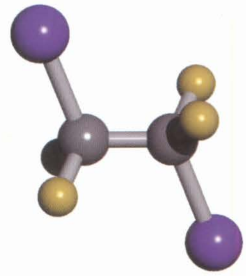
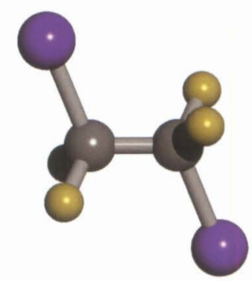
California Institute of Technology

Annual Report 1998–99



On the cover: model of a $C_2F_4I_2$ (diiodotetrafluoethane) molecule.



Ahmed H. Zewail, Caltech's Linus Pauling Professor of Chemical Physics and professor of physics (pictured above), received the 1999 Nobel Prize in chemistry for his pioneering work in femtochemistry—the study of chemical reactions that occur on the femtosecond time scale. (A femtosecond is a millionth of a billionth of a second; one femtosecond is to one second as one second is to 32 million years.)

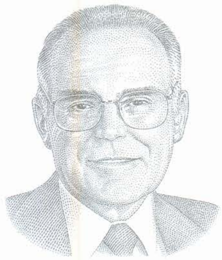
Femtochemists use ultrafast lasers to "photograph" chemical reactions as they actually take place. These pictures are to a complete reaction as the individual frames of a movie are to the entire film.

The small pictures at the right edges of pages 1–31 represent the frame-by-frame, femtochemical view of the two-iodine elimination from $C_2F_4I_2$, one of the many reactions elucidated by Zewail and his colleagues. To see the complete "movie" of this reaction, riffle the pages in flip-book fashion.

10.12.99 Zewail wins Nobel Prize

LETTER FROM THE CHAIR OF THE BOARD

"The more things change, the more they stay the same." I was reminded of that aphorism more than once last year, as the Institute repeatedly made headlines. Novice Caltech-watchers might think this level of media attention is a new development. However, having been associated with the Caltech community for a half century now—first as a graduate student, and later as a member of the Board—I have a somewhat different perspective. Caltech's accomplishments have always been newsworthy in the scientific community. The news is that the *nonscientific* world has finally realized how special we are.



Gordon Moore

10.14.98 Multilayered Silicon Could Be Breakthrough for Electronic Technology

Caltech Science in the News

Here and on the following pages: selected research headlines from 1998–99.

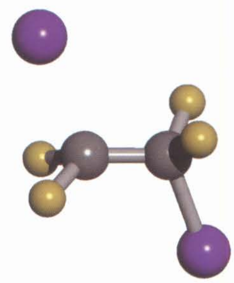
It is no exaggeration to say that the work of Caltech scientists and engineers has changed the world. Consider for a moment some of the research that was "cutting edge" when I became a graduate student in 1950, and where that work has since led.

Fifty years ago, Caltech biochemist Arie Haagen-Smit had just identified the eye irritants in local smog as the products of hydrocarbon combustion. Thanks in part to his pioneering research and leadership, air quality standards were eventually established that have reduced the incidence of first-stage smog alerts in Los Angeles County by 94 percent since 1975, despite the population's having grown by some 2.5 million people. At the same time, Haagen-Smit and biologist Henry Borsook were also studying how amino acids accrete into proteins, which was then one of biology's unsolved problems. Today, Caltech biologists and chemists understand the process well enough to design their own proteins.

On another part of campus, Renato Dulbecco was investigating "photoreactivation of bacterial viruses" in the lab of physicist-turned-biologist Max Delbrück. Delbrück would go on to share the 1969 Nobel Prize in physiology or medicine for his studies of virus-infecting bacteria. Dulbecco, along with David Baltimore and Caltech alumnus Howard Temin, would win the same prize in 1975 for their joint discovery of the enzyme reverse transcriptase, work that has since proven to be profoundly important to understanding retroviruses like HIV.

Linus Pauling, Harvey Itano, and S. J. Singer had just discovered that the hemoglobin in the blood of sickle-cell anemia patients is chemically and electrically different from normal hemoglobin—the first time the cause of a disease had been traced to the molecular level. Medical science's present ability to understand, detect, and intervene in a host of genetically linked diseases owes much to the pioneering work of Pauling and his contemporaries.

The 200-inch Hale Telescope at Palomar Observatory had just completed its first full year of operation. Astronomers working with Palomar's 48-inch Oschin Telescope had just begun the first Palomar Sky Survey, a pioneering attempt to photograph and catalog the entire sky visible from the Northern Hemisphere. The Institute's family of astronomical observatories has since expanded to include the Owens Valley Radio Observatory, the Caltech Submillimeter Observatory, and the W. M. Keck Observatory (operated jointly with the University of California), and a second Palomar Sky Survey is now nearing completion.



Charles Richter (of Richter Scale fame) was studying the Desert Hot Springs earthquake of December 1948, using data from two seismometers he had installed near the epicenter after the quake, as well as from the eight permanent stations then in existence. Today, Caltech, the U. S. Geological Survey, and the California Division of Mines and Geology are partners in TriNet, a project to modernize the existing network of seismic sensors across Southern California. TriNet has made possible real-time transmission of earthquake data, allowing seismologists to determine the magnitude and epicenter of an earthquake within minutes, rather than days or even months, after a quake.

I could probably go on indefinitely giving similar examples, but even these few convey my point. Caltech was at the forefront of scientific exploration 50 years ago, and it is still at the forefront today. Just as the discoveries of people like Haagen-Smit, Pauling, and Richter paved the way for today's achievements, so today's investigations will lay the foundation for discoveries most of us can only dream about. Keep watching; chances are you'll see Caltech people make those dreams come true.

Gordon E. Moore
Chair of the Board of Trustees

10.22.98 Caltech Physicists Achieve First Bona Fide Quantum Teleportation

11.26.98 New Study Explains Motions of the Emerson Fault in the Years Following the Landers Earthquake

LETTER FROM THE PRESIDENT

Despite the fact that Caltech is usually described as a small institution, it has occurred to me more than once how misleading that assessment can be. With the exception of our deliberately small and constant student and faculty population, everything else about us is huge and growing—from the excellence of our people and facilities, to the reach and audacity of our research, to the impact of that research on human society. I often try to convince people outside our campus to see us in this light, but it can be difficult to carry my message beyond the academic and business audiences I generally address. Imagine, then, my delight when the national media unwittingly became my ally in educating the public about what a **large** small university we are.

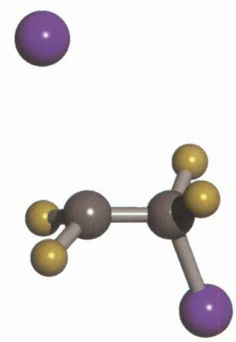
David Baltimore

12.16.98 Domesticated Wolves May Have Given Humans a Leg Up in Conquering the Early World

Three important events last year helped to support my case. The most recent one occurred in October 1999, when **Ahmed H. Zewail won the Nobel Prize in chemistry for his research using femtosecond spectroscopy to study the transition states of chemical reactions,** work that has had a wide-ranging impact on chemistry and photobiology. We've known for a long time that all of chemistry, indeed all of life, is based on the formation and breaking of chemical bonds; but it was Professor Zewail who gave us the means to see these reactions on the femtosecond timescale in which they actually occur (a femtosecond is one quadrillionth of a second). His award brings the total number of Nobel Prizes received by Caltech faculty and alumni to 28—a large number, considering the size of our faculty and our alumni body.

Only a few weeks before the announcement of our newest Nobel laureate, *U.S. News & World Report* ranked Caltech first in its annual list of "America's Best Colleges." Many academics, especially those of us with scientific or technical backgrounds, feel that any rankings have an arbitrary character, so we generally take them with a grain of salt. This year, however, I've found it easier to put aside my skepticism and allow myself to contemplate how the ranking might contain elements of truth (if not downright wisdom). **I've concluded that it's not quite accurate to call Caltech number one; it's more precise to describe us as *unique*.** (Even by the magazine's criteria, we're in a class by ourselves: the next most highly ranked institutions trailed us by seven percentage points.) The rankings pointed out that 100 percent of our freshmen were in the top 10 percent of their high school class; these students also had the highest average SAT scores in the nation. We have a lower student-to-faculty ratio—and a much higher spending-to-student ratio—than any other school on the list. We generate more undergraduate research opportunities than we have undergraduates to take advantage of them. When *U.S. News* began awarding quantitative, rather than just qualitative, credit for these benefits, we shot to number one. Thus, whether or not the magazine's ranking is "scientific," the attributes it is based on are real. They're things that give Caltech students opportunities on a scale that is inconceivable elsewhere.

Our first-place standing was preceded by another remarkable occurrence: the January 1999 announcement that the estate of alumnus Rea Axline and his wife, Lela, had given the Institute more than $60 million to endow student support. **The Axlines' bequest was the largest single gift from an individual donor in Caltech's 108-year history.** One of the Institute's single greatest challenges is finding sufficient financial aid to attract the very best undergraduate and graduate students; the Axlines' magnificent endowment will be invaluable to us.



These events were indeed high points in the year; but there was also less-publicized good news. I'm happy to report that several other continuing projects are coming to fruition. Topping the list is the Biological Sciences Initiative (BSI), the goal of which is to raise funds for the facilities, equipment, and people needed to pursue new and expanded programs in the biological sciences. **The BSI has now reached 80 percent of its $100 million goal.** Work is also moving ahead on the BSI's centerpiece, the Broad Center for the Biological Sciences. Architect James Freed, of Pei Cobb Freed & Partners, was selected in March 1999 to design the Broad Center and has produced one of the most imaginative research buildings ever designed. Meanwhile, the spirit of the BSI is also in evidence in the recruitment of the new faculty whose labs the facility will house. These faculty are both in Biology and in other divisions, realizing a major goal of the BSI: bringing to bear the strengths of the other sciences on biology.

3.25.99 Caltech Astronomers Observe Brightest Gamma-ray Burst So Far

There has also been progress on an off-campus project in which the Institute nonetheless has a great interest: the city of Pasadena's plan to create a high-technology cluster, known locally as the Biotech Corridor, near Huntington Memorial Hospital. The first building in the corridor should be completed by 2002, and more are sure to follow. In reality, the corridor will encompass much more than just biotechnology, as the market brings a rich mixture of technological companies to Pasadena, many of them Caltech spin-offs. **With the assistance of our technology transfer office, we're currently hatching about 10 spin-off companies a year—an accomplishment that few other academic institutions can match.** We are eager to keep as many of these start-ups and licensees as possible near the campus, and developing the corridor is an effective way to accomplish that goal. The Institute expects to be a supporting tenant in the initial effort and will continue to provide intellectual capital for the corridor.

5.29.99 Aeronautics Researchers Generate Cracks That Move as Fast as the Speed of Sound and Resemble Certain Earthquake Shear Ruptures

After months of uncertainty, this year finally brought positive news from Washington, D.C., about federal funding for research institutions. We have always followed the allocation of federal research dollars with great interest, because more than half of Caltech's revenues come from government grants and contracts. The issue took on added urgency last summer, when Congress threatened to cut the budget at the Jet Propulsion Laboratory, which Caltech manages for NASA, by as much as 11 percent. If you're not a congressional insider—and most of us aren't—it is sometimes tempting to conclude from the reports of their budgetary wrangling that federal support for science and technology R&D is in danger. As I found last summer, however, it can be misleading to listen to the day-to-day news from Washington.

