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In This Issue

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Caltech News

ON THE COVER
Mind over matter? The cover image may look like an experiment in levitation, but it's actually sophomore Stephanie Schulze of the Caltech swimming and diving team practicing her forward somersault pike in February at the Alumni Pool. While the floating cloud and snow-capped mountains in the background are real, they were levitated into the image thanks to the wonders of Photoshop. For a look at the genuine powers of the human mind, turn to the facing page.

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Up Front

THE PRICE IS WRONG

After all the sniffing, swishing, and swirling is done, if you've ever wondered whether you could fool your dinner guests by filling an empty bottle of a premium Cabernet Sauvignon with that $3.99 special at the supermarket, here's the scientific skinny. In a study released earlier this year, a team of investigators, including Caltech associate professor of economics Antonio Rangel '93, determined that the stated price of wine directly affects how much people like it. When they drink cheap wine that they're told is expensive, they say they like it more than pricey wine that's masquerading as the cheap stuff.

Hundreds of past marketing studies have compared price to preference. What's new about this experiment is that Rangel and his colleagues put their subjects—20 Caltech undergraduates, graduate students, and postdocs—in a functional MRI machine that allowed them to observe brain activity during the wine tastings. While people might lie, the latest research suggests that brains don't. To track changes in mental activity, Rangel measured changes in the blood flow in the subjects' medial orbitofrontal cortex, a region of the brain believed to be involved in people's experience of pleasure. The study, Rangel says, showed that "prices, by themselves, affect activity in an area of the brain that is thought to encode the pleasure of an experience." Most people believe that the more they pay for something, the better it must be, and this study shows that, in the case of wine, at least, they seem to like "expensive" stuff more, regardless of its actual attributes.

Not much of a wine drinker himself, Antonio Rangel used wine in a study showing that perception of value heavily influences taste.

Like oenophiles at the opening of the Pinot Noir season, the public seemed to lap up Rangel's wine study, which made headlines and news reports around the world, and even sparked vigorous consumer debates over the Internet about wine pricing. Rangel says that following the report's January release, he was deluged with phone calls from reporters, a phenomenon that he had never experienced before. His reaction to the outpouring of public interest is restrained: "I don't have anything interesting to say about this."

It's not surprising that Rangel would be mum about the media onslaught, since he hasn't generally investigated such intoxicating subjects. Rangel, who grew up in Madrid and Mexico City, came to Caltech in 1989 with an interest in physics. But during his sophomore year, he took a class with John Ledyard, Davis Professor of Economics and Social Sciences, was immediately inspired, and became an economics major.

"I just fell in love with economics," he says. "The fact that you could think analytically about real–world problems was exciting."

Rangel got his PhD in economics from Harvard in 1998 and then became an assistant professor of economics at Stanford. He focused on theoretical studies of public policy issues such as how to inspire people to take into

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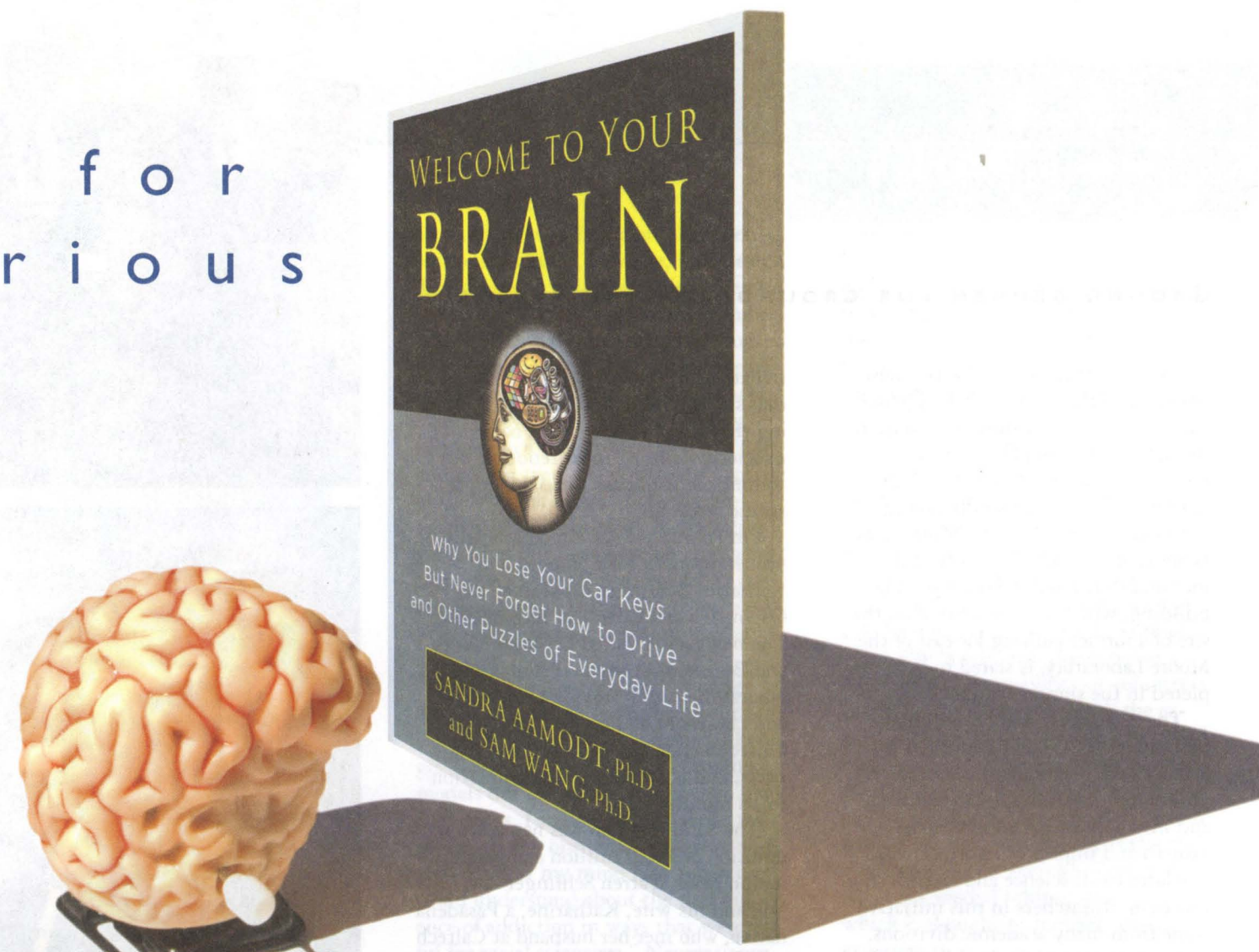
A Book for the Curious Brain

By Barbara Ellis



You know how it is—the person you meet at a party or on the plane starts up a conversation, and inevitably the subject turns to "So, what do you do?" For some academics—mathematicians or theoretical chemists, perhaps—the answer to that innocent question can be a conversation stopper. But for others, it can lead to a barrage of questions. This has always been the case for Sam Wang '86, associate professor of molecular biology in Princeton's Neuroscience Institute, and not just on planes or at parties. Wang studies the brain, and taxi drivers, barbers, even scientists from other disciplines, ply him with questions once they find out his field. "Is it true that alcohol kills brain cells?" "Does Sudoku improve my memory?" "Can blind people hear better than sighted people?" Wang heard so many variations on this theme that he finally decided "it would be fun to write a popular book for nonscientists that would bust some popular myths and tell all those curious people some real facts—a kind of user's manual for the brain."

That user's manual has now been published as *Welcome to Your Brain* by Bloomsbury USA (the same publisher whose British counterpart brought out an unassuming little series about a child-wizard named Harry Potter) and is subtitled *Why You Lose Your Car Keys But Never Forget How to Drive and Other Puzzles of Everyday Life*. Early reviews have been encouraging. "If all scientists could write like this," enthused science writer Sandra Blakeslee, a frequent contributor to the *New York Times*, "professional science writers would be out of a job." Wang wrote the book with Sandra Aamodt, the editor of *Nature Neuroscience*, who had been thinking of writing a book along the same lines when a mutual acquaintance brought them together.

When the New York Times ran a "teaser" from the book last fall on how to keep aging brains healthy, it became the most e-mailed article of the newspaper for almost a month.

It's "a book about the brain for people who own one and are interested in how it works, and how to use it better," Wang says. It has "practical advice for people in their 40s who are feeling a little less smart than they were; a parent worried about raising a child; and a businesswoman who wants to use her cell phone better." With its soft cover and almost-square shape reminiscent of the *For Dummies* series, and amusingly quirky illustrations by Lisa Haney, the book has the look and feel of a graphic novel. It's precisely that user-friendly aura that Sam hopes will make it accessible and appealing to a broad audience, including "high-school students in Illinois, an art gallery owner in Los Angeles, or a taxi driver in Boston." It's written in a humorous, direct style with references to popular culture, personal stories, and puzzles, and although it's scientifically accurate (every chapter was checked by at least two colleagues in the field), there are no daunting scientific terms, tables, diagrams, or references to papers. Readers who want to know more are directed to a website.

It's hard not to be drawn into this book, whose shaded boxes in three categories—"Practical tip," "Myth," and "Did you know?"—break up the text and carry eye-catching titles such as "Men learn to be gay," "Go see it on the mountain: The neuroscience of visions," and "Warning signs of a stroke—and what to do." (We'll leave it to you to decide which heading fits which category.) The manual's six sections, each dealing with a different aspect of the brain, encourage readers to leaf and dip. Wang and Aamodt hope at least some of them will start by taking the quiz that opens the book, to test what they already know, rightly or wrongly, about the brain. (We've included a sampling of the questions on page 8.) Even Techers shouldn't be dismayed if they score less than 100 percent. "Surprisingly, even neuroscientists don't do so well in that quiz," Sam says. "The people who do best are physicians, because they learn the most *useful* information about the brain during their medical training."

Naturally, Wang hopes the book will be a critical and popular success. But he was motivated to write it because "I spend my time in the lab looking for fundamental facts on brain function, and had been wondering how an ivory tower person like myself could do something that's useful for people." He points out that over the last 20 years, new techniques have greatly increased scientific understanding of how the brain functions. "We used to look at brain tissue in the dish, and now we're imaging brain function in the intact animal." The general public, however, hasn't had much opportunity to keep up with these advances, because many of them are published in journals that only neuroscientists tend to read. The information needs to be tweaked into something that's relevant to people.

"When I read scientific papers," Sam says, "I'm always thinking in the back of my mind how I could make what I'm reading into something to interest a lay person. For example, mice cannot appreciate Diet Coke because the sugar receptors in their tongues can't bind to the sugar substitute aspartame. A neuroscientist may not think this is a particularly interesting fact, but perhaps a lay person would." Of course, he adds, "I use different criteria when designing laboratory experiments or thinking up projects for my lab team."

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Left, Sam Wang in his Princeton office. Above, a toy wind-up brain toys with the idea of self-contemplation.

GROUND BROKEN FOR GROUNDBREAKING RESEARCH

Caltech broke ground for two new laboratories this winter, each of which will provide the Institute with state-of-the-art facilities to pursue work at the forefronts of science and technology. On December 7, a groundbreaking ceremony was held for the Walter and Leonore Annenberg Center for Information Science and Technology. The building, which will be located on the site of a former parking lot east of the Moore Laboratory, is slated to be completed in the summer of 2009.

The Annenberg Center will house participants of the IST (Information Science and Technology) initiative, a program of interdisciplinary research and instruction that addresses the growth and impact of information as it relates to all science and engineering practices; researchers in this initiative come from many academic divisions.

Construction of the building was made possible by a $25 million gift from the Annenberg Foundation. Walter H. Annenberg's widow, Leonore, the president and chairman of the foundation, was personally involved in the bequest, and in aesthetic aspects of the design process.

At the ceremony, her daughter, Wallis, vice president of the Foundation, said that as the scientists at IST are reinventing the very boundaries of science and the way it can improve lives, they deserve a research home "as collaborative and inclusive and revolutionary as the work itself." She noted that she is especially pleased to be helping that along because "as a nation, as a society, we . . . . must redouble our commitment to basic, undirected, scientific research."

On February 13, Caltech officially broke ground for the Warren and Katharine Schlinger Laboratory for Chemistry and Chemical Engineering. The new facility, sited between Noyes and Beckman Behavioral Biology laboratories, will provide laboratories and classroom and conference space for Caltech's chemists and chemical engineers, and is scheduled for completion in 18 months.

The Schlinger Lab was named in recognition of a $20 million campaign donation from Warren Schlinger '44, PhD '49, and his wife, Katharine, a Pasadena native, who met her husband at Caltech while working as a department secretary for chemical engineering.

Additional gifts have come from an array of supporters, including the Moore Foundation, the estate of former trustee Victor K. Atkins; trustee G. Patricia Beckman (daughter of Mabel and Arnold Beckman, PhD '28); Barbara J. Dickinson (widow of Richard Dickinson '52); The Ralph M. Parsons Foundation; the John Stauffer Charitable Trust; John W. Jones '41; Helen and Will Webster '49; Gregory P. Stone '74; and others.

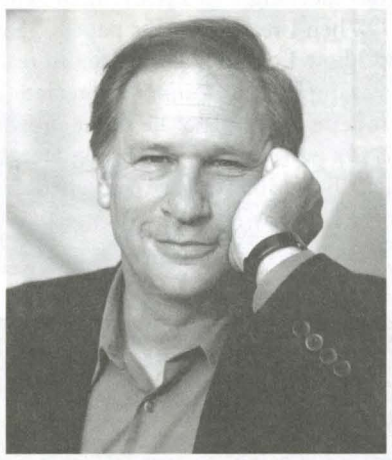
Top photo: Participants dig in at the Institute's official groundbreaking for the Walter and Leonore Annenberg Center for Information Science and Technology on December 7. From left are Moore Professor Shuki Bruck, Pasadena Mayor Bill Bogaard, Wallis Annenberg, Engineering and Applied Science Division Chair David Rutledge, Trustee Steve Onderdonk, architect Frederick Fisher, and President Jean-Lou Chameau. Above, on February 13, the first spades of earth were turned for the Warren and Katharine Schlinger Laboratory for Chemistry and Chemical Engineering, named for alumnus Warren Schlinger '44, PhD '49, and his wife, Katharine. From left are Chemistry and Chemical Engineering Division Chair David Tirrell, Katharine and Warren Schlinger, and President Chameau. Scheduled for completion next year, both laboratories have been designed with environmentally sustainable construction in mind, with the aim of achieving a Silver Rating under the Leadership in Energy and Environmental Design (LEED) Green Building Rating System for environmentally sustainable buildings.

NPR SCIENCE CORRESPONDENT TO SPEAK AT COMMENCEMENT

NPR science correspondent and ABC News Special Correspondent. Robert Krulwich will be the speaker at Caltech's 114th commencement on June 13. Krulwich, who has been called "the most inventive network reporter in television" by *TV Guide*, specializes in explaining the complexities of science, technology, and economics in a style that is clear, compelling, and entertaining.

He has explored the chemistry of global warming and the mysteries of RNA, created an Italian opera, *Ratto Interesso*, to explain how the Federal Reserve regulates interest rates, and pioneered the use of new animation on ABC's *Nightline* and *World News*, and on NPR's Internet site to explore cellular biology and subprime lending.

