule's diffraction pattern we can 'see' the structure. Our ultimate goal is to see how the atoms move as they perform a biological function. You can imagine watching a protein, for example, moving around as it catalyzes a reaction, or as it recognizes and binds to an antibody. With diffraction you see the entire ensemble at once, in real time. You can see why I'm excited." Douglas Rees, professor of chemistry and an investigator with the Howard Hughes Medical Institute, is collaborating on the protein work.

Caltech, being small by choice and interdisciplinary by inclination, is a good place for collaborations. Since 1996, Zewail has also been the director of the National Science Foundation's Laboratory for Molecular Sciences at Caltech. The other members are Fred Anson (BS '54), the Gilloon Professor of Chemistry, who is studying catalytic reactions driven by electricity; Barton; Professor of Chemistry Dennis Dougherty, who is looking at the receptor proteins in nerve cells; Rudolph Marcus, Noyes Professor of Chemistry and Nobel laureate, whose field is electron transfer (see *E&S*, Fall '92); Professor of Theoretical Chemistry B. Vincent McKoy, who models wave-packet motion; Associate Professor of Chemical Physics Mitchio Okumura, who is examining the behavior of dissolved molecules by using small clusters of solvent molecules as a proxy for a whole beaker's worth; and Rees. "Together," beams Zewail, "the eight of us are doing truly exciting interdisciplinary work on very complex systems from electrocatalysis to DNA, from photoelectron spectroscopy to protein structure and dynamics—this lab is unique in the world."

Zewail takes great pride that his entire professorial life has been spent here, so the prize is truly a Caltech one. "It all started here," he says. He takes even greater pride in being at the same institution where his hero, Linus Pauling (PhD '25), did his own Nobel Prize–winning work on the nature of the chemical bond. (As the forces of history would have it, both men were the same age, practically to the day, when they won the prize.) Pauling worked from crystallographic data, and his bonds were static, stable, and enduring. Now, 45 years later, Zewail has set those bonds in motion, making them as alive and dynamic as chemistry itself. "I think the connection from the structure of the chemical bond to its dynamics is a wonderful legacy for Caltech to give the world."



Chemistry and Physics

by Romy Wyllie

Drinking fountains in West (left) and East (see page 22) Bridge add to the Spanish ambiance of Goodhue's designs. The marble basins are surrounded with faience tile in a variety of designs and colorful glazes.

The book's cover (above right) also comes from chemistry—the interior hallway dome of Gates Annex library. It is decorated with rings of gold tiles, the names of the donors, and circular stained glass skylights containing stylized snowflakes.

Back in 1915, when Caltech was not yet Caltech and the campus was 22 acres of orange groves, George Ellery Hale pursuaded the board of trustees to hire Bertram Goodhue to design an architectural master plan for the young school. Although the campus has expanded far beyond its initial acreage and the buildings that house Caltech's laboratories and classrooms represent a number of different architectural fashions, Goodhue's plan and his eclectic, ornate Spanish Renaissance style dominate the look of the oldest part of campus, where the first chemistry and physics laboratories still stand (although the metamorphosis of High Volts into Sloan Lab leaves little to be seen of Goodhue).

This chapter is reprinted with the permission of Balcony Press from Romy Wyllie's book, Caltech's Architectural Heritage: From Spanish Tile to Modern Stone, *published in December. Wyllie traces the history of Caltech's unique architectural development, illustrating it with rare historical photos and pictures of stone and tile details that the average campus visitor (or student or faculty member) is likely to miss.*

Wyllie is an interior designer and cofounder of CATS (the Caltech Architectural Tour Service of the Caltech Women's Club). And she happens to be married to Peter Wyllie, professor of geology, emeritus. The Wyllies came to Caltech in 1983, and Romy shortly embarked on the mission of sharing the beauty of the campus with visitors and documenting its architectural history.

The book, which is available at bookstores or can be ordered from the Caltech Bookstore, is dedicated to President Emeritus Tom Everhart and his wife, Doris, who gave generous support to the project from discretionary funds.

CHEMISTRY

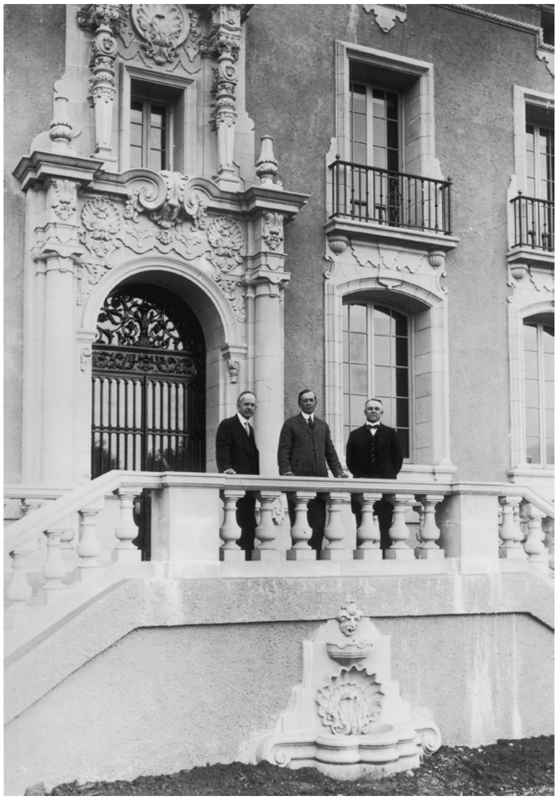
While President Scherer focused on the management of the school and raising funds, Hale worked at building up its faculty. It took many meetings, a two-year, part-time teaching appointment and the promise of a new building for Hale to persuade Arthur Amos Noyes to break a long and strong bond with MIT and become head of the Division of Chemistry at Throop College of Technology. Like Hale, Noyes believed in the importance of research in pure science, and that to be thoroughly educated scientists should study the humanities.

On March 10, 1916, ground was finally broken for Noyes' promised chemistry laboratory. The building was named for the principal contributors, Charles and Peter Gates, Pasadena businessmen, who had made their money in lumber. Arthur Fleming paid for equipment and an annual maintenance income.

The 18,000-square-foot building would contain offices, a lecture room, large and small laboratories, chemical stock rooms, and a library with Professor Noyes' office in the southwest corner of the first floor. Goodhue suggested locating the new structure, now called the Gates Chemistry Laboratory, to the northwest of Throop Hall, near San Pasqual, where it would help to form the layout of his central square.

He agreed with Scherer's suggestion to move it 12 feet closer to Throop Hall, so that its long axis would be centered on Michigan Avenue, a north-south street intersecting San Pasqual Street.

Elmer Grey was the principal architect of the laboratory but Hale asked Bertram Goodhue to design the exterior. Fortunately Grey and Goodhue, who already knew each other and were good friends, cooperated amicably. Hunt and Grey's master plan had made Throop Hall, sitting on an elevated site, the highest building on the campus with a two-story, chemistry laboratory at a lower level. But Goodhue tried to persuade Grey to raise the height of Chemistry because he wanted the buildings flanking his central courtyard or "Court of Honour" to have more presence. Scherer ended the discussion by prohibiting any competition with Throop Hall.



Above: Goodhue's rendering of Gates Laboratory of Chemistry with the Memorial Building dome (which was never built) in the background. To strengthen his Spanish Renaissance theme, Goodhue used baroque ornamentation called Churrigueresque. The style is named for the Churrigueras, a family of Spanish architects. Right: The triumvirate, George Ellery Hale, Arthur Amos Noyes, and Robert Andrews Millikan, in front of Gates Laboratory of Chemistry. Underneath the double stairway is one of Goodhue's many charming fountains with a head and shell design above the basin.

Although Goodhue was not responsible for the Gates Chemistry Laboratory plan and interior, his revision of Grey's "frontispiece, fenestration and cornice" established the Spanish Renaissance decoration which Hale had designated as the overall theme for the campus. He retained Grey's arrangement of doors and windows but made his ornamental balconies functional. Goodhue also added his own embellishments, consisting of interpenetrating lambrequin shapes under the windows, a rope design framing the cornice and an elaborate Churrigueresque style carving of shells, spirals, and leaf-entwined columns framing a grand entry door made of ornamental iron work.

All of Goodhue's ornamental stone work was made from "cast stone," an artificial sandstone-like material formed by cement-casting sand in molds. The decorations for the Gates Laboratory were prepared from models made by a Mr. Piccirilli, whom Goodhue refers to as his "pet modeller here in New York." The Piccirilli family were in fact well-known sculptors and stone cutters and responsible for several of New York's civic monuments.

To the south of the building Goodhue and Grey cooperated in the design of an arcade using a style of column found at Mission San Juan Capistrano. Goodhue changed Grey's three arches to five and replaced Grey's plaster ceiling with wood beams. These Spanish portales would be extended as other buildings were constructed.

Noyes' new laboratory was completed in 1917, but it was not until 1919 that he broke his ties with MIT and took a full-time position at Throop College.

PHYSICS

As early as 1912 Hale had hoped that the Carnegie Foundation would add to the Mount Wilson Observatory project by funding physical chemistry and physics laboratories in Pasadena. But his hopes were dashed when the Carnegie Foundation experienced financial problems. By 1917, with a chemistry laboratory completed and a director designated, Hale (urged on by Noyes) renewed his efforts to find the funding for a physics division. Both men agreed that Robert Millikan was the obvious choice, but an inducement in the form of a laboratory with assurance of money for research would be needed.

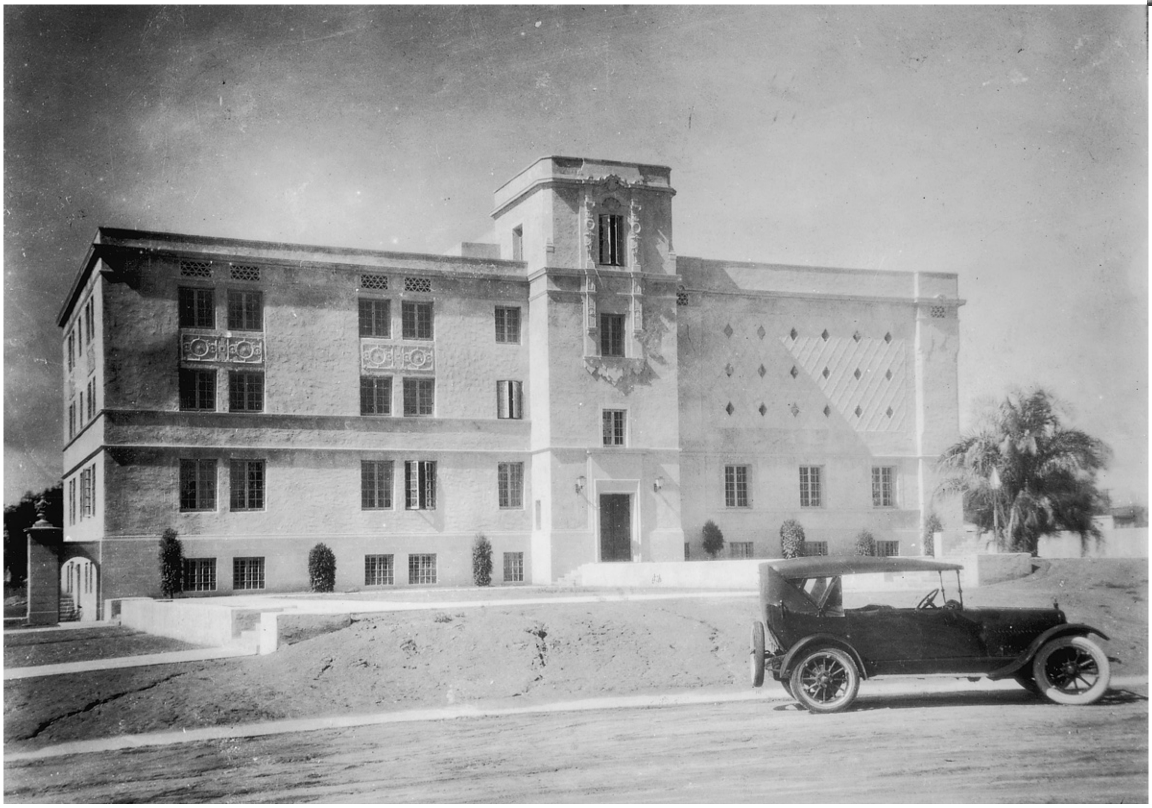
Robert Andrews Millikan was born in 1868 in Illinois where his father was a Congregational minister. After obtaining his doctorate in physics from Columbia, he studied at the universities of Berlin and Göttingen before joining the faculty at the University of Chicago. In 1917, just before America entered World War I, Millikan agreed to spend three months a year at Throop College. He was appointed director of physical research and began a series of public lectures.

In 1920, with the war over and the school's educational program now encompassing chemistry and physics in addition to engineering, the leaders decided that the California Institute of Technology was a more appropriate name than Throop College of Technology.