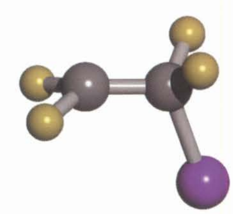
Most people in the federal government are well aware that the engine of American economic success is science and technology, and a review of the support that research universities have received during the second half of this century shows that the dollars have followed that belief. **In fact, most of the Institute's federal sources of funding have fared moderately well in recent years.** Not too long ago, Congress committed itself to doubling the budget of the

6.30.99 Many Life-Bearing Planets Could Exist in Interstellar Space, Says Caltech Planetary Scientist

6.16.99 Caltech Chemists Use the "Unnatural Selection" of Directed Evolution to Alter a Bacterial Enzyme

National Institutes of Health—a major supporter of Caltech research—over 5 to 10 years, and we are on that trajectory. The National Science Foundation, another important source of research funds, has seen increases in its budget, which may be greatly increased in the next fiscal year. The budgets of other, smaller agencies—the United States Geological Survey, for example—have increased slightly or at least kept up with inflation. It should be noted that NASA is the major exception to this trend, its budget having decreased for some time now. However, JPL has managed to keep its share of the available resources. Overall, the outlook for continued funding of basic research in universities is far from gloomy. **Caltech continues to have success in finding support for our faculty's cutting-edge research.**

It is worth pointing out that federal funds do not come with carte blanche to spend them in any way we please. We are constantly negotiating with the government over matching requirements, facilities funding, overhead rates, and other expenses for which federal agencies will not take full responsibility. The government's policy not to fund basic research on a full-cost-reimbursement basis means that we must raise private money to make up the difference. In this sense, every federal dollar we get *costs* us money. But from another perspective, it also means that the private money we raise is very highly leveraged. **Each private dollar we receive can support about 10 federal dollars.**



Taken together, the public and private funds Caltech receives give our scientists and engineers the freedom to pursue some of the most remarkable, ambitious research being done in the world today. This funding makes possible projects like LIGO, the Laser Interferometer Gravitational-Wave Observatory, conceived in 1990 and now nearing operational readiness. LIGO consists of two detectors—one in Louisiana and one in Washington State—with one daunting goal: to observe phenomena that so far only exist in theory. To find what it's looking for, LIGO will have to detect movements as small as one thousandth the diameter of a proton. Achieving this degree of sensitivity will require an unprecedented combination of innovations in such fields as vacuum technology, precision lasers, and optical systems, including mirrors so smooth it's difficult even to measure their smoothness.

Research funding also supports achievements like last year's breakthrough in quantum physics. Institute physicist Jeff Kimble and his colleagues succeeded in transporting a quantum state of light

8.11.99 Computation and Neural Systems Researchers Mutate Digital Organisms

from one side of an optical bench to another without its traversing any physical medium, a feat that brings to mind *Star Trek*'s "transporter" technology. *Science* magazine named Kimball's experiment one of the top 10 scientific advances of 1999. Yet another remarkable accomplishment is the work of artificial intelligence expert Chris Adami and his colleagues at UCLA and Michigan State. These investigators have designed computer programs that act like digital organisms: they self-replicate, mutate, and adapt by a process akin to natural selection. By observing how the programs interact in a virtual-reality "petri dish," Adami hopes to answer fundamental questions about how life evolved on Earth and whether it exists elsewhere in the universe.

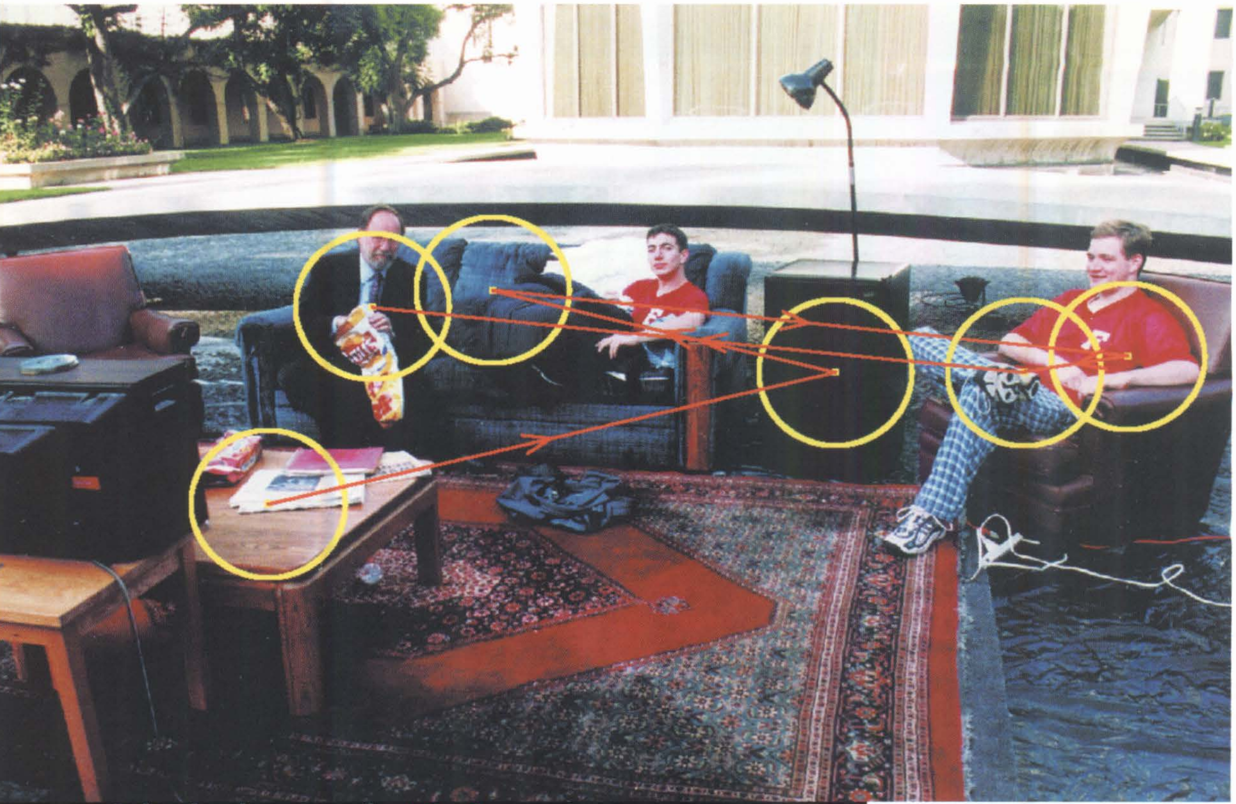
Even though Caltech would be just as important a place without it, the year's media coverage did produce some collateral benefits. We do not exist in a vacuum; we are a facet of much larger environments, including the very vital Southern California research community. In calling attention to Caltech, the press has both raised the public's awareness of Los Angeles as a locus of scientific and technological innovation and underscored how essential creativity and imagination are to the scientific enterprise. **Caltech investigators have the freedom—even the mandate—to dream, to imagine and pursue solutions to the most puzzling questions nature can pose.** All things considered, I suspect that last year's high public profile will not be anomalous. I expect that Caltech will only become better known, not only as a place with a unique approach to research and education, but also as a vital piece of the complex mosaic that is Los Angeles—the city of the 21st century.

9.27.99 A Heart Medication Is Found Effective in Treating Skin Cancer, Caltech Biologists Discover

David Baltimore
President

9.7.99 Edgar Rice Burroughs's Tarzan Novels and Tarzana Suburb Both Reflected a "White Flight" Mentality, Literature Professor Says

Research Highlights

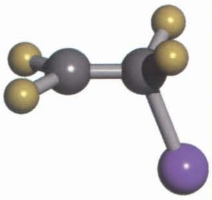


Division of **Biology**

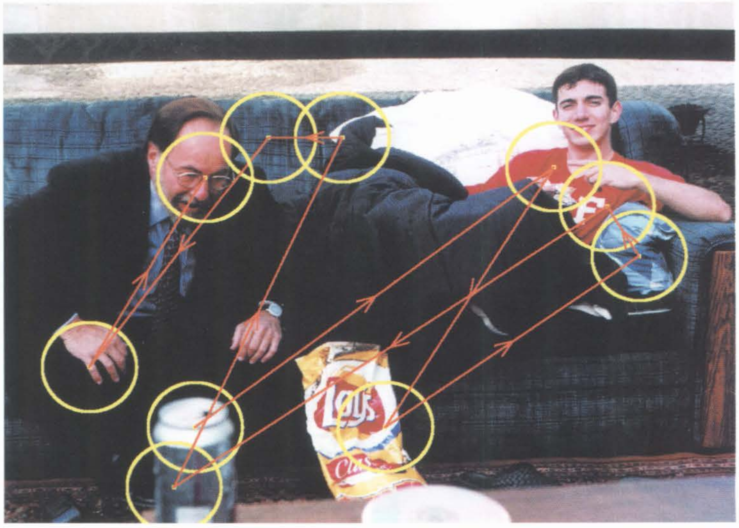
What do *you* find most interesting about these photos? Well, if you're a member of the Caltech community, it's probably seeing President David Baltimore in an unexpected place (the Millikan Pond home-away-from-home of some undergraduate pranksters). But what if you weren't familiar with any of the subjects pictured, and knew nothing about the context? **What would catch your eye—and thereby your brain—first? And why?** To answer these kinds of questions about visual processing, investigators in the lab of biologist Christof Koch have developed a computational model that attempts to mimic the unconscious neuronal mechanisms responsible for attracting our attention to "salient," i.e., conspicuous, objects in our environment.

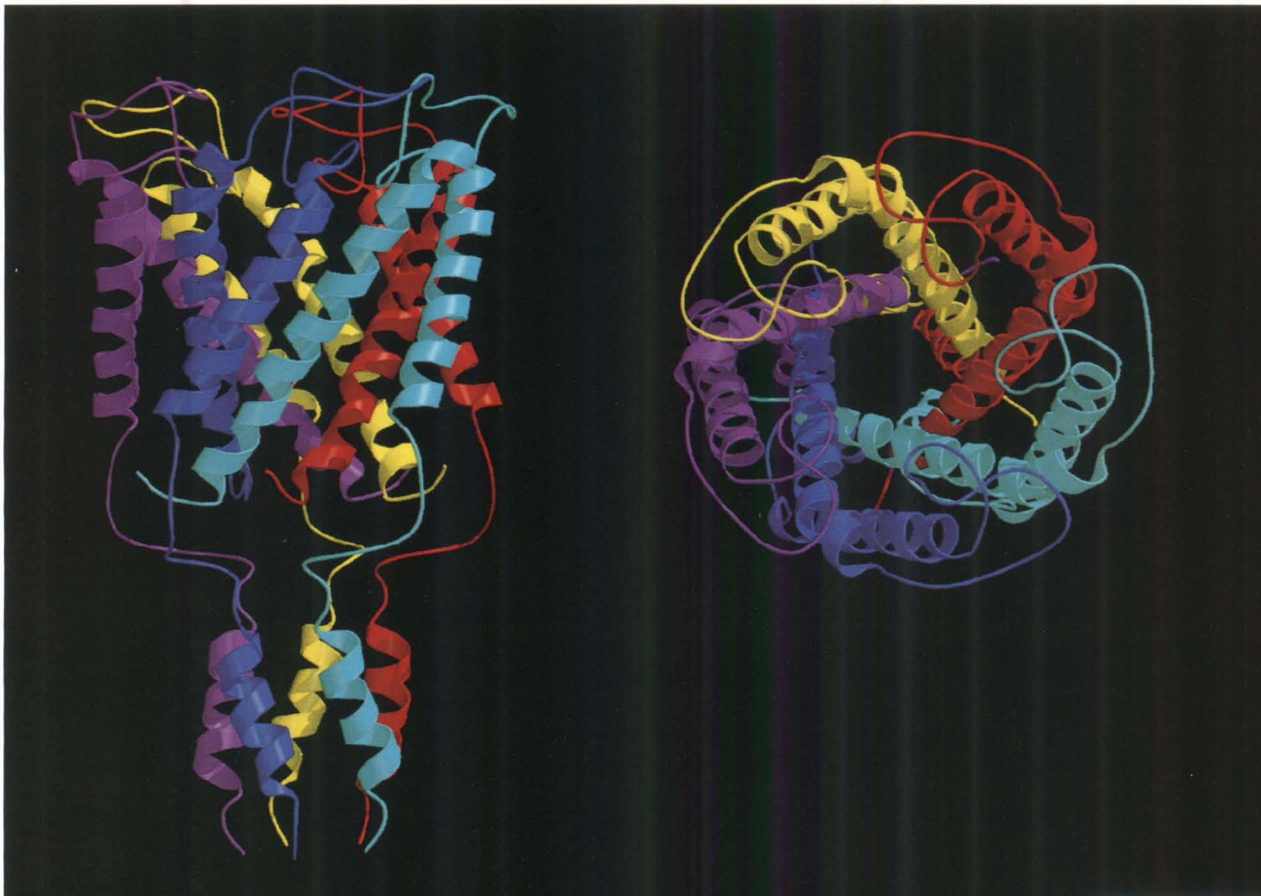
When we look at a scene, we don't perceive all of its components as equally compelling; some objects automatically and effortlessly stand out from their surroundings. Focal attention acts as a rapidly shifting "spotlight" that selects particular items, puts them into short-term memory, and keeps them there long enough to reach our conscious, cognitive mind. Attention can be both voluntarily directed and unconsciously attracted to salient visual locations. Unconscious direction of attention is of particular behavioral importance, because it helps us (and other primates) become rapidly aware of unexpected dangers.