Krulwich regularly appears on ABC's *World News* and on NPR's *Morning Edition* and *All Things Considered*. He cohosts NPR's *Radio Lab*, a national



radio series that highlights new developments in science for people who are curious but not usually drawn to science shows.

"I like talking about ideas, and I especially like creating images that will keep those ideas in peoples' heads," he says.

Krulwich first joined NPR in 1978 and was the station's economics reporter until 1985, when he joined CBS News. Since 1994, Krulwich has been an ABC News correspondent, and he has collaborated on projects with the network's leading news personalities, including Barbara Walters, the late ABC News anchor Peter Jennings, and longtime *Nightline* host Ted Koppel, with whom he cohosted the eight-part prime-time series "Brave New World," which probed the "eight biggest questions facing humankind."

Krulwich is also a regular correspondent on the PBS investigative series *Frontline*, where he won an Alfred I. duPont-Columbia University Award for his coverage of campaign finance in the 1992 presidential campaign. He has also received a national Emmy Award for his investigation of privacy on the Internet, "High Stakes in Cyberspace," and a George Polk Award for a show on the savings and loan scandal. His ABC special on Barbie, a cultural history of perhaps the world's most celebrated doll, also won a national Emmy.

His other reporting awards include the Eleanor Nealon Extraordinary Communicator's Award from the National Cancer Institute in 2000 and a Science Journalism Award from the American Association for the Advancement of Science in 2001 for a *NOVA* special on the human genome. Most recently, he shared a 2007 Communication Award for TV/Radio reporting from the National Academies Keck Futures Initiative. Krulwich and his co-winners were honored for "imaginative use of radio to make science accessible to broad audiences."

Krulwich, who holds a BS from Oberlin College and a law degree from Columbia, lives in New York City with his wife, Tamar Lewin, a national reporter for the *New York Times*.

RECOGNITION

For an up-to-date list of awards and honors bestowed recently upon Caltech faculty and staff, go to http://today.caltech.edu/today/oncampus.tcl and scroll down to Honors and Awards in the right-hand column, as well as to the Archives link in that section.

Caltech professor Tirrell and four alumni named to NAE

David Tirrell, the McCollum-Corcoran Professor, professor of chemistry and chemical engineering, and chair of Caltech's Division of Chemistry and Chemical Engineering is one of 65 new members to be elected to the National Academy of Engineering (NAE).

Tirrell was cited by the academy for his "pioneering contributions to bioengineered materials and synthesis of novel artificial proteins." His research combines organic, biological, and materials chemistry to make new macromolecular systems with exquisite control of structure and function.

NAE membership is among the highest professional distinctions accorded to an engineer. It honors those who have made important contributions to engineering theory and practice, and those who have demonstrated unusual accomplishments in the pioneering of new and developing fields of technology.

Tirrell's research explores artificial proteins made by the expression of artificial genes in microbial cells. He uses biological cells to make proteins, just as nature does, but reprograms the cells to produce specific materials that are targeted toward important biomedical technologies. He is also investigating the creation of novel amino acids that are the building blocks for applications in biology, biotechnology, and medicine.

In addition to Tirrell, four Caltech alumni were named to the NAE: Michael Hunkapiller, PhD '74, general partner with Alloy Ventures Inc., Palo Alto ("for the invention and commercialization of DNA and protein sequencers and DNA synthesizers that have revolutionized comparative genetics and the mapping of the human genome"); Alex Livanos '70, PhD '75, president, Northrop Grumman Space Technology ("for contributions to the development and insertion of advanced semiconductor technology for commercial and government space systems"); David Luenberger '59, professor, department of management science and engineering, Stanford ("for contributions to control theory, optimization algorithms, and economic dynamics"); and Yanis C. Yortsos, PhD '79, dean, Viterbi School of Engineering, USC ("for fundamental advances in fluid flow, transport, and reactions in porous media applied to the recovery of subsurface resources").

Chemistry professor David Tirrell is Caltech's newest member of the National Academy of Engineering.

Founded in 1964, the NAE is an independent, nonprofit institution that advises the federal government on issues of science and technology policy while conducting studies to articulate the societal implications of rapid technological change. The NAE also initiates programs designed to encourage international cooperation between engineering societies, to improve the public's technological awareness and understanding, and to enhance the dialogue between scientists, engineers, and policy makers.

Dan Rather, former CBS *Evening News* anchor and cohost of *60 Minutes*, visited Caltech in February to talk with director of admissions Rick Bischoff about the admissions process at the Institute and other universities throughout the United States. His focus was the impact of preferential admissions policies that some schools utilize in areas such as legacy, benefactors, diversity, and sports. The two met in Caltech's historic chemistry library in the Gates Annex, which received a temporary futuristic makeover courtesy of a reflector and TV lights. The interview is slated to air in April on Rather's new show *Dan Rather Reports* on the cable channel HDNet.

Wine . . . from page 2

account the well-being of future generations. In 2001, however, his research direction took a different turn when he collaborated with Stanford economics professor Douglas Bernheim on studies involving addiction and decision–making processes. They developed a theory based on evidence from psychology, neuroscience, and clinical practice that addicts, far from being helpless captives of their addictions, actually understand their susceptibility to addictive substances but have developed ways of tuning out or misinterpreting the environmental signals that would normally help people recognize the costs of an addiction.

"I was always interested in understanding behavior and public policy in situations that weren't standard," Rangel says. "But the standard economic models did not apply to behaviors like addictions. I started to read about neuroscience. For one year, I just read and read. It blew my mind how much one could understand about the neuroscience of addiction in ways that were useful for social scientists." Neuroscience research could be used, for example, to improve public policy regarding addiction.

Rangel's interest in neuroscience coincided with the emergence of the field of neuroeconomics. About five years ago, social scientists began using brain-imaging techniques like MRIs to obtain visual data of how people make decisions. These scans literally show which parts of the brain are active when people are making economic choices, and scientists believe that as they learn more about the brain, they will be able to develop a neural blueprint of behavior that will have numerous economic, political, social, and even medical applications.

With the opening in 2002 of Caltech's Broad Center for the Biological Sciences and its sophisticated imaging facilities, the Institute became one of the leaders in neuroeconomics, and in 2006, Rangel departed Stanford for Caltech.

"Caltech has a shot over the next few decades to crack the problem of how the brain makes decisions," Rangel says. "Why do some people have self–control and others don't? Why can some people take addictive substances with no ill effects while others become trapped? These and other questions go to the core of who we are, and we now have tools to make significant steps. That's too beautiful not to be done."

Switching from theoretical to experimental economics has been "a huge change," says the Caltech professor. Previously accustomed to sitting alone in his office with a pencil and pad, he now works with a team of graduate students, postdocs, and technicians, and collaborates on experiments with several Caltech biologists.

Rangel, who drinks at most one glass of wine a week, says that the wine study reflects his interest in how the brain distinguishes between attraction and aversion. "We spend more money on products that we believe are higher quality," he says. "How much is driven by an object's characteristics, and how much just by our beliefs that it is superior?"

In the wine study, the 20 volunteers sipped wine that they thought were five kinds of Cabernet Sauvignon, ranging in price from $5 to $90. But they were actually only treated to three different brands—the $5 wine presented in both its cheap incarnation and disguised as a $45 brand, along with a $35 brand and a $90 bottle, also presented as a $10 variety. The majority of volunteers preferred the cheap wine over the expensive wine when they thought it had a higher price, but were less enamored of the expensive wine when told it had a price tag of $10. Scans of their brains while they were sipping the wines they said tasted better showed higher activity in the medial orbitofrontal cortex, which is thought to register positive experiences.

"Strictly speaking, all we know is that this area of the brain is more active when subjects believe that wine they are drinking is an expensive brand," Rangel says.

Although Rangel could conceivably parlay his research findings into a new career as a wine-industry consultant, he says he has no particular interest in marketing. Thus far, only one company has contacted him about his wine study and then only to request a copy of his paper.

Not surprisingly, Rangel says that he had no trouble rustling up volunteers for his wine study. Gathering subjects for an upcoming investigation may not prove so easy. "I want to do a study about pain," he says. The study will evaluate whether subjects getting a mild electric shock will say that they experience more pain if they are told that the shock is bigger than it actually is, and report feeling less pain if they are told that the shock is smaller than the one they are receiving. "There are applications here for pain management," Rangel says, "but what I'm really after is understanding the basic science of how we make decisions." Rangel says that there are strict protocols for conducting experiments involving electric shock, adding, "I put myself through every experiment first. I wouldn't make anyone else do what I wouldn't do."

Mike Rogers

Baker's Dozen with Anneila Sargent

"I often feel my life has been a series of fortunate accidents," says Anneila Sargent, Caltech's newly appointed vice president for student affairs. As a young girl with an aptitude for math and science, she says she was lucky to come of age at a time when her native country, Scotland, was busy creating new opportunities for young people in scientific and technical fields, and to have parents who encouraged her to excel. After earning her B.Sc. with honors in physics from the University of Edinburgh in 1963, she had the "good fortune" to come to America as a graduate student with her husband, Wal Sargent, who had been hired onto the astronomy faculty of UC San Diego, and to meet accomplished female scientists who encouraged her to persevere in her career. In 1966, Wal joined Caltech (today he is the Bowen Professor of Astronomy), and Anneila transferred her graduate studies to the Institute. She took a break to raise two daughters, then received her PhD in 1977 and joined Caltech's research faculty. More luck followed in the form of an opportunity to do pioneering research into the interstellar medium and star and planetary formation, which earned her an international reputation in the 1980s and 1990s, and saw her appointed associate director (1992–1996) and then director (1996–2007) of the Institute's Owens Valley Radio Observatory (OVRO), and in 2003 the founding director of CARMA (Combined Array for Research in Millimeter-wave Astronomy). She was named professor of astronomy in 1998 and the Rosen Professor in 2004.

Late last year, Sargent, who also served as president of the American Astronomical Society from 2000 to 2002, took on a new administrative challenge when she agreed to head up Caltech's student affairs office, whose diverse portfolio includes oversight of undergraduate and graduate studies, admissions, athletics, campus life, and a range of other offices related to student education and well-being. In this 13-question interview with Caltech News editor Heidi Aspaturian, Sargent talks about her new job, her life in science, and a variety of other topics, including Shakespeare's unjust portrait of Macbeth, and how serving on committees reminds her of Mary Queen of Scots.

You graduated from the University of Edinburgh in 1963 with a physics degree, which was rare for a young woman at that time. What motivated you, and what was that experience like?

The fact is, it was kind of cute in those days to be a woman in science in Scotland. I came of age in the post-Sputnik era when Scotland, like the United States, was putting tremendous emphasis on educating scientists. No one really cared at the time what gender you were. Obviously there were relatively few women in science fields: maybe four women out of 24 students in both my high-school physics and chemistry classes. But I never felt that anything stopped me from going into science. It's also an interesting fact that people from more modest backgrounds, as I was, find they have a more level playing field in the sciences. I may well have been good at humanities, but not as good as the doctor's daughter. And in fact my father, who worked in the local shipyard, thought it was wonderful that I did science well.

There was also the influence of teachers. I went to the largest high school in Scotland, and a number of graduates later became prominent in one way or another, including Gordon Brown, Britain's current prime minister. What was unusual at the time I went were the number of female teachers. Teaching is a highly respected profession in Scotland, and traditionally the upper-level positions were filled by men, but then came the Second World War. The men went off to fight, and many of the women who took over their jobs stayed in them, unmarried, after the war ended. Many of them had in fact lost their fiancés in the war. And so I was taught by a large number of these effective, clever, lively, independent women. Eventually, nearly all of them achieved a position with the curious name of "lady supervisor," which was essentially the equivalent of being a headmaster. So these were definitely early role models for me.

What led you to study physics at Edinburgh?

I started as a math major, and then I realized I wasn't any good at it. I've talked to quite a few people who have had the same experience. You do well up to a certain point, and then one day your brain just says, "I can't go any farther, I can't go there." Once I discovered that I was not the brilliant mathematician I thought I was, physics beckoned. For a while I thought about a career in nuclear physics, but I also took astrophysics and discovered that the field came naturally to me. Then I went to the Royal Greenwich Observatory as a summer astronomy student, and that was a great deal of fun. I also met Wal there, and by then I had started to think about a PhD. We were planning to get married, and he said "I'm going to teach in the States; why don't you plan to get a PhD there?" At one point, I also applied for a nuclear physics position in the British civil service that would have led to a PhD, but I didn't get it. Years later I met one of the men who had interviewed me for the job, and he told me, "I wanted to hire you, but the head of the lab said, 'No. If we hire her, she'll just get married and be of no use to us. Or, she won't get married and cause trouble in the lab.'" And that's how I didn't become a nuclear physicist.

But I didn't realize that this had been an issue at the time. In fact, I never felt it was an impediment to be a girl in science, until I started graduate work at UC San Diego, where Wal taught for two years before we came to Caltech. I was in a math class with two other women and the usual 20 or 25 males, and the professor just dumped on me, sneering, "What does the lady in our class think?" I had never encountered this attitude before. I was not intimidated by it, but I was certainly outraged.

I got quite an education in many ways at La Jolla. One of my teachers there was Maria Goeppert Mayer. She had won the Nobel Prize in Physics in 1963, and this was one of her first professorships! There was also Margaret Burbidge, an outstanding astronomer who couldn't be a professor of physics at UCSD because of nepotism

laws—her husband, Geoffrey, already had the appointment on the physics faculty. So Joe Mayer, who was Maria Mayer's husband and head of the chemistry department, came to the rescue and made her a professor of chemistry. It sounds outrageous in retrospect, but both of these women were quite good-natured about everything. I saw that they both had good research careers as well as fulfilling lives with families. For me, this was a wonderful background to draw on.

Your personal background is quintessentially Celtic—Scottish on your mother's side, Irish on your dad's. How do you relate to this heritage? Is it important to you?

I'm conscious of it every day. I think it's a wonderful heritage to have. I like to say I'm imbued with the self-righteous Puritan ethic on the Scots side, and a very well-honed sense of the ridiculous on the Irish side. So I find it easy to laugh at situations that others might find simply frustrating or infuriating. I also grew up Catholic in a militantly Protestant country, and that was a very good experience too. My father's perspective was so important here. He was a consummate Irishman, and he taught me how to interact with other people. The one piece of advice he repeated most frequently and which I have really taken to heart is, "You have to see the other fellow's point of view." In fact my father would not send me to a parochial school. He sent me to a public school, where nearly all my teachers and classmates were Presbyterian, and that experience taught me a lot about life. Encountering sexism was nothing to me, compared with having to deal with that kind of environment. Without going into too much detail, it's the kind of background that makes you very aware of who and what are important to you, and if people dismiss you for various reasons, it actually toughens you up.

Are there Scottish traditions that you still observe?

Brussels sprouts! We always have them at Christmas. And despite my Catholic background, I think the influence of Scotland's Puritan ethic on my life has been very strong. My daughters certainly think so, and I've talked about it with friends who grew up in Scotland. The single piece of advice we all remember hearing from our mothers—and I guess my daughters heard it from me—is, whatever is bothering you, get over it and get on with it. This is wonderful advice, if you can follow it.

How do you like to spend your free time?

Wal and I like to go to the opera and to concerts. We also like to hike, particularly in the northwest of Scotland. Wal was already hiking there when he was young. In those days, women were not actually encouraged to go along, so he was really quite surprised when I said I'd like to hike too! We love to travel—Edinburgh and Florence are two of our favorite cities, although the food is definitely better in Italy.