To help make the expansion into physics a

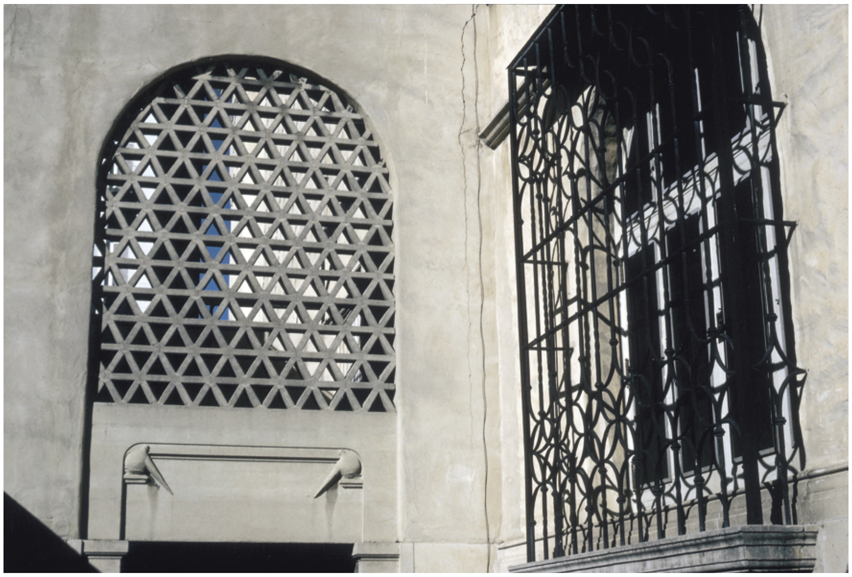
In 1920, with the war over and the school's educational program now encompassing chemistry and physics in addition to engineering, the leaders decided that the California Institute of Technology was a more appropriate name than Throop College of Technology.

Below: The East Bridge tower. On one side of the tower a plain wall is enlivened with 18 elongated quatrefoil-shaped windows set like jewels into an overall repetitive motif called a diaper design. The same Moorish-inspired pattern is repeated on the north and west facades, so that the building would relate to the Memorial Building with its tiled dome overlooking the central court.



Left: Bridge Laboratory of Physics, 1922–24. The first unit, East Bridge, is a fine example of Goodhue's sense of balance and proportion. Between the rectangular upper windows he placed medallions representing Fire, Water, Earth, and Air, the four essential components of all matter, according to the ancient Greek philosophers. Similar panels of medallions on West Bridge symbolize modern science: one medallion represents the Compton effect (the scattering effect of electrons), the other the structure of the carbon atom.

Right: Drinking fountain in East Bridge.



Bridge Annex with two distillation flasks below an arch. The geometrical stone lattice-work filling the arch is similar to mashrabiyya grilles used in Muslim architecture to provide privacy but allow breezes to cool the interior.

reality, Trustee Norman Bridge had agreed to provide the funds for a complex of three buildings. Dr. Bridge had practiced and taught medicine in Chicago before moving to Southern California, where he turned his assets into a fortune by investing in oil exploration. In Pasadena he promoted music, art and education, and helped establish La Viña Sanatorium. He was President of Throop's Board of Trustees for many years.

Goodhue's early plans located a physics building on the north side of the campus to prevent the vibration of trolley cars on California Boulevard from interfering with delicate machinery. Located next to the Gates Chemistry Laboratory, it would have butted up to the science museum on the west and the Memorial Building on the south. But when it became necessary to enlarge the package to attract Millikan, Goodhue suggested that an area south of Throop Hall parallel to California Boulevard would provide ample space for several buildings. The new plan consisted of an open court, which would be flanked by a U-shaped physics complex on the west side and a High Potential Research Laboratory on the east side.

The physics group, built between 1920 and 1924, represents the essence of Goodhue's academic buildings. East Bridge, asymmetrical but perfectly proportioned, has strong horizontal lines interrupted by a vertical entry tower whose upper windows are decorated with Churrigueresque and lambrequin ornamentation. The two buildings flanking the "U" of the physics group are three stories high with two floors below ground, but the joining annex, which runs parallel to the central court, has only one story to permit the dome of the Memorial Building to be viewed from the street.

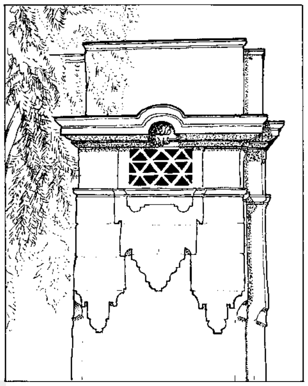
The construction is reinforced concrete with the columns, outside walls, and floor slabs carrying the weight. Interior partitions of hollow tile free of wiring or piping could be removed, or additional walls could be added. The main lecture hall seated 260 people and was lit by a skylight with motorized curtains. Earnest C. Watson, who began a public lecture series which continues today, was hired in 1920 to supervise the construction of the buildings. Students in electrical engineering installed the electrical wiring and equipment. For the convenience of scientists who wished to play tennis during the day, two showers and a dressing room were installed in the subbasement.

In order to create continuity between the academic buildings, Goodhue designed the first floor

For the convenience of scientists who wished to play tennis during the day, two showers and a dressing room were installed in the subbasement.

corridors with similar features and materials: padre tile floors, vaulted ceilings, decorative light fixtures, wrought-iron stair railings and doors opening onto important rooms, and water fountains set in marble basins surrounded with faience tile in a variety of designs and colorful glazes. East Bridge sets the standard for other buildings on campus. Opposite the entrance and double staircase, a wrought-iron door crowned by the newly created initials of the California Institute of Technology opens onto a reading room with a central light fixture in the form of a medallion of the four elements. The central library of the Institute, moved from under the dome in Throop Hall, filled the annex between East and West Bridge. Many years later it was divided into offices and its decorative beamed ceiling destroyed.

In 1921, with the physics laboratories under construction, research funds found, and equipment promised, Millikan agreed to move permanently to California.

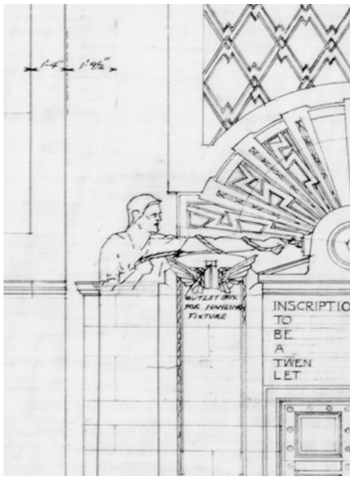


Above: Delicate overlapping lambrequins flowed down from the tops of piers, breaking up their scale.

High Volts Building from California Avenue. Goodhue covered the exterior walls in a diamond-shaped diaper pattern to detract from the absence of windows. Although Goodhue refers to Moorish architecture as his inspiration, similar patterns are also found on Mayan ruins, in particular those in Uxmal, where the walls of several buildings are decorated with repetitive geometric shapes.

When Hale realized that a laboratory dedicated to high voltage research might be the deciding factor in persuading Millikan to join the Caltech faculty, he devised “the Edison scheme.” Hale’s plan, in which the Southern California Edison Company would help to fund a laboratory in return for using its facilities, was supported by trustees Fleming and Robinson, both of whom were directors of Edison.

Caltech’s bulletin of December 1923 stated, “It (High Volts) will be available both for the pursuit of special scientific problems connected with the structure of matter and the nature of radiation,



The entrance to High Volts (now Sloan Laboratory). Goodhue's sculptor, Lee Lawrie, originally showed a drawing of a man and a woman with extended arms, holding a cable and creating a powerful discharge of electricity (below). Perhaps because Caltech was an all-male institution, the sculpture over the door was changed to two men, mirror images of each other.

and for the conduct of the pressing engineering problems having to do with the improvement in the art of high tension transmission." Although such a cooperative effort was unusual, the effort paid off. The February 1949 issue of *Engineering and Science* described the early work in High Volts as "the first laboratory in the country to have a reliable 1,000,000 volt power frequency, provided by a chain system of transformers designed by Prof. Sorensen [who had been hired in 1909 as the school's first instructor in electrical engineering] . . . These facilities have been used to aid Southern California Edison in the development of high-voltage transmission lines [enabling them to bring power to Southern California from the Hoover Dam], to furnish lightning protection of oil storage tanks for the oil industry, to test insulators for numerous utility companies."

The final cost of the building was $139,915. Southern California Edison provided $105,000 and the Institute paid the balance. Alternately called the Edison High Tension Laboratory and the High Voltage Research Laboratory, it became known affectionately as "High Volts."

In a letter to Goodhue dated February 10, 1922, Millikan made sure that the interior space would be suitable for the high-powered work planned for it. "There must be a minimum clearance of 47 feet between the floor and the roof truss in order that the high potential discharge may not pass to the building; this means about 56 feet from the top of the building to the floor. An inside width of 58 feet will give the required clearance for a million volts." The letter went on to explain the

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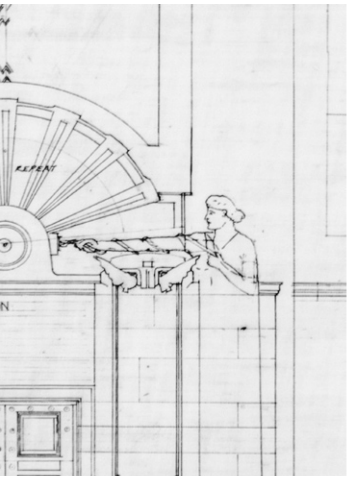

need for ventilation to allow ozone gas to escape but at the same time it must be light-tight. The final size of the building was 50 feet high, 60 feet wide, and 100 feet long. The construction consisted of a steel frame set on 9-foot-wide footings to offset the absence of floors. The frame, designed by the Edison engineers, was only the second one made of steel to be used in Pasadena.

To offset the plain industrial interior, Goodhue designed a decorative exterior. He covered the walls in a diamond-shaped diaper pattern to detract from the absence of windows, and lightened the visual weight of the piers with overlapping lambrequins. A sculpture over the entry door of two men holding a cable to create an arc of electricity symbolized the purpose of the building.

After the completion of High Volts and Bridge laboratories, arcades were built to connect the buildings and form the southern edge of the central courtyard. The arcades terminated in a wall with a tiled fountain outside the Bridge Annex building. At the northern end of the court between High Volts and East Bridge, another small fountain with a bronze background was set into the wall below the arcades. Both of these fountains have since been removed. ☐

Below: The spigot of a small fountain that once stood in front of the arcade wall between East Bridge and High Volts.

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by Romy Wyllie

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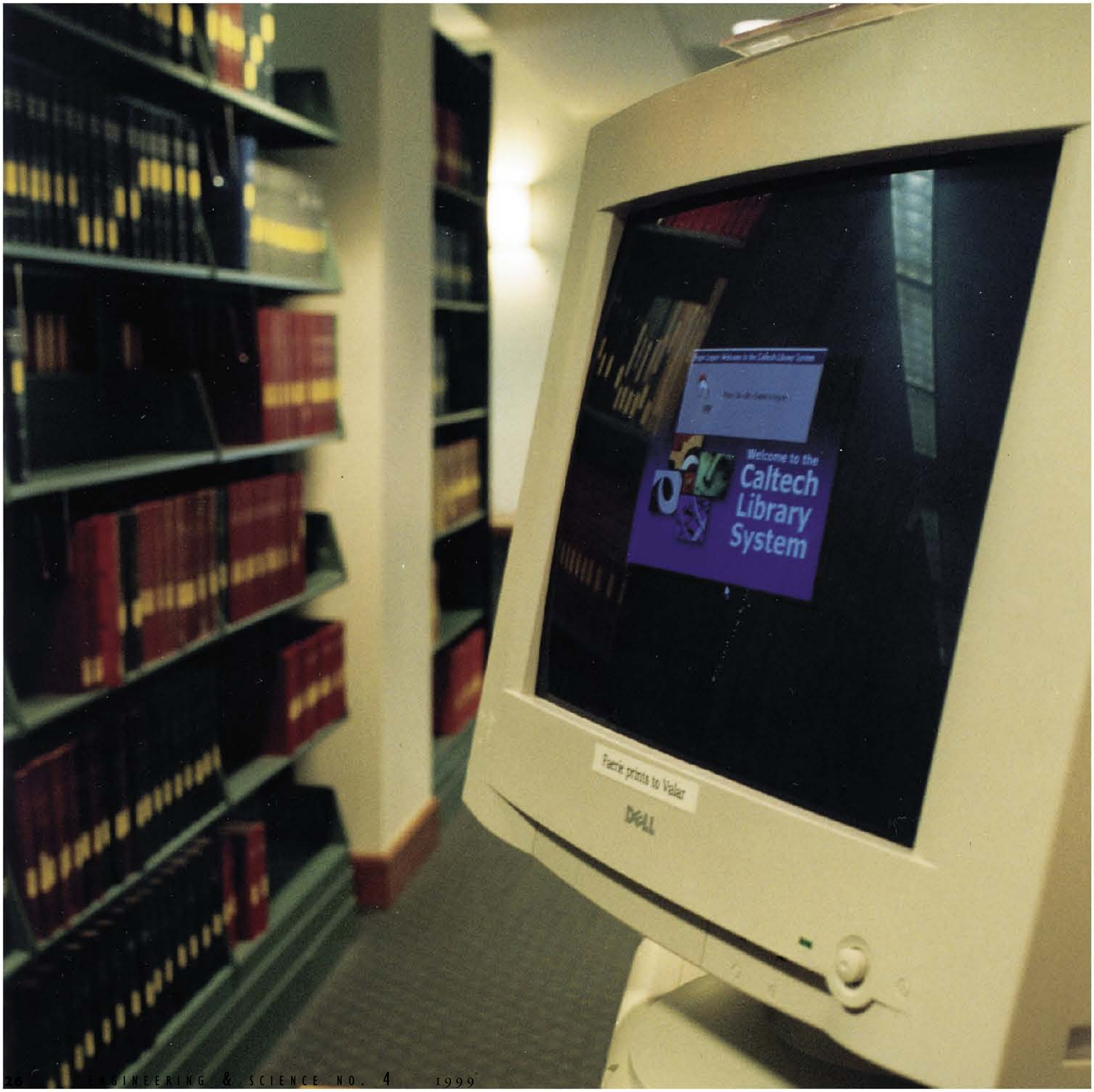
It's more than costs now; it's control of our property. I think universities have realized that what they are producing, whether it's papers or course material, has a value. — *Steve Koonin*, PROVOST AND PROFESSOR OF THEORETICAL PHYSICS



E-Journals:
Do-It-Yourself Publishing

by Jane Dietrich

What's scholarly research worth? A year's subscription (that's 131 issues) to *Brain Research* costs $16,344; *Biochimica Biophysica Acta* (129 issues) will set you back $11,362; the full set of *Physics Letters* (288 issues) goes for $13,843. These journals are all published by Reed Elsevier, the world's largest commercial publisher of science journals.