The Koch lab's computer program works by imitating the processes that nerve cells in the brain go through when they receive visual input. To evaluate an image, the program breaks it down into a set of "feature maps," which detect such things as color contrasts and isolated dark spots on bright backgrounds. These maps are composed of visually driven neurons, each of which responds to what is present at a given location in the image. The outputs of all the feature maps are combined into a unique "saliency map," a generalized, abstract representation of what is conspicuous in the image. Saliency maps generated by the computer have some of the same properties as the neuronal maps found in certain areas of primate brains.



The computer program then directs its focal attention by means of a "winner-take-all" neural network that selects the most active location in the saliency map. Once a given location has been visited by attention, it is suppressed from the saliency map, and the winner-take-all picks the next most salient location. With time, the system generates attentional scanpaths, represented on these photos by the yellow and red circles and arrows. In this case, the scanpaths suggest that our unconscious attention would be drawn to a bright white newspaper or a shiny soda can sooner than to a man in a dark-colored suit sitting on a dark-colored sofa. Sorry, Dr. Baltimore.

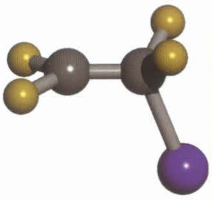




Division of Chemistry and Chemical Engineering

The cells of any organism could not survive without being able to regulate how they interact with their environment. The cell membrane—the place where a cell and its surroundings meet—is key in this regulation process, because in it are embedded the proteins that control how molecules move into and out of the cell. Some of the best known of these proteins are the ion channels, the basic structural elements of neurophysiology.

The computer-generated "ribbon" model shown here represents the structure—determined for the first time by chemist Douglas C. Rees and his research group—of the closed state of a protein found in the cell membrane of *Mycobacterium tuberculosis*. This protein is **a simple type of mechanosensitive gated ion channel**—so called because it opens and closes in response to mechanical pressure on the cell membrane. The channel is thought to act as a sort of safety valve in the tuberculosis bacterium, to keep the cell from exploding when it finds itself in a hostile environment. In the side view of the channel (left-hand image), the five folded ribbons at the top represent the alpha helices that span the cell membrane. The right-hand diagram is a top view down the center of the channel.

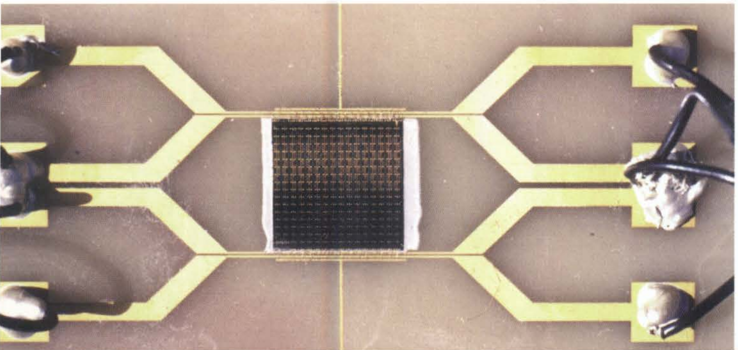


Now that Rees and his colleagues know the structure of the closed state of this channel, they're working on determining what its open state looks like. They'd also like to know how the protein switches between the two states in response to environmental changes. This would be useful information to have, because it could shed light on how similar channels in other organisms work. "It's likely," says Rees, "that this channel's mechanism will turn out to be one of a fairly small number of possible ways that all gated ion channels open and close."

Imagine being able to connect to the Internet at extremely high speeds without a modem or Ethernet hookup—without any wires at all, in fact. Too good to be true? Not at all, according to Professor of Electrical Engineering David B. Rutledge. The devices that are the focus of his research—radio and microwave circuits—are at the heart of the wireless communications revolution, with applications to radar, satellite broadcasting, deep-space communications, and eventually to broadband wireless networks.

Why are the Rutledge lab's inventions so important? One reason is the worldwide proliferation of wireless devices. AM and FM radio stations and commercial TV, which operate at frequencies of about 300 kilohertz to 300 megahertz, have monopolized the lower and middle parts of the spectrum. As a result, newer devices—cellular telephones,

fig. 1



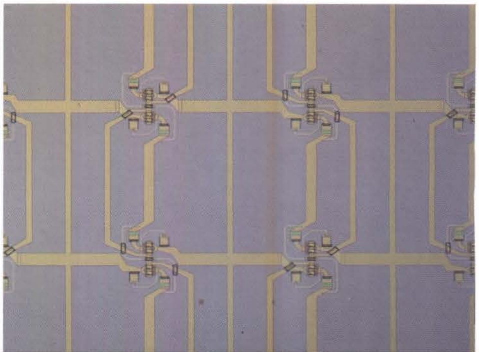


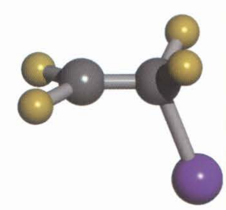
fig. 2

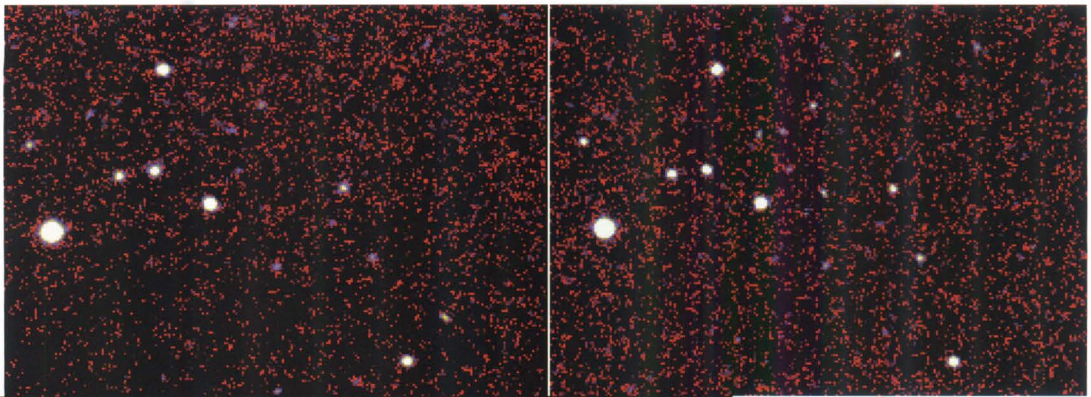
Division of **Engineering and Applied Science**

satellite TV antennas, and the like—must operate in the higher, gigahertz range. The great advantage of this movement up the spectrum is that higher frequencies allow data to be sent at much faster rates. The disadvantage is that available power from transistors drops rapidly as frequency increases. Transmitting at higher frequencies requires much faster transistors. **To be very fast, a transistor must also be very small,** which limits the device to a relatively low power-handling capability.

Enter Rutledge and his colleagues. Figure 1 shows one of their most recent projects, a grid amplifier that measures a mere one square centimeter, yet contains 512 transistors. The pattern of the transistors on the grid (fig. 2) is an integrated amplifier and antenna array that sends out a beam of microwaves. The grid (in operation in the lab, fig. 3) is presently capable of producing an output of 5 watts at 37 gigahertz, which is, according to Rutledge, "very competitive, and certainly some kind of record for this frequency range for solid-state transmitters." The grid can produce this high power level because it combines the outputs of all the transistors into a single beam. This process overcomes the losses that plague traditionally designed amplifiers, which combine outputs using printed circuits.

fig. 3

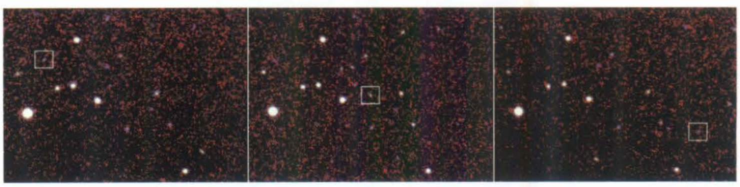




Division of Geological and Planetary Sciences

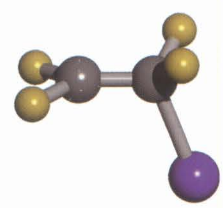
We've all known it since grade school: there are nine planets in our solar system, and Pluto is the farthest from the sun. We may have to revise our thinking very soon, however, if planetary scientist Michael Brown has anything to say about it. Based on his recent surveys of a region in the outer solar system called the Kuiper Belt, Brown believes **it's entirely possible there's a 10th planet**—perhaps larger than Pluto—lurking somewhere out past Neptune.

If such a body exists, why has no one discovered it yet? Probably because it hasn't occurred to them to look for it, Brown speculates. Most planetary scientists accept the standard argument: there can't be a 10th planet because the perturbation of Neptune's or Pluto's orbits it would cause has never been observed. But, as Brown points out, only a very large planet located close to Neptune or Pluto could cause such a per-



turbation; a body located, say, twice as far away from the sun as Neptune wouldn't affect the other planets at all.

Brown is searching for just such a body in a way that combines both traditional and up-to-the minute methods. Most astronomy these days "is done with huge telescopes and very, very sensitive electronic detectors, which can see things like gamma-ray bursts in a very tiny area of the sky," he says. Huge telescopes are inefficient for locating the relatively few large objects out there, however, because it's unlikely that the telescope will ever be pointed at just the right little part of the sky at the right time. To get around this difficulty, Brown uses a relatively old, small instrument, the 48-inch Oschin Telescope at Palomar Observatory, to capture large segments of the sky on 14-inch-square photographic plates. Each sky segment is photographed for three nights in a row. At this point, Brown's approach diverges from the traditional. He has the photographic images digitized so that they can be analyzed by a computer, rather than compared by eye (the method used to discover Pluto 70 years ago). The computer is programmed to ignore objects that don't move and identify those that do. Brown can then use a more powerful telescope to examine promising objects in more detail.



The images on these pages show the movement over three consecutive nights of an object that Brown thinks might be a previously unknown body about 1,000 kilometers across—half the size of Pluto. (The total area shown in each picture is less than one-millionth of the total area of his survey.) To appreciate the role computers play in these analyses, see if you can track the moving body in the larger photos. (See the smaller photos for help.)

Division of the Humanities and Social Sciences

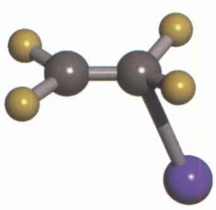
The J. Walter Thompson Co. ran the "Miss Rheingold" contest for Liebmann Breweries, Inc., for more than 25 years.

	Portfolio Managers	*Economics PhDs*	*Caltech Board*	*Caltech Undergraduates*
sample size	26	16	73	27
mean	24.31	27.44	42.62	21.88
median	24.35	30.00	40.00	23.00
standard deviation	16.15	18.69	23.38	10.35
% choosing 0	0.08	0.13	0.03	0.07

This table compares p-Beauty Contest results obtained from four of the many groups who have served as Camerer's research subjects.

