CALIFORNIA INSTITUTE OF TECHNOLOGY

Annual Report 1997–98

WORKING AT THE KNOWN LIMITS OF MEASUREMENT

... a glossary of terms.

TERAFLOP: a measure of computer speed equaling one trillion floating-point operations per second. A floating-point operation is one that requires the computer to move the decimal point (e.g.,dividing 24 by 10). **GIGABASE PAIRS:** a measure of the size of a piece of DNA equal to one billion base pairs. A base pair is one "rung" on the DNA ladder (or, if you prefer, one "tread" on the spiral staircase). **MEGAPARSEC:** a measure of distance equal to one million parsecs, or 3.26 million light-years. "Parsec" (short for "second of parallax") describes how far you'd have to be from our solar system for the earth to appear to be one arc-second away from the sun (an arc-second is 1/3600 of a degree). **HYPERNOVA:** a term used by astronomers to describe the catastrophic collapse of a really massive star. Hypernovae are similar to the better-studied supernovae, but are at least 100 times more violent. It has been theorized that hypernovae are what fuel gamma-ray bursts. **NANOMETER:** one billionth (10^{-9}) of a meter. As a point of reference, a piece of cellophane tape is approximately 300,000 nanometers thick. **FEMTOSECOND:** one quadrillionth(10^{-15}) of a second. One femtosecond is to one second as one second is to 30 million years. **ATTOMOLE:** not, as you might guess, what you say to encourage a gopher; rather, one quintillionth (10^{-18}) of a mole. A mole is the chemist's standard measure of the number of molecules in a sample (6.02 times 10^{23} molecules). Thus, an attomole is 602,000 molecules. **MICROKELVIN:** one millionth of a Kelvin. The Kelvin scale measures temperature from absolute zero (-273.15 Centigrade), the point at which all molecular motion ceases, and thus is favored for describing extremely cold substances.

LETTER FROM THE CHAIR OF THE BOARD

THIS SPRING marks the first anniversary of David Baltimore's inauguration as Caltech's president, as well as his first opportunity to speak from the pages of this publication. However, the Institute's sixth CEO actually arrived in Pasadena in October 1997, giving both him and the campus closer to a year and a half to take each other's measure.

From my perspective as Board chair, this period of acquaintance has gone extremely smoothly. Under Dr. Baltimore's direction, the business of Caltech—world-class research and education in science and engineering—hasn't missed a beat. The Institute welcomed its largest-ever freshman class in September 1998: 254 students (31 percent of them women). The work of Caltech scien-

tists continued to receive wide recognition, of which Professor of Geophysics Don L. Anderson's Crafoord Prize is an especially notable example. Faculty publications continued to have a profound impact in the worldwide research community. According to *Science Watch's* count of citations in the scientific literature, 12 Caltech research areas rank in the top 10 nationally in their respective fields.

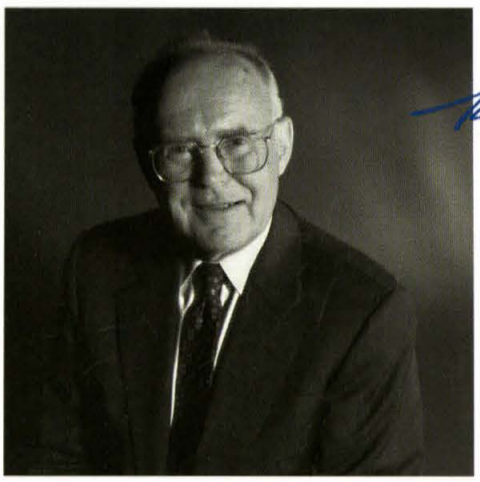
During his first year, Dr. Baltimore presided over several significant institutional milestones—the 75th anniversary of the Earnest C. Watson lectures; the 40th and 50th anniversaries of the Owens Valley Radio Observatory and the Palomar Observatory, respectively; and the 20th anniversary of the Summer Undergraduate Research Fellowships (SURF) program. He also oversaw the May 1998 launch of the Biological Sciences Initiative (BSI). This effort, ably cochaired by Institute trustees Camilla Frost and Ben Rosen, aims to provide funds for the facilities, equipment, and people needed to pursue new and expanded programs in the biological sciences, with emphasis on bringing expertise from multiple disciplines to bear on the challenges facing biology today. The BSI received its largest single gift to date in September 1998, when Southern California business leader and Caltech trustee Eli Broad contributed $18 million to the cause. This donation will help fund construction of the Broad Center for Biological Sciences, a 100,000-square-foot building that will house 10 to 12 biological research groups. More than $60 million has now been raised toward the BSI's $100 million goal.

Since Dr. Baltimore took office, the Institute has also undergone several significant administrative changes. Following the departure of John Curry in November 1998, two longtime members of the Caltech community graciously agreed to take over his duties while a search for his successor was under way. Professor of Civil Engineering and Applied Mechanics and former Provost Paul C. Jennings is serving as acting vice president for business and finance, and Provost Steven Koonin has assumed oversight of the Administrative Process Engineering project, which Curry had directed. Professor of Mechanical Engineering Christopher E. Brennen was named vice president for student affairs, succeeding Professor of Mathematics Gary Lorden, who had held the post for the previous eight years. Thomas A. Tombrello, the William R. Kenan, Jr., Professor and professor of physics, was appointed chair of the Division of Physics, Mathematics and Astronomy, succeeding physicist Charles W. Peck, who held the post from 1993 to 1998.

As usual, the Board of Trustees also underwent changes in 1997–98. We welcomed five new trustees, four of whom are Caltech alumni: Lounette Dyer, MS '87, PhD '91, cofounder and chief technical officer of Cogit Corporation, San Francisco; Alexander Lidow '75, CEO of International Rectifier Corp.,

El Segundo, California; York Liao '67, cofounder of Varitronix Ltd. of Hong Kong; Patrick H. Nettles, Jr., PhD '71, president and CEO of CIENA Corporation; and Ronald L. Olson, a senior partner at the law firm of Munger, Tolles & Olson, Los Angeles. In addition, Thomas E. Everhart was elected to the Board in September 1998, having been named president emeritus the previous October. On a more somber note, the Board was saddened by the deaths of Life Trustees William A. Hewitt, James E. Robison, and William E. Zisch.

Reflecting on David Baltimore's first year as president reminds me yet again what a debt of gratitude is owed the faculty search committee that recruited him. They clearly understood their mission, and the entire campus community is now reaping the rewards of their expertise. I must also congratulate my fellow trustees for their perspicacity in following the faculty committee's recommendation. Once again, this extraordinary institution has had the great good fortune to find an equally extraordinary leader. All of us—faculty, students, staff, and trustees—can carry on our work with easy minds; we are in good hands.



Gordon E. Moore

Chair of the Board of Trustees

"...looking for a scale rich enough to measure the Institute's true significance."

LETTER FROM THE PRESIDENT

COMING TO CALTECH has been one of the most exhilarating experiences of my life. How exciting to discover this village of science embedded within the lovely city of Pasadena! It is a great testament to my predecessors that an institution so small, so physically enchanting, and so young can be at the pinnacle of so much of modern-day science, social science, and technology and at the same time be training the leaders of tomorrow.

One of my first goals when I assumed the presidency of Caltech was to immerse myself in its culture, so that I could begin to feel like a member of the community. Toward this end, I have tried to observe and analyze the Institute from as many points of view as possible. Recently, as I was trying to describe what I've been doing for the past 18 months, a phrase occurred to me: I have been *scaling Caltech*. Because this phrase can be interpreted in a number of ways, it effectively expresses the multiplicity of perspectives I've needed to adopt in the course of learning about this unique institution.

First, I think of "scaling Caltech" as something like scaling a fish: peeling back the protective shell deposited over time to reveal the vital organism inside. To understand how Caltech became what it is today, I had to look beneath the surface at the interplay of tradition and inno-

vation in its history. Along these same lines, a second meaning occurred to me, that of placing Caltech in the right scientific, social, and historical contexts. I was looking for a scale rich enough to measure the Institute's true significance.