On the other hand, an institution can subscribe to the weekly *Journal of the American Chemical Society* for a mere $2,165. (And an annual subscription to four issues of *E&S* is still a bargain at $10.)

Why are commercial scholarly journals so expensive? The commercial sector's share of the scholarship market began to expand after World War II as the explosion in scientific information exceeded the capacity of the more traditional publishing avenues—the professional societies. The number of new scientific journals quadrupled between 1940 and 1970, a phenomenon that didn't seem to have a down side until prices began escalating. Between 1986 and 1996, the cost of scholarly journals rose 148 percent (the consumer price index rose 44 percent during the same period), and by the mid-90s librarians had taken notice and were becoming increasingly uneasy. And then prices skyrocketed between 1996 and 1997.

"We were shocked in 1997," says University Librarian Anne Buck, when prices rose 21 percent across the board. Caltech's highest journal increase that year was 29 percent; its lowest about 19 percent. When Buck informed Provost Steve Koonin of the impact on the library's journal budget, a revolt was born. "This is what *we* are producing," thought Koonin, "Why do we have to pay for it?"

As the universities see it, faculty and their research groups, supported by their universities and funding agencies, do the research, write it up, and submit it to a journal's editor or editorial board, which consists of other "volunteer" academic scientists. They send it out to yet another scholar for review (these volunteers are rarely paid). If the paper is accepted, the original scientist makes any required revisions, and eventually it's printed in the journal. Then the universities have the privilege of buying back their own work. Elsevier, responsible for some of the largest price hikes, is making its profit, according to Buck, "on the backs of the libraries and the universities." (Caltech's journal budget stands at around $1.9 million this year, even after the Institute—with faculty collaboration—purged its subscription list of a number of nonessential journals with a high cost per use.)

How do the journal publishers get away with this? Traditionally, an article may be published in only one place, so the publisher has a virtual monopoly on that information. In addition, "the publishers discovered that the market was inelastic," observes Rick Flagan, professor of chemical engineering and former chair of the faculty library committee, "and it's inelastic for a reason: the people who pay the bills and the people who demand the subscriptions are two different sets."

There's also a disconnect between the objectives of the commercial publishers and those of the authors (and the universities that employ them). Scientists want to get their research out to as wide a community as possible, and as quickly and accessibly as possible, whereas publishers are mainly interested in the return on their investment. Professional societies are usually less greedy, and many of them use the profits on their journals to fund member services in their fields. Yet, say critics, those member services should be supported by the societies' members and not by university libraries, who are the ones actually footing the bill.

To rub salt in the wound, the publishers have insisted on holding the copyright, in effect seizing ownership of the intellectual output of the universities. If a scholar at Caltech asks the library to make multiple copies of his own work published in a journal owned by the library to, say, distribute to his class or send to colleagues, only the first copy is royalty-free. Buck points out that recent proposals to revise American copyright law are pursuing a "one-size-fits-all approach" in an attempt to serve the entertainment world and the software industry as well as publishing. "The entertainment and software businesses want to put up as many barriers as possible to anyone getting their material, particularly in its initial use," she notes. "The problem came when some of the large publishing houses, and basically all of them in scholarly publications, saw this as a great way to piggyback on the process and get a lot of money for themselves—even though their product is not like a movie or a piece of software."

Koonin considers copyright the linchpin of scholarly communication. "The researchers want nothing more than to disseminate their information, yet they are held captive in many ways by the publishers who hold the copyright," says Koonin. "I think that with the electronic media developing, copyright has become a barrier to dissemination of scholarly material rather than the incentive it was originally meant to be." Copyright certainly makes sense for commercial authors, who write for income, but not for researchers, who are only interested in exposure for their work. A licensing agreement allowing the publisher the right to print an article, but not own it, would be fairer, say critics of the current system.

"It's more than costs now; it's control of our property," says Koonin. "I think universities have realized that what they are producing, whether it's papers or course material, has a value. Universities are 'content providers,' and the new electronic media opened ways of disseminating that content in much more cost-effective ways than we could before." Print journals have not ignored the potential of the Internet, and many of them do have on-line versions; these can usually be had, though, only by "pay-per-view."

Librarians and scientists both fear that if a commercial journal exists *only* in electronic form, the unprofitable archives of back files would not be a high priority and might get dumped. Not only that, but when your on-line subscription expires, so does your access. In contrast, if you don't renew a print journal, the back issues you've already paid for are still yours to keep.

But e-journals have a lot of advantages over printed publications: papers can be disseminated almost instantaneously; all sorts of search options are available; papers on similar topics can be retrieved through links; references and an author's previous work can be linked to the current paper; comments and comments on comments can be hooked onto a paper; video, sound, 3-D graphics, and data sets can be incorporated into the text. Even something as simple as color images can be added without the extra charges that publishers currently impose. So it isn't only the economics of journal pricing that is prompting the revolution; the technology is already there and waiting for it.

Caltech's first action was to convene a conference on "The Future of Scholarly Communication"

On his paperless (at least for the photo) desk, Provost Steve Koonin logs onto the no-frills physics e-print archive of xxx.lanl.gov. Koonin posts all his research papers on the site before publication in a paper journal.

A 21-percent increase in the price of scholarly journals in 1997 helped motivate University Librarian Anne Buck to look at how to tap technology. She is coauthor of the proposal for *Scholars Forum*, a model for a multi-disciplinary electronic journal.

When you go into an entirely electronic world, there are some very serious issues in my mind about what happens to the past, what happens to the record of scholarship. — *Anne Buck*, UNIVERSITY LIBRARIAN

in March 1997. Attended by 55 representatives of 29 universities, the conference featured four speakers who were prominent proponents of electronic publishing, as well as two panels—one of university provosts and one made up of representatives of professional societies.

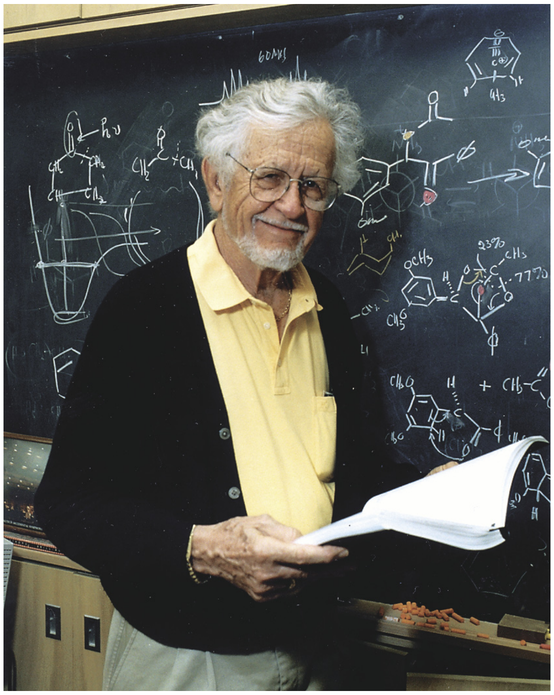
"We brought together people who had the power to make decisions," says Flagan, an avid advocate of the e-revolution, "some librarians, but also people who oversee the library budget and who are motivated to see something happen. The questions that were addressed at that conference were basically: What is it that universities need to communicate for the future? What would we do with a clean slate? Suppose there were no journals today, and suddenly this thing called the Internet came along and we wanted to do something to communicate the results of our research? How would we do it if we were starting from scratch?"

Journals do, of course, contribute some value for the money: they provide mechanisms for editing, for distribution, for easy access to information, for preservation of the scholarly record, and for certification. Certification, in the form of peer review, is critical to the functioning of research universities, and it's what gives the journals their enormous clout. This stamp of approval on someone's work determines who gets hired, who gets tenured, who gets promoted. But the main insight to come out of Caltech's 1997 conference is that peer review is not inherently tied to a print journal. Academics are doing this work for free anyway; they could just as well do it in another kind of distribution system, say an electronic one, if universities agreed to stand together to accept this stamp of approval. Koonin is credited with advancing this notion, henceforth referred to as "decoupling" the refereeing from the journals. And it goes further: you can also decouple the editorial function and the archiving.

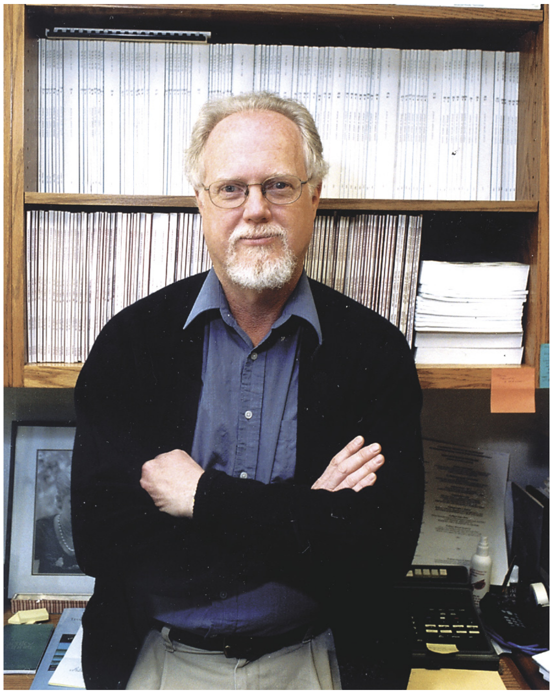
The librarians (who have to pay the journal bills) and the provosts (who have to come up with the money for the librarians) left the conference inspired by the prospect of decoupling. The group most dependent on the journal system, however—the faculty—was not so easy to convince. If tenure and promotion are tied up with the old system, who would want to take a risk on something new and unknown? Many believe that what the journals provide—vetted and edited papers aggregated into neat little packages as the traditional ticket to tenure—is worth the cost to libraries, as well as the price of giving up copyright.

But in a faculty meeting in the spring of 1998, Koonin issued a challenge. He noted that Caltech already requires faculty members to sign an agreement that all patents and copyrights that result from their Institute- or grant-supported work belong to Caltech. No one had ever thought much about copyright, and that part of the agreement was never enforced. But suppose we started enforcing it? mused Koonin and then suggested that Caltech authors withhold copyright from the publishers. No groundswell emerged of professors eager to attempt this, and Caltech, of course, never followed through on the implied threat. Koonin, at least, has practiced what he preached, and one journal to which he contributed subsequently changed its copyright policy in response to his raising the issue.

The copyright challenge did rouse a few adherents at both poles—those enthusiastic about taking on the journals and those who fervently believed that the present system worked just fine—with the vast majority of the faculty indifferent to the entire issue. Professor of



Jack Roberts, Institute Professor of Chemistry, Emeritus, defends traditional journal publication and usually has nothing good to say about the increased computerization of his professional life. Here he looks over the proofs of his most recent book, *ABCs of FT-NMR*, which he admits he did write on a computer.



Behind Professor of Chemical Engineering Rick Flagan are shelves full of two journals to which he contributes: the *Journal of Aerosol Science* (bottom shelf), published by Elsevier, and *Aerosol Science and Technology.* Flagan negotiated an agreement with Taylor and Francis, publisher of the latter, to limit the journal's price increases to the inflation rate.