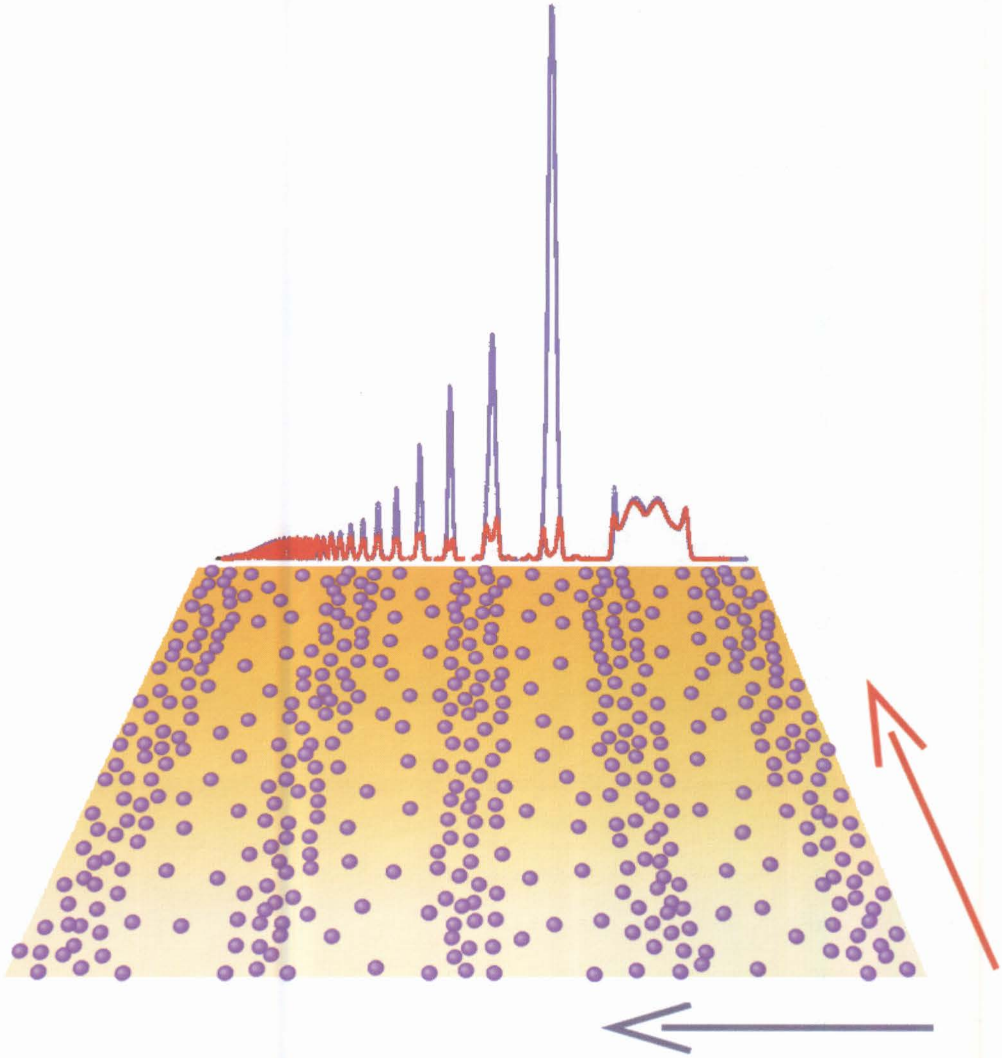
The phrase "game theory" might make most of us think of a coach strategizing about batting order or football plays. To social scientists, however, a *game* is any situation in which a person's decisions are influenced by the behavior or knowledge of others in the same situation. Real-life games include such activities as bargaining, entering into contracts, even speaking a comprehensible language. Standard (that is, highly mathematical) game theory characterizes how rational people play games to achieve the best outcome for themselves—but such theory tends to assume that players are more rational than they actually are.

Standard game theory frequently does not pay enough attention to the cognitive processes or social preferences of average people in everyday life, maintains Professor of Business Economics Colin Camerer. He aims to correct these deficits with a different approach—what he calls **"behavioral game theory."** Camerer is interested in describing actual human behavior by combining rational, mathematical modeling with empirical observation—often using his students as test subjects. One of the first games Camerer tries out on his Psych 101 class is "p-Beauty Contest" (named after a newspaper contest in which readers guessed which one of a group of faces other readers would consider the most beautiful). In this game, each member of a group chooses a number from 0 to 100. The median of the chosen numbers is found. Two-thirds of the median is then computed and becomes the "target number." The player whose chosen number is closest to the target number wins the game. A player's task is to intuit which number the other players are most likely to pick, as a starting point from which to deduce the target number. But what if all the other players are reasoning in the same way? What if they're *not*?



In the world of game theory, exercises like p-Beauty Contest test the principle of "iterated dominance," which holds that players first rule out strategies that they reason will never be chosen because they are "dominated" (i.e., are always worse than other strategies), then eliminate the strategy that becomes dominated, and so on. In many games, going through enough rounds of this iterative process yields a unique choice—a "right" answer—to the problem posed by the game. (In p-Beauty Contest, the right answer is 0.)

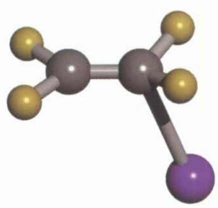
But is the theoretical right answer actually the one most players are likely to come up with? Camerer's behavioral approach says no; realistically, most people will not go through enough iterations to arrive at the ultimate solution. Winning this game—and many others as well—depends less on an academic understanding of game theory than on how accurately one judges the knowledge and sophistication of one's fellow players.



Division of **Physics, Mathematics and Astronomy**

A diagram of ocean evaporation, or perhaps earthquake faults? No—this image actually depicts a **previously unobserved pattern of electron arrangement** produced last year by experimental physicist James Eisenstein and his colleagues. The Caltech investigators found that a current sent in one direction through electrons trapped at the interface between two layers of semiconductor material can, in some circumstances, encounter much greater resistance than an equal current sent in a different direction. This is revealed clearly in the graph above, which shows the variation of the resistance with magnetic field. Currents flowing parallel to the blue arrow feel larger resistance at certain magnetic fields than do currents flowing parallel to the red arrow. Data like these suggest that instead of dispersing evenly across the semiconductor surface, the electrons apparently group themselves into highly concentrated ribbons. This was a startling discovery, says Eisenstein, "because we thought we already understood how electrons behave under these conditions—at temperatures just above absolute zero and in the presence of a large perpendicular magnetic field. But we're seeing a whole new set of configurations that we really didn't know about before."

The "normal" arrangements of electrons described by the quantum Hall effect (a phenomenon that won its three discoverers the 1998 Nobel Prize in physics) have been known since the early 1980s—so why did it take so long to observe this exception to the rule? Simple: only recently has semiconductor technology become sophisticated enough to produce the virtually flawless, layered-crystal structures needed for Eisenstein's experiments. Of the crystal-growing wizard (and good friend) at Bell Labs who keeps him supplied, Eisenstein says, "I'm always after him to make a better sample, so he's working at the very top of the industry that makes these things." Eisenstein values this technology chiefly because it helps him pursue his basic research; but the same technology is also responsible for a variety of more mundane benefits, like the lasers used in CD players. As Eisenstein sees it, "That's where the connection often is between fundamental physics and applications. It's not a one-to-one correlation; it can be highly indirect. It can be very hard to establish why a certain technical thing happened, yet when you look into it really carefully, it's connected to the fact that people wanted to, say, get the cleanest crystals in the world."



The Year in Review

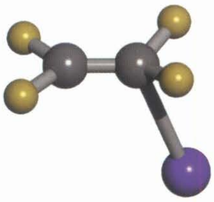
The Evolving Campus

March '99: James Freed, the architect who designed the United States Holocaust Memorial Museum in Washington, D.C., and a senior partner in Pei Cobb Freed & Partners, was selected to design the Broad Center for the Biological Sciences. Construction of a new parking structure to accommodate future residents of the Broad Center got under way on Wilson Avenue.

April '99: The renovation of the Booth Computing Center was completed. The new building, now known as the Powell-Booth Laboratory for Computational Sciences, was dedicated April 2.

July '99: Caltech's new business systems—the result of more than four years of work by Administrative Process Engineering teams—went live. In August, the new payroll system became operational. Oracle software is being used for Human Resources, Acquisition, and Finance transactions; Exeter software for Student Services; and Prism's FAMIS system for Physical Plant job-cost processing. WEBSTER, the new on-line "data warehouse," has replaced much paper reporting. The benefits of the new systems include campuswide Y2K compliance and increased access to more accurate and timely information for system users.

VIPs



July '99: William A. Jenkins was appointed vice president for business and finance. Jenkins was previously vice chancellor for administration at Vanderbilt University. He succeeded Professor of Civil Engineering and Applied Mechanics Paul Jennings, who had served as acting VP during fiscal year 1998.

August '99: Life Trustee Earle Jorgensen died at age 101. A self-made Southern California steel pioneer whose products fortified the area's economic boom, Jorgensen also served as a member of President Reagan's "kitchen cabinet." He had been a member of the Caltech Board since 1957.

September '99: David Tirrell, the Ross McCollum–William H. Corcoran Professor and professor of chemistry and chemical engineering, was named new chair of the Division of Chemistry and Chemical Engineering. Tirrell succeeded Bren Professor of Chemistry Peter B. Dervan, who had served as chair since 1994.

Andrew Shaindlin was appointed executive director of Caltech's Alumni Association, succeeding Judith Amis, who retired in 1998. Shaindlin was formerly senior director of alumni programs at the University of Michigan.

Shirley M. Malcom, director of education and human resources programs at the American Association for the Advancement of Science in Washington, D.C., was elected to the Board of Trustees.

October '99: Sandra Ell was promoted to treasurer and chief investment officer, having served as acting treasurer since July 1998. She had held several different positions in the Institute's finance organization since coming to Caltech in 1984.

Caltech and the Community

November '99: Caltech presented the 1998 Biology Forum, entitled "Gene Therapy: The Promise and the Progress." President David Baltimore introduced the panelists, who included Nancy Wexler, Columbia University; Gary Nabel, University of Michigan; and biology professor Raymond Deshaies, Caltech. The panel moderator was Robert Lee Hotz, science writer for the *Los Angeles Times*, and sponsors included the Huntington Hospital, the Pasadena *Star-News*, and the Wellness Community.

March–June '99: Caltech became partners with the *Los Angeles Times* in a program to familiarize a large external audience (the *Times*'s three million–plus readers) with the Institute's history, research, and plans for the future. The program had three components: a four-page supplement entitled "The Caltech Story: Research, Exploration, Discovery"; a weekly science strip for children, "Caltech Connection for Kids," and its associated interactive Web site, *whyville*; and "Caltech Science Sightings," newspaper-based science instruction (and part of the larger Times in Education program) for secondary schools in Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties.

April–June '99: The Chemistry 0.1 lecture series took place on campus. Like previous years' programs sponsored by the Divisions of Biology, Geological and Planetary Science, and the Humanities and Social Sciences, the lectures were designed to acquaint nonspecialists with new developments in the field. Attendance was open to all members of the campus community.

May 16–June 19, '99: Caltech hosted "Linus Pauling and the Twentieth Century: Quest for Humanity." Sponsored by the Linus Pauling family, Soka Gakkai International, and Oregon State University (Pauling's undergraduate alma mater), the touring exhibit featured notes, diaries, photographs, drawings, molecular models, and other artifacts of Pauling's life and career.

June 21–26, '99: The Institute hosted the first annual Jack R. Howard Science Institute for Journalists. Sponsored in collaboration with the Foundation for American Communication, the program gave 25 journalists from across the country an opportunity to hone their skills in science writing by offering them seminars, experiments, writing exercises, and visits to research labs.

Notable Visitors

February 25, '99: Seamus Heaney, Irish poet, winner of the 1995 Nobel Prize in literature, read from his work.

April 9, '99: Jonathan Miller, British author, television producer, theater director, and sometime physician, gave the eighth James Michelin Distinguished Visitor Lecture. The Michelin Lecture series was established in 1992 to "foster creative interaction between the arts and sciences."

May 6, '99: Mark Shields, a political commentator currently seen on CNN's *Capital Gang* and on the PBS nightly *NewsHour*, was interviewed by Doyle McManus, the Washington Bureau chief for the *Los Angeles Times*. The program was sponsored by Southern California Edison and the Ritz-Carlton Huntington Hotel.

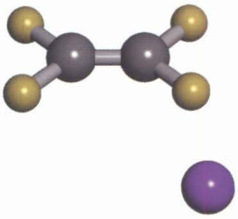
Supporting Caltech

The Institute received a record-setting $131,469,000 in cash and pledges from private donors in fiscal year 1999. Caltech gratefully acknowledges the following individuals and organizations for their generous support.

- Bequests totaling more than $65.6 million from the estates of 29 individuals. Particularly notable among these gifts was a bequest of more than $60 million from the estate of alumnus Rea Axline ('31) and his wife, Lela, representing the initial distribution of the largest single gift in the Institute's history. When all distributions have been made, the Axline bequest will likely total close to $70 million. These funds will be used to support student financial aid, reflecting Rea Axline's gratitude for the financial assistance the Institute provided him during his undergraduate years.

  Rea and Lela Axline

  Also noteworthy was a bequest of more than $2.6 million from the estate of alumnus Albert Atwood Jr. ('32, MS '33), the founding editor of the *Caltech Alumni Review* (later *Engineering & Science* magazine), to support research in the field of electrical engineering.