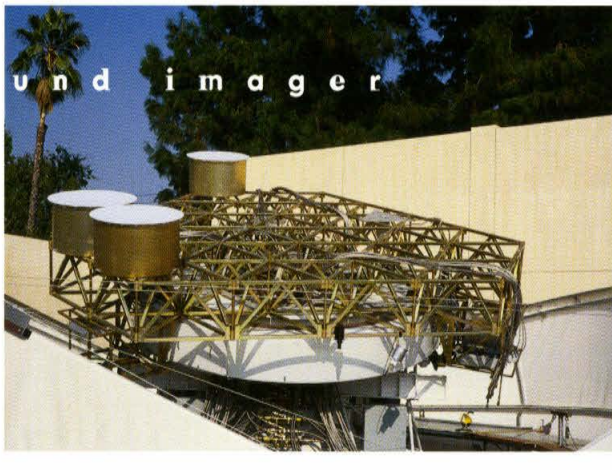
A third—and for me, more personal—reading of the phrase was that of getting to the top. Much as a traveler might visit Switzerland with hopes of scaling the Alps, I came to Caltech expecting peak experiences—and I haven't been disappointed. From becoming acquainted with the remarkable people who make up the Caltech community to experiencing the pomp and circumstance of inauguration, a significant portion of my presidency has felt like an ascent into rarefied air.

Each of these notions could be explored in greater depth, but instead I'd like to focus on yet a fourth meaning, one that probes even closer to the core of Caltech's greatness. That fourth sense of "scaling Caltech" has to do with the scales used to measure its science.

When I first arrived on campus and began talking with the faculty, I was impressed that most of them were working at the known limits of measurement in their particular fields. The computer scientists were considering *teraflops*. The astronomers were peering out to *megaparsecs*. The biologists were sequencing *gigabase pairs* of DNA while examining events at *nanometers* of resolution, the chemists were resolving events within *femtoseconds*, and the physicists were examining molecular behavior at *microkelvins* of temperature. Many investigators were going even further, pushing measurement to unprecedented extremes, forcing us to learn new terms like *attomoles* and *hypernovae*. The objects of their investigations ranged in size from the largest and oldest structures in the universe to the tiniest components of matter.

This letter would quickly expand into a textbook if I tried to relate everything I've learned so far about the scales of concern in each Caltech division. Instead, I'd like to cite a few examples drawn from the remarkable work our faculty pursued throughout 1997–98.

cosmic background imager



The CBI being tested on the Caltech campus before transportation to its final destination near San Pedro de Atacama, Chile, 5,000 meters above sea level.

FIRST, THE BIG PICTURE: ASTRONOMY, with scales of measurement that describe very large or very distant phenomena. With its remarkable array of observatories, Caltech has more and better tools to probe the solar system, the galaxy, and the universe than any other institution. These range from the Owens Valley Radio Observatory in Big Pine, California, to the legendary Palomar Observatory in northern San Diego County, to the Submillimeter Observatory and the W. M. Keck Observatory on Mauna Kea, Hawaii, to the new Cosmic Background Imager (CBI), which will begin to operate at an altitude of 16,600 feet in Chile's Atacama Desert later this year. These observatories are limited to the windows of clarity in the atmosphere—the visible, near infrared, and certain radio frequencies. To extend our observational abilities beyond atmospheric limitations, we also have flying observatories, some of which operate aboard spacecraft designed at the Jet Propulsion Laboratory, a member of Caltech's "extended family." (See page 24 for more information on recent JPL missions.)

One interesting flying-observatory project is Boomerang, which was designed to loft a 1.3-meter telescope over Antarctica aboard a high-

boomerang

The "flying observatory" on launch day, December 29, 1998. Mt. Erebus appears in the background.

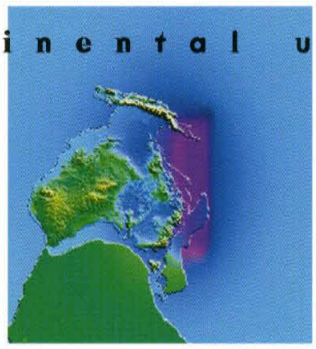
altitude balloon. Boomerang (see page 7) was developed by Professor of Physics Andrew Lange and his research group, in collaboration with colleagues in Rome, Florence, Berkeley, Santa Barbara, and Amherst. The observatory employs detectors, developed at JPL by Visiting Associate in Physics Jamie Bock, that have unprecedented sensitivity to variations in the cosmic microwave background (CMB), the uniform glow of microwave radiation in the sky. The CMB came into existence only seconds after the Big Bang and has apparently remained unchanged ever since. It thus represents by far the richest, most pristine "fossil" scientists can study to determine what the early universe was like.

Boomerang successfully completed an 11-day mission in January 1999, mapping the millimeter-wave sky from 120,000 feet above the Antarctic. In addition to gathering data from their balloon observatory, Lange and his group have used both the Owens Valley Radio Observatory and the Caltech Submillimeter Observatory to study the CMB—and they have plans to extend their observations even further. They will send instrumentation similar to that used on Boomerang into space aboard the Planck Surveyor, a satellite that will be launched by the European Space Agency in 2007 and is expected to provide the most detailed map yet of the CMB.

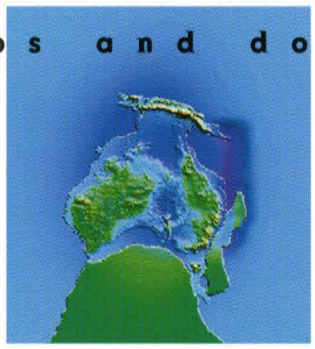
The Cosmic Background Imager is an array of thirteen 90-centimeter antennas that will make images of the CMB with unprecedented precision on scales down to four arc minutes. The instrument, developed by Professor of Astronomy Anthony Readhead and his research group, is presently making test observations from the Caltech campus. It will be packed and shipped to Chile in May and will begin operation in August. Boomerang and the CBI complement each other both in terms of frequency of operation and resolution. Together they make a powerful combination that will allow Caltech scientists to mine much of the cosmological information that is contained in the cosmic microwave background.

Thanks to technological innovations like the CBI and Boomerang, cosmological research is proceeding at a rapid pace. Many current questions (How old is the universe? Will it expand forever?) will likely be answered definitively within the next 10 to 20 years. Other questions (What is the nature of the dark matter?) will move from the realm of speculation to that of scientific inquiry. Still others (What existed before the Big Bang? Are we one of many universes?) may become less the province of metaphysics and more that of astrophysics. The study of the CMB will give us a profoundly deeper understanding of the role microscopic quantum effects may have played in forming the galaxies we observe today, thus clarifying the connections between the very small and the very large constituents of the universe.

continental ups and downs



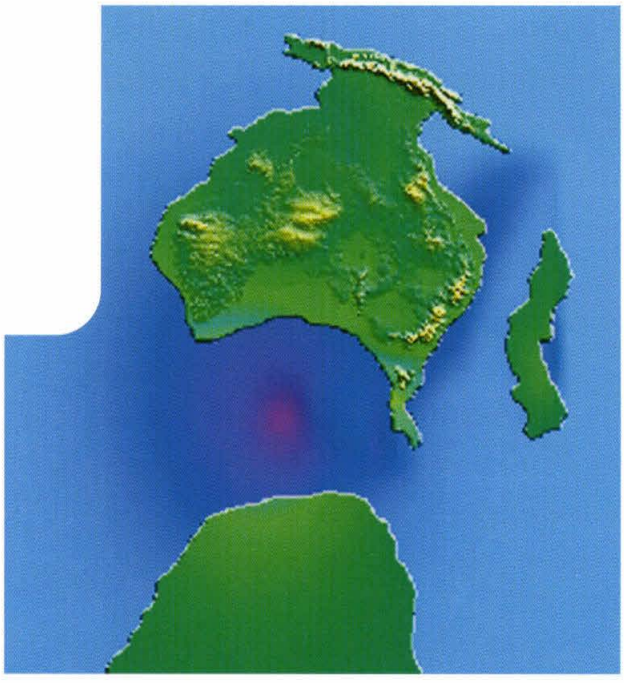
120 million years ago



90 million years ago

60 million years ago

MUCH AS COSMOLOGISTS STUDY TEMPERATURE FLUCTUATIONS in the CMB to learn about the history of the universe, Caltech geologists study fluctuations in the earth's crust to understand the history of our planet. One notable line of research in this area is that of Michael Gurnis, professor of geophysics and associate director of Caltech's Seismological Laboratory. Gurnis and two Australian colleagues have integrated the theory of plate tectonics with the laws of physics to produce a dynamic, three-dimensional model for the large-scale evolution of the earth.



10 million years ago

Four frames from a computer simulation showing the horizontal and vertical movement of Australia. At its lowest point, 120 million years ago (Ma), the continent was partially covered by a shallow marine sea. From about 90 Ma to 60 Ma, the shallow sea retreated as Australia slowly rose upward in response to convective motions in the earth's interior.