Planetary Science Bruce Murray set up an on-line, "threaded" discussion system—a "hyperforum"—to discuss copyright and the question: "Will the accelerating trends toward electronic publishing and Internet commerce overturn traditional relationships between university researchers, publishers, and the scientific endeavor?" Over the three months that it was up in the fall of 1998, the hyperforum attracted log-ons from only 40 members of the faculty, 16 grad students, 1 postdoc, and 40 members of the staff. Of these, only 16 posted comments.

While you might think that those who had the most to lose by shaking up the system on which their tenure depends—the junior faculty—would be the most passionate about leaving things as they are, it was Institute Professor of Chemistry, Emeritus, Jack Roberts who led the defense. He contributed numerous comments to the hyperforum, arguing that everything the journals provided was well worth giving up his personal ownership of copyright, and that it was unreasonable and naive to expect the journals to do all the work of publishing and then allow anyone to copy articles or disseminate them on the Web for free.

Roberts also touched on the importance of permanent archives and the differences among disciplines. "There seems to be an operational feeling in physics that anything that is older than a few years is of little interest, except as history," he wrote. "Chemistry is different. Chemists need all kinds of tidbits of information, particularly about preparations, that can be supplied by papers published more than a century ago."

Facetiousness also crept into the hyperforum. Under the title "A Brave New World," Roberts posted a mock news release announcing the new "all-electronic, World Wide Web-based *California Institute Journal for Engineering, Science, Humanities and Social Sciences* (*CALJESHSS*), edited by the Institute's own B. C. Murray, S. E. Koonin, and R. C. Flagan" which would be "free of all of the restrictions which for two centuries have cramped the style of the authors of old-fashioned research journals as to time taken for reviews, length, copyrights, number of illustrations . . . audio records and animations." He went on to describe the wonders of the electronic future and ended with the news that "*CALJESHSS* is developing hardware and software so that research can be published that involves direct transmission of research data on odors, tastes and tactile responses."

> There seems to be an operational feeling in physics that anything that is older than a few years is of little interest, except as history. Chemistry is different. Chemists need all kinds of tidbits of information, particularly about preparations, that can be supplied by papers published more than a century ago.
>
> — *Jack Roberts*, INSTITUTE PROFESSOR OF CHEMISTRY, EMERITUS

David Goodstein, the Gilloon Professor and professor of physics and applied physics, as well as vice provost, responded that *CALJESHSS* sounded like "a magazine devoted to the Second Coming in California" and suggested *The Beaver Dam* instead.

Neither name, fortunately, was destined to catch on. In the meantime, Buck and Flagan (along with Betsy Coles, manager of digital library systems) had come up with their own title and full-fledged proposal, which they posted last March on the library's Web site: "Scholars Forum: A New Model for Scholarly Communication." The site <http://library.caltech.edu/publications/ScholarsForum> has been getting about 1,500 hits a month. *Scholars Forum* lays out a plan for a dual system consisting of a multidisciplinary database of papers, including preprints (posted by the authors) and certified papers (posted by editorial boards) that have successfully undergone peer review. These final papers could be compiled into electronic journals and would remain accessible through electronic indexing and archiving.

Buck and Flagan don't advocate that Caltech go it alone, but envision a trilateral partnership between a consortium of universities, the professional societies, and the authors themselves. Professional societies within the various disciplines would continue to maintain editorial boards to validate papers and distribute them in print or electronic form, but other editorial boards could also spring up under the aegis of the *Scholars Forum* consortium. None of these boards would be granted exclusivity, and authors would retain copyright.

> The publishers discovered that the market was inelastic, and it's inelastic for a reason: the people who pay the bills and the people who demand the subscriptions are two different sets.
>
> — *Rick Flagan*, PROFESSOR OF CHEMICAL ENGINEERING

The proposal considers universities and university libraries the natural choice to control and archive the work that they produce, and endows the university consortium with the responsibility for maintaining the servers, developing and maintaining operating standards and protocols, and supporting the preservation of the scholarly record. "The operator of the server should be an institution that has a likelihood of long life," states Flagan. "There has to be more than one server, and there has to be a commitment by the operators of the servers to translate as technology changes. It takes people, it takes computers, it takes institutional memory. So you want the people who have the commitment to do it, and they are the institutions that support the sciences."

Who would pay for this? "Who benefits the most from publishing?" asks Flagan. "The author and the author's institution." So they (preferably the institution, he adds) should bear the costs, which wouldn't be large, although no one really knows yet what something like the *Scholars Forum* will cost. But many journals already require page charges from authors, so it wouldn't be unreasonable to ask the equivalent of page charges to support the office and secretarial costs, as well as the cost of putting refereed papers on the server. And the *Scholars Forum* suggests that the author pay for copy editing and for any necessary writing assistance.

Is Caltech willing to back up something like the *Scholars Forum* with funding? Says Koonin: "A part of what we're supposed to do in a university is promote the dissemination of knowledge, and I would much rather pay whatever it costs for us, the universities, to put it on the Net for free, worldwide access, than pay some commercial publisher or even a society for one or two copies."

As for the business of indexing and archiving, "the logical thing would be to say this is a new role for libraries," Flagan adds. "The libraries have traditionally been the holders of the print archive; let's make them the holders of the electronic archive."

Librarians, haunted by the incineration of much of the written knowledge of the ancient world when the great library of Alexandria burned a couple of thousand years ago, take this very seriously. "When you go into an entirely electronic world," remarks Buck, "there are some very serious issues in my mind about what happens to the past, what happens to the record of scholarship. This is especially true in science, because science is a cumulative process." To prevent another catastrophe of Alexandrian proportions (until the long-term retention of electronic files is secure), the *Scholars Forum* proposes that a few copies of the "journals" still be deposited in widely dispersed libraries on acid-free paper guaranteed to last 200 years.

"The nice thing about paper," notes Eric Van de Velde, director of Caltech's Library Information Technology Group, "is that benign neglect works. You put it in a room and you forget about it. It gathers dust, but it will remain readable." But how *will* you store a digital library? For example, CD-ROMs disintegrate in 15 to 20 years, says Van de Velde, but they'll be obsolete soon anyway, taken over by DVDs. And although DVD players can still read CD-ROMs, will the next generation of technology be able to read them? The same is true of other technologies. Benign neglect isn't going to work here, according to Van de Velde. "The digital archive must be actively managed." An electronic format also makes it possible to publish the raw data of experimental results, video, three-dimensional structures; how will that be stored? "There are so many different things that you could store," says Van de Velde, "but how do you insure that Microsoft Word 700, or 3000, or whatever, can still read it?"

I can easily imagine a future where every university is basically the stakeholder of its intellectual information, keeps track of the papers it produces, and gives access to people under policies that it decides. — *Eric Van de Velde*, DIRECTOR, LIBRARY INFORMATION TECHNOLOGY GROUP

Van de Velde, who moved over to the library from applied mathematics, does believe that this will be possible, "but difficult." Buck, as an information manager, worries about "chaos in the record in the interim." What happens to articles that are published during the period of transition, when there is no way to preserve them to guarantee that they can be read in the future? That period could last a generation, she believes.

But before you can even think about storing them, e-prints must be collected into a uniform database, and the other principal technical problem is developing common protocols or formats for submission. "Each discipline has its way of producing its manuscripts," observes Van de Velde. "You have many different possibilities for submitting manuscripts, and somehow the same system has to be able to handle them with as little human intervention as possible. Right now, we need to be able to support a wide variety of formats," he adds.

Neither the Conference on Scholarly Communication nor the *Scholars Forum* dealt in depth with the technological nuts and bolts. Fortunately, there already is a flourishing prototype of such a system. In 1991 Paul Ginsparg at Los Alamos National Laboratory created a self-archiving preprint server <xxx.lanl.gov> for high-energy physics, where scientists can post their papers, or "e-prints." It has now expanded to all of physics, as well as astronomy and mathematics, and holds more than 100,000 records in its database (and claims over 50,000 users daily). Most physicists assert they couldn't live without it, and journals have come around to coexisting with the site, since without peer review, they can rationalize that this isn't really "publication," so the article can still be published in a journal. Koonin says that "for the last decade all of my papers have been posted there at the same time that they're submitted to a journal." Ginsparg has proved e-publishing can be done and be very successful.

The National Institutes of Health has proposed something similar for the biomedical sciences. Originally called *E-biomed*, it would have a governing board of scientists and consist of two sections—one for peer-reviewed papers (which would be done by the relevant scientific societies) and another for unreviewed e-prints. Former NIH Director Harold Varmus touted the proposal for providing instantaneous, cost-free access to research, which would accelerate the exchange of information among scientists. But the proposal caught a lot of flak, mainly from medical journals published by medical societies and commercial publishers, who were decidedly unenthusiastic. Critics point to the dangers of concentrating too much power in a governmental agency and of allowing public access to unvetted medical information. Undaunted, the NIH planned to put its electronic archive, renamed *PubMed Central* and expanded to encompass all the life sciences, on line in January. "Biomedical is the big gorilla here," this would be very clean and straightforward. Realistically, however, we must expect and plan for archives by many other organizations, such as publishers and societies."

Eric Van de Velde, director of the Library Information Technology Group, is on the front lines of Caltech's venture into electronic publishing. As a delegate to the newly formed Open Archives Initiative, he has faith in the virtual public library of the future. But the journal stacks he leans against here are not likely to become extinct anytime soon.

says Koonin, who believes things may change rapidly if this venture succeeds.

Even as electronic publishing is catching on within particular scientific fields, visionaries want to extend these models to all disciplines. The Open Archives Initiative (formerly known as the Universal Preprint Service Initiative) aimed to do just that in its first meeting in Santa Fe this past October: link the archives of many disciplines "to ensure that they work together so that any paper in any of these archives could be found from anyone's desktop worldwide, as if it were all in one virtual public library." Representatives, mostly digital-library experts and computer scientists, from universities, libraries, and various electronic publishing undertakings attempted to combine their knowledge into a usable system. Van de Velde represented Caltech.

"Interoperability" was the key word: how to structure the various kinds of archives that are likely to emerge from different institutions and different fields so that they are universally accessible to the end-user. Some initial standard mechanisms and technical requirements were formalized by the Open Archives Initiative as the Santa Fe Conventions, which will be implemented in already existing archives over the next six months.

Van de Velde served on a panel discussing the pros and cons of institutional archives versus those oriented around disciplines. He advocates the former. "I can easily imagine a future where every university is basically the stakeholder of its intellectual information, keeps track of the papers it produces, and gives access to people under policies that it decides. If each university maintains such a database, the universities can link them in a way that you can search them all. Organizationally, this would be very clean and straightforward. Realistically, however, we must expect and plan for archives by many other organizations, such as publishers and societies."

Van de Velde is confident that with enough people working on it, this can all be done. "Everybody knows it can be done, and in many respects it already *has* been done. But you can always make it easier to use, and that is definitely important for widespread user acceptance."

Acceptance remains the biggest hurdle. Who would want to publish in a *Scholars Forum* or in some vast anonymous archive if they could publish their paper in, say, *Brain Research* or *Physics Letters* instead? Many peer-reviewed, start-up electronic journals have experienced credibility problems. How do you establish a reputation? Will electronically published papers count for tenure? And judging from the lack of interest in the hyperforum, it will be tough to persuade many Caltech faculty members that this is the way to go.

The nature of publishing seems to be changing inexorably, like it or not, and Van de Velde believes that electronic publishing has "a very, very high probability of success, because scientists do want access to the literature in easy electronic form. We can actually see it in the library here. For the last few months we have been able to provide some documents through Ibid, a Caltech electronic document-delivery service. A big majority of users prefer electronic document delivery, and even though we can't do everything electronically yet, you can see that the electronic format is important to researchers here."

But there's still a lot of convincing to do, and the revolution will progress in increments. Van de Velde and his Library Information Technology Group (which consists of six people, none of whom are librarians) are currently installing various kinds of software including NCSTRL (National Computer Science Technical Report Library) and NDLTD (Networked Digital Library of Theses and Dissertations), a system developed at Virginia Tech for submitting dissertations electronically. The *Caltech Undergraduate Research Journal* (CURJ) is looking into going on line. And another likely candidate for early digitizing is conference proceedings, say the creators of the *Scholars Forum* proposal.

Whether Caltech's do-it-yourself entry into electronic publishing will actually take the form proposed in the *Scholars Forum* is debatable. "It's a framework," says Buck, "but I don't think it's going to be taken really seriously by the science community until we have some findings. It's suffering from a lack of 'and here's what it looks like.'"

"It's an interesting model," says Koonin. "It's caught some attention among the people who are interested in this. My guess is that the final system won't look exactly like that, but it's a good start." ☐

L.A.'s netizens who checked out the ShakeMap quickly learned that the epicenter was waaay out in the Mojave Desert, under the Marine Corps training center at Twentynine Palms, so life could go on; as their adrenaline rushes subsided, thousands of them did something totally unprecedented—they reported their own experiences to a computerized seismologist.

Did You Feel It?

by Douglas L. Smith

The Hector Mine earthquake, epicentered in a desert-warfare training grounds, bounced tanks like peas on a snare drum, but did no damage. The tank tracks came in handy for measuring displacements (above), and potentially live ammo made mapping the fault trace more interesting (below).