- Forty-three gifts in the form of charitable trusts and other life income arrangements with a total value of more than $9.6 million. Noteworthy among life income donors are John ('42, MS '43, PhD '44) and Herberta Marie Miles and Clifford ('40) and Marcella Burton, whose current contributions have significantly increased their already substantial unrestricted charitable trust and annuity gifts.
- **David L. (PhD '74) and Ellen Lee** — $11.6 million to establish the David and Ellen Lee Center for Advanced Networking, a research facility dedicated to improving computer networking through such innovations as wireless links.
- **Arthur and Toni Rock** — $1.5 million for the lecture hall in the Broad Center for the Biological Sciences.
- **Ronald (MS '62, PhD '64) and Maxine Linde** — a $1.25 million challenge grant to the Alumni Fund, for the Ronald and Maxine Linde/Alumni Laboratories on the ground floor of the Broad Center.
- **Kiyo ('40) and Eiko Tomiyasu** — more than $1 million to endow the Kiyo and Eiko Tomiyasu Professorship in Electrical Engineering.
- **Cecil ('50) and Sally Drinkward** — $1 million to endow the Drinkward Postdoctoral Fellowship, a gift to the Biological Sciences Initiative.

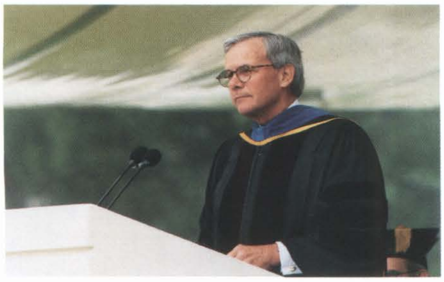
- **William (Ex '59) and Sonja Davidow** — $600,000 to endow the William H. and Sonja Davidow Institute Graduate Fellowship.
- **The Kenneth T. and Eileen L. Norris Foundation** — $1.5 million to fund the Owens Valley Radio Observatory site relocation.
- **The L. K. Whittier Foundation** — $1.444 million to establish the L. K. Whittier Gene Expression Center.
- **The Charles Lee Powell Foundation** — $1.318 million for bundle grants for faculty start-up, equipment, and research in Engineering and Applied Science.
- **The Colvin Foundation** — $700,000 for the Colvin Fund for Research Initiatives in Biomedical Research.
- **The Henry L. Guenther Foundation** — $600,000 to endow the Guenther Graduate Fellowship Fund.
- **Amgen** — $600,000 to fund the creation of the Norman Davidson/Amgen Endowed Graduate Fellowship.
- **Southern California Edison** — a pledge of $250,000 toward partnership in the TriNet project, whose purpose is to build a next-generation, completely digital earthquake monitoring network for Southern California.
- **Burroughs Wellcome Fund** — a pledge of $188,000 to fund a career award in the biomedical sciences.
- **Applied Materials** — a $40,000 matching grant to develop curriculum for a PhD program in advanced materials processing.
- Through the **Alumni Fund**, Caltech alumni gave more than $3.1 million in fiscal year 1999. In a particularly generous show of support, 1,384 alumni from every division gave more than $351,000 in response to the Linde Challenge. (Caltech trustee and alumnus Ronald Linde and his wife, Maxine, will match gifts donated to the challenge on a one-to-one basis, up to $1.25 million.)
- **Members of the Associates** — $7.4 million in restricted and unrestricted gifts in fiscal year 1999. These contributions, when added to gifts over $1 million and the present value of trusts, resulted in total Associates donations of more than $9.5 million for the same period.

Student Life

January '99: Caltech launched the Cambridge Scholars Program, offering qualified juniors and seniors the opportunity to spend a fall or winter term at Cambridge University. Students were hosted by and lived in one of the Cambridge colleges participating in the exchange—Corpus Christi, St. John's, or Pembroke. The first four Caltech participants were Michael Atkin, James Buckwalter, Joseph Renes, and Michael Westover. In return, four Cambridge students worked with Caltech faculty during the summer of 1999.

June 11, '99: Caltech's 105th Commencement

Degrees awarded: 198 bachelor's (91 with honor); 112 master's; 2 engineer's; 166 doctoral.



The 1999 commencement speaker, news anchor Tom Brokaw.

Plans of BS graduates: Eighty-three went on to graduate school. Top school choices were Stanford, UC Berkeley, and UC San Diego. As in past years, Caltech students had considerable success in competing for graduate fellowships.

1999 Fellowship Winners

(members of the class of 1999, unless otherwise noted)

National Science Foundation Fellowships:
Amy Chang-Chien
Oliver Dial
Uri Eden
Angela Lin
Michael Westover

Alumni
Seth Blumberg
David Chavez
Kerwyn Casey Huang
Egon Pasztor

Graduate Students
Zie Wei Susan Chen
Jason P. Davis
Michael Feldmann
Shane Foister
Rowena Lohman
Saleem Mukhtar
Ramanathan Sankaran
Ian Spielman
Christopher Voigt

Churchill Scholarship:
Andrea Hasenstaub

Fulbright Fellowships:
Michael Grebeck
John Niccolai

Hertz Fellowship:
Joshua S. Bloom *(graduate student)*

Hertz Research Grants:
Todd Murphey *(graduate student)*
Michael Santos *(graduate student)*

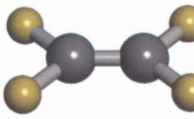
Howard Hughes Predoctoral Fellowship in Biological Sciences:
Jason P. Davis *(graduate student)*

Department of Defense National Defense Science and Engineering Graduate Fellowships:
Brian L. Bircumshaw *(alumnus)*
Robert Z. Osada

NSEP (National Security Education Program) Undergraduate Fellowships:
Angela Snow *(alternate, class of 2002)*
Yuki Takahashi *(class of 2001)*

Rotary Scholarships:
Angela Han
Rory Sayres *(alternate)*

Thomas J. Watson Fellowships:
C. Michael Atkin
Brigitte Roth



Of the bachelor's degree recipients who chose not to attend graduate school, 53 accepted full-time employment. Others chose to pursue volunteer work with Habitat for Humanity or the Peace Corps. One student returned to his home country as a naval officer; another has enlisted in the U.S. military. Two other graduates will teach abroad, one in South Korea and the other in Denmark.

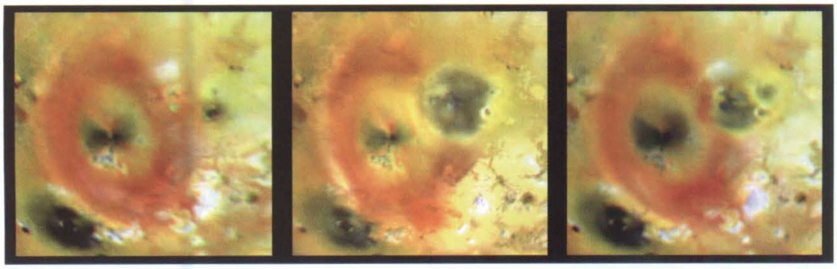
Thirty-seven different organizations hired at least one BS graduate. Adobe Systems, Bellcore, Caltech, Cheshire Engineering, Mitchell Madison Group, Oracle, and Scient each hired more than one.

Plans of PhD graduates: Eighty-one accepted academic employment—15 of them as tenure-track faculty and 61 as postdoctoral scholars. Fifty-one found employment in industry. McKinsey, Exeter, Lucent, Intel, Lehman Brothers, and General Electric all hired more than one Caltech PhD.

JPL Highlights

The Galileo spacecraft established this year that it is one of the endurance champions of planetary exploration, completing an extended mission and a total of four years in orbit around the giant planet Jupiter. In the fall it capped the extended mission with two daringly close flybys of the volcanic moon Io, and it remains in orbit at Jupiter for more possible encounters with the planet's moons. The Cassini spacecraft, launched in 1997, flew by Venus and Earth on its way to Saturn, where in 2004 it will release a probe called Huygens, provided by the European Space Agency, that will descend to the surface of the moon Titan. Deep Space 1 was launched and completed a successful mission flight-testing new technologies, including an ion engine. The Stardust spacecraft, meanwhile, was launched toward an encounter with comet Wild 2 in 2004, where it will collect cometary dust it will return to Earth in 2006. Mars Global Surveyor, which entered orbit in 1997, concluded fine-tuning its orbit and embarked on a science mapping mission, viewing the planet with unprecedented resolution. Despite the loss of a Mars orbiter and lander in late 1999, future missions to the red planet are in preparation.

Among Earth missions, the year saw the launch of the Quick Scatterometer satellite, which carries a radar instrument designed to map near-surface ocean winds. It joins the U.S.-French TOPEX/Poseidon satellite, which continues to return high-quality data on global sea-surface heights, providing valuable insight into such phenomena as El Niño and La Niña. At the end of 1999, JPL launched key instruments on NASA's Terra satellite, as well as an Earth orbiter called the Active Cavity Radiometer Irradiance Monitor Satellite (AcrimSat), which studies the sun's energy output.



Images taken by Galileo show Io's volcanically active Pillan Patera region in (l. to r.) April '97, September '97, and July '99.

Awards and Honors

National awards and honors

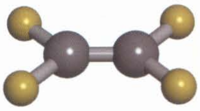
American Academy of Arts and Sciences, Fellow:
John O. Ledyard, Professor of Economics and Social Sciences and Chair of the Division of the Humanities and Social Sciences
Dennis A. Dougherty, Professor of and Executive Officer for Chemistry

National Academy of Engineering, Member:
John F. Brady, Chevron Professor of Chemical Engineering
Wilfred D. Iwan, Professor of Applied Mechanics
William L. Johnson, Ruben F. and Donna Mettler Professor of Engineering and Applied Science

National Academy of Sciences, Member:
Kerry E. Sieh, Professor of Geology

Office of Naval Research, Young Investigator:
Andrea J. Goldsmith, Assistant Professor of Electrical Engineering

International awards and honors



Fluka Chemie AG, 1998 Prize for Development of the Reagent of the Year:
Robert H. Grubbs, Victor and Elizabeth Atkins Professor of Chemistry

North American Council on British Studies, 1999 British Council Prize:
Alison Winter, Associate Professor of History

Royal Astronomical Society, Eddington Medal for Theoretical Astronomy:
Roger D. Blandford, Richard Chace Tolman Professor of Theoretical Astrophysics

Royal Society of Chemistry, S F Boys–A Rahman Lecturer:
Aron Kuppermann, Professor of Chemical Physics

Royal Swedish Academy of Sciences, Nobel Prize in Chemistry:
Ahmed H. Zewail, Linus Pauling Professor of Chemical Physics and Professor of Physics

Russian Academy of Sciences, Foreign Member:
Kip S. Thorne, Richard P. Feynman Professor of Theoretical Physics

Stockholm Water Foundation, 1999 Stockholm Water Prize, Corecipient:
James J. Morgan, Marvin L. Goldberger Professor of Environmental Engineering Science

Local awards

California Council on Science and Technology, Chair:
Paul C. Jennings, Professor of Civil Engineering and Applied Mechanics

Awards and honors from professional societies

American Astronomical Society, President:
Anneila I. Sargent, Professor of Astronomy and Director of the Owens Valley Radio Observatory

Centennial Lecturers:
Anneila I. Sargent, Professor of Astronomy and Director of the Owens Valley Radio Observatory
Edward C. Stone Jr., Vice President, Director of the Jet Propulsion Laboratory, and David Morrisroe Professor of Physics
Kip S. Thorne, Richard P. Feynman Professor of Theoretical Physics

American Chemical Society, Colloid and Surface Chemistry Division, 1999 Langmuir Award Lecturer:
Mark E. Davis, Warren and Katharine Schlinger Professor of Chemical Engineering and Executive Officer for Chemical Engineering

American Chemical Society, Puget Sound, Oregon and Portland Sections, 1999 Linus Pauling Medal:
Peter B. Dervan, Bren Professor of Chemistry

American Geophysical Union, Macelwane Award:
Kenneth A. Farley, Professor of Geochemistry

American Institute of Chemical Engineers, 1999 Professional Progress Award:
Mark E. Davis, Warren and Katharine Schlinger Professor of Chemical Engineering and Executive Officer for Chemical Engineering

American Mathematical Society, 1999 Bôcher Memorial Prize:
Thomas H. Wolff, Professor of Mathematics