I love to read, and I read a lot of detective novels. I'm addicted to the mysteries of Ian Rankin, who writes about Edinburgh in a very literary way. I like Ian McEwan—particularly *Saturday* and *Atonement.* One of my favorite books ever is *King Hereafter*, a book about Macbeth by the author Dorothy Dunnett. Whenever I read it, I weep. I like James Joyce's *Ulysses* and *Portrait of the Artist as a Young Man*—that's the Irish side of me. While I was working on my thesis, I read masses of books about Japan and by Japanese authors, especially Mishima. I suppose the suicidal aspect had a certain appeal.

You weep over Macbeth! What about the popular image of him as a tyrant and usurper?

Ah, no, everyone in Scotland knows that's wrong. Macbeth actually was a very good king. The problem with his reputation was created by James VI of Scotland, who became James I of England while Shakespeare was writing his plays. James believed very strongly in the divine right of kings, and wanted to trace his own hereditary line back to Duncan and Duncan's son, Malcolm. So Shakespeare, who of course as a court playwright had to please his patron, made Macbeth the very wicked assassin of Duncan. The historical facts suggest that Macbeth either killed Duncan or wounded him very seriously in hand-to-hand single combat, and that Macbeth himself was killed the same way by Duncan's son, Malcolm.

How about other historic figures or role models whom you admire?

Here's my Scottish side coming out again. There's Robert the Bruce, the great 12th-century king who put an end to the English occupation of Scotland. And, of course, possibly because of my religious background, Mary Stuart—Mary Queen of Scots. What a fascinating woman—way, way better than Elizabeth Tudor [her cousin, the queen of England, who had her executed in 1587]. A few years ago, I saw a revival of *Maria Stuart*, the 18th-century play by the German writer Schiller. It was an amazing portrayal of these two very different women, and I have to say I saw interesting parallels to people I have known on committees and how they handle things. There's Elizabeth, the savvy politician, never quite taking the blame and always passing the buck. Mary Stuart wasn't the greatest of managers, but she was never afraid to show her fallible human side. I've met people on committees who simply never can be wrong, and it's just plain not helpful.

In your career as an astronomer, is there one piece of research that you have found most rewarding?

I think it was the work that Steve Beckwith [then at Cornell, now vice president for research and graduate studies for the University of California system] and I collaborated on in the mid-1980s to '90s. This was when we found that the immense disks of gas and dust around T-Tauri stars might be moving in accord with Kepler's laws of planetary motion, suggesting that we were seeing the very early stages of solar-system formation around these stars. This work was so much fun, because Steve and I complemented each other very well, and because we were doing something that no one else was doing at the time. There were hardly any appropriate telescopes for these investigations in those days, and it took us a long time to build up our data. I can remember to the day when we got our second set of results on the star HL Tau. Our first results had been okay, but when Steve and I proposed to make further observations, everybody told us that we probably wouldn't see anything useful. In actual fact, our second set of observations was better than our first, and while they were improved upon later, our work really provided the first indication that you could measure velocities in the clouds of dust and gas around these stars and actually observe what might be the very first phase of planetary-system formation. That was terribly exciting. And I think we did make a real difference to the field.

Having successfully combined a scientific career with raising a family, do you have advice for young women in science today who want to follow your example?

Don't think about it; just do it. Or as my mother would say, Get over it and get on with it. I really don't see that there's any other way. I'm not saying that women don't face different issues in science than men—they do, and I frequently argue that point when I serve on committees for hires. Men on the fast track are often extremely assertive and willing to take big risks when they're young. From my limited observations, it seems to me that many women prefer to establish solid research credentials

I like to say I'm imbued with the self-righteous Puritan ethic on my Scots side, and a very well-honed sense of the ridiculous on my Irish side.

first, and then they become more willing to assert themselves and take those riskier steps. And it is certainly not easy, balancing a commitment to family with the demands of being a scientist. If I had my career to do over again, I think I might have had my children earlier, rather than dropping out of graduate school as I did after I got my Caltech master's degree in 1967. But my timing when I decided to return turned out to be very fortunate because I got in on the ground floor of this new millimeter-wave research into the interstellar medium, a field that hardly existed at the time I left. I was just very lucky in that regard. I often say my whole life has been a series of fortunate accidents, including this new job.

That's right. You told the California Tech that you never even applied for it.

I didn't! [Professor of Chemical Engineering] Julie Kornfield, who was heading up the search committee, got in touch with me and said, "You've been at the Institute for such a long time and have probably seen a lot of changes, and we'd like to have you come talk to us about them." I said sure, and I went and I had a blast. They asked me about this and that, and I gave them my opinions, and then they thanked me and I left. I really hadn't a clue that this was in some sense an interview, and when Jean-Lou [Chameau] later called to offer me the job, I was shocked.

I did understand that the administration desired someone with a strong management background, and I certainly do have that because of my directorship of OVRO and CARMA. But I've also been busy for the last 10 years teaching and doing research in astronomy, overseeing the building of telescopes, and serving on committees. So the student affairs area is very new to me. But in management, there are certain basic skills that apply across the board. And working with students seemed a great opportunity. It's rejuvenating!

Continued on page 9 . . .

Brain . . . from page 3

Wang grew up in Riverside, California, the sociable, outgoing son of Chinese-born parents who settled there in the 1960s. When he came to Caltech in 1982, he quickly immersed himself in student life. "I was the social cochair of Ruddock, the campus social chair, and the business manager for the *little t*," he says. "Caltech has an exceptional playing field when it comes to being social—it's a very accessible place, 'friendly' being the operative word, and a lot of activities are available to the individual person if they want to take advantage of it. It's like a liberal-arts college, but at the same time, it's a great tech college as well. It's the only place like that that I'm aware of."

Wang majored in physics, but was drawn to neuroscience after taking Professor of Physics Jerry Pine's course on the biophysics of the nervous system in his sophomore year, and a neurobiology course taught by biologists David Van Essen (now at Washington University in St. Louis) and Mark Tanouye (now at UC Berkeley) in his final year. He went on to graduate school in the neurosciences at Stanford, where he conducted research into calcium-signaling among nerve cells for his doctorate.

Although other physicists, among them Caltech's renowned practitioners Max Delbrück and Seymour Benzer, moved into biological research with great success, it's not an easy transition. Surrounded by fellow graduate students whose backgrounds in biology were far more extensive than his, Sam initially spent much of his time in the library, putting himself through a crash course in the field. One of the greatest challenges, he says, was replacing some of the intuitive approaches he had come to rely on in physics with different modes of thought. Another was the large mass of knowledge that had to be acquired. "The field was a zoo—literally," he says. Researchers have "accumulated a large body of information, but they're still trying to find out the organizing principles behind it."

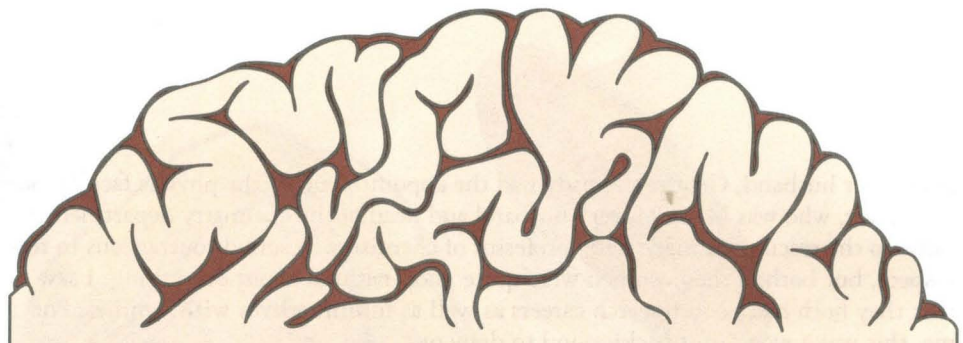
Wang went on to postdoctoral research at Duke University in 1994, but after a year he decided to try something new. He applied for and was awarded a Congressional Science Fellowship by the American Association for the Advancement of Science. It gave him a year off his studies to work in Washington, first as a legislative assistant for Texas Democrat Lloyd Doggett in the House of Representatives, whom he advised on energy and environmental issues, then as a legislative fellow for Senator Ted Kennedy. "Getting to see how Congress functioned was a fantastic experience," he recalls. While working for Kennedy, he wrote speeches for the senator and worked on science and education policy. At the end of the year, he was invited to apply for a position at the Clinton White House to work on education policy, but says that his break from lab work helped him realize that his first love really was scientific research. He doesn't rule out a science policy position in his future, though.

After finishing out his postdoc at Duke, Wang spent two years at Bell Labs in New Jersey, before joining Princeton's department of molecular biology as an assistant professor in 2000 (he was named associate professor in 2006). One of the things his research group investigates is the way in which brain circuits process and store information. The focus is mainly on the cerebellum, the large region at the back of the brain that integrates sensory information to guide movement and cognition. "Our current project, which is very exciting to me, is to understand how cerebellar circuits can encode—and decode—real-world events in a useful way to be processed by the rest of the brain," he says.

As a Caltech undergraduate, Wang thought about pursuing a double major in physics and literature (as his classmate Sandra Tsing Loh '83 actually did), and today he continues to emphasize to his students the importance of lively, lucid writing. "Verbal expression is an extremely important skill for any working scientist, and it's something many don't do well," he feels. His model for excellence in science writing is one of his own teachers, Richard Feynman. "In popular books about science, it's very hard to get things across clearly and still be faithful to the science. Feynman could do this." One of his fondest memories of Caltech is attending Feynman's special evening lecture course, "Physics X," which the irreverent Nobel laureate held weekly for undergraduates. "Feynman would walk into a room at a prearranged time and make himself available to answer any question anyone had, then riff off about it. He was remarkable in his clarity; we felt we understood everything he told us." Then Sam adds, "But later, we found we didn't." (This phenomenon, experienced by many, even has a name: the Feynman Effect.)

Wang's coauthor, Sandra Aamodt, shares his passion for precision and polish in writing. Together, they spent about three years (on and off) reading through hundreds of scientific papers, writing, and passing their individual contributions back and forth until both felt they had got it right. But progress was slow because Aamodt lives on the outskirts of Davis, California, and Wang in Princeton, so in April 2006 they obtained a writer's residency grant from the Rockefeller Foundation that allowed them to spend a very productive month together at the foundation's study center in

In 1985 Sam Wang (highlighted) took part in a Ruddock House stunt for the 1985 *Big T* that could probably not be repeated now without an aerial assault unit appearing overhead. During the morning rush hour, a group of juniors calling themselves "The House Wasted Union" stopped the traffic heading downtown on the 110 freeway expressly for this photo. Wang recalls that the other drivers were so shocked they didn't even honk their horns.



Quiz: How Well Do You Know Your Brain?

1. When are the last neurons born in your brain?
   a) Before birth
   b) The age of six
   c) Between the ages of 18 and 23
   d) In old age

2. Men and women have inborn differences in
   a) Spatial reasoning
   b) Strategies for navigation
   c) Ability to leave the toilet seat down for someone else
   d) Both a and b
   e) Both b and c

3. Which of the following is not likely to improve brain functioning in old age?
   a) Eating fish with omega-3 fatty acids
   b) Getting regular exercise
   c) Drinking one or two glasses of red wine per day
   d) Drinking a whole bottle of red wine per day

4. Which of the following activities is likely to improve performance in school?
   a) Listening to classical music while you sleep
   b) Listening to classical music while you study
   c) Learning to play a musical instrument as a child
   d) Taking frequent breaks from studying to play video games
   e) Both c and d

5. Which of the following strategies is the best one for overcoming jet lag?
   a) Taking melatonin the night after you arrive at your destination
   b) Avoiding daylight for several days
   c) Getting sunlight in the afternoon at your destination
   d) Sleeping with the lights on

6. Blind people are better than sighted people at which of the following?
   a) Understanding words
   b) Hearing sounds
   c) Remembering stories
   d) Training dogs

7. Which depiction of neurological damage is the least realistic?
   a) Guy Pearce's character Leonard in *Memento*
   b) Drew Barrymore in *50 First Dates*
   c) Dora the Fish in *Finding Nemo*
   d) John Nash in *A Beautiful Mind*

8. What fraction of your brain do you use?
   a) 10%
   b) 5% when you are sleeping, 20% when you are awake
   c) 100%
   d) Varies according to intelligence

Answers are provided at the end of the article.

Sandra Aamodt, left, and Sam Wang, right, pose on the beautiful grounds of the Rockefeller Foundation's Bellagio Center, seemingly unfazed by the gruesome statuary between them.

Bellagio, Italy. Inspired by the romantic setting on the shores of Lake Como, Sam proposed to his girlfriend, Becca Moss, who had joined him for the stay. The two married that September and now have a daughter, Vita, in whose developing brain Sam takes a keen parental and professional interest. He's not making her listen to Mozart to make her smarter, one of the myths debunked in the book, but will encourage her to learn a musical instrument when she gets older, as this improves spatial reasoning skills. "The important thing, however, is to give babies a lot of experiences," he adds.

This spring Wang will embark on a five-city book tour, with accompanying interviews arranged by his publishers. He has already had some media experience: in the fall of 2004, he appeared on Fox News to talk about a computer program—or, more precisely, an electoral college meta-analysis—that he'd written to provide a snapshot of the dozens of state polls available at any given moment. On each day, it gave a view of who would win the presidential election if it was held that day. "Fox is very oriented toward a right-wing point of view that is far from my own, so for me it was a bit like descending into the heart of darkness. I armed myself with a power tie and talking points. It was close to Halloween, and in the ready room were three jack-o'-lanterns, painted and carved to resemble John Kerry, George W. Bush, and Ann Coulter. Truly frightening! When I went on air, I talked about polls and probabilities for about a minute, then I was cut short to make way for a story about the country going on a level-orange terror alert. I'm not sure how much the viewers learned, but it was certainly an education for me."

Sam's electoral prediction based on state-by-state exit polls, that Bush would receive 286 electoral votes, and Kerry 252, was the actual result. The *Wall Street Journal* duly took note, writing in an article that appeared shortly after the election, "Sam Wang and his computer look pretty smart." But this wasn't what he was predicting on his website on election day, because he felt that he needed to add a correction to take into account undecided voters who might break for the challenger, something that had often happened in other presidential elections. "Thus my big headline was a narrow Kerry victory," he admits. "It was a lesson to me to not get too clever."

The 2008 presidential race gives Wang a new laboratory for experimenting with his predictive electoral models, but this time around, he is thinking about how to automate the process. His first effort was very labor-intensive; the polling data had to be harvested from news sources and updated each day. "Come to think of it," he says, "Caltech students and alumni are an ideal source of data-crunching talent, so if any fans are out there reading this, contact me at election.princeton.edu."

Sam is the first to admit that coming to grips with the political mind-set is likely to stump even the most dedicated neuroscientists for quite some time. In the meantime, there are plenty of slightly less daunting topics to consider for future books, such as *Welcome to your Child's Brain* and *Welcome to Your Pet's Brain*. Would such a series be as successful as the *For Dummies* collection? Early indications are favorable. When the *New York Times* ran a "teaser" from *Welcome to Your Brain* on the Op-Ed page last fall on how to keep aging brains healthy, it became the most e-mailed article of the entire newspaper for almost a month. Its kernel of wisdom was precisely the kind of thing Wang thinks people should know, but generally don't—that the best way to improve brain function is not Sudoku, not crossword puzzles, not computer games. It's simple physical exercise, which by increasing the supply of oxygen and glucose to the brain's nerve cells, brightens up gray matter far more effectively than mind-training exercises.