At 2:46 in the morning on Saturday, October 16, the magnitude 7.1 Hector Mine earthquake rolled several hundred thousand Angelenos out of bed and straight to their PCs, making this what the *Los Angeles Times* has dubbed the world's first-ever cyberquake. They logged in to http://pasadena.wr.usgs.gov, where real-time seismology data were appearing as fast as the computers could spit them out. It was the biggest workout yet for TriNet, a collaborative effort of Caltech, the United States Geological Survey, and the California Division of Mines and Geology. This system of digital, computer-linked seismometers provides preliminary location and magnitude estimates within minutes—90 seconds for Hector. Within another few minutes (four, in this case), TriNet generates a large-format, printable map, naturally called a ShakeMap, of how strongly the ground shook all over Southern California. This information, which is primarily for the benefit of emergency personnel, is posted on the Web for all to see.

Strong shaking equals severe damage, and the epicentral area isn't necessarily where the jolt was worst. For example, downtown Santa Cruz got trashed in the 1989 Loma Prieta quake, but since that sleepy city lies over the mountains from the major media center of San Francisco, nobody but the Santa Cruzans knew it for several hours. The same fate befell Fillmore, and to some degree Santa Monica, in the Northridge quake. ShakeMap eliminates the guesswork in dispatching rescue and repair crews, and TriNet automatically fires copies off to computers at the state Office of Emergency Services, the Federal Emergency Management Agency, and some utilities. This list will soon be expanded to include the railroads, Caltrans, and the media.

Creating a ShakeMap is no small feat. A seismometer tells you the ground's acceleration and velocity, but not what a human at that location would have actually felt or what damage might have occurred. Software developed by a team led by David Wald (PhD '93), a research geophysicist in the USGS's Pasadena office and a visiting associate in geophysics at Caltech, converts the recorded ground motions into shaking intensity, a measurement people can relate to. Then, by applying a set of corrections for soil type and other local geologic factors specific to each widely scattered and irregularly spaced seismometer, the software extrapolates the data to a grid of 45,000 points spaced 2.8 kilometers apart. The same set of corrections are applied to these points, which are combined with the corrected readings from the real seismometers to produce the maps. TriNet and ShakeMap debuted with a handful of sensors on March 18, 1997, during a magnitude 5.4 Landers aftershock (see *E&S* 1997, No. 2). The system now includes 120 Caltech-USGS real-time broadband seismographic stations and nearly 200 Mines and Geology dial-up strong-motion sensors. When completed in 2002, it will include over 600 instruments.

L.A.'s netizens who checked out the ShakeMap quickly learned that the epicenter was waaay out in the Mojave Desert, on the Marine Corps training center at Twentynine Palms, so life could go on; as their adrenaline rushes subsided, thousands of them did something totally unprecedented—they reported their own experiences to a computerized seismologist. By clicking on a link called "Did You Feel It?" they reached the Community Internet Intensity (CII) site, an experiment in collecting human observations over the 'net. CII, the brainchild of Wald and Vincent Quitoriano (BS '99), now a graduate student in geophysics at Stanford, allows users to fill in an electronic questionnaire from a menu of standardized choices. Example: "Did pictures on the walls move or get knocked askew? __No. __Yes, but did not fall. __Yes, and some fell." Each choice has a point value, explains Wald, so that "when you submit the form, we compute, based on your responses alone, what your intensity was. We also calculate the average intensity for your ZIP code—maybe you were a little too nervous, or a little too blasé, compared to your neighbors. We display those two numbers, and then right away you see a color-coded map, by ZIP code, of all the accumulated responses." The map is updated every five minutes.

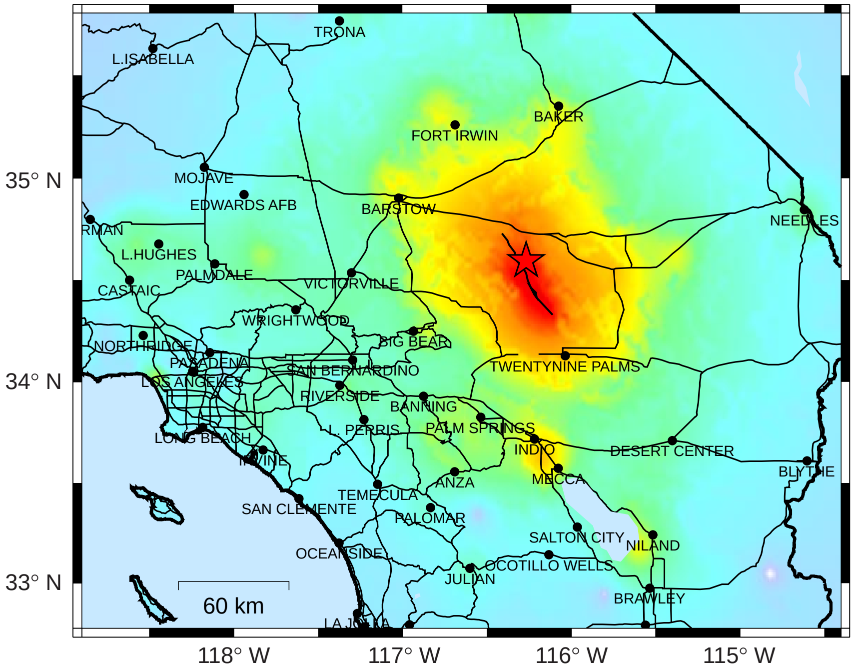
Like ShakeMap, the CII site is completely automated. If TriNet records an earthquake greater than magnitude 3.5, it triggers the CII site to create a Web page for that event, labeled with the time, epicenter, and magnitude. "If everything works perfectly," says Wald, "I don't have to deal with it at all. But if, for instance, the magnitude changes, I have to reflect that in the map. And once you see where the quake is, you might want to make the map bigger or smaller, or if it happened on the coast you might want to shift the map to show more land and less ocean."

Wald chose the ZIP code as the CII's geographic unit because "it's a simple, natural reference frame. People don't know their latitude and longitude, but everybody knows their ZIP code. And it's nonspecific enough that people don't mind giving it out, although we do ask for a street address as an optional piece of information, and typically they give it." (A future version will convert street addresses to latitude and longitude, but the process remains wobbly—it doesn't cope with sloppy typing very well.) ZIP codes, although a practical solution, are far from ideal. For one thing, a chunk of sparsely populated desert with a tiny hamlet down in one corner will be colored according to the responses of the townsfolk, even though the shaking out in the boonies where the aqueduct runs may have been quite different. And you need a minimum of five responses per ZIP code to get a nice, stable average. With fewer, each fresh contribution makes the average as skittish as a cat during an aftershock, and one hypersensitive person can really skew it. Furthermore, says Wald, "people caught on the road can't identify their ZIP code very well. And people who are at work tend to forget that they're at work, and they enter the wrong ZIP code. But it all gets washed out in the numbers if enough people respond. If we have 150 people in one ZIP code, like we have for Hector, a few radical deviations from the norm just don't show up."

These data contain a wealth of detail the ShakeMap misses. Says Wald, "I have a seismic instrument in my garage as part of the National Strong Motion Program. Now if we have an earthquake, and I call home, I'm not going to ask, 'What was the ground motion like?' I'm going to say, 'What happened to the house?' And that's exactly the difference between these two maps. However, if Lisa [his wife, who works for the USGS, too] were to go out to the garage and tell me that it was half a *g*, I'd have a pretty good idea that the place shook like crazy, it was scary, and that there was going to be some damage. But I wouldn't know whether the chimney fell or not… it probably should have." On the other hand, the ShakeMap, which doesn't depend on humans (nor their PCs, Internet service providers, and phone lines) in any way, is the much more reliable tool for directing the emergency response teams.

Detailed intensity maps have traditionally been drawn by combining data from field surveys, reports of damage from emergency agencies and the press, and a questionnaire mailed to the postmaster of each ZIP code in the affected area. The process takes months, and, says Wald, "you have to have one person looking at things, in order to be consistent. Jim Dewey, of the National Earthquake Information Center in Boulder, Colorado, is the one official government representative who does intensities for the whole country. He's been working with us, and he's been a lot of help in making our adaptation consistent with the original questionnaire." Intensity data, including ShakeMaps, are reported on the Modified Mercalli scale, which uses Roman numerals so as not to be confused (at least in print!) with magnitudes, and which runs from I (not felt, no damage) to X+ (very heavy damage). A Northridge-type earthquake will max out in the VIII–IX range.

Wald and Quitoriano's other collaborator is Lori Dengler at Humboldt State University. "She realized, after doing a phone survey of several thousand people after Northridge, that it would be easier to assign numerical values to answers than to try to interpret them subjectively," says Wald. "I read about that, and thought it would be a really good thing to apply to the Internet, and it evolved naturally from there." The collaboration launched the CII in 1988 with a questionnaire for the Northridge quake. Explains Wald, "I put up Northridge, because I figured everyone would remember it. If you were in an area that shook hard, it's a life-changing experience. And even though the fish may get bigger every time you



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	***<.17***	***.17-1.4***	***1.4-3.9***	***3.9-9.2***	***9.2-18***	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	***16-31***	***31-60***	***60-116***	***>116***
INSTRUMENTAL INTENSITY	**I**	**II-III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X+**

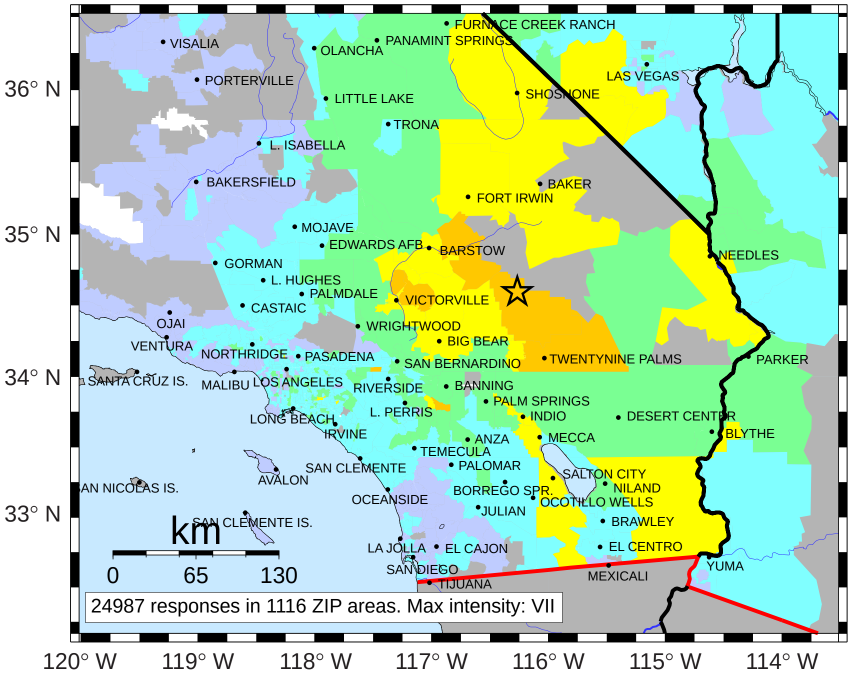
Above: TriNet's ShakeMap for the Hector Mine earthquake. The open star marks the epicenter, which ruptured segments of the Bullion and Lavic Lake faults, shown as the black diagonal line under the star. The other lines are major roads. The circles are sesismic stations. Intensities are mapped using the Modified Mercalli scale (described in the box on the opposite page). The computer uses peak accelerations, to which people are sensitive, to calculate intensities I–VI, which are keyed to human perceptions. Intensities VII and above reflect structural damage, which is related to peak velocity.

tell the story, our questions are very specific: Did your chimney come down or not? So the answers remain pretty accurate, and thus the solution is fairly robust." They garnered about 800 responses—enough to do a statistically meaningful calibration against the USGS's traditionally acquired Mercalli maps and to publish a brace of papers. "Northridge gave us a numerical connection between what people respond to and the official Modified Mercalli intensity. And once you can do that, it's automated. You don't have to interpret people's responses. That's a major step forward. A couple of other places have put questionnaires on line, but they don't do anything with the answers. Somebody might look at them at some point, but it's not automated, so it's a big chore." Dengler, Wald adds, "had a lot of good advice on how to ask the questions, because there are subtleties involved. For instance, there's a big difference between solicited and unsolicited responses. If you ask people what they felt, on average you get a different answer than if they volunteer the information." Volunteers are usually a bit more, shall we say, enthusiastic about their subject, and their intensities tend to be a bit higher. "It turns out that this bias is fairly systematic, so we can correct for it, but you have be aware that it's there."

The site, which had not been advertised and had very few links to it, nonetheless got 25,000 responses after Hector—8,000 in the first eight hours!—and has developed a faithful following. "A couple of weeks ago, we had a 3.9 in Orange County, and there were over 1,600 responses. That's not a big earthquake. We even get people who respond when they didn't feel an earthquake. Now, *that's* dedication—to have regulars who hear about an earthquake on the news, and come in and say, 'I didn't feel it,' means they feel that they can contribute to science. And that's what we want. We'd like to be able to define where it wasn't felt, as well."