American Philosophical Society, Member:
Jacqueline K. Barton, Arthur and Marian Hanisch Memorial Professor and Professor of Chemistry
Kip S. Thorne, Richard P. Feynman Professor of Theoretical Physics

Chinese American Faculty Association of Southern California, 1999 Achievement Award:
Alice Huang, Senior Councilor for External Relations and Faculty Associate in Biology

Council of Graduate Schools, 1999 Gustave O. Arlt Award in the Humanities:
Fiona Cowie, Associate Professor of Philosophy

Earthquake Engineering Research Institute, Honorary Member:
Ronald F. Scott, Dotty and Dick Hayman Professor of Engineering, Emeritus

1997 Outstanding Earthquake Spectra Paper:
Paul C. Jennings, Professor of Civil Engineering and Applied Mechanics

Econometric Society, Fellow:
Matthew O. Jackson, Professor of Economics

Engineering Council, 1999 Distinguished Engineering and Science Research Project Award:
LIGO Project (Barry C. Barish, Director)

Foresight Institute, 1999 Feynman Prize for Theoretical Molecular Nanotechnology:
William A. Goddard III, Charles and Mary Ferkel Professor of Chemistry and Applied Physics

Genetics Society of America, 1998 Thomas Hunt Morgan Medal:
Norman H. Horowitz, Professor of Biology, Emeritus

History of Science Society, 1999 Watson Davis and Helen Miles Davis Prize:
Daniel J. Kevles, J. O. and Juliette Koepfli Professor of the Humanities

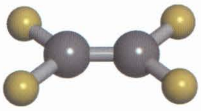
Materials Research Society, Vice President/President-Elect:
Harry A. Atwater Jr., Associate Professor of Applied Physics

National Water Research Institute, 1999 Clarke Prize:
James J. Morgan, Marvin L. Goldberger Professor of Environmental Engineering Science and Executive Officer for Environmental Engineering Science

Southern Regional Council, 1999 Lillian Smith Book Award:
J. Morgan Kousser, Professor of History and Social Science

Foundation awards

The Camille and Henry Dreyfus Foundation, 1999 New Faculty Award:
Jonas C. Peters, Assistant Professor of Chemistry



Ellison Medical Foundation Senior Scholars in Aging Program, 1998 Ellison Medical Foundation Senior Scholar:
Seymour Benzer, James G. Boswell Professor of Neuroscience, Emeritus

Haynes Foundation, 1999 Faculty Fellowship:
R. Michael Alvarez, Associate Professor of Political Science
William F. Deverell, Associate Professor of History

Alfred P. Sloan Foundation, Research Fellow:
Hideo Mabuchi, Assistant Professor of Physics
Rahul Pandharipande, Associate Professor of Mathematics

University honors

Auburn University, 1999 G. M. Kosolapoff Award for Scientific Distinction:
Jacqueline K. Barton, Arthur and Marian Hanisch Memorial Professor and Professor of Chemistry

Columbia University, 1999 Chandler Medal:
Harry B. Gray, Arnold O. Beckman Professor of Chemistry and Director of the Beckman Institute

Harvard University, 1999 Max Tishler Prize Lecturer:
Peter B. Dervan, Bren Professor of Chemistry

G. B. Kistiakowsky Lecturer:
Harry B. Gray, Arnold O. Beckman Professor of Chemistry and Director of the Beckman Institute

Massachusetts Institute of Technology, Lemelson-MIT Prize:
Carver A. Mead, Gordon and Betty Moore Professor of Engineering and Applied Science

United States Military Academy at West Point's Association of Graduates, 1999 Distinguished Graduate:
Lew Allen Jr., Senior Faculty Associate

University of Alberta, Distinguished Alumni Award:
Anatol Roshko, Theodore von Kármán Professor of Aeronautics, Emeritus

University of Texas, Austin, Antoinette de Vaucouleurs Memorial Lectureship and Medal:
Peter M. Goldreich, Lee A. DuBridge Professor of Astrophysics and Planetary Physics

Institute honors

Endowed Professorships:
John F. Brady, Chevron Professor of Chemical Engineering
Donald S. Cohen, Charles Lee Powell Professor of Applied Mathematics
Richard D. McKelvey, Edie and Lew Wasserman Professor of Political Science

Associated Students of the California Institute of Technology (ASCIT), 1999 Teaching Awards:
Peter M. Goldreich, Lee A. DuBridge Professor of Astrophysics and Planetary Physics
Robert J. McEliece, Allen E. Puckett Professor and Professor of Electrical Engineering
Daniel I. Meiron, Professor of Applied Mathematics
E. Sterl Phinney, Professor of Theoretical Physics
Beena Khurana, Visiting Assistant Professor of Psychology

Honorable Mentions:
Marianne Bronner-Fraser, Professor of Biology
Kip S. Thorne, Richard P. Feynman Professor of Theoretical Physics
Sara Lippincott, Lecturer in Creative Writing
Michael Shumate, Instructor in Applied Physics

Graduate Student Council, 1999 Excellence in Teaching Award:
Stephen R. Wiggins, Professor of Applied Mechanics

Excellence in Mentoring Award:
Aron Kuppermann, Professor of Chemical Physics

Richard P. Feynman Prize for Excellence in Teaching, Recipient:
Emlyn W. Hughes, Professor of Physics

Caltech strengthened its financial foundation in 1999 due primarily to endowment performance and the generosity of alumni and friends. This solid financial base allows us to compete successfully for the best faculty and students.

Financial Report Letter
Fiscal Year 1999

Net Asset Foundation

Caltech's total net assets were $1,882 million as of September 30, 1999, up $230 million over last year. From a strategic planning and fiduciary perspective, Caltech views its net assets in the functional categories shown here.

Net Assets as of September 30, 1999 *(dollars in millions)*	
Endowment	$1,239
Property, Plant, and Equipment	490
Trusts, Pledges, Loans	125
Operating	28
Total Net Assets	$1,882

Endowment assets represent two-thirds of Caltech's total net assets. These assets act as our reserve, providing financial stability and flexibility to our operations. The pooled endowment ($1,172 million) is under the oversight of the investment committee of the Board of Trustees. The remaining endowment of $67 million is invested separately in accordance with donor and other restrictions. To protect the value of the endowment, only a portion of the investment returns is allocated for operations each year.

Property, plant, and equipment net assets, stated at historical cost less related depreciation and debt, are the next largest category, amounting to $490 million. Trusts, pledges, and student loans include life income and annuity funds restricted by donors. Operating net assets are funds designated for future operations.

Even before the record growth in net assets in 1999, our strong asset base was a critical variable in Caltech's Aaa/AAA debt rating by both Moody's and Standard and Poor's. Only six other private research universities have earned this top rating.

Summary of Revenues and Expenses

Caltech manages the Jet Propulsion Laboratory (JPL) for the National Aeronautics and Space Administration under a cost-reimbursable contract, with an annual budget of approximately $1.3 billion. On a consolidated basis, JPL represents more than two-thirds of the operating budget of Caltech. The Summary of Revenues and Expenses below lists JPL separately and focuses on the university. It combines operating and non-operating revenues and expenses, as well as the activities in unrestricted, temporarily restricted, and permanently restricted net asset categories, in accordance with Statement No. 117 of the Financial Accounting Standards.

Summary of Revenues and Expenses

Operating and non-operating activity in all net asset categories *(dollars in thousands)*

Revenues	1999	1998
Net Tuition and Fees	$ 15,597	$ 15,655
Investment Return	235,459	32,054
Gifts	131,469	91,063
Grants and Contracts	226,015	235,133
Auxiliary Enterprises and Other	41,135	34,460
Total Revenues, Gains, and Other Support	649,675	408,365
Expenses		
Instruction and Departmental Research	116,980	110,904
Organized Research	169,265	168,980
Institutional and Student Support	70,683	54,377
Plant Operation and Maintenance	35,114	33,390
Auxiliary Enterprises and Other	27,445	19,787
Total Expenses	419,487	387,438
Jet Propulsion Laboratory		
Reimbursement of Direct Costs	1,303,978	1,236,901
Direct Costs of Organized Research	1,303,978	1,236,901
Total Increase in Net Assets	$ 230,188	$ 20,927

Overview of Revenues

Caltech has three major revenue sources: sponsored research, gifts, and investment returns. U.S. government research grants and contracts have grown 250 percent in the past decade, making our faculty among the most productive in the country. Last year, the professorial faculty numbered 275.

Gifts and contributions set another record in 1999. With fewer than 20,000 alumni, the support has been exceptional. Our alumni and friends have been both financially successful and extremely generous to Caltech.

Our investment income and gains continue strong in a bull market. The performance of Caltech's endowment ranked in the top quartile among university endowments, with a total return of approximately 25 percent net of fees over the past year. Over the longer five- and ten-year periods, Caltech's performance ranked in the top decile.

A less significant revenue resource, by design, is tuition. Due to our planned enrollment of 900 undergraduates and 1,000 graduate students, tuition revenue is limited, and is further reduced by our comparatively low price. In 1994 the administration decided to limit tuition increases to attract even better students. This strategy has proved successful, as evidenced by the fall 1998 and 1999 entering classes—all of whom graduated in the top 10 percent of their high school class. They also had the highest average SAT scores in the nation.

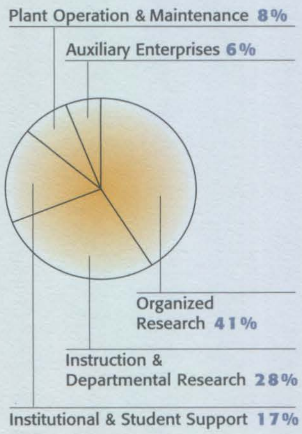
While the number of Caltech's revenue sources is limited, they are stable and strong due to our consistent performance. We are aggressive in seeking and obtaining sponsored research. Our endowment growth is the result of generous gifts and strategic investments. Both management and the trustee investment committee have played key roles in doubling the market value of endowment assets over the last five years. Gifts and contributions are perhaps our most precious resource, as these funds provide the flexibility for making wise investments that leverage and support our teaching and research programs.

Overview of Expenses

We are committed to being at the forefront of research and modern science. However, this strategy, which enables us to be among the best research institutions in the world, is also very expensive to pursue. We are equally committed to maintaining an extremely low 3-to-1 undergraduate student-to-faculty ratio, which fosters interactions among faculty and students that are not possible at other universities.

In fulfilling our mission of education and research, we continually monitor our expenses. The chart at the right shows that instruction and research

Campus Operating Expenses



drive almost 70 percent of campus operations. The majority of our research is supported by grants, contracts, and other agreements from external sources. In addition, reflecting a historically conservative use of debt, interest represents less than 2 percent of operating expenses.

Outlook

As we begin the new millennium, Caltech is recognized as a premier U.S. institution for research and education. A small but superb faculty and student body underpin this strong position among major universities. Our net asset increase was the largest in our history. At year end, our endowment stands at $1,239 million, double its value in 1994. Gifts, including pledges, set a new record at $131 million. It was a great year by almost any measure. Caltech has had much success in the past and certainly has continued that record this year, but we will achieve more.

Caltech may never have been stronger than it is today, but we recognize there is much more to do. As President Baltimore points out in his letter, the private money we raise is very highly leveraged. No other university has the opportunity to leverage financial support to this degree. Our faculty attracts sponsored research at an unprecedented level, and the Caltech-managed Jet Propulsion Laboratory is a research and development center whose size and quality are unmatched. Our unique culture and success provide an unparalleled opportunity to use unrestricted gifts to benefit our society.

On the expense side we are reviewing every facet of Institute operations to ensure that we are maximizing resources and providing the services that our faculty and students deserve. We are also improving relations with our sponsoring federal agencies through better financial reporting, more efficient administrative systems, and more effective cooperation.

We have changed, yet we continue to follow our founders' vision of doing a few things extremely well. During its 108 years Caltech has emerged as one of the world's foremost research universities. Success has bred success, and we expect that trend to continue. With visionary leadership, an unmatched faculty, outstanding students, committed staff, and a solid financial base, Caltech is poised for future successes fully as remarkable as those of the past.