Traditional plate tectonics describes only how the earth's crust has moved horizontally over millions of years. But besides moving horizontally, land masses also move vertically, ascending and descending over time by thousands of feet. Both kinds of motions are driven by mantle convection, the "heat engine" operating far beneath the earth's surface. By showing the connections between plate motion and mantle convection, Gurnis's model explains for the first time certain features of the earth's present-day appearance that were mysteries in terms of traditional plate tectonics.

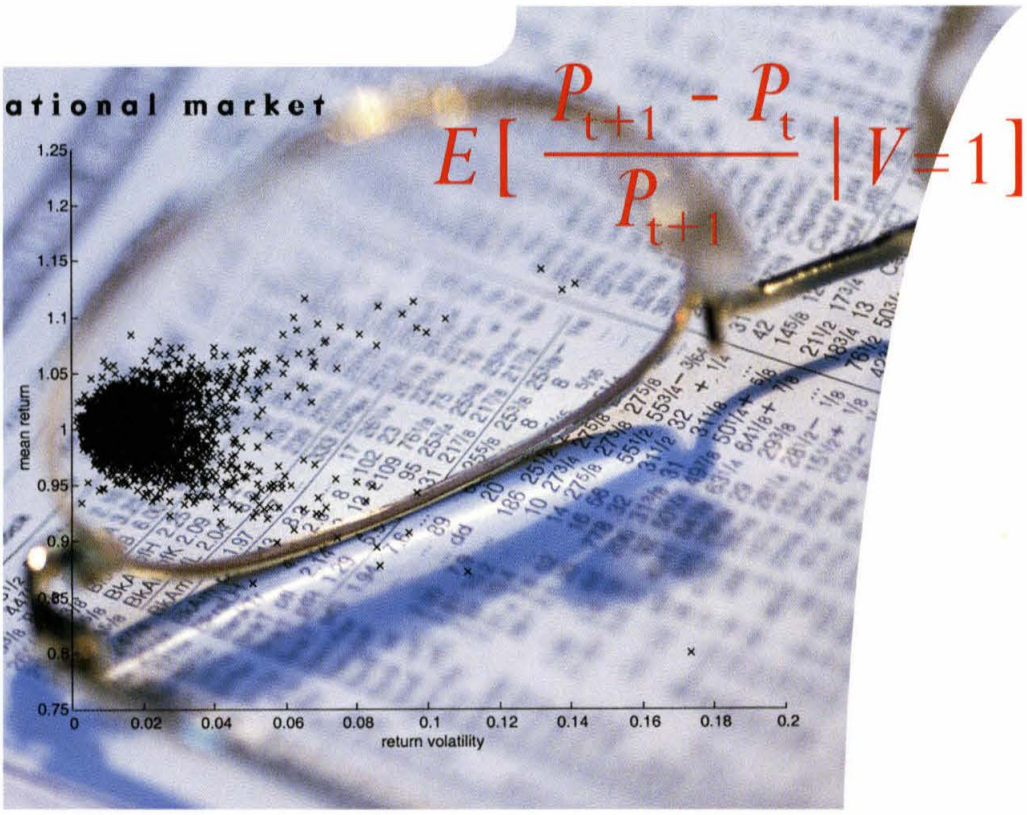
Gurnis's recent work has focused on what the movement of the Australian plate reveals about these motions and forces (see illustrations, page 9). Geologists already knew that about 70 million years ago, when half the continents were under water, Australia was high and dry. In addition to detaching itself from Antarctica and migrating northward, Australia had evidently moved vertically—but why? Gurnis's new model demonstrates that Australia rose in elevation when another plate passed under it, sticking in the earth's mantle long enough to force the continent upwards. Over and above what it reveals about Australia, Gurnis's work could open up a new scientific frontier. It may help geophysicists predict the motions of plates from computer models of the earth's internal heat engine, much as meteorologists use global circulation models to predict climate change.

WHILE IT'S CERTAINLY A COMPLEX UNDERTAKING to predict changes in our physical environment, explaining the behavior of human beings and their institutions is no less challenging—as faculty in Caltech's Division of the Humanities and Social Sciences can attest. In attempting to decipher the puzzles of human society, Institute political and social scientists often use the same quantitative methods as their colleagues in mathematics and the sciences. One interesting example of this approach is Professor of Finance Peter Bossaerts's study of the behavior of a particularly complex human institution: the stock market.

The recent wild fluctuations in the Dow Jones Average and the poor performance of certain highly touted initial public offerings led many experts to conclude that the stock market had become irrational. Bossaerts didn't agree. It seemed to him that these analysts might mistakenly have colored their present judgments with the benefit of hindsight. In order to prove this, he set about devising a mathematical model that would not require information about the accuracy of investors' beliefs at any particular time in order to test the market's rationality. Empirical tests of the model showed that, even though the market had been chaotic and unpredictable, it was far from being irrational.

a rational market

$$E\left[\frac{P_{t+1} - P_t}{P_{t+1}} \mid V=1\right]=0$$



A graph plotting average return against volatility (risk) of the S&P 500 index, measured over five-day intervals from January 4, 1928, to December 31, 1997. Contrary to standard asset pricing theory, higher volatility is not associated with a higher average return. Rather, large price movements—which lead to average returns far above or below zero—are always accompanied by abnormally high volatility. This relationship is to be expected in a rational market, for otherwise there would be arbitrage opportunities.

In addition, Bossaerts's model demonstrated that volatility was actually the sign of a rational market, because it showed that the market was responding appropriately to the events of a restless world. In fact, the model predicted a peculiar relationship between the size of price changes and the volatility with which they occur. The Dow Jones Average and the S&P 500 indices incontestably displayed this previously undiscovered relationship (see graph, above). Bossaerts plans to continue testing how well the market reads the news until the "experts"—like those at the *Wall Street Journal,* which recently published an article criticizing mathematical models like his—are persuaded that he's right.

The hemochromatosis protein at the cell surface. The multicolored ribbons depict HFE; the purple "eggs" represent the still-unknown structure of the transferrin receptor; and the floating green squiggles represent transferrin carrying iron (red dots) to the cell.

THE PROJECTS I'VE DESCRIBED SO FAR might all be said to concern "outer space"—if that definition can be stretched to include the cosmos, the outer surface of our planet, and the observable behavior of human institutions. Equally impressive, however, are the Institute's achievements in "inner space"—in the chemistry, biology, and engineering being pursued at molecular and atomic scales.

One such accomplishment in the past year is the Bjorkman lab's determination of the X-ray crystal structure of the human hemochromatosis protein, HFE. Professor of Biology Pamela Bjorkman and her colleagues were able to obtain a three-dimensional image of HFE at 2.6-angstrom resolution (an angstrom is one ten-billionth of a meter)—a very small scale indeed. They then used the 3-D structure to generate the "ribbon" model pictured opposite, which depicts the protein on the surface of a cell interacting with another cell-surface protein and an iron-containing protein in serum. Determining the structure of HFE is an important step in understanding how it and similar proteins interact with other cell structures. The work may also have implications for the treatment of anemia and other iron-related conditions, as well as for the understanding of hereditary hemochromatosis (HH).

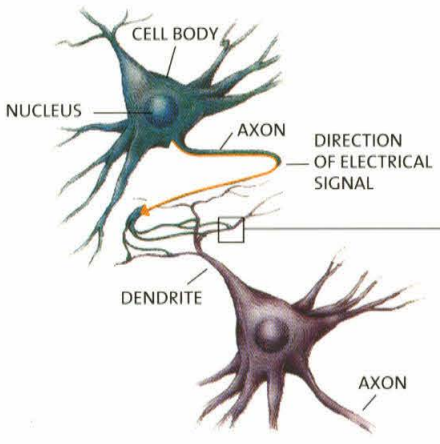
Hereditary hemochromatosis is the most common, and probably least familiar, inherited disease in the United States, affecting approximately one in 300 people of Northern European descent. It occurs when, due to a genetic mutation, the hemochromatosis protein does not form properly, thus allowing the body's cells to absorb too much iron. The disease is eventually fatal if not treated. Unfortunately, HH often remains undiagnosed, because it typically produces no symptoms until middle age. Even when its serious effects—such as heart disease, cirrhosis, and diabetes mellitus—begin to appear, HH tends not to be suspected as the cause. The Bjorkman lab's findings are relevant to an understanding of the regulation of iron absorption under normal and pathological conditions and, by contributing to a growing body of information about HH, may increase awareness of the disease and prompt more people to be tested and treated.