So put *Caltech News* down for a while and go for a walk.

Answers for the quiz: 1) d, 2) d, 3) d, 4) e, 5) c, 6) c, 7) b, 8) c

Sargent . . . from page 7

Do you come to the job with a particular set of priorities?

In some respects, I think things are going fine. In others, a committee chaired by Melany Hunt, one of our two new vice provosts, recently completed a report on the quality of Caltech student life that has identified some areas of concern. We want to take a close look at those issues while also keeping a close eye on our budgets. In Scotland we always say, you have to cut your coat according to your cloth, and so I really do need to become well acquainted with my budgets before I begin to do very much else. I want to proceed carefully. I don't want to make decisions that will have long-term repercussions without a lot of thought.

Anneila Sargent signs the final beam in the topping out ceremony earlier this year for the Cahill Center for Astronomy and Astrophysics, currently under construction on campus.

You've said that you think students could be happier here, and that you've been distressed that they often seem to lose what you describe as their initial passion for science.

That's true, and I am not the only faculty member who thinks like this. It really came home to me when I gave a talk at Frosh Camp a few years ago. I found it an especially moving experience because it was just after 9/11, and here I was with all these hopeful kids and realizing that their parents had just put them on airplanes in September to come here. I gave my little pep talk about astronomy, and afterward they asked so many enthusiastic questions! And I found myself thinking, "Why don't they ask questions like this in my class? Where does the enthusiasm go?" Well, for one thing, they're all so tired all the time. They work so hard, and many of them routinely take too many courses. I really believe that if they spent more of their school year working with a professor in a lab or doing something more creative than just taking classes, it would be extremely beneficial. Part of being a scientist is that there are always opportunities to learn something completely different.

I had some of these unusual experiences as a young person. The summer before I started college, I worked at the Kirkcaldy branch of the British department store Marks & Spencer. I worked on the lingerie counter, which included what we called the "bloomers counter" with huge piles of cotton knickers. These large farmwives would come in from the countryside, pick up these vast cotton underthings, look at me, and say, "Well, lassie, can you bile them?" They wanted to boil them before wearing them to be sure they were clean. And they wanted to be sure they wouldn't shrink or be ruined by this necessity for cleanliness. It was absolutely hilarious, but it was also an education for me.

So, are you saying . . .

That selling undergarments is invaluable preparation for life? No. I actually had a much more lasting life experience working one summer as a temporary teacher of math in a middle school in a truly rough working-class area—like teaching in the projects here. It was shocking to me to see how their circumstances already constrained the futures of these kids. Education meant very little to a lot of them because already the doors were closed. I, a university student, was as foreign to them as if I had come from another country. In fact they asked me if I was "English." It was certainly a lesson for me in what a privilege it is to be educated. I've never taken it for granted again. Life is full of learning opportunities if you are open to them.

I'd like to think we are preparing Caltech students to make the most of every opportunity as well as creating new possibilities for them. I'm looking forward to working with many others on campus to make that happen. I think it is great that our new vice provosts—Melany and Steve Mayo—have offices just down the hall from mine and that there will be many opportunities for interaction and collaboration between us. I do feel that the Student Affairs office has grown a little isolated from the rest of Caltech over the past few years, and one of my main goals is to bring it back into the mainstream of campus life. The Institute is so small that there's no reason to have these stovepipe divisions among different areas of campus. Our interactions with and on behalf of the students should bring together the academic side as well as the life side. These areas can all be integrated into our thinking about student affairs. And that's one thing that I think would help very much.

The Sun Also Catalyzes

By Michael Rogers

Tucked away in a cluttered Caltech chemistry lab filled with expensive, sophisticated equipment sits an ordinary $200 desktop printer. No paper ever passes through this printer and it's always out of ink, but it may hold a key to solving the world's energy crisis.

A little more than 1,000 miles northeast of Pasadena, a similar office printer is ensconced in a lab on the Fort Collins campus of Colorado State University. Both labs are run by Caltech alumni who think that the energy from the sun offers the best alternative to fossil fuels, with more potential than any other renewable energy resource. And they're both betting that their relatively low-tech inkjet printers could play a big role in deriving clean-burning fuels from the sun.

The scientists are Nate Lewis '77, MS '77, Argyros Professor and professor of chemistry at Caltech, and Bruce Parkinson, PhD '78, professor of chemistry at Colorado State. Although the two were only casual acquaintances in their Institute days, Parkinson's best friend was fellow graduate student Kent Mann, PhD '77, who recruited Lewis for assistance on a couple of solar energy experiments and was instrumental in turning Lewis's focus from physics to solar photochemistry.

At Caltech, both Lewis and Parkinson got training in electrochemistry, a discipline that is useful in the development of solar cells. In electrochemistry, energy can be converted when an electrode—typically a metal or semiconductor such as silicon—comes in contact with a solution of chemicals dissolved in water. After graduation, Lewis and Parkinson went their separate ways. Lewis went on to graduate school at MIT, joined the Stanford faculty in 1981, and then returned to Caltech as a professor in 1988. Parkinson conducted research in government and industry labs for several years before going to Colorado State in 1991.

For about 30 years, both Lewis and Parkinson have been involved in basic research on photoelectrochemistry, or "wet" solar cell technology, investigating the electrical energy that is produced when light shines on a semiconductor in a solution, and its application to solar energy conversion. In the past few years they have found themselves converging on what Lewis likes to laconically call "a large climate problem." He's referring of course to the planetary changes caused by humans' near-insatiable consumption and burning of fossil fuels. As Lewis wrote in a recent issue of Caltech's *Engineering & Science* magazine, "With population and GDP growth conspiring together, we can expect a tripling of energy demand by 2050," which will lead to more CO_2 pumped into the atmosphere, effecting even more changes than we see now. Without immediate action, he says bluntly, the world is headed for the biggest uncontrolled experiment humans have ever done. "The CO_2 we produce over the next 40 years, and its associated effects, will last for a timescale comparable to modern human history. Within the next 20 years, we either solve this problem or the world will never be the same."

Caltech alumni and solar research colleagues Nate Lewis (at left) and Bruce Parkinson got together recently in Caltech's Beckman Institute courtyard during a National Science Foundation site visit. Lewis adapted the standard inkjet printer at top to print out metal oxides after reading about Parkinson's novel method to search for a way to produce solar energy.

Both Lewis and Parkinson are convinced that solar energy offers the best hope both for resolving civilization's excessive reliance on fossil fuels and for averting a looming environmental catastrophe. "In one hour, more energy shines on the earth than all the energy consumed by humans in one year," Lewis says. But there's a big problem. "There's plenty of sunlight, but you have to be able to capture, store, and distribute its energy to people when and where they want it. Just to make electricity, without the ability to store and transport it, doesn't solve the problem. We don't have the technology that can capture solar energy at low enough cost to make it economical at scale compared with fossil fuels."

Many experts believe that one key to efficiently harnessing solar energy is to find an economical way of using sunlight to break up water molecules into their constituent oxygen and hydrogen atoms, so that the energy can be recovered from hydrogen when needed. This was a view that began to take shape when Parkinson and Lewis were at Caltech. In 1975, two Japanese scientists showed that ultraviolet light illuminating titanium oxide electrodes splits water into oxygen and hydrogen. Titanium oxide is a metal oxide that is the primary ingredient in white paint, so the fact that such a common material could break up water was big news. Since that time, says Parkinson, "Efficient and inexpensive production of hydrogen from water and sunlight has been the holy grail of photoelectrochemistry."

"The CO_2 we produce over the next 40 years, and its associated effects, will last for a timescale comparable to modern human history. Within the next 20 years, we either solve this problem or the world will never be the same."

Parkinson recalls that the Japanese breakthrough "had an impact on all the Caltech chemists on the third floor of Noyes. It probably had some influence on my choosing to do a postdoc in semiconductor photoelectrochemistry." Lewis says that the Arab oil embargoes of the 1970s were also a factor. "There was an energy crisis at the time, and solar research was the thing to do," he says. During his senior year, he was part of a Caltech team led by Harry Gray, the Beckman Professor of Chemistry, and Kent Mann that discovered a metal complex with hydrogen-producing properties similar to titanium oxide. "The compounds used visible light, but could not complete the water-splitting cycle robustly," Lewis says. "TiO_2 is robust, but uses ultraviolet light."

"There's not much power in ultraviolet light," Parkinson says. "Only a few percent of the photons emitted by the sun in this portion of the spectrum get through the atmosphere." (It's for this same reason that ultraviolet astronomical observatories are all space-based, where they can operate above the earth's atmosphere.) Progress toward finding a viable successor to the first generation of metal oxides has been slow. Those that have been shown to work are "not efficient enough or don't last long enough," Lewis says.

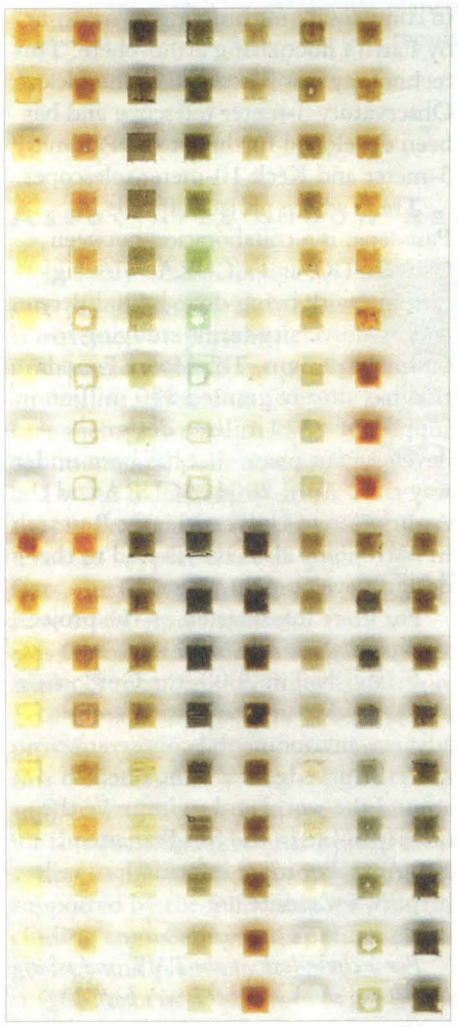
For a metal oxide to work, it needs to meet several criteria, Lewis says. Ideally, it should be fairly abundant in nature, and able to absorb solar radiation across a wide portion of the electromagnetic spectrum so as to maximize the use of sunlight. It also

has to be stable. Some compounds can split water across several wavelength ranges, says Lewis, but they essentially self-destruct in the process. (Sun-kissed silicon, for example, no sooner separates water into hydrogen and oxygen than it begins to corrode in the presence of the oxygen that's released and breaks down ignominiously into sand.) Third, the electrons in the metal oxide have to be arranged in a suitable configuration for water to split into hydrogen and oxygen.

Parkinson says that while any viable candidate will most likely consist of several metals, there's not enough theoretical knowledge to confidently determine which combinations of metals possess the requisite properties to perform efficient photoelectrolysis of water. So actual trial-and-error testing is needed to identify the best candidates.

For years, Lewis, Parkinson, and others have been studying metal oxides, using time-consuming methods that basically have involved analyzing one compound at a time. A couple of years ago, however, rapidly rising energy prices coupled with the looming environmental crisis made it clear that they had to find a way to speed up their investigations. With fuel consumption reaching unprecedented levels throughout the world, and signs of significant climate change appearing worldwide, even the most ardent cheerleaders for cheap oil and the most vocal global warming skeptics had begun to alter their views. "This was no longer just intellectual fun," Parkinson says. "We needed to find a way to make hydrogen cheaply."

Four years ago, Parkinson was attending a conference when he heard a research chemist talk about how he had used a standard inkjet printer to spew out different combinations of chemical compounds to then test for catalytic properties. He realized that he could use the same procedure to screen metal oxides for their suitability as solar energy photocatalysts. Part of his idea was to empty ink cartridges and load them with different combinations of chemicals to create different metal oxide compounds.



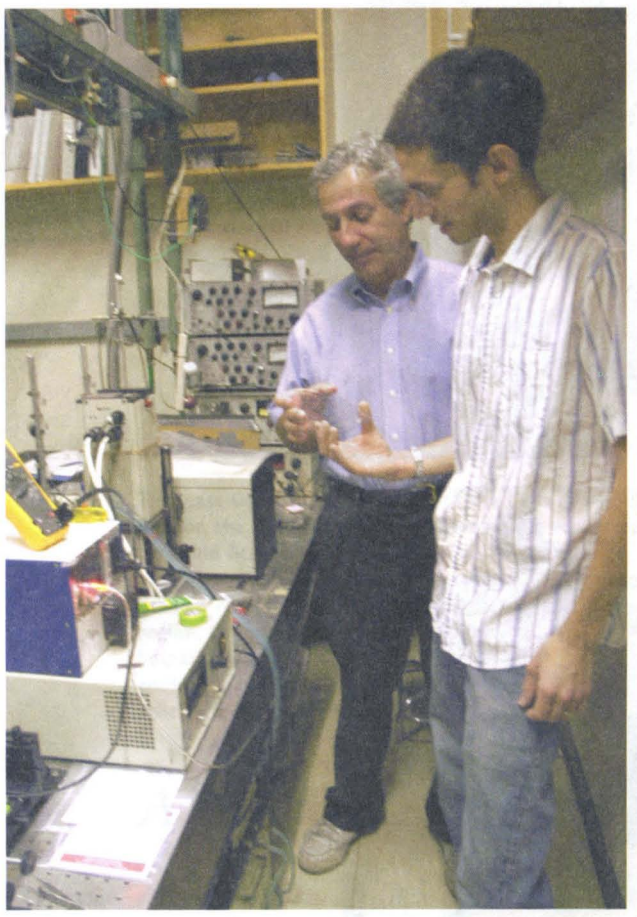
This glass plate from the Lewis lab is printed with different metal oxides that can then be evaluated for their ability to split water and produce energy when irradiated.

Back in his Colorado lab, he and his graduate student Mike Woodhouse built a system using an inkjet printer in which they substituted dissolved metals for ink. They modified the printer to accept thin glass plates rather than paper, and programmed it to print out different combinations of the metals on the plates. Heating the printed plates in a furnace for two hours at 500°C converted the metal salts into metal oxides, after which the plates were submerged in a solution, while a laser, serving as a stand-in for the sun, irradiated the material. By checking the plates with an amplifier to measure whether any current was produced by each compound, they could determine whether water molecules were being split and energy was being stored.

"It was extremely simple and easy," Parkinson says. In 2005, he and Woodhouse described the process in a paper published in the journal *Chemistry of Materials*.

When Lewis read about Parkinson's procedure, he called him up and asked if he could get more information so he could develop his own system. "I interact with Bruce frequently," Lewis says. "He is always very collegial and helpful in assisting people to advance the science of this area." So, in the summer of 2006, he sent one of his graduate students, Jordan Katz, and an undergraduate, Todd Gingrich, to visit Parkinson and find out how his system worked.