William A. Jenkins

William A. Jenkins
Vice President for Business and Finance

Balance Sheets

September 30, 1999 and 1998
(dollars in thousands)

Assets	1999	1998
Cash	$ 645	$ 447
Accounts Receivable, Net		
United States Government	199,251	198,441
Other	22,364	22,560
Contributions Receivable	43,869	46,541
Investments	1,396,103	1,187,686
Deferred United States Government Billings	150,522	136,914
Prepaid Expenses and Other Assets	101,661	90,323
Property, Plant and Equipment, Net	623,138	562,618
Total Assets	$2,537,553	$2,245,530

Liabilities		
Accounts Payable and Accrued Expenses	$262,873	$273,164
Deferred Revenue and Refundable Advances	21,528	20,926
Annuities, Trust Agreements, and Agency Funds	73,137	79,113
Bonds and Notes Payable	148,821	89,075
Accumulated Postretirement Benefit Obligation	148,942	131,188
Total Liabilities	$ 655,301	$ 593,466

Net Assets		
Unrestricted	$1,362,324	$1,235,631
Temporarily Restricted	123,405	105,198
Permanently Restricted	396,523	311,235
Total Net Assets	$1,882,252	$1,652,064
Total Liabilities and Net Assets	$2,537,553	$2,245,530

See Accompanying Notes to Financial Statements.

Statements of Activities

Fiscal Years Ended September 30, 1999 and 1998
(dollars in thousands)

	1999	1998
Changes in Unrestricted Net Assets:		
Revenues		
Tuition and Fees (net of student financial aid of $18,261 and $18,132, respectively)	$ 15,597	$ 15,655
Investment Return	227,489	30,742
Gifts	20,284	29,471
Grants and Contracts		
Jet Propulsion Laboratory—Direct	1,303,978	1,236,901
Other US Government—Direct	146,862	160,634
Non-US Government—Direct	9,435	8,510
Indirect Cost Recovery and Management Allowance	69,718	65,989
Auxiliary Enterprises	22,169	18,787
Other	18,966	15,673
Net Assets Released from Restrictions	15,660	25,059
Total Unrestricted Revenues	$1,850,158	$1,607,421
Expenses		
Instruction and Departmental Research	$ 116,980	$ 110,904
Organized Research		
Jet Propulsion Laboratory	1,303,978	1,236,901
Other Campus Research	169,265	168,980
Institutional and Student Support	70,683	54,377
Plant Operation and Maintenance	35,114	33,390
Auxiliary Enterprises	24,957	19,787
Loss on Extinguishment of Bonds Payable	2,488	0
Total Unrestricted Expenses	$1,723,465	$1,624,339
Increase/(Decrease) in Unrestricted Net Assets	$ 126,693	$ (16,918)
Changes in Temporarily Restricted Net Assets:		
Investment Return	$ 5,780	$ 1,649
Gifts	28,087	44,560
Net Assets Released from Restrictions	(15,660)	(25,059)
Increase in Temporarily Restricted Net Assets	$ 18,207	$ 21,150
Changes in Permanently Restricted Net Assets:		
Investment Return	$ 2,190	$ (337)
Gifts	83,098	17,032
Increase in Permanently Restricted Net Assets	$ 85,288	$ 16,695
Increase in Total Net Assets	$ 230,188	$ 20,927
Total Net Assets at Beginning of Year	1,652,064	1,631,137
Total Net Assets at End of Year	$1,882,252	$1,652,064

See Accompanying Notes to Financial Statements.

Statements of Cash Flows

Fiscal Years Ended September 30, 1999 and 1998
(dollars in thousands)

Cash Flows From Operating Activities	1999	1998
Total Increase in Net Assets	$ 230,188	$ 20,927
Adjustments to Reconcile Total Increase in Net Assets		
to Net Cash (Used In)/Provided By Operating Activities		
Depreciation	37,498	37,276
Decrease in Accounts and Contributions Receivable	2,058	11,365
Increase/(Decrease) in Accounts Payable and Accrued Expenses	7,463	(6,768)
Loss on Extinguishment of Bonds Payable	2,488	
Contributions Restricted for Long-Term Investment	(83,098)	(17,032)
Realized and Unrealized Losses/(Gains) on Investments	(209,009)	(6,185)
Other	(28,464)	(15,940)
Net Cash (Used In)/Provided By Operating Activities	$ (40,876)	$ 23,643

Cash Flows From Investing Activities	1999	1998
Proceeds From Sales of Investments	$ 738,295	$ 641,030
Purchases of Investments	(737,703)	(647,365)
Capital Expenditures	(98,616)	(77,577)
Net Cash Used In Investing Activities	$ (98,024)	$ (83,912)

Cash Flows From Financing Activities	1999	1998
Contributions Restricted for Long-Term Investment	$ 83,098	$ 17,032
Proceeds From Issuance of Bonds Payable	93,075	
Repayment of Bonds Payable	(43,075)	(1,500)
Draw on Line of Credit	6,000	16,000
Net Cash Provided By Financing Activities	$ 139,098	$ 31,532
Net Increase/(Decrease) in Cash	$ 198	$ (28,737)
Cash at Beginning of Fiscal Year	447	29,184
Cash at End of Fiscal Year	$ 645	$ 447

Supplemental Disclosure	1999	1998
Interest Paid	$ 6,928	$ 3,602

See Accompanying Notes to Financial Statements.

September 30, 1999 and 1998
(dollars in thousands)

Note A
Description of the California Institute of Technology

The California Institute of Technology (the Institute) is a private, not-for-profit institution of higher education based in Pasadena, California. Founded in 1891, the Institute provides education and training services, primarily for students at the undergraduate, graduate, and postdoctoral levels, and performs research, training, and other services under grants, contracts, and similar agreements with sponsoring organizations, primarily departments and agencies of the United States Government.

Note B
Summary of Significant Accounting Policies

Basis of Presentation — The accompanying financial statements include the accounts of the Institute and the Jet Propulsion Laboratory (JPL), a federally funded research and development center managed by the Institute for the National Aeronautics and Space Administration (NASA). The Institute and JPL are exempt from federal income taxes under the provisions of Internal Revenue Code Section 501(c)[3]. The Institute is also generally exempt from payment of California state income, gift, estate, and inheritance taxes.

The financial statements of the Institute have been prepared on the accrual basis of accounting.

The Institute prepares its financial statements in accordance with the provisions of Statement of Financial Accounting Standards No. 117 (SFAS 117), "Financial Statements of Not-for-Profit Organizations." SFAS 117 requires the classification of net assets into three categories according to donor-imposed restrictions or provisions of law: permanently restricted, temporarily restricted, and unrestricted. Permanently restricted net assets include gifts, charitable remainder unitrusts, pooled income funds, gift annuities, other split-interest agreements, and contributions receivable in which the donor has stipulated that the corpus be invested in perpetuity. Investment income generated from these assets may be used in accordance with donor restrictions and is recorded as unrestricted revenue if spent during the same fiscal year as earned. Capital gains or losses, both realized and unrealized, related to permanently restricted investments are reported as unrestricted revenue unless their use is restricted by donor-imposed stipulations. Temporarily restricted net assets include gifts for which donor-imposed restrictions have not been met (primarily for future capital projects), charitable remainder unitrusts, pooled income funds, gift annuities, other split-interest agreements, and contributions receivable on which the donor has placed certain restrictions. These restrictions are removed either through the passage of time or because certain actions are taken by the Institute that fulfill the restrictions. Unrestricted net assets are those not subject to donor-imposed restrictions.

Investments — Investments are stated at fair value (Note C). The fair value of marketable fixed income and equity securities and short-term commercial obligations is estimated based on quoted market prices for those or similar financial instruments. The fair value of real estate, mortgages, notes, and other investments is estimated by professional appraisers or Institute management. Purchases and sales of securities are recorded on trade dates, and realized gains and losses are determined on the basis of the average cost of securities sold.

All investments of endowment and similar funds are carried in an investment pool unless special considerations or donor stipulations require they be held separately. Pooled endowment and similar funds are invested on a total return basis to provide both income and investment appreciation. The Institute utilizes a pooled endowment spending policy that establishes allocations for current spending, consistent with an annual budget plan approved by the Board of Trustees. The spending policy allows the expenditure of a prudent amount of the total investment return over a period of time that preserves the future purchasing power of endowment principal.

Fair Value of Financial Instruments — For those financial instruments for which it is practical, the following methods and assumptions are used to estimate fair value: *Cash and accounts receivable* — The carrying value approximates fair value. *Bonds and notes payable* — The fair value of revenue bonds payable is estimated based on quoted market prices for the bonds or similar financial instruments and approximates $113,388 at September 30, 1999. At September 30, 1998, the carrying value of revenue bonds payable approximates fair value.

Property, Plant, and Equipment — Campus properties are recorded at cost of construction or acquisition, or at appraisal value at date of gift, less accumulated depreciation computed on a straight-line basis over the estimated useful lives (Note D). The Institute provides for the renewal and replacement of its campus properties from funds made available for this purpose from various sources.

Split-Interest Agreements and Perpetual Trusts — The Institute's split-interest agreements with donors consist primarily of irrevocable charitable remainder trusts for which the Institute serves as trustee. Assets held in these trusts are included in investments. Contribution revenues are recognized at the dates the trusts are established after recording liabilities for the present value of the estimated future payments to be made to the beneficiaries. The liabilities are adjusted during the term of the trusts for changes in the value of the assets, accretion of the discount, and other changes in the estimates of future benefits.

The Institute is also the beneficiary of certain perpetual trusts held and administered by others. The present values of the estimated future cash receipts from the trusts are included in assets. Contribution revenues are recognized at the dates the trusts are established. Distributions from the trusts are recorded as investment income and the carrying value of the assets is adjusted for changes in the estimates of future receipts.

Jet Propulsion Laboratory — The Institute manages JPL under a cost plus award fee contract with NASA which includes a management allowance. JPL land, buildings, and equipment are owned by the United States Government and excluded from the Institute's financial statements. However, receivables and liabilities arising from JPL operating activities are those of the Institute and reflected in its financial statements. The direct costs of organized research and the related reimbursement of these costs arising from JPL activities are segregated in the Statement of Activities.

Tuition and Fees — Tuition and fees revenues are reported in the Statement of Activities net of student financial aid expenses.

Gifts — Gifts from donors, including contributions receivable (unconditional promises to give), are recorded as revenues in the period received. Contributions receivable are reported at their discounted present value, and an allowance for amounts estimated to be uncollectible is provided.

Donor-restricted gifts which are received and spent within the same fiscal year are reported as unrestricted revenue. Gifts of long-lived assets with no donor-imposed time restrictions are reported as unrestricted revenue in the fiscal year received. Gifts restricted to the acquisition or construction of long-lived assets are reported as temporarily restricted revenue. The temporarily restricted net assets resulting from these gifts are reclassified as unrestricted when the donor-imposed restrictions are fulfilled.

Accounting Estimates — The preparation of financial statements in conformity with generally accepted accounting principles requires management to make estimates and judgments that affect the reported amounts of assets and liabilities and disclosures of contingencies as of the date of the financial statements and revenues and expenses recognized during the reporting period. Actual results could differ from those estimates.

Reclassifications — Certain amounts in the 1998 financial statements have been reclassified to conform to the current year's classification.

Note C
Investments

Institute investments consisted of the following at September 30:

	1999	1998
Long-term Investment Securities		
Government Fixed Income Securities	$ 194,559	$ 144,131
Corporate Fixed Income Securities	94,615	121,199
Domestic Equity Securities	766,558	675,188
International Equity Securities	203,278	128,784
Limited Partnerships/Alternative Investments	77,651	19,712
Total Long-term Investment Securities	$1,336,661	$1,089,014
Short-term Commercial Obligations	23,526	27,784
Real Estate, Mortgages, Notes, and Other	35,916	70,888
Total Investments	$1,396,103	$1,187,686

At September 30, investments are comprised as follows:

	1999	1998
Consolidated Endowment Pool	$1,167,567	$ 948,287
Separately Invested Endowments	67,701	93,143
Trusts, Annuities and Other	160,835	146,256
Total	$1,396,103	$1,187,686

Investment return for the years ended September 30, 1999 and 1998, was as follows:

	1999	1998
Interest and Dividend Income	$ 26,450	$ 25,869
Net Realized Gains	55,710	200,557
Net Unrealized Appreciation/(Depreciation)	153,299	(194,372)
Total Investment Return	$235,459	$ 32,054

Note D
Property, Plant, and Equipment

Property, plant, and equipment (including construction in progress) consists of the following at September 30:

	1999	1998
Land and Land Improvements	$ 39,641	$ 23,627
Buildings	368,876	356,759
Equipment	561,773	493,051
Property, Plant, and Equipment — Cost	$970,290	$873,437
Less Accumulated Depreciation	(347,152)	(310,819)
Property, Plant, and Equipment — Net	$623,138	$562,618

Depreciation has been calculated with estimated useful lives of 20, 40, and a range of 3 to 50 years for land improvements, buildings, and equipment, respectively.