WHILE BJORKMAN AND OTHER BIOLOGISTS try to determine how proteins are constructed, Professor of Chemistry Dennis Dougherty asks a complementary question: how do proteins function at the chemical level? Especially notable in the past year is Dougherty's discovery about how the neurotransmitter acetylcholine binds to its receptor—a revelation from the atomic end of the Caltech neuroscience scale.

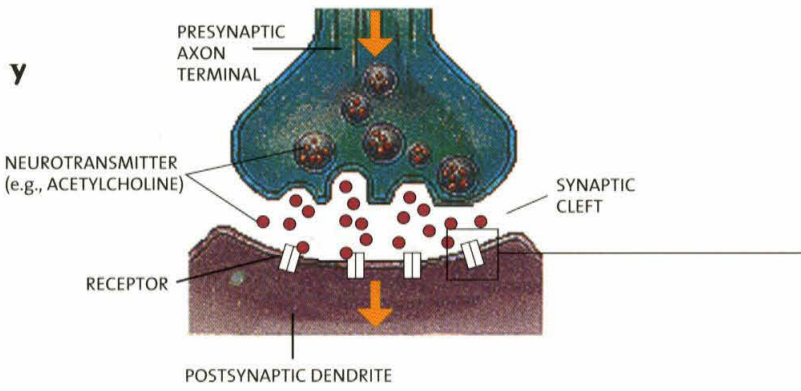
The cells of the brain and nervous system (neurons) communicate by sending small organic molecules (neurotransmitters) across the gaps (synapses) that separate one neuron from another. Acetylcholine is the most common neurotransmitter, and its messages are received by large proteins called nicotinic acetylcholine receptors. These receptors come into play at neuromuscular junctions whenever a nerve signals our muscles to move, and also figure prominently in neuron-to-neuron communications within the brain.

Although it is critical to our understanding of the brain to know how neurotransmitters and their receptors interact, receptor structures have been notoriously difficult to study. Unlike proteins that circulate through the blood (HFE, for example), most molecules on the surface of neurons don't crystallize. In fact, they just randomly aggregate when they are removed from the cell membrane in which they're embedded.

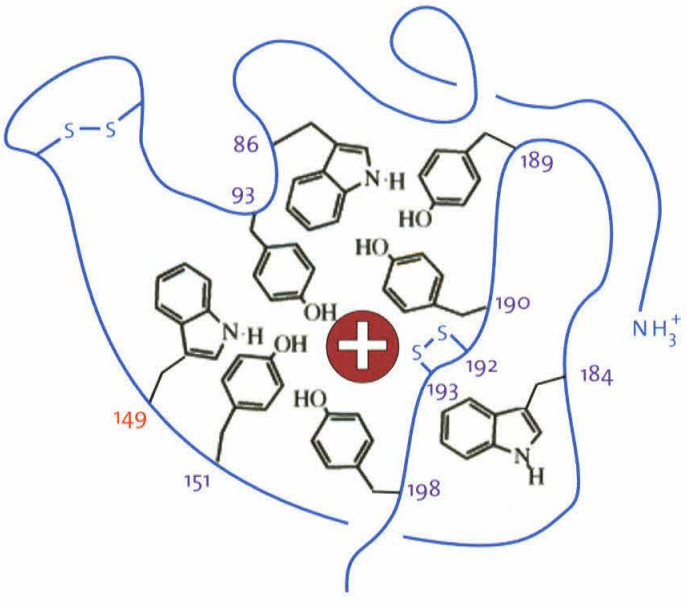
brain chemistry



The Neuron

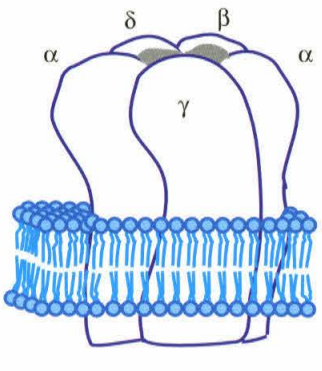


The Synapse

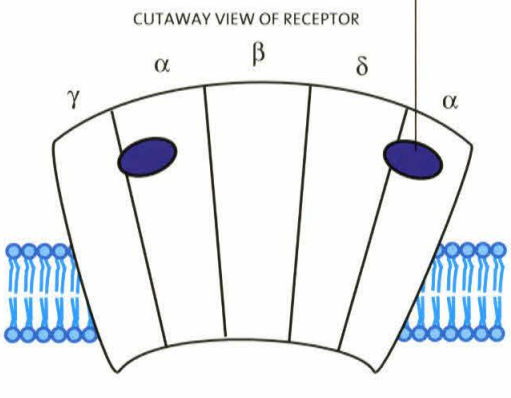


The "venue" of Dougherty's and Lester's research, in increasing magnification from the cellular to the chemical scale. The top figure shows the various amino acids that were candidates for acetylcholine binding. The investigators established amino acid 149 as the most important contributor to the binding site.

Neurotransmitter Binding Site



Neurotransmitter Receptor

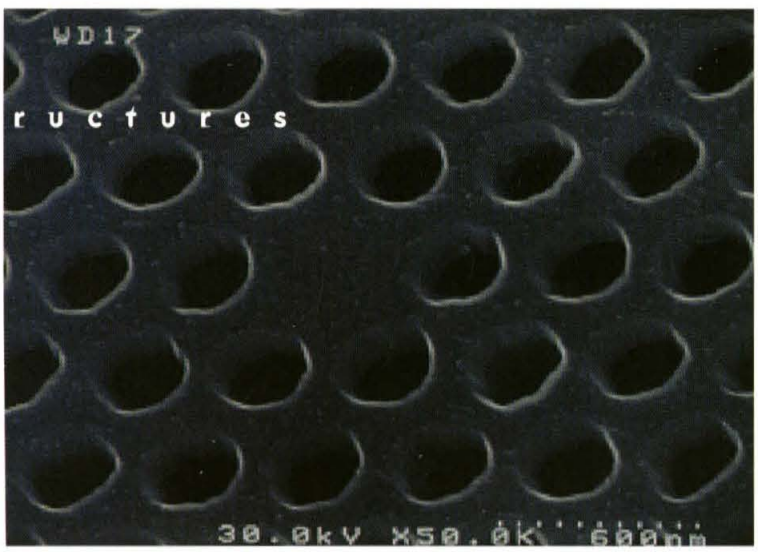


Dougherty, however, working with Caltech Professor of Biology Henry Lester, has developed a technique that sidesteps these difficulties. Using several of the most powerful tools of modern science—methods borrowed from molecular biology, organic chemistry, electrophysiology, even quantum mechanics—the two investigators modified the nicotinic acetylcholine receptor atom by atom until they pinpointed the exact spot where acetylcholine binds to it (see diagrams, left and above).

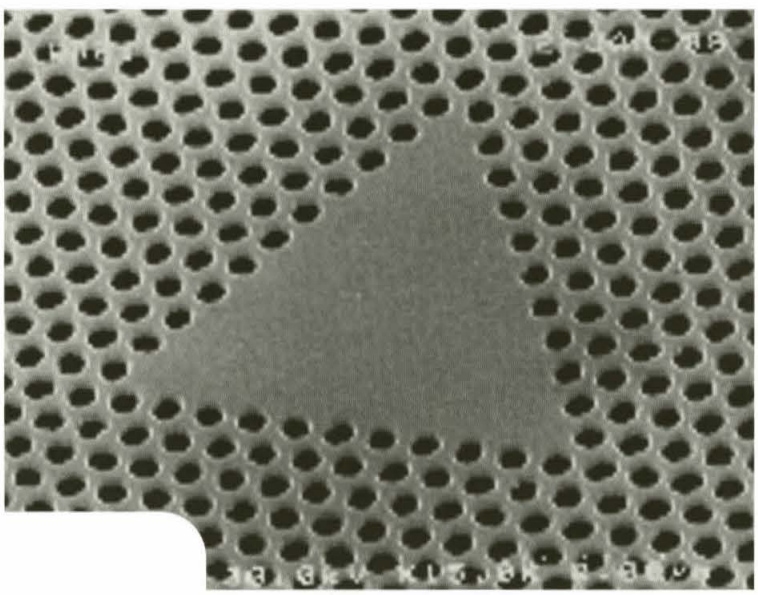
Having the ability to change the structure of molecules with this degree of precision will allow investigators to ask equally precise questions about how other molecules function. In particular, Dougherty's and Lester's work could have far-reaching

implications in the treatment of brain-chemistry disorders. Acetylcholine travels in the same neural pathways that are targeted by substances like nicotine; ABT-594, an exciting new analgesic; and tacrine, the first drug approved for the treatment of Alzheimer's disease. Understanding how these substances influence the brain at the molecular level could give scientists greater insight into the mechanisms of disease and addiction, as well as leading to more effective interventions.

tiny structures



A scanning electron micrograph of a photonic crystal microcavity fabricated in indium-gallium-arsenic-phosphorus semiconductor material. This "defect" cavity (so called because one hole is missing) is only two cubic half-wavelengths in volume, or 0.03 cubic microns.