"Bruce shared everything that he did with us and helped us with an initial setup method, which was great," Lewis says. While still in the testing phase, "Bruce's work helped legitimize screening as something one can do and actually get funded for, instead of just being a 'fishing expedition,' which it still partly is but hopefully can be done intelligently to find new materials."



Nate Lewis and Jordan Katz, PhD '08, study one of the glass plates (shown in closeup, below left) that are evaluated in the apparatus on the table to determine which metal oxides split water to produce energy.

Once Katz and Gingrich came back from Colorado, they started building their own metal oxide analyzer, and had one up and running by the end of the summer of 2006. They spent much of the next year modifying some of Parkinson's design features, including adding a method to analyze voltage, which makes it possible to obtain precise measurements of the electrons generated by the material. While it registers the presence of current when water is split, Parkinson's technique is not designed to detect charges below this threshold.

"Knowing the voltage is important because that figure tells us just how close we are to the needed number," Lewis says. "It takes 1.23 volts of potential to split water." If we only get 1.2 volts, says Katz, "while that material could not split water as is, it would still be interesting and worth further investigation, because it would be awfully close to giving enough voltage" to split water and perhaps could be modified to work effectively.

Lewis's system also makes it possible to test up to 250 separate compounds on each plate, whereas Parkinson's system produces a continuous gradient pattern of different ratios of three or four metals at a time. "We want to mass-produce thousands of compounds as quickly as possible," Katz says. "The printer is like pouring from the beaker, using microliter spritzes of ink. Printers are good at spraying liquid and mixing in proportions. In a few minutes, we can put 250 dots on a plate and test them. In an hour, we can do 1,000 just using a commercial $200 printer."

In reconfiguring Parkinson's system to evaluate dozens of compounds per plate, Katz says that one of the challenges was writing the software to instruct the printer to print the dissolved metals in different combinations and concentrations. He and Gingrich also had to create software to keep track of the photoelectrochemical results.

"It's not a trivial process," Katz says. "You have to fabricate the glass so that there are no interfering signals between metal oxides, you have to print the compounds on the glass, you have to bake it, and then screen it. Each process takes time."

Common sense dictates which candidates are chosen for analysis. "We first consider the abundant metals in the crust of the earth," Katz says. "For any successful electrode to have an impact on a global scale, we need a colossal amount of the appropriate material. We don't want to use a metal oxide that costs $5,000 a gram. We probably won't use radioactive elements, either." He sees promise in metal oxide candidates whose current utility is limited by how selectively they absorb light.

"To solve the problem, you can take a compound that you know works and try to extend its light-absorbing region to absorb more sunlight" by gradually adjusting the ratios of the metals that compose it to see if you can optimize the electrical response. "Or you can try to make an unstable compound that only works up to a point more stable. Or you can try to find a new and completely different compound that just works."

Says Katz, "There's no reason why we can't find a stable metal oxide that absorbs visible light that doesn't degrade and that can produce energy. If the third compound that we test works, that's great, but it could be the ten millionth compound. It's unlikely we'll find something quickly, but there's only one way to find out."

Katz, who recently left Caltech for a postdoctoral fellowship at UC Berkeley, figures that once the screening system is out of the test phase in a month or two, it will be able to analyze about 20,000 metal oxides a week. Parkinson says that he's tested

Continued on page 12 . . .

Solar Power . . . from page 11

Undergraduate students at Colorado State University examine one of the metal oxide analyzers that they built on a shoestring partly out of Legos.

about 500 metal oxides, with no major breakthroughs so far. He says that he only recently read Katz's thesis describing the Lewis lab's screening system and so hasn't decided yet whether it is worth copying. But he is convinced that to have any chance of finding a metal oxide that works, he has to expand the project.

To that end, Parkinson hopes to enlist dozens of university labs around the country, using simple but effective testing kits operated by an army of undergraduates. "I want to use undergraduate students' hands and brains," he says. "The kits should be inexpensive and easy to use." With that in mind, he taught a class last year in which he had students build metal oxide screening kits out of Lego Mindstorms robotic kits, using a laser pointer. The prototype kits worked, but before he can ramp up production, he needs to test them further.

Parkinson recently received a grant from the Camille and Henry Dreyfus Foundation to send kits to nine undergraduate universities that have offered to recruit students to test them. He hopes to expand the project later this year by joining up with a National Science Foundation–funded Caltech initiative called the Chemical Bonding Center, in which investigators, including Lewis, are seeking ways to efficiently store solar energy in the form of chemical bonds. "The more people who do this, the better," Parkinson says. "There has to be a national commitment here. It's a difficult project, but the payoff is so big and so important."

Although metal oxide devices offer a promising route to capturing and utilizing solar energy on a global scale, other alternatives do exist, some of which have been around for eons. We call them plants. More than two billion years ago, algae evolved the trick of splitting sunlight through photosynthesis. Could this ancient biological breakthrough be the basis of new solar-energy technologies today? It's a nice idea, Lewis says, but "plants are not the optimum color to absorb sunlight efficiently. In addition, a significant amount of the energy of a living system that it derives from the sun is used just to regenerate and keep the system living. We know that metal oxides already work. They just have the problem that the ones that work well are unstable and the ones that are stable don't work well. We know it can be done, we just don't yet know how we can do it under commercially feasible conditions." Cost is key, says Katz. "We're trying to beat out coal. No one is going to be interested in exploiting solar energy for 10 times the cost of burning coal, just because we have global warming."

Friends

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THE CAMPAIGN

Moore Foundation commits $200 Million to Thirty-Meter Telescope

Caltech and the University of California have received a $200 million commitment, extending over a nine-year period, from the Gordon and Betty Moore Foundation toward the further development and construction of the Thirty-Meter Telescope (TMT). Funding under this commitment will be shared equally between the two universities, with matching gifts from the two institutions expected to bring the total to $300 million. The completed TMT will be the largest telescope in the world.

The telescope design is being developed by a U.S.–Canadian team that includes Caltech, the University of California, and the Association of Canadian Universities for Research in Astronomy (ACURA), with completion of the design development expected by March 2009.

"The impressive scope of this project has now been matched by the extraordinary generosity of the Gordon and Betty Moore Foundation," said Caltech president Jean-Lou Chameau. "Caltech and the UC system are thrilled with the foundation's confidence in the project. We and our partners are eager to create this history-making instrument."

Using the TMT, astronomers will be able to investigate the structure and dynamics of the universe and cosmic objects in unprecedented detail. They will locate and analyze the light from the stellar systems born shortly after the Big Bang, the event that gave birth to the universe; conduct detailed investigations of the physical processes governing the formation and evolution of galaxies like our own Milky Way; study the formation of planets around nearby stars; and make observations that test the fundamental laws of physics. However, as with every new astronomical instrument, unexpected discoveries made with the TMT are likely to be the most exciting.

"This is a tremendous investment by the Gordon and Betty Moore Foundation in a path-breaking scientific tool with great potential for unlocking new insights about the nature of the universe," said UC President Robert C. Dynes. "UC and Caltech are pleased that the foundation has recognized the tremendous research capacity of our institutions, and we look forward to the exciting findings that this telescope will deliver in the future."

The TMT will consist of a primary mirror with 492 individual 1.45-meter segments that together measure 30 meters in diameter, providing more than eight times the light-collecting area of the current largest telescope. All segments will be under precision computer control so that they will work together as a single mirror. This revolutionary technology was developed for the 10-meter mirrors in the two Keck telescopes in Hawaii.

In addition to being the largest optical-infrared telescope in the world, the TMT will also be at the forefront of technology in virtually every aspect of its design. Adaptive optics (AO) will allow the telescope to achieve a resolution superior to that of the Hubble Space Telescope.

The TMT AO system will use six laser beams to create six luminous spots in a layer of sodium atoms high in Earth's upper atmosphere. These bright artificial stars serve as references for measuring the turbulence in the atmosphere, allowing the AO system to compensate for blurring of starlight by Earth's fluctuating atmosphere. This technology was pioneered at the Lick Observatory 3-meter telescope and has been developed further at the Palomar 5-meter and Keck 10-meter telescopes.

TMT, whose project office is in Pasadena, is a collaboration between Caltech, UC, and ACURA, with significant work being done by industry and by university teams studying instrument designs. The Moore Foundation has already granted $50 million in support of a $79 million design-development phase that has been under way since April 2004. ACURA and the Association of Universities for Research in Astronomy also contributed to the design-development phase.

For more information on the project, see http://www.tmt.org.

Established in 2000, the Gordon and Betty Moore Foundation seeks to advance environmental conservation and cutting-edge scientific research around the world and to improve the quality of life in the San Francisco Bay Area. For more information, visit http://www.moore.org.

For a closer look at the TMT and what it will see, check out this issue's back-page poster.

Keck Foundation funds Space Studies Institute at Caltech

The Institute has received an eight-year $24 million grant from the W. M. Keck Foundation to establish the W. M. Keck Institute for Space Studies, which will bring together scientists and engineers to develop new space-mission concepts and technology.

Scientists at Caltech and JPL, as well as visitors, students, and postdoctoral researchers from many institutions will address enduring questions that have fascinated humanity for centuries, such as How did the universe begin? What is it made of? What is its ultimate fate? Has life evolved elsewhere in the cosmos? Each year, the institute will adopt one or more new themes and explore those topics through symposia, in-depth studies, and development of emerging-technology prototypes for future space missions.

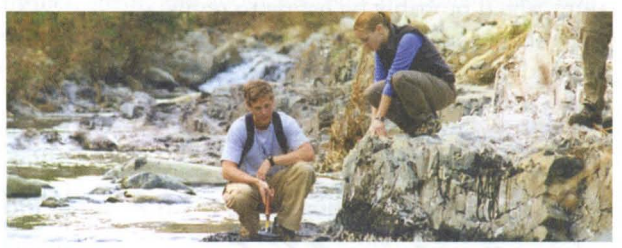
Currently such brainstorming efforts occur in this field, but they are temporary and sporadic. The Keck Institute will provide an ongoing framework for this kind of dialog as a sort of think tank, with design and prototype development as part of its mission.

"Over the last 50 years, the Caltech campus and JPL have been working together in ways that have helped shape the course of space exploration, with major accomplishments in the areas of planetary exploration, space astronomy, Earth remote sensing, and aerospace engineering," said Tom Prince, who will serve as the director of the new Keck Institute for Space Studies. "This groundbreaking new grant from the Keck Foundation will help open a new chapter in this relationship by establishing an institute devoted to revolutionary advances in space science and engineering. The institute will bring together the best talent from JPL, the campus, and the wider community to create the innovative new approaches and techniques that will influence the course of space exploration for decades to come."

The program will consist of a one-year study phase, followed by a one- to two-year technical follow-up phase in which the Keck Institute will fund laboratory investigations and technology developments that were identified as high priorities during the earlier study phase.

The first year of Keck Institute activities includes plans for three study programs: New Directions in Robotic Exploration of Mars, Large Space Apertures, and Instrumentation for Cosmic Microwave Background Observations. Possible future topics include the search for extra-solar planets, new approaches to probing dark energy, and next-generation launch and propulsion systems. The selection of topics for study will be an annual process.

Associates endow new fellowship



Assistant Professor of Geobiology Alex Sessions and graduate student Lisa Walp are among the Caltech faculty and students working at the forefront of research in global environmental sciences.

In today's increasingly interdependent world, it is extremely important to understand and address environmental science issues such as climate change, environmental pollution, and water management and supply problems at a global level. To support these efforts, the Caltech Associates have established the Associates Global Environmental Science Graduate Fellowship, partnering with faculty and students to address the most challenging global environmental science problems.

The endowment of the Associates Global Environmental Science Fellowship will provide in perpetuity a mechanism to support the training of graduate students in this critical field. With an original goal of raising $600,000, generous membership support has exceeded expectations, and the Associates currently have raised $657,000 for this exciting and much-needed fellowship.

Environmental science is very much an interdisciplinary enterprise, and students supported by the fellowship will interact with faculty in a wide range of fields, including engineering and applied science, chemistry and chemical engineering, and geology and planetary science.

The Associates look forward to hosting future events at which they will have the opportunity to hear firsthand from faculty and students about the vital and essential research supported by this fellowship. To learn more about the Associates and the Global Environmental Science Fellowship, please call 626/395-3919 or visit http://associates.caltech.edu.

This past October, 34 members of the Caltech Associates President's Circle joined John Brewer, the Broad Professor of Humanities and Social Sciences and professor of history and literature, on a trip to the Italian province of Tuscany. The group toured the exquisite medieval hill city of Siena and enjoyed a visit and luncheon at the nearby Villa La Foce, hosted by its owner, Benedetta Origo. Traveling through Italy's Chianti region, famed for its vineyards, participants also spent the day at the Castello di Volpaia Winery, where Nicolo Mascheroni Stianti (center), son of the owners, taught a cooking class for the group. Pictured are Associates Marlene Konnar, Ginger Jenkins, Julie Farr, and Janet Holladay.

Associates Activities

All events are held at the Caltech Athenaeum, unless otherwise noted.

March 29, *Northern California Associates Dinner and Program at the Garden Court, Palo Alto.*

April 8, *Associates Dinner and Program*—"Engineering Biosensors to Program Living Systems," with Christina Smolke, assistant professor of chemical engineering.

April 25, *Associates Luncheon and Program*—"Diamonds Are *Not* Forever," with Jennifer Jackson, assistant professor of geophysics.

May 9, *East Coast Associates Dinner and Program*, with Kip Thorne '62, Feynman Professor of Theoretical Physics, Cosmopolitan Club, New York City.

May 13, *West Los Angeles Associates Dinner and Program*—"Caltech Knows Numb3rs," with Gary Lorden '62, professor of mathematics and advisor to the CBS series *Numb3rs*, the Regency Club, Westwood.

Established in 1926, the Caltech Associates is a philanthropic organization with nearly 1,450 members from the Pasadena area and around the world. For eight decades, it has played a valuable role in fostering connections among the worlds of academia, science, engineering, business, and philanthropy, while providing members with opportunities to meet, network, and socialize with individuals who share their intellectual curiosity about the world. For more information, call 626/395-3919 or visit http://associates.caltech.edu.

Tech Talk

Dear Editor,

What an intriguing cover on your last issue! I recognized many of the photographs, and searched the campus to find most of the rest, but there's one for which I need help: where is that enigmatic red decoration that forms the letter N?

C Polyhedral fountain in the Beckman Institute courtyard
A Windows on the north side of Dabney Lounge, seen from Dabney Gardens
L Tree branch, seen looking northeast at Thomas
T North pillar of the Broad Cafe, a distinctive fragment of Caltech architecture
E South facade of the Broad Center
C Bicycle wheel by handicap access ramp to Sherman Fairchild Library (I think)
H North door of East Bridge, well known to every freshman physics student!
N ?
E North door of North Mudd, for which I had to search the campus carefully
W East gate of Dabney Gardens
S Bottom of the Gene Pool, a most identifiable Caltech landmark.

While hunting for these, I was entertained, as always, by the wide variety of creatures cast in the pillars and doorways on so many of the buildings.

Kenneth Andrews '90
Pasadena, CA

The N is part of the red metalwork above the mosaic fountain in Dabney Gardens. Ed.

Continued on page 18 . . .

Letter from the Association President—Caltech in the Global Village

"The world-renowned California Institute of Technology." How often have you heard Caltech described in this way?