Note E
Contributions Receivable

Contributions receivable consist of unconditional promises to give to the Institute in the future and are recorded after discounting the present value of the future cash flows. A discount rate of 4.50% and 6.00% was used in fiscal year 1999 and 1998, respectively. At September 30, contributions receivable are expected to be realized as follows:

	1999	1998
Within One Year	$17,993	$17,819
Between One Year and Five Years	29,129	31,037
More than Five Years	880	2,617
Subtotal	$48,002	$51,473
Less Allowance for Uncollectible Pledges	(1,387)	(1,439)
Less Discount	(2,746)	(3,493)
Total	$43,869	$46,541

When collected, contributions receivable will generally be used for establishing new endowments or to support Institute capital projects.

Note F
Bonds and Notes Payable

Bonds and notes payable as of September 30 were as follows:

			Principal outstanding	
Issuer	Description	Interest rate	1999	1998
California Educational Facilities Authority (CEFA)	Series 1991 Revenue Bonds		$ 0	$43,075
	Series 1994 Revenue Bonds due January 2024	Variable-weekly reset (3.40% at 9/30/99)	30,000	30,000
	Series 1998 Revenue Bonds due October 2028 (net of issue discount of $7,044)	4.25% to 4.50%	96,821	0
Bank of America	Revolving Bank Credit Facility (unsecured) with a limit of $75,000, expires June 2001	Variable-LIBOR + 0.2% (5.58% at 9/30/99)	22,000	16,000
Total Bonds and Notes Payable			$148,821	$89,075

In October 1998, CEFA issued $103,865 of revenue bonds on behalf of the Institute (with an original issue discount of $7,044) for the purpose of financing the acquisition, construction, and completion of additional academic, research, administrative, and maintenance facilities, and to advance refund the $43,075 outstanding principal amount of the CEFA Series 1991 bonds. The Series 1998 bonds are repayable with interest from the general revenues over a 30-year period. The bonds are subject to an early redemption premium if redeemed prior to October 1, 2010. The early extinguishment of the Series 1991 bonds has resulted in a loss of $2,488, which is reflected in the Statement of Activities.

Principal repayments on bonds and notes payable for the next five years and thereafter is as follows:

Year ending September 30	Principal amount due
2000	–
2001	$ 22,000
2002	–
2003	–
2004	–
Thereafter	126,821
Total	$148,821

Note G

Allocated Expenses

Campus operating expenses for the fiscal years ended September 30, 1999 and 1998, included the following allocated expenses:

	1999			
	Operating Expenses	Depreciation	Interest	Total
Instruction and Departmental Research	$108,849	$ 6,639	$1,492	$116,980
Organized Research	141,166	25,869	2,230	169,265
Institutional and Student Support	69,218	654	811	70,683
Plant Operation and Maintenance	31,876	2,934	304	35,114
Auxiliary Enterprises	22,254	1,402	1,301	24,957
Total	$373,363	$37,498	$6,138	$416,999

	1998			
	Operating Expenses	Depreciation	Interest	Total
Instruction and Departmental Research	$101,737	$ 8,278	$ 889	$110,904
Organized Research	143,426	24,279	1,275	168,980
Institutional and Student Support	53,685	612	80	54,377
Plant Operation and Maintenance	29,810	3,442	138	33,390
Auxiliary Enterprises	17,924	665	1,198	19,787
Total	$346,582	$37,276	$3,580	$ 387,438

Note H

Components of Net Assets

The following presents the net asset categories by purpose as of September 30:

	1999			
	Unrestricted	Temporarily Restricted	Permanently Restricted	Total
Operating Funds	$ 27,667			$ 27,667
Contributions Receivable		$ 33,441	$ 10,428	43,869
Student Loan Funds			11,208	11,208
Invested in Plant	480,213	9,971		490,184
Life Income and Annuity Funds		34,991	35,625	70,616
Endowment and Other Funds				
Functioning as Endowment	854,444	45,002	339,262	1,238,708
Total	$1,362,324	$123,405	$396,523	$1,882,252

	1998			
	Unrestricted	Temporarily Restricted	Permanently Restricted	Total
Operating Funds	$ 44,034			$ 44,034
Contributions Receivable		$ 41,384	$ 5,157	46,541
Student Loan Funds			10,552	10,552
Invested in Plant	449,627	6,292		455,919
Life Income and Annuity Funds		26,502	27,445	53,947
Endowment and Other Funds				
Functioning as Endowment	741,970	31,020	268,081	1,041,071
Total	$1,235,631	$105,198	$311,235	$1,652,064

Note I

Retirement Plans

Institute retirement plans, covering substantially all of its employees, are funded by periodic transfers to the respective insurance companies. Academic and senior administrative staff are covered by a defined contribution pension plan. Non-academic staff were covered by a defined benefit pension plan that was terminated effective December 31, 1993. The Institute provided two plans effective January 1, 1994, for employees who were participants in the terminated defined benefit pension plan: (1) a successor defined benefit pension plan which could be elected by participants who attained age 55 and had 10 or more years of service and (2) the defined contribution plan for all other employees. Substantially all of the participants in the terminated defined benefit pension plan irrevocably elected to participate in the defined contribution pension plan.

Retirement benefits under the terminated defined benefit pension plan and the successor defined benefit plan are based on years of service and career average compensation, and accrued partially on a fixed dollar basis and partially on a variable dollar basis. The Institute's defined benefit plan funding policy is to contribute amounts sufficient to maintain retirement plan assets at levels adequate to cover all accrued benefit liabilities.

The net pension benefit for the successor defined benefit plan for the fiscal years ended September 30, 1999 and 1998, was as follows:

	1999	1998
Service Cost – Benefits Attributed to Service During the Year	$ 253	$ 298
Interest Cost on Projected Benefit Obligation	2,280	2,723
Actual Return on Plan Assets	(4,167)	2,793
Amortization and Deferral	1,359	(5,985)
Net Periodic Pension Benefit	$ (275)	$ (171)

The reconciliation of funded status as of September 30, 1999 and 1998, was as follows:

	1999	1998
Projected Benefit Obligation at Beginning of Year	$36,698	$39,610
Service Cost	253	298
Interest Cost	2,280	2,723
Benefits Paid	(2,083)	(1,946)
Actuarial Gain	(3,872)	(3,987)
Projected Benefit Obligation at End of Year	33,276	36,698
Fair Value of Plan Assets at Beginning of Year	36,137	40,876
Actual Return on Plan Assets	4,167	(2,793)
Benefits Paid	(2,083)	(1,946)
Fair Value of Plan Assets at End of Year	38,221	36,137
Funded Status	4,945	(561)
Unrecognized Net Actuarial (Gain)/Loss	(2,617)	2,614
Prepaid Benefit Cost	$ 2,328	$ 2,053

An annual discount rate of 7.50% (6.50% in 1998), an expected return on plan assets of 8.00% (8.00% in 1998), and a 5.00% (5.00% in 1998) annual rate of increase in compensation were assumed for 1999.

Pension costs for the defined contribution plan for the fiscal year ended September 30, 1999, were $10,783 ($10,031 in fiscal 1998) for the campus and $34,480 ($33,019 in fiscal 1998) for JPL.

Note J

Postretirement and Postemployment Benefits Other Than Pensions

The Institute provides certain postretirement health and life insurance benefits. The Institute's policy is to amortize any actuarial deferrals resulting from changes in the accumulated postretirement benefit obligation over the average future working lifetime of its employees.

Amounts included in the Statement of Activities are summarized as follows:

	1999	1998
Service Cost – Benefits Attributed to Service During the Year	$ 6,968	$ 6,133
Interest Cost on Accumulated Benefit Obligation	14,705	12,903
Amortization of Actuarial Deferral	4,152	4,259
Net	$25,825	$23,295

The reconciliation of unfunded status as of September 30, 1999 and 1998, was as follows:

	1999	1998
Benefit Obligation at Beginning of Year	$218,519	$115,145
Service Cost	6,968	6,133
Interest Cost	14,705	12,903
Retiree Contributions	1,455	1,346
Benefits Paid	(9,526)	(8,598)
Actuarial (Gain)/Loss	(6,031)	91,590
Accumulated Postretirement Benefit Obligation	226,090	218,519
Remaining Actuarial Deferral	(77,148)	(87,331)
Total	$148,942	$131,188

The Institute expects to recover approximately one-half for the campus and all for JPL of this postretirement obligation through future charges to United States government grants and contracts. The amount relating to JPL of $119,045 ($105,123 in 1998) is included in the Balance Sheet as part of accounts payable and accrued expenses. A deferred United States government billing of the same amount has been recorded because certain provisions set forth in the Institute's contract with NASA provide for reimbursement of such costs if the contract should ever be terminated. The Institute also has recorded a deferred United States government billing of approximately $31,477 ($31,791 in 1998) relating to accrued vacation benefits that are covered by similar contract provisions. Although these deferred billing amounts may not be currently funded, and therefore may need to be funded as part of future NASA budgets, the Institute believes it has the contractual right to insist that such funding be made available.

An annual discount rate of 7.50% (6.75% in 1998) and a 5.50% (5.50% in 1998) annual rate of increase in the per capita cost of covered health care benefits for retirees were assumed for 1999. This cost trend rate is assumed to remain the same in 2000 and thereafter. The health care cost trend rate has a significant effect on the amounts reported. A one-percentage-point change in assumed health care cost trend rates would have the following effects:

	1% Increase	1% Decrease
Effect on Total of Service and Interest Cost Components	$ 4,201	$ (3,259)
Effect on Postretirement Benefit Obligation	36,546	(29,257)

Note K
Contingencies

The Institute receives funding or reimbursement from governmental agencies for various activities, which are subject to audit, and is a defendant in various legal actions incident to the conduct of its activities. Except as specifically discussed below, management does not expect that liabilities, if any, related to these audits or legal actions will have a material impact on the Institute's financial position.

In February 1997, the Office of Inspector General of NASA issued a subpoena for a large number of financial records relating to the operation of JPL. The Institute has provided the requested financial records and Institute representatives have had ongoing discussions with appropriate government officials. Government officials have made no claims against the Institute but their investigation of the financial records has not been concluded. The Institute is unable to predict whether any claims may be made, or if made, the ultimate resolution thereof.

The Institute is also a defendant in a civil lawsuit seeking to recover damages arising out of the alleged discharge of toxic materials at or near JPL. The Institute has denied all of the plaintiffs' material allegations, has asserted various affirmative defenses and has asserted claims against the United States for indemnification. The Institute intends vigorously to defend this case and to press its indemnification claims.

The Institute has been named as a potentially responsible party (PRP) by NASA under the Comprehensive Environment Response, Compensation and Liability Act, as amended. As a PRP, the Institute may be jointly liable for contribution towards clean-up costs, estimated to be in excess of $100 million, of the NASA/JPL Superfund site. The Institute believes that it will have recourse to the government for any liabilities it may incur in connection with being named a PRP for that site.

Officials of the Institute presently are not able to predict the impact, if any, that final resolution of the matters discussed in the preceding three paragraphs will have on the Institute's financial position or operating results.

PRICEWATERHOUSECOOPERS

To the Board of Trustees of the California Institute of Technology

In our opinion, the accompanying balance sheets and the related statements of activities and of cash flows present fairly, in all material respects, the financial position of the California Institute of Technology ("the Institute") at September 30, 1999 and 1998, and the changes in its net assets and its cash flows for the years then ended in conformity with generally accepted accounting principles. These financial statements are the responsibility of the Institute's management; our responsibility is to express an opinion on these financial statements based on our audits. We conducted our audits of these financial statements in accordance with generally accepted auditing standards which require that we plan and perform the audits to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements, assessing the accounting principles used and significant estimates made by management, and evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for the opinion expressed above.

PricewaterhouseCoopers LLP

January 14, 2000

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As of February 2000

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as of February 21, 2000

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1998–99 Annual Report

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