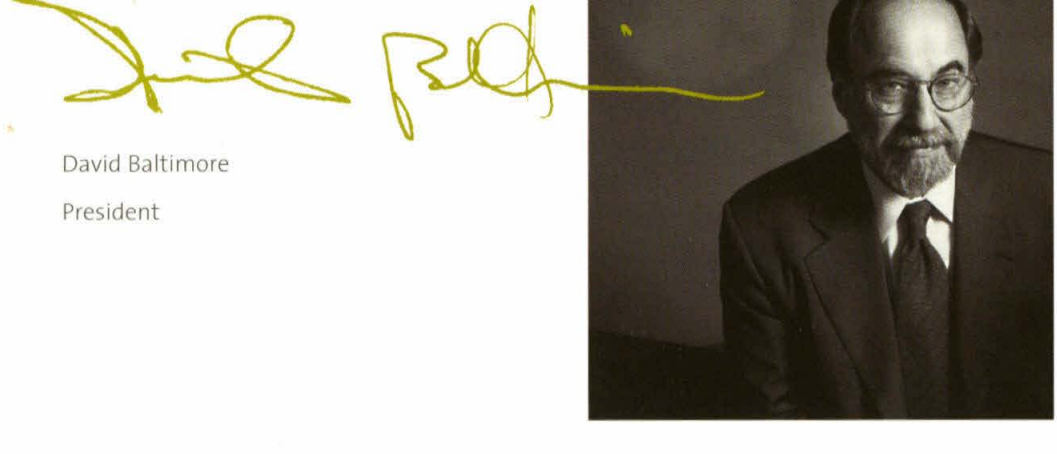
A scanning electron micrograph of a different photonic crystal—one with a triangular, slightly larger cavity. While the defect cavity pictured above supports only a single localized mode, the triangular cavity can also support a host of localized modes, which bounce around inside, trapped by the photonic crystal walls.

WHILE LABS LIKE BJORKMAN'S AND DOUGHERTY'S investigate minuscule organic structures, other Caltech research groups are engaged in designing and building tiny artificial structures—machines and devices only nanometers (billionths of a meter) in size. Professor of Electrical Engineering, Applied Physics, and Physics Axel Scherer and his colleagues, for instance, have used such techniques as chemically assisted ion-beam etching to carve patterns as small as three atoms wide into a variety of materials. Especially notable among their recent inventions are optical crystals for use in laser applications (see illustrations, opposite). These so-called photonic bandgap crystals are etched with tiny cavities that are lined with mirrors to capture and reflect light. The structure of the crystal virtually eliminates light scattering, significantly improving laser efficiency. Scherer's lab is also at work on the smallest man-made magnets ever built—a mere 17 nanometers in diameter. When these magnets are perfected, they could dramatically increase the data storage capacity of computer disks, from the current standard of 10 gigabytes per square inch to perhaps 65 gigabytes per square inch. A third Scherer project provides yet another illustration of the interdisciplinary nature of much of Caltech's research. In collaboration with Assistant Professor of Applied Physics Stephen Quake, Scherer is exploring the application of nanotechnology to biology. The two investigators hope to produce devices that can be used to control the way molecules interact or to manage them after they interact—DNA-sorting channels, for instance, or even "intelligent sieves" that mimic the functions of a cell membrane.

THESE PAGES, unfortunately, can only accommodate glimpses of the dazzling science I've been trying to "scale." My report wouldn't be complete, however, without mention of one other path of discovery that has become increasingly important to me. I'm referring to learning about the lives of our undergraduate and graduate students—1,900 or so of the brightest, most promising young scientists and engineers in the world.

The Caltech community has in its students an extraordinary resource. But in pursuing our primary focus on world-class research, we sometimes think of them too narrowly. Because they are so gifted, we owe them a student life that addresses all their gifts, not only their potential as scientists. I believe that education ought to be about identifying and developing the wonderfully complex amalgam of strengths and challenges within each human being. To this end, we ought to pursue a variety of means to create greater balance in our students' lives. We can encourage participation in and appreciation of the arts, which teach us so much about life's intricate mixture of rationality, passion, and history. Under the aegis of organizations like the Caltech Y, we can offer students the lessons and rewards of giving service to the local community. And we can continue our efforts to increase the diversity of our student body; the broader the range of backgrounds and experiences students encounter in each other, the richer their educational experience will be.

It's been an eventful and rewarding year and a half. I've gotten to know quite a few members of the Caltech community, I've heard remarkable accounts of research at the frontiers of human understanding, and I've had a variety of opportunities to share those accounts with audiences both on and off campus. After spending the past 40 years immersed in the realm of biology, it's exhilarating to be a part of the multiplicity that is Caltech science. Having "scaled" this far, I can say that the view from the top of Caltech is hard to beat. I look forward to savoring it for many years to come.



David Baltimore
President

The Caltech community has in its students an extraordinary resource.

1998 FELLOWSHIP WINNERS

(all students are members of the class of 1998, unless otherwise noted)

National Science Foundation Fellowships
Karen Bletzer
Nicholas J. Choly
John (Jake) Christensen
Brian D'Urso
Alexander Dunn
Jeremiah Mans
Keri Ryan
Melissa Sáenz
Julius Su
James Turner
Patricio Antonio Vela

Alumni:
Stephen Bennett
Shirley Chen
Sham Kakade
Dmitri Linde
Kevin Neville

Graduate Students:
Sujata Bhattacharyya
Patrick Cirino
Heather Ann Cox
Roman Ginis
Keith Matthews
Robert Peters
Matthew Pritchard
Alice Shapley
Pavel Strop
Matthew Sumner
Yi Tang
Patricia Udomprasert
David Vakil

Churchill Scholarship
Kerwin Casey Huang

Department of Defense National Defense Science and Engineering Graduate Fellowships
Brian D'Urso
Mason Porter
Evan Reed

Hertz Fellowships
Brian D'Urso
Alexander Dunn

Howard Hughes Predoctoral Fellowship in Biological Sciences
Sujata Bhattacharyya
(graduate student)

NSEP (National Security Education Program) Undergraduate Fellowship
Reuben (Walt) Ogburn, IV
(class of 1999)

Thomas J. Watson Fellowship
Jeanne Wilson

Bourses Chauteaubriand
Jean-Paul Davis *(alumnus)*

"...prob[ing] even closer to
the core of Caltech's greatness."

The Evolving Campus

- NOVEMBER '97: The renovation of San Pasqual Street was completed, changing it to a pedestrian mall. The project had been planned for years, but was postponed until the Holliston Avenue parking structure was finished.
- MAY '98: Installation of CITnet 2000, a state-of-the-art computer network, reached the halfway point (the project began in August 1997 and is scheduled for completion in summer 1999). The new network will be capable of handling all campus administrative activity, as well as the research and educational functions performed by the old network—an essential capability for the successful implementation of the Administrative Process Engineering project.

- SEPTEMBER '98: The remodeling of the Caltech Bookstore in Winnett Center, begun in September 1997, was completed. The spacious new facility houses a separate computer store, Caltech Wired, and the relocated Red Door Cafe.
- FISCAL '98: Administrative Process Engineering, the campuswide redesign of the Institute's business practices, completed its software selection phase. Oracle products were chosen for the areas of financials, human resources, and payroll; Exeter software for student services; JSI Millennium for fund-raising data management; and Prism for physical plant operations. Business system redesign was largely completed by spring 1998. A period of analysis followed to determine which software configuration would be most responsive to Caltech's policies and procedures.

  Student services was the first area to become operational, introducing new systems for financial aid and seven other student services areas in August 1998. On

another front, two purchasing systems were tested in pilot programs: an on-line, Web-based catalog called WebAlog, and a corporate procurement card known as the Caltech Passport.

The official debut of the new systems is planned for July 1999.

Milestones

- The 75th anniversary of the Earnest C. Watson lectures, October 1997.