Caltech's international fame is reflected in its student body. Almost 10 percent of undergraduates and more than one-third of grad students are non-U.S. nationals. More than half of our postdoctoral fellows also come from outside the United States. This is a far cry from the 1960s and earlier, when foreign students were rare and most of the Institute's undergraduate student body came from California high schools.

This shift mirrors societal changes. A generation ago, a vacation in Europe or Asia was a trip of a lifetime for most Americans. Now, with hundreds of large aircraft crossing the oceans daily, many Americans have experienced the majesty of European cathedrals, the stark beauty of the Serengeti, or the elegance of the Taj Mahal. Similarly, many Singaporeans have seen the Grand Canyon; Spaniards hike among Northern California's redwoods; and Londoners flock in droves to New York's shopping districts.

Caltech benefits in numerous ways from this "global village," particularly in the great opportunities for collaboration it affords. Overseas students with a broad variety of backgrounds can now further their careers at Caltech. And let's not forget that Caltech's current president is a wonderful French chef. This is quite remarkable to those of us who survived America's Wonder Bread era!

Caltech's international student activities flow both ways, and the Institute's administration is looking to create new opportunities for Caltech undergraduates to gain overseas experience as part of their education. In an interview last year in *Caltech News*, President Chameau called himself "a strong believer in the idea that it's advantageous for young people to have the opportunity to experience at least two different cultures, particularly in our increasingly global society. . . . What you want to offer students is enough time to appreciate other cultures and discover for themselves how people in other parts of the world act, think, and behave, and how they might approach and solve problems differently. . . . It is very important for such students to have overseas experience, because that is what their employers will expect from them." ("A New Kind of World," v. 41, no. 2, and online at http://pr.caltech.edu/periodicals/CaltechNews/articles/v41/chameau.html).

Caltech's growing multiculturalism extends to our alumni. While some overseas arrivals go on to pursue careers in the United States, many return to their native countries or move on to other nations. And many Americans relocate abroad for all or part of their lives.

Some alumni start early, as Watson Fellows, immediately after receiving their BS degrees. A recent *Caltech News* article profiled some of these Watsons ("Graduates Abroad," v. 41, no. 3, and online at http://pr.caltech.edu/periodicals/CaltechNews/articles/v41/graduatesabroad.html). Other Techers branch out into overseas assignments later in their careers. In my many journeys abroad, I've had the pleasure of meeting alumni who are university professors involved in field studies or international collaborations, who work for multinational companies, and who are serving in embassies. Sharing the benefits of their Caltech education with their counterparts in other cultures is often the highlight of their careers.

To further the Alumni Association's mission of promoting Caltech and building the greater Caltech community, we have organized alumni gatherings in many locations outside the United States in recent years. Our most active group is in Hong Kong. We also have enthusiastic alumni in London.

In locations with smaller alumni numbers, we are opportunistic. For instance, the Association hosted a dinner in Beijing during the 2006 COSPAR (Committee on Space Research) meeting, organized by Jinlin Zhu, PhD '86.

An Alumni Association trip can also be a great chance to renew acquaintances. The most elegant of the CAA's international events was a reception at the Icelandic President's House in the summer of 2006, hosted by Steingrimur Hermannsson, MS '52, a recipient of Caltech's Distinguished Alumni Award and Iceland's prime minister during the Reykjavik Summit meeting of Ronald Reagan and Mikhail Gorbachev in 1986.

So, wherever you are on our home planet, you're not far from another alum who'd probably be happy to reminisce about long-ago physics problem sets and catch up on current interests and activities. "World-renowned Caltech" has connections around the world.

Caltech alumni travelers walk toward the Icelandic President's House for a reception in the summer of 2006. The event at the 18th-century home was hosted by Steingrimur Hermannsson, MS '52, Iceland's prime minister from 1983 to 1987 and 1988 to 1991.

MAKE A DATE FOR '08

Reunions, May 15–17

Seminar Day, May 17

Alumni College, September 12 and 13

CAA Honor Roll

The value of Alumni Association events and programs is significantly increased thanks to partnerships with Caltech's inimitable faculty. Over the past year, many have played a valuable role in our services to alumni, students, potential students, postdocs, and staff. Below is a list of those faculty members we wish to thank for their time and enthusiasm.

Tom Apostol
Jean-Philippe Avouac
David Baltimore
Jackie Barton
Jesse Beauchamp '64
Seymour Benzer
Pamela Bjorkman
Bill Bridges
Marianne Bronner-Fraser
Mike Brown
Jed Buchwald
Joel Burdick
Carol Carmichael
Jean-Lou Chameau
Fred Culick
Kenneth Farley
Scott Fraser
Harry Gray
David Grether
Bob Grubbs
Jim Heath
Tom Heaton, PhD '78
Melany Hunt
Andy Ingersoll
Jeff Kimble
Diana Kormos-Buchwald
Julia Kornfield '83
Jenijoy La Belle
Jared Leadbetter
Tony Leonard '59
Ken Libbrecht '80
Gary Lorden '62
Steven Low
Rudy Marcus
Sarkis Mazmanian
Preston McAfee
Elliot Meyerowitz
Leonard Mlodinow
Richard Murray '85
Ray Owen
Oskar Painter '01
David Politzer
Steven Quartz
Mark Richardson
David Rutledge
Anneila Sargent, PhD '77
Axel Scherer
Erin Schuman
John Schwarz
Christina Smolke
Joann Stock
Ed Stone
Kip Thorne '62
David Tirrell
Thomas Tombrello
Jeroen Tromp
Erik Winfree, PhD '98
Changhuei Yang
Leeat Yariv
Jiji Zhang

At commencement 2005, physicist David Politzer enjoys a joke told by speaker Sandra Tsing Loh '83. The two will share a stage again as the speakers at the General Session of Seminar Day.

Loh and the Laureate Featured in Seminar Day Q&A

He says quarks, she says quirks, let's call the whole thing the Alumni Seminar Day General Session. On May 17, David Politzer, who won the 2004 Nobel Prize in Physics for his insights into the nature of quarks—the building blocks of matter—and radio commentator, writer, and all-round sociocultural scrutinizer Sandra Tsing Loh '83 will be the featured speakers at the General Session of the Alumni Association Seminar Day. This first-of-its-kind session pairs the laureate with *The Loh Down on Science* host, who, despite (or perhaps because of) earning a BS in the subject at Caltech, remains secretly scared of physics. In this lively Q&A format, Politzer and Loh may discuss anything from performance art to dining out in Stockholm to charmonium states. Family members of all ages are welcome.

David Politzer, Caltech's Tolman Professor of Theoretical Physics, shared the 2004 Nobel Prize for his independent codiscovery in 1973 of "asymptotic freedom," the principle that quarks—the building blocks of protons and neutrons—become more tightly bound the farther apart they move. Asymptotic freedom was subsequently established to be a key property of the strong nuclear interaction, the force that essentially keeps matter from falling apart. After receiving his BS at the University of Michigan and his PhD at Harvard, Politzer joined the Caltech faculty in 1975 as a visiting associate. He was named professor in 1979 and Tolman Professor in 2004, and served as executive officer for physics from 1986 to 1988. In 1989, film director Roland Joffé recruited him to play physicist Robert Serber in the movie *Fat Man and Little Boy*, starring Paul Newman, about the Manhattan project to build the atomic bomb.

Sandra Tsing Loh has hosted her eponymic 90-second science radio spot since its debut in December 2005, and her weekly *Loh Life* segment first began airing on NPR station KPCC in 2004. Her career as a performance artist began in the mid-'80s with piano concert "spectacles" that were covered by *People* magazine, the *Wall Street Journal*, *GQ*, *Glamour*, the Associated Press, and CNN. Since then, she has written and performed several one-woman shows, composed and performed music for film, and authored four books. She is currently a contributing editor for *The Atlantic Monthly* and was a 2006 finalist for the National Magazine Award. Loh received a Caltech Distinguished Alumni Award in 2001, and in 2005, she was the Institute's first alumna commencement speaker.

For more on Loh, go to http://pr.caltech.edu/periodicals/CaltechNews/articles/v34/loh.html. Read about Politzer's Nobel Prize at http://pr.caltech.edu/periodicals/CaltechNews/articles/v38/asymptotic.html; and about his foray into movie-making at http://pr.caltech.edu/periodicals/CaltechNews/articles/politzer.html.

Rocket Girl to premier on Seminar Day

What happens when a North Dakota farm girl leaves home to become a rocket scientist in a man's world? The answer is the subject of a new play called *Rocket Girl*, whose premier performance by Theater Arts at Caltech (TACIT) will be presented in conjunction with Seminar Day. Show times are Saturday, May 17, at 1:30 and 8 p.m., and Sunday, May 18, at 1:30 p.m. in Caltech's Beckman Institute Auditorium.

The story's protagonist, seeking neither fame nor fortune, finds her calling as a major player in the 1958 launch of Explorer 1 and as the wife of a Caltech alumnus.

Although her colleagues refer to her as "America's first female rocket scientist" who "single-handedly saved America's space program," Mary Sherman Morgan works quietly on a secret Army project and shuns publicity throughout her life. Few know that she manages the development of a propellant powerful enough to allow the Redstone rocket to launch America's first satellite. The Army chooses the name Hydyne for the propellant that Morgan develops for North American Aviation, the forerunner of Rocketdyne.

Ironically, the incognito rocket scientist and her like-minded husband, G. Richard Morgan '49, produce a son who becomes a screenwriter. Enough rocket fuel remains in the bloodline to propel son George to write a play about his mother.

According to TACIT director Shirley Marneus, Morgan has written "an absolute love letter to his mother" in the form of *Rocket Girl*. TACIT will perform the play for general audiences in the future at dates and times to be announced later.

To read a full account of George Morgan's inspiration for *Rocket Girl*, go to http://pr.caltech.edu/periodicals/CaltechNews/ and follow the links for this issue (Vol. 42, No.1).

ALUMNI ASSOCIATION
CALIFORNIA INSTITUTE OF TECHNOLOGY
STATEMENTS OF FINANCIAL POSITION
SEPTEMBER 30, 2007 AND 2006

ASSETS

	2007	2006
Assets		
Cash and cash equivalents	$ 160,433	$ 170,716
Accounts receivable	17,617	26,679
Prepaid expenses	4,538	7,337
Caltech pooled investment accounts	8,529,327	7,311,683
Computer equipment	-	-
Total Assets	$ 8,711,915	$ 7,516,415

LIABILITIES AND NET ASSETS

Liabilities		
Accounts payable	$ 73,513	$ 35,746
Unrestricted Net Assets	8,638,402	7,480,669
Total Liabilities and Net Assets	$ 8,711,915	$ 7,516,415

STATEMENTS OF ACTIVITIES AND CHANGES IN NET ASSETS

	2007	2006
Support, Revenues and Other Income		
Membership dues	$ 76,913	$ 74,990
Life membership dues	108,785	195,025
Seminar day	67,855	68,830
Alumni college (continuing education)	21,465	39,230
Class reunions	23,611	31,404
House reunions	3,440	3,510
Regional programs	29,651	20,480
Travel study programs	7,595	19,000
Net investment returns - pooled accounts	1,498,730	688,878
Interest income	7,956	6,311
Miscellaneous income	1,410	5,556
Total Support, Revenues and Other Income	1,847,411	1,153,214
Expenses		
Program Expenses		
Regional programs	160,666	98,048
Seminar day	87,394	93,985
Class reunions	80,865	73,683
Communications - print	63,026	50,337
Communications - electronic	42,674	20,573
Alumni college (continuing education)	41,616	56,864
Leadership conference	37,544	25,456
Career services	26,525	15,140
Membership	15,717	11,371
Undergraduate admissions support	13,960	11,573
House reunions	12,099	8,628
Sponsorships	7,500	7,500
New opportunities	4,822	17,500
Travel study programs	4,505	2,920
Total Program Expenses	598,913	493,578
Administration Expenses	90,765	98,910
Total Expenses	689,678	592,488
Change in Net Assets	1,157,733	560,726
Net Assets, Beginning of Year	7,480,669	6,919,943
Net Assets, End of Year	$ 8,638,402	$ 7,480,669

STATEMENTS OF CASH FLOWS

	2007	2006
Cash Flows from Operating Activities		
Cash received from service recipients	$ 337,197	$ 441,230
Cash paid to suppliers	(636,522)	(553,221)
Interest received - pooled accounts	66,770	72,938
Interest and dividends received - other	7,956	6,311
Net Cash Used in Operating Activities	(224,599)	(32,742)
Cash Flows from Investing Activities		
Net change in Caltech pooled investments	214,316	44,841
Net Increase (Decrease) in Cash	(10,283)	12,099
Cash and Cash Equivalents, Beginning	170,716	158,617
Cash and Cash Equivalents, Ending	$ 160,433	$ 170,716
Reconciliation of the Change in Net Assets To Net Cash Used in Operating Activities		
Change in Net Assets	$ 1,157,733	$ 560,726
Adjustments to reconcile the change in net assets to net cash used in operating activities		
Realized and unrealized gains on investments	(1,431,960)	(615,940)
(Increase) Decrease in:		
Accounts receivable	9,062	(16,795)
Prepaid expenses	2,799	10,889
Increase (Decrease) in:		
Accounts payable	37,767	28,378
Net Cash Used in Operating Activities	$ (224,599)	$ (32,742)

Alumni Notes

1936

Simon Ramo, PhD, a Caltech Life Trustee as well as the R in TRW Inc., has joined the faculty of USC's Viterbi School of Engineering as a Presidential Chair Professor and professor of electrical engineering. After receiving his doctorate at the age of 23, Ramo established 25 patents and was voted one of America's top electrical engineers before the age of 30. As a General Electric scientist, he pioneered research in microwaves, the extremely high radio frequencies fundamental to radar and advanced communications, and he developed GE's electron microscope. A founding member of the National Academy of Engineering and a member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society, he was chief scientist for the U.S. intercontinental ballistic missile program. He is in addition a recipient of the National Medal of Science and a fellow of the American Physical Society and several other professional societies. His writings on technology and society have appeared in numerous books and periodicals, and his books *Cure for Chaos* and *Century of Mismatch* advocate the application of science to social programs. He is also the author of *Extraordinary Tennis for the Ordinary Player*. A Caltech Life Trustee since 1985, he was elected to the Institute's board in 1964.

1939

Hsue-Shen Tsien, PhD, widely considered the father of China's space program, has been named the 2007 Person of the Year in an *Aviation Week & Space Technology* cover story released January 7. He is being recognized for his contributions to aerospace science in both the United States and China. A cofounder of JPL, Tsien was deported against his will back to China during the "Red Scare" of the 1950s, and he eventually became administrator of the Chinese missile and space program. "China is now at the forefront of space exploration, with two key developments in 2007: a successful anti-satellite (ASAT) weapons test and a planetary mission," points out *Aviation Week & Space Technology* editor in chief Anthony L. Velocci Jr. "*Aviation Week*'s profile of Tsien discusses these aspects of China's space program in rich detail, and analyzes the far-ranging impact Tsien has had on the global aerospace industry—indeed, the world—at large." According to the publication's press release, "The Person of the Year distinction, the third in *Aviation Week*'s 91-year history, recognizes the impact individuals have on the broader aviation, aerospace and defense community. *Aviation Week* staff editors selected Tsien from an international field of candidates. Prior recipients include Finmeccanica's Pier Francesco Guarguaglini in 2005 and Alan R. Mulally, currently of Ford Motor Co. and previously of Boeing Co., in 2006." Despite his contributions, Tsien was forced by the Red Guard into a period of hard labor during the Cultural Revolution. Currently 96 and said to be in poor health, he is no longer active in the Chinese space program. He was the subject of *Thread of the Silkworm*, a 1995 biography by U.S. author Iris Chang, as well as a reminiscence by Frank Marble, Caltech's Hayman Professor of Mechanical Engineering and Professor of Jet Propulsion, Emeritus, published in *Caltech News*, volume 36, number 1, 2002, and accessible at http://pr.caltech.edu/periodicals/CaltechNews/articles/v36/tsien.html. The actual *Aviation Week* article can be found at http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=space&id=news/POY01048.xml (where his name has been romanized as Qian Xuesen).