The CII home page has a running index of all the quakes that have questionnaires, and visitors are encouraged to fill out as many as they can. It worked—when people did Hector, some took a whack at Northridge too, doubling the number of forms previously submitted. Now Wald is reaching back even farther, he says. "Somebody asked me, 'I was here in 1971—why don't you put Sylmar on?' So I did. Then somebody else said, 'What about Kern County in 1952?' So I added that one, and I just got a request to put Long Beach on. That was 1933! Now, I'm not putting 1906 on there, but *Long Beach?!* But I figure this is something for the people by the people, and if they want Long Beach, I'll put it up and see what comes in."

The questionnaire ends with a catchall box for additional comments, which has become a gold mine of first-person tales—people seem to find telling their stories very therapeutic. The Northridge compendium, says Wald, "is a huge data set for people involved in emergency response, in terms of how people react psychologically to disasters. We've already had requests for that data. I'm not an expert in sociology, so it's hard for me to gauge what its value is, but other people have told me what an amazing data set it is." And describing what you were doing when a big quake hits provides a pretty good snapshot of what we, as a population, are up to. "At any given time, in Southern California, somebody is doing every



Right: The Community Internet Intensity map for Hector. In a Java-equipped Web browser, moving the cursor across the map reveals the ZIP code, number of responses, and average intensity for the point beneath the cursor. Gray areas are ZIP codes from which no responses have been received. Although clarity considerations prevent each individual ZIP code from being outlined as on the Web version, and thus ZIP codes of the same intensity run together, the size disparity between ZIP codes in urban L.A. and out in the desert is still apparent.

INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

possible thing you can conceive of. I'd love to put together a Top Ten for Hector. There was a police officer on top of a six-foot cinder-block wall with a flashlight, trying to trap a burglar. He was directing other units toward the burglar, and then the earthquake hit, and he got knocked off the wall. Landed on the ground, collected his thoughts, looked up, and tried to get the operation back in gear, and the end of his form says, 'Thief got away due to divine intervention.'"

About one percent of the respondents follow up with an e-mailed question or comment. The latter range from rehashing their story to reporting an error (usually in the ZIP code they gave) to suggesting improvements to the graphic interface. "We've actually had people send HTML code," Wald says in amazement. "There's a huge resource of technical expertise out there, and some of it is very impressive. I get occasional screwballs, but that's the Internet."

The collaboration's next step is for Dewey to map Hector's intensity the old-fashioned way and compare the results to the CII map. Some tweaking of the formulas used to calculate the intensities will probably result, and it may take a few more decent-sized data sets (i.e., widely felt earthquakes) to get things just perfect—an advantage to developing the system in Southern California, where earthquakes are an inexhaustible natural resource.

But it's already clear that the CII maps match ShakeMaps remarkably well. Shaking normally dies off with distance, for example, but a basin filled with soft soil or alluvium will amplify seismic waves and cause people there to feel a tremor more strongly than people on bedrock closer to the source. "After a magnitude 5 near the San Andreas fault, we got observations from people who happened to be near one of our instruments near San Bernardino. The instrument validated their report of a higher intensity than people closer to the epicenter. This implies that

The Modified Mercalli Scale

I. No one feels it. Doors may swing slowly.

II. A few people indoors, especially on the upper floors, notice it.

III. Many people indoors feel a vibration like that of a light truck passing. Hanging objects may sway slightly.

IV. Most people indoors feel a vibration like a passing heavy truck, or a jolt like a heavy ball hitting the wall. Hanging objects swing. Dishes, windows, and doors rattle. A few people outdoors feel it. Parked cars rock.

V. Almost everyone feels it. Sleepers awakened. Doors swing open or closed. Some dishes break. Pictures on walls move. Small objects move or fall over. Trees and bushes may shake.

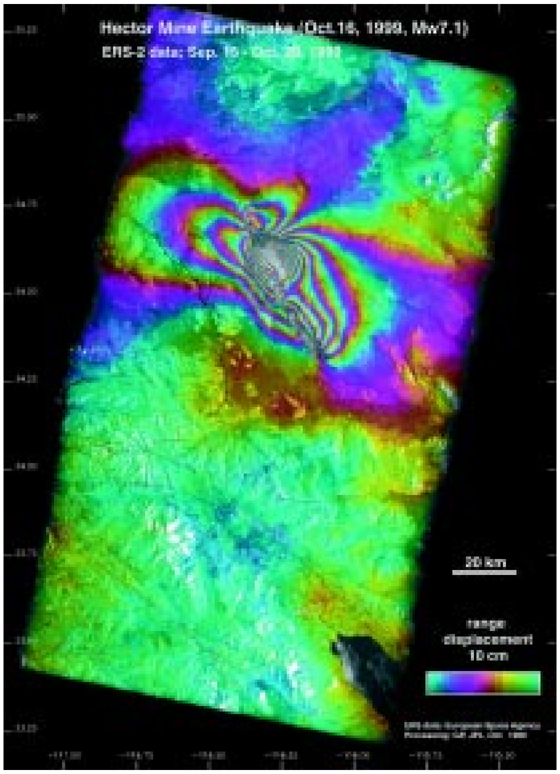
VI. Everyone feels it. It's hard to walk. Objects fall from shelves; pictures from walls. Furniture moves. Plaster walls may crack. Trees shake, small church bells ring. Slight damage to poorly built buildings.

VII. It's hard to stand. Drivers feel their cars shaking. Some furniture breaks. Loose bricks fall from buildings. Large bells ring. Negligible damage to buildings designed for quake resistance; slight to moderate damage to ordinary well-built buildings; considerable to poorly built ones.

VIII. It's hard to steer. Houses not bolted to their foundations may shift on them. Some chimneys, water towers, other tall structures fall. Quake-resistant buildings slightly damaged; ordinary buildings considerably, with partial collapse; poorly built ones severely. Wet ground and steep slopes crack open. Tree branches break. Well water levels, temperatures change.

IX. Quake-resistant buildings considerably damaged. Unbolted houses move off their foundations. Some underground pipes break. The ground cracks. Reservoirs seriously damaged.

X+. Most buildings and their foundations destroyed. Dams seriously damaged. Large landslides occur. Water thrown onto the banks of canals, rivers, lakes. Paving cracks or buckles. Railroad tracks bend.



Another map available on the Web site is this interferometric one, made from radar data taken by the European Space Agency ERS-2 satellite on September 15 and October 20, 1999 and processed by Frédéric Crampé, Gilles Peltzer, and Paul Rosen of Caltech's Jet Propulsion Lab, and Assistant Professor of Geophysics Mark Simons of Caltech. Ground displacements that occurred along the radar's line of sight between the "before" and "after" scans show up as colored bands. One full color cycle represents 10 centimeters of displacement. Dotted lines are previously mapped faults, and the thick, solid lines mark the Landers (1992) surface rupture. The thin, solid lines within the zone of dense fringes are surface breaks inferred from the radar data.

Among the geologists doing the field mapping was Caltech senior Aron Meltzner, who checks out a fissure with Jill Dahlman, a student at Cal State San Bernardino. Here the ground moved up and down as well as sideways.

we can sample our data very densely to map out these variations in detail. We'd have to go beyond the ZIP code boundaries, but we archive all the questionnaires, so as soon as we have the time to figure out how to do that efficiently, we will."

The USGS has been impressed enough to give Wald the okay to go nationwide. "I might live to regret this, but we've decided to run everything from here. Otherwise, every time we changed the software, we'd have to redistribute it to every regional seismic network in the country. I don't have the ZIP codes for Guam—they're hard to get—but I have the ZIP codes for Puerto Rico and every other American territory. I'm the only person doing the community map right now, so I have a pager, and every time there's an earthquake anywhere in the U.S. I know about it. It's a lot to keep up with, but I've got work-study money, and I'm hoping to find an undergrad to help part time." The National Earthquake Information Center in Colorado, whose pager it is, collects information from digital seismometers scattered across the country—around the world, actually—and automatically triggers Wald's computer in Pasadena to generate the maps. The Northern California, Nevada, and New England regional networks are interested in taking a more active role, so as the system gets more sophisticated, the plan is to have the CII interface carry the logo of the appropriate network, which will then create local links to it. Then, when the next earthquake hits that area, the local net can unveil the site to the public through the Web and the media. The northern California site is already pretty well developed—the list of automatically generated questionnaires begins on August 17, 1999, and the "historical" list reaches back to the Parkfield earthquake of 1966. At the moment, the entire rest of the country is lumped in a third site, which at this writing contains three Alaskan earthquakes and nothing else. Sometimes you have to wait for nature to take its course…

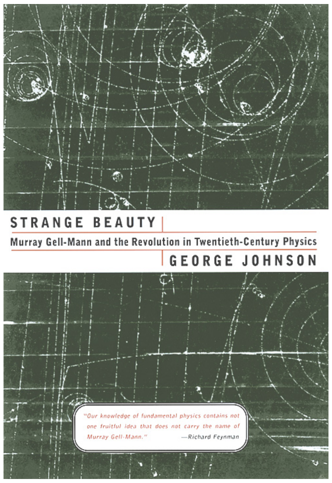
The Canadian and Mexican governments are also interested, which may be a foreshock, as it were. The e-questionnaire, appropriately translated and modified to reflect local building practices (the nature of the damage in, say, Guatemala would be quite different than it is here) could eventually find use around the globe. The jungle isn't wired yet, but there are more laptops with satellite links or wireless modems out there than you might think, and any town with telephone lines is bound to have at least one computer.

The rest of the country is years behind TriNet, and the low-risk areas may never catch up. But no part of the nation is immune to the earth's occasional hiccup, and it seems that everybody and their dog has Internet access these days. So the CII offers a way of getting good observations without an elaborate and expensive digital seismic network. But unlike the ShakeMap, the CII is not a disaster tool. For one thing, when your house has collapsed in flaming ruins around you, even the hardest-bitten Internet junkie will be out in the middle of the street in his jammies, just like everyone else. And less catastrophic quakes bring power failures, downed phone lines, and busy signals. So the CII information will eventually come in, and much faster than it would through the post office, but it won't be as timely as the ShakeMap. Meanwhile, the USGS, in a report to Congress on the state of the nation's seismic networks, is touting TriNet and ShakeMap as a model for what should be done across the rest of the nation. ☐

PICTURE CREDITS: 34 — Aron Meltzner; 36, 37 — Dave Wald; 38 — Sally McGill

STRANGE BEAUTY: MURRAY GELL-MANN AND THE REVOLUTION IN TWENTIETH-CENTURY PHYSICS

by George Johnson
Alfred A. Knopf, 1999
434 pages



STRANGE BEAUTY
Murray Gell-Mann and the Revolution in Twentieth-Century Physics
GEORGE JOHNSON

"Our knowledge of fundamental physics contains not one fruitful idea that does not carry the name of Murray Gell-Mann." —Richard Feynman

by David L. Goodstein,
Professor of Physics and Applied Physics, the Gilloon Distinguished Teaching and Service Professor, and Vice Provost

One day when he was four or five years old, Murray Gell-Mann was given some ancient Roman coins by a relative named Israel Walker, who explained they were from the time of the Emperor Tiberius. Murray corrected Israel's pronunciation of Tiberius, nearly earning a punch in the nose, then examined the coins and pronounced that they weren't from Tiberius's reign at all, but rather from that of a later emperor. The story, true or not, has many meanings. Murray was a prodigy, and Murray was insufferable, and Murray was irresistible, and not a thing has changed in the 65 or so years since then.

Strange Beauty is a biography of Murray Gell-Mann, one of the great theoretical physicists of the 20th century, written by George Johnson, a *New York Times* science writer, who happens to live in Santa Fe, where his subject has lived since retiring from Caltech. In a prologue Johnson tells us of the difficulty of getting into the good graces of his neighbor, made wary not only by his life-long disdain of journalists, but also by his vague thoughts of writing an autobiography of his own. I'm glad Johnson succeeded.

For me, reading this book was like being the child accidentally locked overnight in a toy store. Not only did I know Murray from the many years we were colleagues on the Caltech physics faculty, I know many of the other characters in the book, and many of the stories Johnson has to tell were new to me. Simply put, I had a ball reading this book. But how will it appear to a less privileged reader?

In writing this book, Johnson had a monumental problem to solve. His subject, although in many ways an admirable man, could come off as little more than a petulant, over-bright, overgrown child of little importance, except for the extraordinary contributions he made to our understanding of the ultimate constituents of matter. Thus, there could be no biography of Murray Gell-Mann without telling the story of his physics. Explaining 20th-century physics to the uninitiated is one of those tasks of legendary difficulty, tried by many, accomplished by few. But Johnson must do it incidentally, on the way to an even more daunting purpose: explaining Murray Gell-Mann. What is a normal person to make of renormalization, current algebras, Yang-Mills theories, and the Higgs Boson? Johnson penetrates all this, hardly ever falters in telling the story, and still makes the people, the quirks and not the quarks, the stars of the show. It is an altogether impressive performance.