  To commemorate the anniversary, David and Judith Goodstein—vice provost, Gilloon Distinguished Teaching and Service Professor, and professor of physics and applied physics; and the Institute registrar and archivist, respectively—presented "Earnest Watson and the Amazing Liquid Air Show." The Goodsteins' talk was a reprise of the late physics professor's demonstration, first delivered in 1919 to spice up a physics course he considered dull. Besides having historical interest in their own right, the Watson lectures are notable for their role in shaping the Caltech campus: Beckman Auditorium was designed with their presentation in mind.

- The 50th anniversary of the 200-inch Hale Telescope at Palomar Observatory, November 1997.

  Located on Palomar Mountain, in northern San Diego County, the Hale was the largest and most powerful telescope of its time. Despite the current availability of larger instruments, astronomers still consider the Hale an important tool. It played a key role, for example, in Caltech investigators' 1995 identification and study of the first brown dwarf ever detected.

- The 10th anniversary of *AirTalk: The Caltech Edition,* January 28, 1998. The *Caltech Edition* is a special monthly installment of the regular *AirTalk* series, which is hosted every weekday evening by Larry Mantle on NPR-affiliated KPCC-FM (89.3). Mantle devotes *AirTalk* to interviews of political figures, celebrities, academic personalities, authors, and others from a wide variety of backgrounds. Listeners have the opportunity during the show to call in and talk to Mantle and the guests directly.
- The inauguration of David Baltimore as Caltech's sixth president, March 9, 1998.

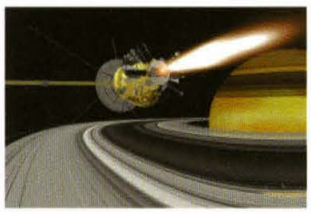
- The 20th anniversary of the Summer Undergraduate Research Fellowships (SURF) program, summer 1998.

  The summer 1998 program was the largest ever, with 293 students participating (100 of them from outside Caltech). Approximately 25 percent of eligible Caltech students now SURF each summer. More than 2,475 students, and close to 700 mentors, have taken part in the program since its inception.

  New in 1998: Caltech Merit Scholars may now SURF during the summer before their freshman year; 22 students did so in 1998. Marcella Bonsall established an award for excellence in technical writing. The Beckman Scholars program was created by a grant from the Arnold and Mabel Beckman Foundation. Thanks to grants from the James Irvine Foundation and General Motors, the Minority Undergraduate Research Fellowships (MURF) program grew to include 20 students and fellowships in two additional divisions—Physics, Mathematics and Astronomy, and Engineering and Applied Science.

- The 40th anniversary of the Owens Valley Radio Observatory, October 1998. OVRO actually comprises three generations of telescopes. The first two antennas, each measuring 27 meters, were dedicated in 1958. The 40-meter dish was finished in 1968. The array of six 10.4-meter millimeter-wave antennas—so sensitive that it can pick up signals 10 billion light-years away—was completed in 1995. OVRO is located outside Big Pine, California.

JPL Highlights



- Saturn is the destination of JPL's Cassini spacecraft, which was launched from Cape Canaveral in October 1997. The first leg of its trajectory took Cassini past Venus in April 1998. The spacecraft will swing by Venus and Earth once more before arriving at the ringed planet in 2004. There, Cassini will drop a European-built probe named Huygens onto the surface of Titan, Saturn's largest moon. Titan intrigues scientists because its atmosphere harbors organic chemistry that may be similar to prebiotic conditions on the early Earth.
- The Galileo spacecraft embarked on an extended mission during its third year in orbit around Jupiter, focusing on close flybys of the giant planet's moon Europa. This mission gave scientists compelling new evidence that Europa may harbor a subsurface ocean below its icy crust.

- Mars Global Surveyor, after arriving at the red planet in September 1997, spent a year adjusting its orbit and taking preliminary data before beginning its prime mapping mission in 1999. The spacecraft captured images of the planet at unprecedented resolutions and helped scientists make important discoveries about Mars's magnetic environment and conditions on its moon Phobos.
- To amateur and professional weather-watchers alike, 1998 was the Year of El Niño—and the joint U.S.-French satellite TOPEX/Poseidon was there to chronicle the phenomenon's effect on the elevation of the Pacific Ocean. TOPEX science team members became media darlings as El Niño coverage became de rigueur on TV news broadcasts.
- The Lab also continued to conduct research on behalf of NASA and other sponsors. In one noteworthy development, Caltech and Ford Motor Co. announced a licensing agreement under which JPL's neural network chip technology will be used in automobiles. During fiscal year 1998 JPL also established new offices for the study of astrobiology and near-Earth objects.

Community Outreach

- OCTOBER '97: Caltech presented its annual Biology Forum, this year entitled "The Quest for a Cure: AIDS Research at the Millennium." The panel of speakers included Caltech President David Baltimore; alumnus David Ho, director of the Aaron Diamond AIDS Research Center; Mel Simon, chair of Caltech's biology division; and, as moderator, Sandra Thurman, director of the White House Office of National AIDS Policy.
- NOVEMBER '97: Soprano Beverly Sills visited campus as the sixth Michelin Distinguished Lecturer.
- APRIL '98: The "0.1" lectures began their third season. Sponsored by the provost's office, the series of Friday-afternoon talks by Caltech faculty is designed to "build ladders" across disciplines by presenting current research in a manner accessible to nonspecialists. The first year's speakers came from the Division of Biology; the following year's were from Geological and Planetary Sciences. The 1998 lectures, presented by social scientists from the Division of the Humanities and Social Sciences, addressed such fundamental questions as how economic and political institutions affect social decisions, and whether it is possible to think about and study this question in a scientific way.

Student Life

- SEPTEMBER '98: The Institute welcomed the largest freshman class in its history. With 254 students, it was 17 percent larger than the class that entered in fall 1997. The class was 31 percent women, a slight increase over last year; the number of underrepresented minority students also increased. The new undergraduates' average SAT scores were 768 math, 715 verbal (versus the national averages of 511 math, 505 verbal).
- DECEMBER '97: Professor of Theoretical Physics Steven Frautschi was named Master of Student Houses, succeeding Professor of Mathematics David Wales, who had held the position since 1991.

- JUNE '98: COMMENCEMENT

Bill Nye "the science guy" was the speaker at Caltech's 104th commencement on June 12.

Degrees awarded: 219 bachelor's; 121 master's; 3 engineer's; 195 doctoral.

Plans of BS graduates: 41 percent went on to graduate school. Top school choices were Stanford, Caltech, and UC Berkeley. Ten '98 BS recipients were accepted into medical schools.

Caltech students continued to be very successful in competing for graduate fellowships. Eleven National Science Foundation Fellowships were awarded to graduating seniors, and five to recent graduates. Other fellowships awarded included the Hertz, the Churchill, the Marshall, the Watson, and the Rotary.

Those students who chose not to attend graduate school found an active and varied job market. Many graduates reported having several job offers.

Forty-nine different organizations hired at least one Caltech BS graduate. Aerojet, Applied Materials, First Quadrant, Integrated Computing Engines, Intel, Mitchell Madison Group, and Tenfold Corporation each hired more than one.

Plans of PhD graduates: 100 accepted academic employment—12 tenure-track faculty positions and 88 postdoctoral positions. Seventy new PhDs accepted industrial positions with such companies as General Electric, Los Alamos National Lab, TRW, and Allied Signal.

Supporting Caltech

The Institute received a total of $91.1 million in cash and pledges—the second-highest amount in its history—from private donors in fiscal year 1998. Caltech gratefully acknowledges the following individuals and organizations for their generous support:

- Eli Broad—$18 million toward the construction of a new research facility, the Broad Center for the Biological Sciences.
- Gordon and Betty Moore—$8.4 million to fund current Institute priorities.
- Mr. and Mrs. William T. Gimbel—$5 million pledge to the William T. Gimbel Discovery Fund in Neuroscience.

- Camilla C. Frost—$5 million toward the Biological Sciences Initiative, to name a floor in the Broad Center for the Biological Sciences.

- Benjamin M. Rosen—$5 million toward the Biological Sciences Initiative.