1959

William Leslie Ko, MS, PhD '63, while studying for his doctorate worked with Paul J. Blatz, at that time a senior research fellow at Caltech, and they established the Blatz-Ko constitutive law for describing the mechanical behavior of hyperelastic compressive materials such as solid rocket fuel grains. Ko writes that classmate Wolfgang Knauss '58, MS '59, PhD '63, now Caltech's von Kármán Professor of Aeronautics and Applied Mechanics, Emeritus, has informed him that many scientists internationally are using the law as the basis for their research and have created a number of technical terms in honor of its originators. As well as Blatz-Ko constitutive law, terms include Blatz-Ko strain energy function, Blatz-Ko function, Blatz-Ko hyperelastic bodies, Blatz-Ko material, Blatz-Ko rubber, and Blatz-Ko model, among others. Ko also reports that a Google search of Blatz Ko revealed as many as 8,580 citations. After a career of successful research with private institutions and a number of technical publications covering a wide spectrum of solid mechanics—including, he notes, his "work on blast-waves/structure interactions," which "provided the basic knowledge in the design of missile silos to withstand nuclear blast waves"—he joined the NASA Dryden Flight Research Center. There he has conducted research in a wide variety of areas, including problems associated with high-speed aerospace vehicles such as the Space Shuttle and hypersonic wing structures. He has recently developed "Ko aging theories for operational life predictions of aerospace critical structural components using the 'half-cycle' theory." This work provides the ability to predict the operational life of critical aerospace structural components and can set the numerical limit for safe test flights at NASA Dryden. Ko also receives requests from scientists and engineers worldwide for his publications. In addition, Ko is an internationally known, award-winning watercolor artist whose paintings have been

published in *American Artist* and *Southwest Art*. His *LBJ Ranch in Spring Time* is part of the permanent collection of the Lyndon Baines Johnson Library, in Austin, Texas.

1962

Peter C. Ford, a professor in UC Santa Barbara's department of chemistry and biochemistry, has received the Inter-American Photochemical Society's 2008 I-APS Award in Photochemistry "for his work on the photochemistry and photophysics of transition metal complexes and the bioinorganic chemistry of NO complexes." After receiving his PhD from Yale in 1966 and serving an NSF postdoctoral fellowship at Stanford, he joined UCSB's faculty in 1967. According to his website, "Our research is concerned with three long-term interests: catalysis, the photochemistry and photophysics of transition metal complexes, and the bioinorganic chemistry of nitric oxide complexes. The common theme is our interest in reaction mechanisms and in applications of quantitative spectroscopic techniques to investigate these systems." Ford is a fellow of the AAAS and has been a Dreyfus Foundation Teacher-Scholar and a Senior Fulbright Fellow. His awards include an Alexander von Humboldt Foundation Senior U.S. Scientist Award (1992) and the American Chemical Society's Richard C. Tolman Medal (1993).

1972

Mark S. Wrighton, PhD, chancellor of Washington University in St. Louis since 1995, has been named St. Louis's 2007 Citizen of the Year—a committee of past winners selected him for the award, which is sponsored by the *St. Louis Post-Dispatch*. During his tenure, the number of applications received by Washington University has more than doubled, allowing the school to become one of the most selective in the nation, and 165 new endowed professorships for faculty have been created. When Wrighton first arrived, the university's endowment was $2 billion, and today it is $5.7 billion. Dozens of buildings have been constructed during his term, including new residence halls, the law school, the biomedical-engineering building, and the Mildred Lane Kemper Art Museum. Buildings to come include a medical research building, a new student center, and an engineering campus. A chemist, Wrighton holds 14 patents and has authored or coauthored over 300 articles. He is a fellow of the American Academy of Arts and Sciences and the American Association for the Advancement of Science and a member of the American Philosophical Society, and his numerous honors include a MacArthur Prize Fellowship and Caltech's Distinguished Alumni Award. He delivered Caltech's commencement address in 1995. After receiving his PhD, Wrighton joined MIT as an assistant professor of chemistry. Appointed associate professor in 1976 and professor in 1977, he held the Frederick G. Keyes Chair in Chemistry from 1981 until 1989, when he became the first holder of the Ciba-Geigy Chair in Chemistry. He was head of the chemistry department from 1987 to 1990, the year he became provost, a position he held until moving to Washington University. Wrighton's research interests include transition metal catalysis, photochemistry, surface chemistry, and molecular electronics. He has served on numerous editorial boards and advisory committees.

1988

Howard Stone, PhD, Vicky Joseph Professor of Engineering and Applied Mathematics and associate dean for academic programs in the Harvard School of Engineering and Applied Sciences, has won the first ever G. K. Batchelor Prize in Fluid Mechanics. Awarded under the auspices of the International Union of Theoretical and Applied Mechanics, this newly established prize is sponsored by Cambridge University Press and the *Journal of Fluid Mechanics*. The award of $25,000 will be presented at the 22nd International Congress of Theoretical and Applied Mechanics, to be held in Adelaide, Australia, August 24–30, 2008. Stone is being recognized "for the breadth and depth of his research over the ten-year period 1998–2007, and for his widely acknowledged leadership in fluid mechanics generally."

1994

David Perlman reports that he has started the PhD program in psychology at the University of Wisconsin–Madison, after more than 10 years of working as a computer consultant in Seattle. He is working in the lab of Dr. Richard Davidson, doing brain-imaging research on meditation with the cooperation of a number of Buddhist monks. As part of his work in that lab, he recently attended the Mind and Life meeting at the home of the Dalai Lama in Dharamsala, India. Perlman moved to Madison from Seattle in August 2006 and is still getting used to life away from the West Coast. Both he and his father, Michael, were residents of Ricketts House, and he "is cautiously optimistic that the recent renovations will benefit current resident Scurves."

2007

Paul J. Miller writes that he has moved to Redmond, Washington, and is working for Microsoft in the area of operating system security.

Tech Talk . . . from page 13

Remembering Wolfgang Panofsky

Dear Editor,

I was saddened to read in the *Chicago Tribune* an obituary of the untimely death of Wolfgang Panofsky, PhD '42, whose passing was also reported in the last *Caltech News*.

Most readers of *Caltech News* probably didn't know Wolfgang Panofsky, or how smart he was, and the following will be illuminating.

In 1942 Caltech awarded Wolfgang a PhD in physics. Wolfgang and his one-year-younger brother had been undergraduates majoring in physics at Princeton, where both took the same physics courses. During their years at Princeton, of all the students in these physics courses—and there were many who were brilliant and achieved great success—Wolfgang was first in scholarship in course work, with the highest grades: 98 and higher out of a possible 100. Close behind came the younger brother, Hans, who was second to Wolfgang in these same courses, with grades in the 95 range. No student had grades that fell between the brothers'.

In consequence, at Princeton, Wolfgang's younger brother was known as "The Dumb Panofsky."

Some years ago, I attended a seminar on particle physics by a Nobel laureate professor of physics. During his lecture, the professor said some kind words about SLAC, the Stanford Linear Accelerator, and noted that Wolfgang Panofsky, a prominent antiwar activist, was the director. At a reception after the seminar, expecting to share a smile with the professor, I asked him if he knew the anecdote about Wolfgang Panofsky and his younger brother.

"Oh, yes," the professor said. "I know that one. You mean the one about Wolfgang and his brother, when they were students at Princeton. When Wolfgang got grades *so much* better than his brother that he was called "'The Smart Panofsky.'"

Go figure.

Bernard Rasof, PhD '50
Skokie, IL

[Editor's note: Hans Panofsky went on to a distinguished career in meteorology at Penn State University, pioneering research in such areas as pollution control and the study of planetary atmospheres using space mission data. He died in 1988.]

KEEP US INFORMED THROUGH THE CALTECH NEWS ALUMNI NOTES!

Keep us informed so we can keep your fellow alums informed! If you're a Caltech graduate (BS, MS, Eng, or PhD) *Caltech News Alumni Notes* is the place to let us know what you've been doing. Send us news about you and your family, about a new job, promotion, awards, etc., that you'd like to see printed in *Caltech News*. All notes submitted to *Caltech News* will also be posted quarterly on the Alumni Association's Online Notes website, unless the writer specifically requests otherwise. Please return this coupon and any additional materials to *Caltech News*, 1-71, Pasadena, CA 91125.

Name_____

Degree(s) and year(s)_____

Address_____

_____New address?_____

Day phone _____ E-mail_____

NEWS_____

1934
Robert D. Boche, PhD '38, on September 24, 2007; **William C. McFadden**, on April 12, 2007.

1935
Jay C. Taylor, on November 30, 2007.

1936
Arthur L. Bishop, on December 24, 2007; **William C. Cooper**, MS, PhD '38, August 29, 2007.

1938
Edward N. Frisius, on November 13, 2007.

1939
Richard H. Bishop, MS '43, in July 1987; **Albert P. Green**, on June 12, 1994; **William M. Green**, on December 14, 2007; **Winthrop G. Jones**, MS, on March 27, 1988; **Walter B. Powell**, MS '40, on May 10, 1994.

1940
Alan T. Waterman, on January 9, 2008; **James W. Whittlesey**, on November 11, 2007.

1942
Robert E. Anderson, on November 15, 2007; **George W. Lind Jr.**, MS '43, on October 11, 2007.

1943
Theodore G. Lawrence, MS '47, on November 8, 2007; **Edwin S. Lee Jr.**, Eng, MS, on October 17, 2007.

1944
Richard B. Escue, PhD, on October 1, 2007; **Lawrence U. Hudson**, on December 1, 2006.

1945
Emil L. Sorenson, MS, on March 22, 2006; **Merle G. Waugh**, on August 27, 2007.

1946
Robert D. Bonner, MS, on June 28, 2007.

1947
Le Val Lund, on November 30, 2007; **George W. Lyon**, on September 16, 2007; **Gordon McClure** on August 14, 2007.

1948
Harold W. Baugh, on June 23, 2006; **Lorne Campbell Dunsworth**, MS '48, on January 10, 2008; **Harry M. Ellis**, PhD '51, on November 4, 2007; **Paul W. Fullerton Jr.**, October 12, 2007; **Keith W. Henderson**, on October 15, 2007; **Robert W. Poindexter**, on May 20, 2006; **Bruce B. Rennie**, on July 4, 2007; **Fred M. Wells**, MS, on October 26, 2007.

1950
John M. Greene, on October 22, 2007; **William F. Jones**, MS, on May 20, 2006; **William D. Warters**, MS, PhD '53, on October 23, 2007.

1952
Paul Dergarabedian, PhD, on November 17, 2007; **James A. Ross**, MS '53, on December 10, 2007.

1955
James M. Bell, MS, PhD '65, on July 1, 2007.

1956
Robert Metzenberg, PhD, on July 15, 2007.

READ COMPLETE *CALTECH NEWS* OBITUARIES ONLINE

The full Caltech News *obituaries may be found at http://alumni.caltech.edu/network/obituaries, where readers can browse expanded content and additional biographical information about the alumni listed here.*

1957
Homer K. Richards Jr., Eng, on October 27, 2007.

1959
Richard D. Wood, Eng, on October 25, 2007.

1960
Henry Dearman, PhD, on October 23, 2007.

1962
Sidney Coleman, PhD, on November 18, 2007.

1981
Brian Herndier, PhD, on January 21, 2007; **Ralph Weeks**, on November 28, 2007.

Seymour Benzer 1921 – 2007

Seymour Benzer, Caltech's Boswell Professor of Neuroscience, Emeritus, died in Pasadena on November 30 after suffering a stroke; he was 86. His long research career spanned solid-state physics, biophysics, molecular biology, and behavioral genetics, and he made significant contributions to each of these fields. After helping to lay the foundations of modern-day genetics with his research on gene mutation and regulation, he decided to investigate the genetic underpinnings of behavior, work that earned him the title of "the father of neurogenetics."

The only son of Polish Jews who emigrated to New York City in 1910, Benzer was interested in biology from an early age, but chose to major in physics at Brooklyn College because the school would not permit him to skip the first-year taxonomy courses that he considered to be boring. After earning his bachelor's degree in 1942, he moved to Purdue University for his PhD, working on a secret military project to develop reliable crystal receptors that could detect radio waves reflected back from moving aircraft. The receptor he developed was subsequently adapted by scientists at Bell Labs to become the first transistor.

After earning his doctorate in 1947, Benzer stayed on at Purdue as an assistant professor in solid-state physics, but developed an interest in genetics after reading Erwin Schrödinger's book *What Is Life?* and hearing about the gene-mapping work of Sturtevant and Morgan at Caltech. He took a summer course in bacteriophage genetics at Cold Spring Harbor in 1948, followed by a year's sabbatical at Oak Ridge National Lab in Tennessee, and another two years at Caltech, where he worked as a postdoc with Max Delbrück. After a year in Paris at the renowned Pasteur Institute, he returned to Purdue to carry out some very elegant experiments on a mutant type of bacteriophage. His work clearly demonstrated that genes were divisible into smaller subsections, overturning the then widely held belief that genes were the smallest units of heredity. His experiments laid the foundation for the later understanding of the fine structure and regulation of the gene, and he rose to the Stuart Distinguished Professor of Biophysics at Purdue. Between 1957 and 1958, he spent a year at Cambridge working with Francis Crick and Sidney Brenner, both future Nobel laureates.

In the 1960s, Benzer became interested in the relationship of genes to behavior. As the father of two daughters, he was intrigued to see how his growing girls, raised in the same household and presumably exposed to the same influences, exhibited very different personalities. As he recounted in 1990 in a series of interviews with the Caltech Archives Oral History Project. "If you have one daughter, you don't notice anything. But if you have a second one, you begin to wonder, 'Are we doing things differently, or is it genetic?'" (The complete oral history can be found online at http://oralhistories.library.caltech.edu/27/.) He decided to investigate this further, and in 1965 he took another sabbatical from Purdue to work in the Caltech lab of future Nobelist Roger Sperry.

At Caltech, Benzer chose the drosophila fly as his experimental organism, because it bred rapidly, produced many offspring, and could easily be mutated with a variety of mutagens. "From this you can make a living?" his mother remarked when her son first told her about his new line of work. "Don't you think, Dottie," she asked the scientist's wife, "that if Seymour is going to examine a fly's brain we should examine his brain?"

Benzer went on to examine tens of thousands of fly brains, virtually inventing the field that later became known as neurogenetics. His first experiments focused on the genes that condition flies to move toward bright light, and over the next two decades, he and graduate students made pioneering discoveries concerning the genetic bases of such drosophila traits as circadian rhythms, mating patterns, cognition, and nervous disorders. He had accepted a tenured position at the Institute in 1967 and was appointed the Boswell Professor in 1975.