Many people who know Murray assume he invented his own last name. After all, his older brother is just plain Ben Gelman, and Murray has a knack for inventing names that capture the imagination (quarks, the eight-fold way, quantum chromodynamics). But Murray was born in Manhattan already hyphenated, on September 15, 1929. It was his father, Arthur, an immigrant from Galicia and Vienna, somewhat pompous and never very successful, who had inserted the hyphen. The Gell-Manns were never well off, and grew poorer with Arthur's failures, but Murray's potential was noticed early on (it was hard to ignore), and he won scholarships, first to Columbia Grammar, then to Yale. When he graduated, somewhat later than necessary at the age of 18, neither Yale nor Harvard made him an offer he couldn't refuse for graduate school, so he wound up in the somewhat grubby halls of MIT. His subsequent career took him to the Institute for Advanced Studies at Princeton (Harvard had snubbed him again), and then to Chicago.

Chicago had, perhaps, the best physics department in the world, but it was a cold place, and it got even colder when, in 1954, the great Enrico Fermi died. Murray wrote, inquiring about job prospects, to a theoretical physics acquaintance, a man of incredible intensity and manic energy named Richard Feynman. Soon Murray and his reluctant bride, Margaret, settled in smoggy Pasadena.

With Feynman and Gell-Mann both in residence, Caltech became the center of the universe for theoretical physics. Gell-Mann repeatedly came up with ideas that were both profound and far-reaching. Feynman, with his more heuristic style and more eclectic taste in physics problems, continued to amaze and delight. Feynman won a share of the 1965 Nobel Prize. Gell-Mann got one all for himself in 1969. The two collaborated, competed, squabbled, and bantered. When both attended the same seminar, the air was electric and the speaker was in danger of being forgotten.

In the meantime, both nurtured and burnished personae designed to set them off from us mere mortals. Feynman hung out in topless bars, where he flirted with and sketched the dancers. Gell-Mann learned a few words of nearly every language on Earth and became a serious birdwatcher, conservationist and collector of art. As his fame grew, his talent for verbal jabs came unleashed: when Feynman struggled with a new theory of what he called partons, Murray mocked them as "put-ons" (they later turned out to be Murray's quarks, plus gluons, the particles that hold quarks together). My own field he sneered at as "squalid-state physics" (Feynman actually made important contributions to squalid—er—solid state physics). It was clear that, without any doubt, Murray Gell-Mann was the smartest person on Earth, except maybe for the guy in the next office.

A few months after Richard Feynman died in 1988, a memorial was held in his honor. In the way these things are done at Caltech, it was to be a celebration of his life rather than a lament for his death. Murray Gell-Mann was listed as one of the speakers. But Murray didn't show up. Many of us in the audience, me included, thought that Murray's feelings about Dick were so conflicted that he couldn't bring himself to speak.

As it turned out, the reason was quite different. Murray was more or less under arrest because a raid on his home had revealed precious Indian artifacts that had been smuggled out of Peru, and bought by Murray from a charismatic but shady dealer. The incident was eventually straightened out, and Murray even became something of a national hero in Peru for returning the artifacts voluntarily.

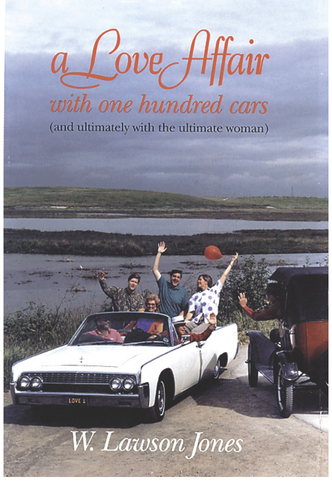
I don't envy Murray the weird experience of reading so penetrating and perceptive a biography of himself. Murray Gell-Mann is a towering, historic figure who will be remembered down through the ages, but he is also a living and breathing human being with hang-ups and problems just like you and me. What a story!

George Johnson has written a fine biography of this important and complex man. □

A LOVE AFFAIR
WITH ONE HUNDRED CARS

by W. Lawson Jones

180 pages



In 1940, Lawson Jones (BS '43) and some pals dismantled a 1923 Model T (purchased for $8) and reassembled it, running at full throttle, in the Ricketts room of an unfortunate colleague who was out on his first date. The first legend in *Legends of Caltech*, this was a stunt that set the stage for countless Ditch Day reprises.

This was not Jones's first car, however. He began his Caltech career with a 1934 Ford V-8, which he rented out for dating, and went through a 1935 Pontiac Silver Streak (a bargain that he found abandoned in a Caltech parking lot) and a 1928 Willys Knight ($25), before graduating the proud possessor of a sexy1935 supercharged Auburn four-door convertible—but not for long. He commenced upon a career of ownership that spanned 88 automobiles (a few borrowed ones make up the full 100), new and used, Detroit-born and foreign, most of which were in some way, well . . . funny.

At least Jones makes them amusing to read about. How many people do you know who actually had the nerve to buy (*new*, no less) such novelties as a Borgward, an Edsel, a Kaiser, and a three-cylinder Daihatsu? And loved them all—especially the 1969 Renault R16, not to mention the Lincoln, the Studebaker, the Rambler, the Graham (the *Graham*?) . . .

Jones clearly learned to write somewhere (could it have been at Caltech?) as well as to restore and dismantle automobiles, and though he once dreamed of a career designing cars in Detroit, went into the advertising business in Silicon Valley instead. Among his clients was Fairchild Semiconductor; he sold the Borgward to Robert Noyce, Fairchild president and later cofounder of Intel, who had been driving a boring 1941 Ford. Jones moved on to a Citroen DS19.

As for the subtitle, when Jones first met his second wife, he was enchanted until he met her nine-year-old Ford Falcon (yes, boring again) in the parking lot. But he gave her a "beautiful baby Buick" Skylark, and they lived happily ever after.

His book has been making the rounds of his fellow alums, several of whom recommended it to *E&S*. To order it, contact the Schobert Publishing Co., 537 Tyndall Street, Los Altos, CA 94022.

Today Jones drives a Saturn. □ —*JD*

FREDRIK ZACHARIASEN
1931 – 1999

In Peter Fay's backyard in France, 1998 (photo by Nancy Zachariasen).

Fredrik Zachariasen, professor of theoretical physics, emeritus, died on December 9 at the age of 68, after suffering a heart attack.

At a memorial service at the Athenaeum January 9, Zachariasen's colleagues, friends, and family celebrated his life: his work in physics, his wide-ranging interests, his love of travel, of the outdoors, of good conversation, good food and, especially, good wine, and his passion to "solve the world."

Zachariasen earned his BS from the University of Chicago in 1951, where one of his classmates was Gerald Wasserburg, now Caltech's MacArthur Professor of Geology and Geophysics. Wasserburg recalled how Zachariasen would draw cartoons and sketches in class and how, as undergraduates, they were "subjected to a string of newly made hotshot professors," including one Marvin L. Goldberger. "We were the targets of his first attempt to teach quantum mechanics." Even Murph admitted later that it was a terrible course, Wasserburg said.

David Elliott, a close friend for almost 50 years, entered graduate school with Zachariasen in 1951. "It was a comradeship that built up almost immediately and remained strong for the rest of our years together." The Elliotts and the Zachariasens did much traveling together over those years: to France, Italy, Portugal, Spain, Greece, Egypt, to name a few. Elliott described how Fred became "a hero to our entire class of grad students" by defying W. R. Smythe on the final exam of his course on electricity—a required course of complex problems, considered a "rite of passage," that didn't touch on what was then called "modern physics." "Fred chafed more than most," said Elliott. "At the final exam, Fred wrote furiously and left after an hour." It turned out he had turned in an essay about how electromagnetism is taught in most places and why Smythe's approach was not helpful. Miraculously, Zachariasen didn't fail the course (it was eventually dropped) and earned his PhD in 1956.

It was also in 1951 that Nina Byers, now professor of physics, emeritus, at UCLA, first met Zachariasen at the University of Chicago, where they were both studying for the dreaded qualifying exam (Zachariasen passed but left for Caltech anyway). "Fred was fierce and friendly." In 1958 they both ended up as assistant professors at Stanford. "Working with him was a whirlwind of fun and a very entertaining challenge. . . .He was a fast and accurate calculator but had a depth of understanding that made working with him very interesting and very rewarding." Zachariasen's main area of research was theoretical studies of the interactions of elementary particles at high energies.

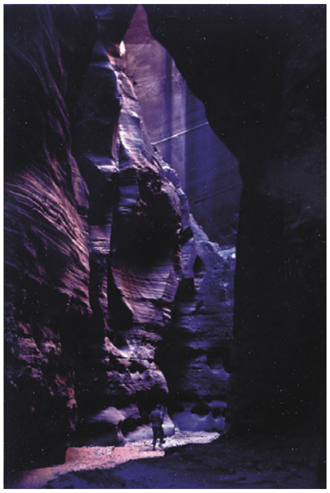
Both Marshall Baker and James Ball met Zachariasen in 1953, Baker as a first-year grad student at Caltech and Ball as a sophomore. Somewhat later they began a long and fruitful collaboration ("longer than many marriages" said Ball), even though Baker was professor of physics at the University of Washington and Ball at the University of Utah. "Fred was full of ideas," said Baker, "particularly ideas that work—and are useful and focused." "A general feeling that physics was fun permeated the whole thing," added Ball, "and that's what kept us working at this for so many years when there were probably lots of easier collaborations that didn't involve flying to Salt Lake City and Seattle."

Ball also recalled the many camping trips to Baja California, as did Peter Kaus, now professor of physics, emeritus, at UC Riverside. "Trips to Baja were always overshadowed by the possibility of impending disaster," said Kaus. "But the disasters never totally stopped us, and we always had a wonderful time, aided usually by the case of beer we had acquired in Mexicali." Kaus also noted the hiking and camping trips around Aspen, where the two were among the original participants in the Aspen Center for Physics. Zachariasen was also a member of its board of trustees from 1978 to 1982.

Sidney Drell, professor of theoretical physics, emeritus, at Stanford, worked with Zachariasen at MIT and Stanford (where, as well as at UC Berkeley, Zachariasen spent the four years between his Caltech PhD and his return as a member of the faculty). "I admired him greatly for his science, for his fundamental modesty, and his irreverence. . . . He spent a fair amount of time teaching my three-year-old son to call him God." Drell also mentioned Zachariasen's membership in Jason, an elite group of physicists formed to advise the government on defense.

"Fred, still in his twenties, was the youngest one brought into that group. Already his brilliance was widely appreciated."

His work with Jason was the subject of his last paper, written with Walter Munk, BS '39, MS '40, on spiral eddies that could be seen in sun glitter photographed from the Space Shuttle, currently in press with the *Proceedings of the Royal Society*. Munk, professor of geophysics at Scripps Institution of Oceanography, worked with Zachariasen in a small Jason Navy group involved in acoustic problems associated with antisubmarine warfare. This research resulted in a book they wrote with others: *Sound Transmission Through a Fluctuating Ocean.* (Zachariasen's other books include *Electromagnetic Structure of Nucleons*, coauthored with Drell, and *Hadron Physics at Very High Energies*, with David Horn.) Regarding his Jason work, Munk thinks "he was motivated by a romantic attachment to the planet Earth, by the love of adventure, of learning about unexpected manifestations of natural processes, and in this pursuit he was aided by a keen sense of observation and a very good memory for diverse facts."



Some of Fred Zachariasen's slides from his hiking and camping trips and from travels around the world were shown at the memorial service. Above: Paria Canyon, Utah, 1981 (Fred's wife, Nancy, carries her pack along the canyon floor), and right: the Maze, Utah, 1977.

Two of of Zachariasen's Caltech colleagues, Steven Frautschi and Steven Koonin, both professors of theoretical physics, also spoke. Frautschi, who had written an early paper on Regge poles with Zachariasen and Murray Gell-Mann, talked about the exciting things going on in the field back in the '60s. But it wasn't all work, said Frautschi. "Fred would get us out of the smog to go hiking or camping. He loved the mountains and deserts. That's the way I like to remember Fred: a pathbreaking researcher of small particles and large oceans, a vigorous outdoor man, an honest and forthright friend."

Koonin, BS '72, who was an undergraduate physics major when he came to know Zachariasen, noted that "if Fred was a hero to his contemporaries, he was a demigod to the students." Later, as faculty colleagues, Koonin was impressed with "his perceptiveness and his frankness. Fred called 'em like he saw 'em, and he was usually right." Through their common Jason connection, "the true range of his intellectual interests began to emerge to me—oceanography, global change, and of course the particle physics that he grew up with." They had also gone "tanking" at Fort Knox with some fellow Jasons. "I think Fred could have made an alternative career as a tank commander."

Military history was an interest he shared with Peter Fay. Fay, professor of history, emeritus, at Caltech, claims that he "never saw the inside of Fred's office. I don't know where it was. I never met any of his students; I attended none of his seminars." Friendship between the Fays and the Zachariasens had developed accidentally out of the friendship of their children, and revolved around theater, good food and wine, visits to the Fays' house in France, a recent trip to Bhutan, and conversation. "We'd talk our heads off about things of compelling interest, and not about what we were doing because we didn't know, either of us, what the other was doing. . . . Fred was cultured; he read things and enjoyed things that had little or nothing to do with his professional work."