- Warren and Katharine Schlinger—$1 million toward a seminar room in the Broad Center for the Biological Sciences.
- The Howard Hughes Medical Institute—$2 million for undergraduate education in the biological sciences.
- The Alfred P. Sloan Foundation—$1.157 million for the Sloan Center for Theoretical Neurobiology.
- The Fletcher Jones Foundation—$600,000 to fund the Chauncey Medberry Endowed Fellowship.
- The Kenneth T. and Eileen L. Norris Foundation—$630,000 for the Caltech-USC MD/PhD program.
- Times-Mirror Foundation—partnership in the TriNet Project, the purpose of which is to build a next-generation, completely digital earthquake monitoring network for Southern California.
- Members of the Associates—$7.1 million in restricted and unrestricted gifts in fiscal 1998. These contributions, when added to gifts over $1 million and the present value of trusts, resulted in total Associates donations of more than $22.1 million for the same period.
- An anonymous alumnus—a $1-million pledge toward the establishment of a discovery fund to support innovative research.
- Through the Alumni Fund, Caltech alumni gave more than $3.5 million in fiscal 1998. Recipients of graduate degrees in chemical engineering, who held their first-ever reunion in 1997–98, were particularly generous, increasing their participation in the Alumni Fund from 23.7 percent in fiscal 1997 to 31.6 percent.
- Bequests totaling more than $8.2 million from the estates of 28 individuals. Especially notable is a $1.56 million bequest from the estate of Olga P. Haerer. Although Mrs. Haerer had no connection with the Institute while she was living, both she and her husband believed that the future would be materially affected by the work of Caltech scientists, and wished to support that work for the good of the world.

The largest bequest of the fiscal year, from the estate of Caltech alumnus Max Alcorn '23, is expected to total more than $3.7 million when distribution is complete. In combination with another $2 million being distributed from charitable trusts he and his wife had established at Caltech, the Alcorns'

gift will total $5.7 million, all of which has been designated for the endowed Max Beeler Alcorn and Ruth Brown Alcorn Undergraduate Scholarship Fund.

- Forty-three gifts in the form of charitable trusts and other life income arrangements with a total value of nearly $8 million. Noteworthy among life income donors is George Housner, the Carl F Braun Professor of Engineering, Emeritus, who has previously made substantial charitable trust gifts and more recently augmented his support by means of generous outright gifts to further research in the area of earthquake engineering.

Rankings

SEPTEMBER '98: Caltech was recognized in *Science Watch*, a publication of the Institute for Scientific Information in Philadelphia, as the first-ranked institution in the nation for the impact of its neuroscience research. To make this determination, *Science Watch* counted the number of times papers published between 1993 and 1997 by Caltech neuroscientists were cited in other scientific papers. The Caltech papers averaged 15.38 citations apiece, as compared to a worldwide average of 6.54 citations per neuroscience paper.

The same survey also ranked 11 other Caltech research areas in the top 10 for impact in their respective fields:

PROGRAM	RANK
Chemistry	2
Materials Science	2
Economics/Business	3
Computer Science	4
Geosciences	4
Physics	4
Astrophysics	5
Biology	6
Biochemistry	6
Mathematics	6
Engineering	7

Especially notable is the third-place ranking of economics/business. Considering that Caltech did not even have an economics program 25 years ago, and that it still comprises a relatively small group of faculty, this is indeed a significant achievement.

FACULTY AWARDS AND HONORS

National awards and honors

National Academy of Engineering, Member:
WOLFGANG G. KNAUSS, Professor of Aeronautics and Applied Mechanics
ROBERT J. McELIECE, Allen E. Puckett Professor and Professor of and Executive Officer for Electrical Engineering

National Aeronautics and Space Administration, NASA Public Service Medal:
ANNEILA I. SARGENT, Professor of Astronomy and Director of the Owens Valley Radio Observatory

National Medal of Science, Recipient:
DON L. ANDERSON, Eleanor and John R. McMillan Professor of Geophysics

National Science and Technology Council, Presidential Early Career Award for Scientists and Engineers:
PAUL WENNBERG, Associate Professor of Atmospheric Chemistry and Environmental Engineering Science

U.S. Department of Energy, E. O. Lawrence Award:
STEVEN E. KOONIN, Vice President and Provost, and Professor of Theoretical Physics
AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics and Professor of Physics

International awards and honors

Chinese Academy of Sciences, Foreign Member:
RUDOLPH A. MARCUS, Aurthur Amos Noyes Professor of Chemistry

Council of the Royal Astronomical Society Associate:
WALLACE L. W. SARGENT, Ira S. Bowen Professor of Astronomy and Director of the Palomar Observatory

1998 Herschel Medal:
GERRY NEUGEBAUER, Robert Andrews Millikan Professor of Physics, Emeritus

International Aerosol Conference, Fuchs Award:
JOHN SEINFELD, Louis E. Nohl Professor, Professor of Chemical Engineering, and Chair of the Division of Engineering and Applied Science

Learned Society of the Czech Republic, Junior Prize:
PETR HORAVA, Sherman Fairchild Senior Research Fellow in Physics

Overseas Chinese Physics Association, 1998 Outstanding Young Researcher Award:
NAI-CHANG YEH, Professor of Physics

Royal Anthropological Institute of Great Britain and Ireland, 1998 Lucy Mair Medal for Applied Anthropology:
THAYER SCUDDER, Professor of Anthropology

Royal Swedish Academy of Sciences, 1998 Crafoord Prize, Corecipient:
DON L. ANDERSON, Eleanor and John R. McMillan Professor of Geophysics

Weizmann Institute of Science, American Committee, 1998 Weizmann Women and Science Award:
JACQUELINE K. BARTON, Arthur and Marian Hanisch Memorial Professor and Professor of Chemistry

Local awards

Young Women's Christian Association of Greater Los Angeles, 1998 Silver Achievement Award:
JACQUELINE K. BARTON, Arthur and Marian Hanisch Memorial Professor and Professor of Chemistry

Awards and honors from professional societies

American Association for Computing, Allen Newell Award:
CARVER A. MEAD, Gordon and Betty Moore Professor of Engineering and Applied Science

American Association of Physics Teachers, 1999 Oersted Medal:
DAVID L. GOODSTEIN, Vice Provost, Professor of Physics and Applied Physics, and Frank J. Gilloon Distinguished Teaching and Service Professor

American Chemical Society
1999 George A. Olah Award in Hydrocarbon or Petroleum Chemistry:
JOHN E. BERCAW, Centennial Professor of Chemistry
1999 Alfred Bader Award in Bioinorganic or Bioorganic Chemistry:
PETER B. DERVAN, Bren Professor of Chemistry and Chair of the Division of Chemistry and Chemical Engineering

American Chemical Society and DuPont, 1999 Peter Debye Award in Physical Chemistry:
JESSE L. BEAUCHAMP, Professor of Chemistry

American Chemical Society, Maryland Section, 1997 Remsen Award:
PETER B. DERVAN, Bren Professor of Chemistry and Chair of the Division of Chemistry and Chemical Engineering

American Chemical Society, New Haven Section, and the Yale University Chemistry Department, 1998 John Gamble Kirkwood Award:
PETER B. DERVAN, Bren Professor of Chemistry and Chair of the Division of Chemistry and Chemical Engineering

American Chemical Society, New York Section, and the Nichols Medal Jury, 1998 William H. Nichols Medal:
AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics and Professor of Physics

American Chemical Society, Puget Sound, Oregon and Portland Sections, 1997 Linus Pauling Medal:
AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics and Professor of Physics

American Chemical Society, Southern California Section, 1997 Richard C. Tolman Medal:
AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics and Professor of Physics

American Geophysical Union, 1998 Harry H. Hess Medal:
DAVID J. STEVENSON, George Van Osdol Professor of Planetary Science

American Institute of Aeronautics and Astronautics, 1998 AIAA Fluid Dynamics Award:
ANATOL ROSHKO, Theodore von Kármán Professor of Aeronautics, Emeritus

American Institute of Chemical Engineers, Professional Progress Award for Outstanding Progress in Chemical Engineering:
JOHN F. BRADY, Chevron Professor of Chemical Engineering and Executive Officer for Chemical Engineering

American Institute of Physics and American Astronomical Society, Danni Heineman Prize for Astrophysics:
ROGER D. BLANDFORD, Richard Chace Tolman Professor of Theoretical Astrophysics

American Philosophical Society, Member:
AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics and Professor of Physics

American Physical Society, Fellow:
MORTEZA GHARIB, Professor of Aeronautics

American Physical Society, Division of Fluid Dynamics, François Frenkiel Award, Corecipient:
THOMAS HOU, Professor of Applied Mathematics

Association of Symbolic Logic, Gödel Lecturer:
ALEXANDER S. KECHRIS, Professor of Mathematics

Economic History Association, Alice Hanson Jones Prize, Corecipient:
LANCE DAVIS, Mary Stillman Harkness Professor of Social Science

Fourth International Conference on Quantum Communication, Measurement, and Computing, 1998 International Award on Quantum Communications:
H. JEFF KIMBLE, William L. Valentine Professor and Professor of Physics

Geochemical Society and European Association for Geochemistry, 1998 Geochemistry Fellow:
THOMAS J. AHRENS, W. M. Keck Foundation Professor of Earth Sciences and Professor of Geophysics

Materials Research Society, MRS Medal:
WILLIAM JOHNSON, Ruben F. and Donna Mettler Professor of Engineering and Applied Science

Mathematical Association of America Board of Governors, Trevor Evans Award:
TOM M. APOSTOL, Professor of Mathematics, Emeritus, and Director of Project MATHEMATICS!