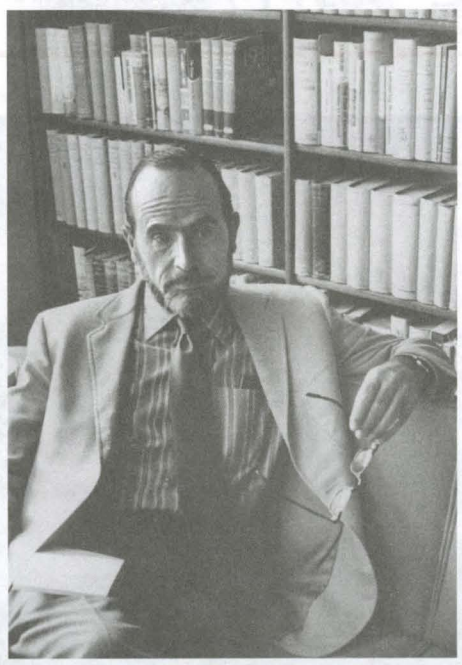
Many of Benzer's drosophila genes were later discovered to have analogs in higher organisms, a finding that led to the founding of the field of behavioral genetics. Benzer increasingly focused his own research on the genetic bases of neurodegeneration and aging in drosophila, and he continued to actively pursue this research after retiring as an emeritus professor in 1992. In the late 1990s, he discovered a gene that enabled drosophila to live longer and resist heat, starvation, and poison; and he dubbed these specimens "Methuselah flies." At the time of his death, his lab was (and still is) studying drosophila models of pain perception and odoriferous alarm response, and working on genetic analyses of appetite and obesity.

Benzer garnered many honors during his long and remarkable career, including election to the National Academy of Sciences, the Royal Society, and the American Academy of Arts and Sciences. He was awarded the National Medal of Science, the Wolf Prize in Medicine from Israel, the Crafoord Prize of the Royal Swedish Academy of Sciences, the International Prize for Biology from Japan, the Albert Lasker Award for Basic Medical Research, and, in 2006, the Albany Medical Center Prize, considered to be the "American Nobel Prize in physiology or medicine." He was also one of few two-time winners of the Gairdner International Award (in 1964 and 2004).

Benzer was the subject of the book *Time, Love, Memory: A Great Biologist and His Quest for the Origins of Behavior*, by Jonathan Weiner, which won the 1999 National Book Award for nonfiction, and of the 2006 book *Reconceiving the Gene: Seymour Benzer's Adventures in Phage Genetics*, by Frederic Lawrence Holmes.

He is survived by his wife, Carol Miller (his first wife, Dorothy, whom he married in 1942, predeceased him); by two daughters, Barbara Freidin and Martha Goldberg; a son, Alexander Benzer; stepsons Renny and Douglas Feldman; and four grandchildren.

David Elliot 1917–2007



David Clephan Elliot, professor of history, emeritus, died on November 21, 2007; he was 90. Born in 1917 in Larkhall, near Glasgow, Scotland, the son of a Presbyterian minister and grandson of a shepherd, he graduated in 1939 with a history MA from St. Andrew's University, and was set to start his graduate studies at Oxford when war broke out and he found himself stranded in Chattanooga, Tennessee. He had gone there to visit the family of his girlfriend, Nancy Haskins, whom he had met at St. Andrew's during her junior year abroad. After finally finding a ship that would take him across the Atlantic, he was selected almost immediately to join the elite Indian Civil Service, which helped govern that country during the colonial era.

After training in Indian law (and horse riding) at a base in the Himalayas, he was posted to the Punjab region in India's northwest, where, at only 23 years of age, he was the district officer and magistrate for millions of people over an area larger than Scotland, riding out to remote villages and holding judicial court on dusty plains in tents or under a banyan tree. After many attempts, Nancy managed to join him in India in 1945, and they were married in Lahore. A year later, Elliot was accepted at Harvard to study for a PhD, and they left India in January 1947, seven months before Independence and the nation's tumultuous partition into India and Pakistan. In 1997, the Indian government invited him back to help celebrate the 50th anniversary of the nation's independence.

Elliot earned his Harvard PhD in 1951, having already joined Caltech's faculty in 1950 as an assistant professor in the humanities division; he was named associate professor in 1953 and professor in 1960. He received an MA in international organizational law from Oxford in 1956.

With his Scottish burr and erudite charm, Elliot was a humorous and well-liked colleague and teacher, who received Caltech's ASCIT Teaching Award in 1977. His research interests encompassed a diverse range of subjects, including Scotland's Liberal Party, the city of London during the English Restoration, arms control, and national defense. He also served as a consultant to the Ford Foundation, the RAND Corporation, NASA, and the Foreign Area Fellowship program. He was the executive officer for Humanities and Social Sciences from 1967 to 1971, secretary to the faculty board from 1973 to 1985, and chaired the Institute's year-long 75th Anniversary celebrations in 1966.

Predeceased by his wife, Nancy, in 1994 and son John Clephan Elliot in 1991, Elliot is survived by his daughters, Nan Elliot Hale of Anchorage, Alaska, and Enid Elliot of Victoria, British Columbia, as well as by Enid's husband, Richard Kool, and their four children and two grandchildren.

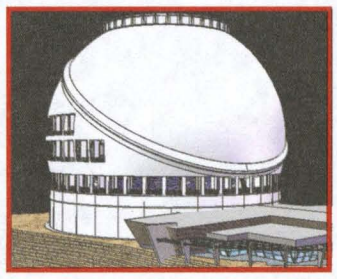
Elliot's oral history, conducted in 1986 for the Caltech Archives Oral History Project, can be found online at http://oralhistories.library.caltech.edu.

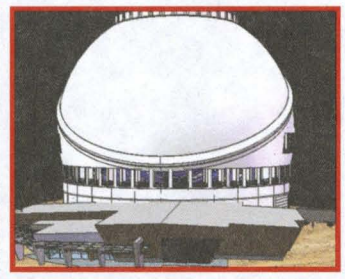
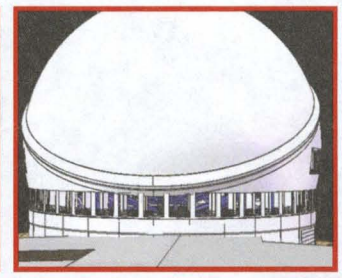
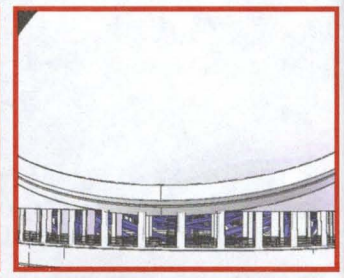
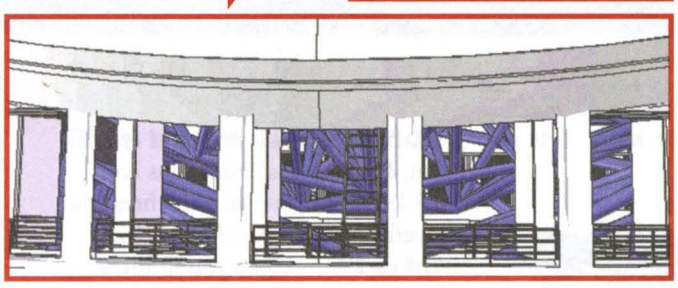
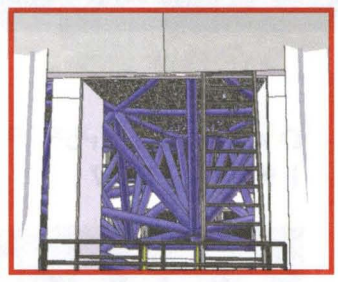
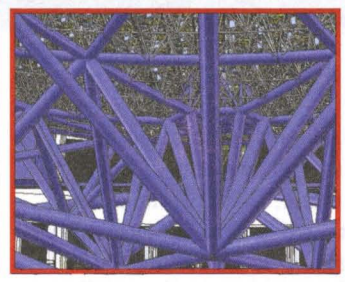
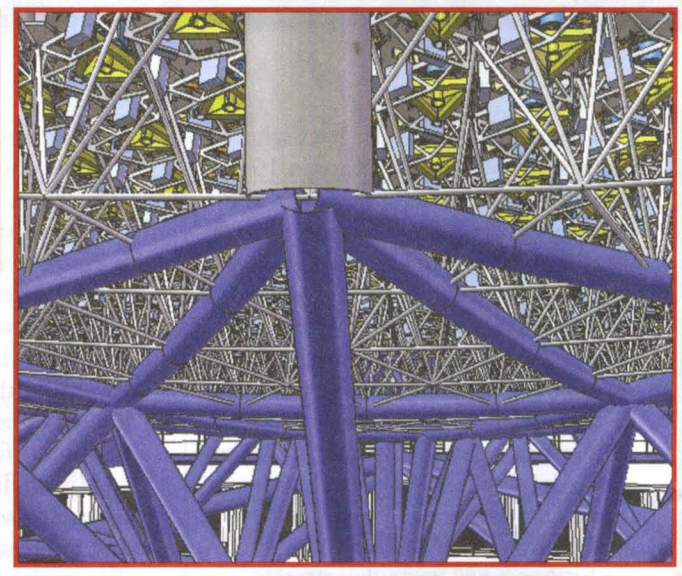
DESIGNS ON THE COSMOS

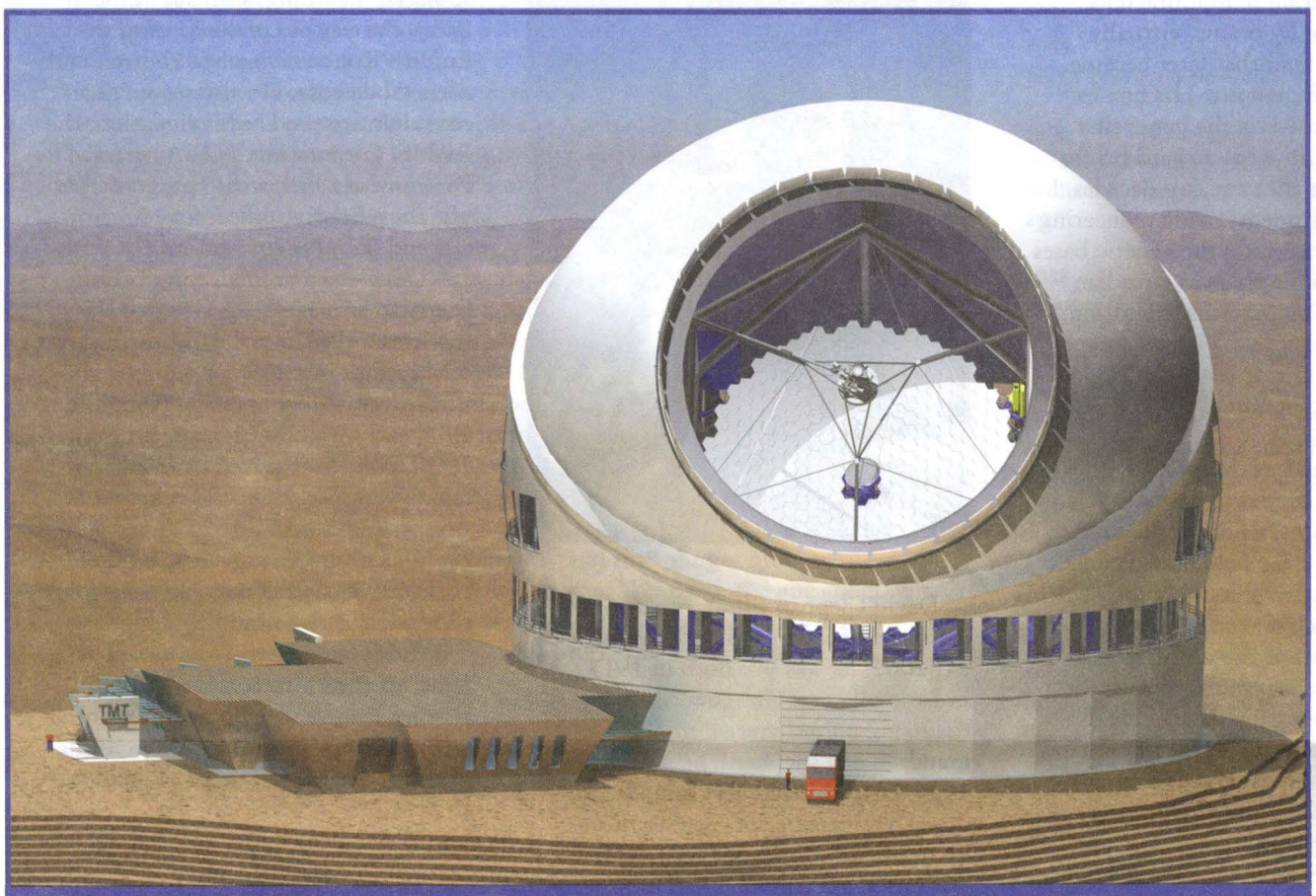
Although the back-page poster may seem reminiscent of futuristic science fiction fantasies that were once featured in the funny pages of newspapers, Caltech's future Thirty-Meter Telescope (TMT) is quite real. The joint project to build what will be the largest and most powerful telescope in the world is currently in the design phase, expected to be completed in early 2009. Last December, the Gordon and Betty Moore Foundation committed $200 million over nine years for further development and construction of the TMT. (See article on page 12.) With a primary mirror consisting of 492 individual 1.45-meter segments that together measure 30 meters in diameter, the TMT will be able to locate and analyze the light from the first stellar systems born soon after the Big Bang, determine the physical processes governing the formation and evolution of galaxies like the Milky Way, and make observations that test the fundamental laws of physics. Even Flash Gordon would be dazzled.

HERE COMES THE **TMT!**

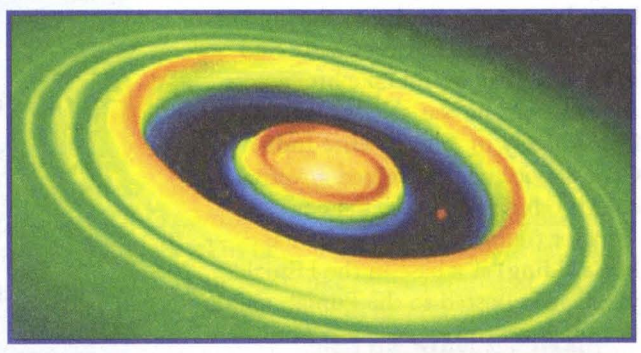
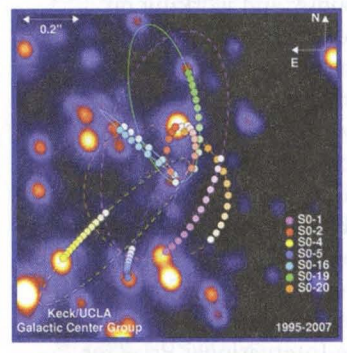
IF YOU **BUILD** IT, THEY WILL **OBSERVE**





WHAT **IT** WILL **SEE**

ABOVE, CLOCKWISE: JUPITER'S EUROPA; GAS AND DUST SURROUNDING A YOUNG STAR; INFRARED IMAGE OF CENTRAL MILKY WAY; EARLIEST GALAXIES; DARK MATTER STRUCTURE; . . . AND **MUCH MORE.**