Daughters Kerry and Judy spoke of their family life and "perfect childhood"—the long dinner-table conversations, the trips to Europe ("before we could even talk"), the family camping, hiking, skiing, and rafting trips. "He gave Judy and me the most incredible lives," said Kerry, "filled with adventures, the thrill of learning, love of the outdoors, and a powerful family bond that's still holding us together." Judy added, "He valued education and instilled that in me to such an extent that I've hardly been able to get myself out of school my entire life. But he was sensible, too, and taught me to keep school in perspective . . . My father taught me the difference between problem sets and science, what classes in school are good for and what they aren't." Kerry spoke for them both when she said, "We have no mixed feelings about his passing. There's nothing we wish we had said, nothing we wish we hadn't said, no amends to make. We know he was crazy about us. He knew we were crazy about him."

Zachariasen was an avid outdoors photographer; a show of some of his slides closed the service. ☐ —*JD*

Letters

After reading the wonderful tribute to the late Professor Robert B. Leighton ("Other Octaves," *E&S*, Vol. LXI, No. 4, 1998), I did not know whether I should proclaim:

Mozart, thou are redeemèd!
or
Leighton, thou art redeemèd!

(The reason for the vacillation, viz.: the quotation: "Imagine the piano keys stand for the electromagnetic spectrum. We have one octave if we confine ourselves to the visual. You can imagine how dull Mozart would be if he had to stay in one octave." Bob referred not to Bach, nor Beethoven, nor Gluck, nor Rossini, nor Gershwin, but to MOZART!)

The background: During my last year at Caltech (1941–42), Bob, Mrs. Wouk, and I were guests at a dinner-musicale at the home of another graduate student. The musicale started with a Bach organ piece played on 78-rpm discs, with vacuum tube amplifiers (emphasis on the word "amplifiers").

When the host asked for requests, I said, "How about some Mozart?"

Bob then remarked, "How can you like Mozart? It's just tra-la-la, tra-la-la," as he hummed a melody from the opening of *Eine kleine Nachtmusik.*

Does anyone know when Bob had his change of heart and came to the opinion that (to paraphrase "Abou Ben Adhem"): "And lo! Mozart's name led all the rest"?

Victor Wouk
PhD '42

Faculty File

HONORS AND AWARDS

Professor of Electrical Engineering and Computer Science *Yaser Abu-Mostafa* has received the Kuwait State Award in Applied Science, for his pioneering work "on neural networks, learning from hints, and computational finance." The November 29 award ceremony was televised live in a number of countries, and a reception by the emir of Kuwait followed at the royal palace. Abu-Mostafa is the youngest person to have received this award since its establishment in 1979.

Caltech president and Nobel Laureate *David Baltimore*, who is also a professor of biology, and Crafoord Laureate *Seymour Benzer*, the Boswell Professor of Neuroscience, Emeritus, have received honorary Doctor of Science degrees from Cold Spring Harbor Laboratory (CSHL), which has just celebrated "its 109-year history of science education." The degrees were awarded on November 5 at the inaugural convocation of the CSHL Watson School of Biological Sciences. A private, nonprofit basic research and educational institution with programs focusing on cancer, neurobiology, and plant biology, as well as molecular and cellular biology, genetics, structural biology, and bioinformatics, CSHL is located in Cold Spring Harbor, New York. Baltimore and Benzer, both of whom are members of the National Academy of Sciences, were recognized for "their long associations with educational activities at the Laboratory."

Colin Camerer, the Axline Professor of Business Economics, has been elected a fellow of the Econometric Society, an international organization for "the advancement of economic theory in its relation to statistics and mathematics."

Professor of Geochemistry *Ken Farley* has been selected to receive the 2000 National Academy of Sciences Award for Initiatives in Research, which "recognizes innovative young scientists and encourages research likely to lead to new capabilities for human benefit." The award will be presented at a ceremony on May 1 in Washington, D.C.

William Goddard, the Ferkel Professor of Chemistry and Applied Physics, and his team of *Tahir Cagin*, staff member in chemistry, and *Yue Qi*, graduate student in materials science, have received the Foresight Institute's 1999 Feynman Prize for Theoretical Molecular Nanotechnology, "for their work in modeling the operation of molecular machine designs." The Feynman Prizes—one for theoretical work and one for experimental work—are awarded to "researchers whose recent work has most advanced the development of molecular nanotechnology." Goddard and his group operate out of Caltech's Materials and Process Simulation Center.

Robert Grubbs, the Atkins Professor of Chemistry, has been awarded the Franklin Institute's Benjamin Franklin Medal in Chemistry, for his "discovery of a method to significantly improve" the chemical reaction olefin metathesis. His work, the institute adds, has led to a broad range of new drugs, and improved materials for laboratory and commercial applications.

Professor of Civil Engineering and Applied Mechanics *Paul Jennings* has had his paper "Enduring Lessons and Opportunities Lost from the San Fernando Earthquake of February 9, 1971" selected by the board of directors of the Earthquake Engineering Research Institute (EERI) as the 1997 Outstanding *Earthquake Spectra* Paper. *Earthquake Spectra* is published by EERI, and the paper appeared in the February

HONORS AND AWARDS CONTINUED

1997 (Vol. 13, No. 1) issue. Formal recognition took place at EERI's 1999 annual meeting, which took place February 3–6 in San Diego. The EERI board "considers recognition of outstanding contributions to the field of earthquake engineering to be one of its most important responsibilities."

For his "outstanding innovatory research in the area of computational chemistry," Professor of Chemical Physics *Aron Kuppermann* has been selected by the Royal Society of Chemistry to be the S F Boys–A Rahman Lecturer.

Assistant Professor of Physics *Hideo Mabuchi* has been selected by MIT's *Technology Review* as one of the TR100, "100 young innovators who exemplify the spirit of innovation in science, technology, business and the arts." The list appeared in the magazine's November/December issue.

Professor of Astronomy *Anneila Sargent*, director of the Owens Valley Radio Observatory; *Edward Stone*, the Morrisroe Professor of Physics, vice president, and director of the Jet Propulsion Laboratory; and *Kip Thorne,* the Feynman Professor of Theoretical Physics, have been selected as Centennial Lecturers for the American Astronomical Society. Beginning in the year 2000 and continuing for two to three years, each lecturer will give two or three lectures in various locations around the country, with the goal of bringing exciting new developments in astronomy to the community at large.

Alexander Varshavsky, the Smits Professor of Cell Biology, and Avram Hershko, of the Technion—Israel Institute of Technology, are corecipients of the 1999 Gairdner Foundation International Award for "the discovery of the ubiquitin system of intracellular protein degradation and the crucial functions of this system in cellular regulation." The award ceremony took place in Toronto last October. Varshavsky has also been selected by the University of Chicago to receive the 2000 Shubitz Cancer Research Prize, and by the German Biochemical Society to receive the 2000 Hoppe-Seyler Award. ☐

BOOK PRIZES

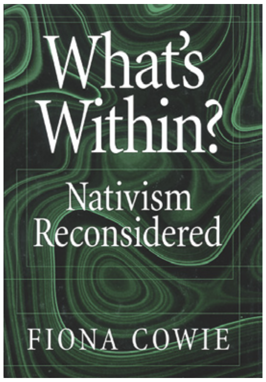
Four books written by faculty members in the Division of the Humanities and Social Sciences have recently received awards.

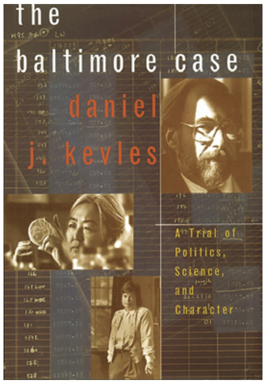
Associate Professor of Philosophy *Fiona Cowie* has been selected to receive the 1999 Gustave O. Arlt Award in the Humanities, for her book *What's Within? Nativism Reconsidered*. The award is given each year to "a young scholar who has written a book that represents an outstanding contribution to scholarship in the humanities."

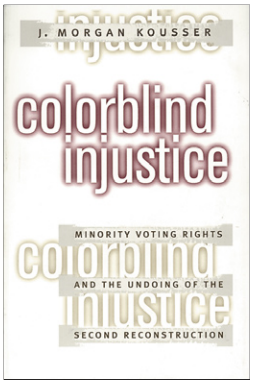
Daniel Kevles, the Koepfli Professor of the Humanities, has been awarded the History of Science Society's 1999 Watson Davis and Helen Miles Davis Prize for his book *The Baltimore Case*. The prize is awarded annually "for an outstanding book that promotes public understanding of the history of science."

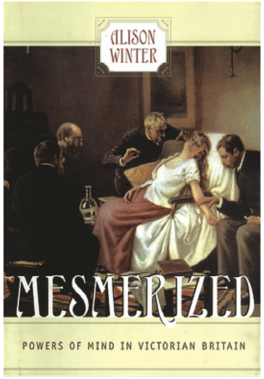
Professor of History and Social Science *Morgan Kousser* has received the 1999 Lillian Smith Book Award for his book *Colorblind Injustice: Minority Voting Rights and the Undoing of the Second Reconstruction*. Presented each year "to recognize and encourage outstanding writing about the American South," the Lillian Smith Book Award is "the region's oldest and best-known" book award.

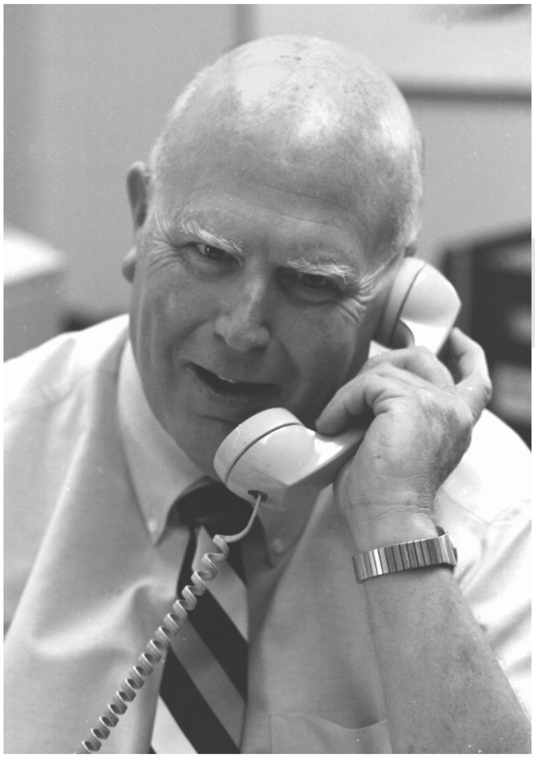
Associate Professor of History *Alison Winter* has won the North American Council on British Studies' 1999 British Council Prize for her book *Mesmerized: Powers of Mind in Victorian Britain*. The award is presented each year "for the best book published anywhere by a North American scholar in any aspect of British studies dealing with the nineteenth and twentieth centuries." ☐











PERPETUATING PERFORMING ARTS ON CAMPUS

Gerald Glen Willis (1938-1997) devoted 33 years to Caltech as a pioneer in bringing performing arts to campus. A native Californian and Phi Beta Kappa graduate of UCLA, Jerry worked in the fine arts production field for most of his life. As the public events manager of Beckman Auditorium, he helped to establish Caltech as an important venue for the performing arts by booking a wide range of interesting acts. Under Jerry's management, Beckman Auditorium hosted Patrick Stewart's highly acclaimed one-man production of *A Christmas Carol* before it appeared on stages on Broadway and in London. Such diverse acts as Mark Russell, Judy Collins, the Capitol Steps, John Houseman, and Ladysmith Black Mambazo were presented during his tenure. He also "unofficially" supervised many commencement activities, most notably Caltech's centennial commencement exercises in 1991, when President George Bush was the keynote speaker and attendance numbered more than 10,000 guests.

"Jerry was one of the founding fathers of presenting performing arts on university campuses," said Tom Lehman, a friend and colleague of Willis who retired as associate manager of technical operations in Public Events in 1998. "He was well known for helping developing artists, and he was a remarkable leader and friend." Preferring to maintain a low personal profile, Jerry concentrated on the interests of the audience and the artists.

In addition to his involvement in the Association of Performing Arts Presenters, Jerry was also the founder or cofounder of three other arts organizations: the Western Arts Alliance, the Southern California Area Arts Administrators, and the California Presenters.

In keeping with Jerry's passion for Beckman Auditorium and its influence, he left a bequest of approximately $240,000 to the Friends of Beckman Auditorium. The funds will be used to establish the Gerald Glen Willis Memorial Fund as an endowment to support his lifelong interest in audience development, outreach, and arts education at Caltech. Chris Harcourt, associate director of public events, remarked, "Jerry was committed to Caltech students and Caltech as an institution." In his eulogy for Jerry Willis, Michael Alexander, artistic director of Grand Performances at California Plaza in Los Angeles, observed, "Jerry was as important in his field as any of the Nobel laureates are in their fields."

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