Midwest Political Science Association, 1998 Robert H. Durr Award, Corecipient:
R. MICHAEL ALVAREZ, Associate Professor of Political Science

Optical Society of America, Esther Hoffman Beller Award:
AMNON YARIV, Martin and Eileen Summerfield Professor of Applied Physics

Society for Applied Anthropology, 1999 Bronislaw Malinowski Award:
THAYER SCUDDER, Professor of Anthropology

Society of American Historians, Fellow:
DANIEL J. KEVLES, J. O. and Juliette Koepfli Professor of the Humanities

Western Political Science Association, Executive Council Representative, 1998–2001:
R. MICHAEL ALVAREZ, Associate Professor of Political Science

Foundation Awards

Arnold and Mabel Beckman Foundation, 1998 Beckman Young Investigator Award:
RICHARD W. ROBERTS, Assistant Professor of Chemistry

Burroughs Wellcome Fund
1997 New Investigator Award in the Basic Pharmacological Sciences:
RAYMOND DESHAIES, Assistant Professor of Biology
1998 New Investigator Award in the Biological Sciences:
BRUCE A. HAY, Assistant Professor of Biology

Ellison Medical Foundation New Scholars in Aging Program, 1998 Ellison Medical Scholar:
BRUCE A. HAY, Assistant Professor of Biology

Gairdner Foundation, Gairdner Foundation International Award for Achievement in Medical Science:
GIUSEPPE ATTARDI, Grace C. Steele Professor of Molecular Biology

Haynes Foundation, 1998 Faculty Fellowship:
D. RODERICK KIEWIET, Professor of Political Science

David and Lucile Packard Foundation, Fellowship:
PETER SCHRÖDER, Associate Professor of Computer Science

Pew Scholars Program in the Biomedical Sciences, 1998 Pew Scholar:
JOSÉ ALBEROLA-ILA, Assistant Professor of Biology

Alfred P. Sloan Foundation, Research Fellow:
MICHAEL E. BROWN, Assistant Professor of Planetary Astronomy

University Honors

Drew University and Novartis, 1998 Novartis-Drew Award in Biomedical Science:
ALEXANDER VARSHAVSKY, Howard and Gwen Laurie Smits Professor of Cell Biology

Rice University, 1998 Distinguished Alumni Award:
THOMAS A. TOMBRELLO, William R. Kenan, Jr., Professor; Professor of Physics; Chair of the Division of Physics, Mathematics and Astronomy; and Technology Assessment Officer

University of Würzburg, Röntgen Prize:
AHMED H. ZEWAIL, Linus Pauling Professor of Chemical Physics and Professor of Physics

Institute Honors

Endowed Professorship:
DAVID A. TIRRELL, Ross McCollum—William H. Corcoran Professor

Associated Students of the California Institute of Technology (ASCIT) Award for Teaching Excellence:
MARIANNE BRONNER-FRASER, Professor of Biology
DONALD S. COHEN, Professor of Applied Mathematics
ANDREW E. LANGE, Professor of Physics
JOHN R. MILES, Mellon Visiting Professor of Humanities
ELLEN ROTHENBERG, Professor of Biology

Honorable Mentions:
JAMES M. BOWER, Professor of Biology
TIMOTHY H. BREEN, Visiting Professor of History
GLEN A. GEORGE, Lecturer in Computer Science and Electrical Engineering
EMLYN W. HUGHES, Associate Professor of Physics
BRUCE C. MURRAY, Professor of Planetary Science and Geology

Award for Teaching Assistant:
ALEXA W. HARTER, Graduate Student in Physics
TRAVIS J. WILLIAMS, Junior in Chemistry

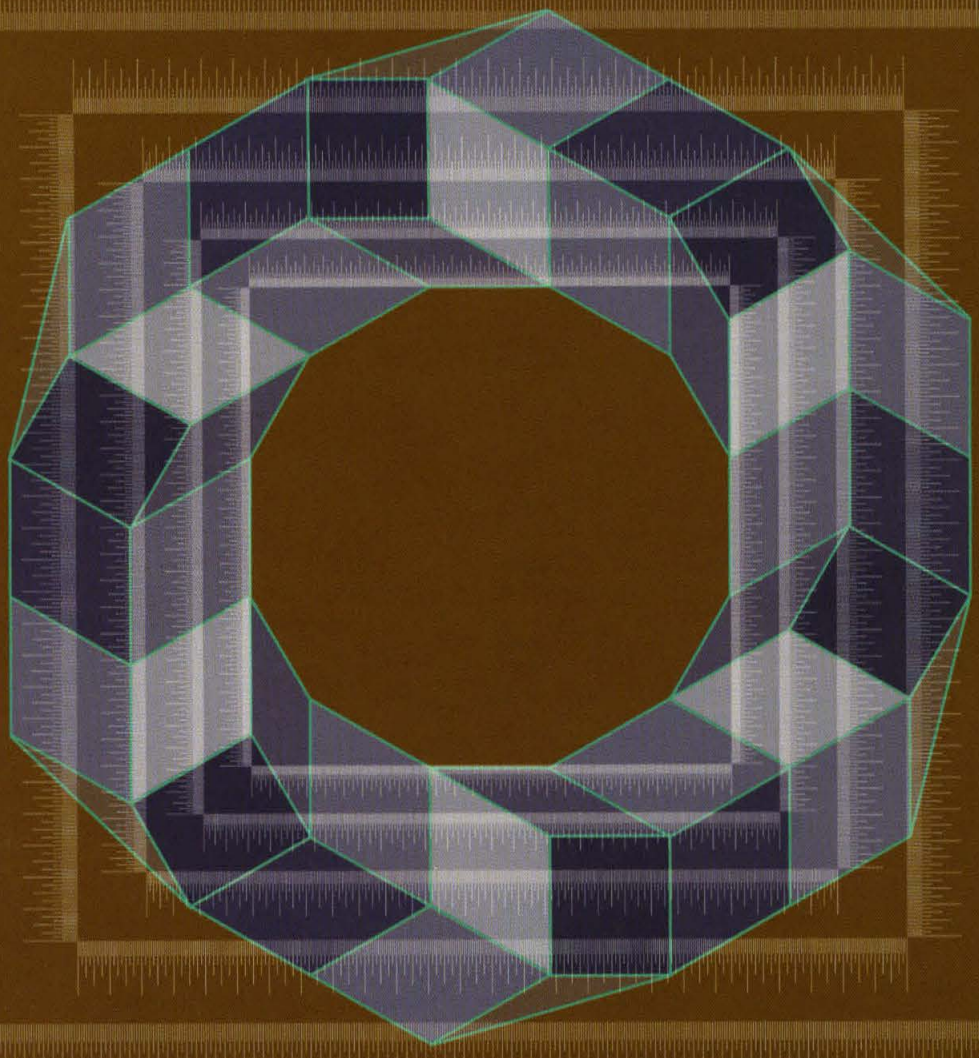
Honorable Mentions:
BENJAMIN D. MILLER, Senior in Mathematics
MICHAEL SIU, Graduate Student in Chemistry

Richard P. Feynman Prize for Excellence in Teaching, Recipient:
BARBARA IMPERIALI, Professor of Chemistry

Graduate Student Council 1997 Teaching Award:
ARES J. ROSAKIS, Professor of Aeronautics and Applied Mechanics

Mentoring Award:
SCOTT E. FRASER, Anna L. Rosen Professor of Biology

Outstanding Teaching Assistant Awards:
ZVONIMIR BANDIC, Graduate Student in Applied Physics
AYHAN IRFANOGLU, Graduate Student in Civil Engineering



"...observ[ing] and analyz[ing] the Institute from as many points of view as possible."

REPORT OF THE CHIEF FINANCIAL OFFICER

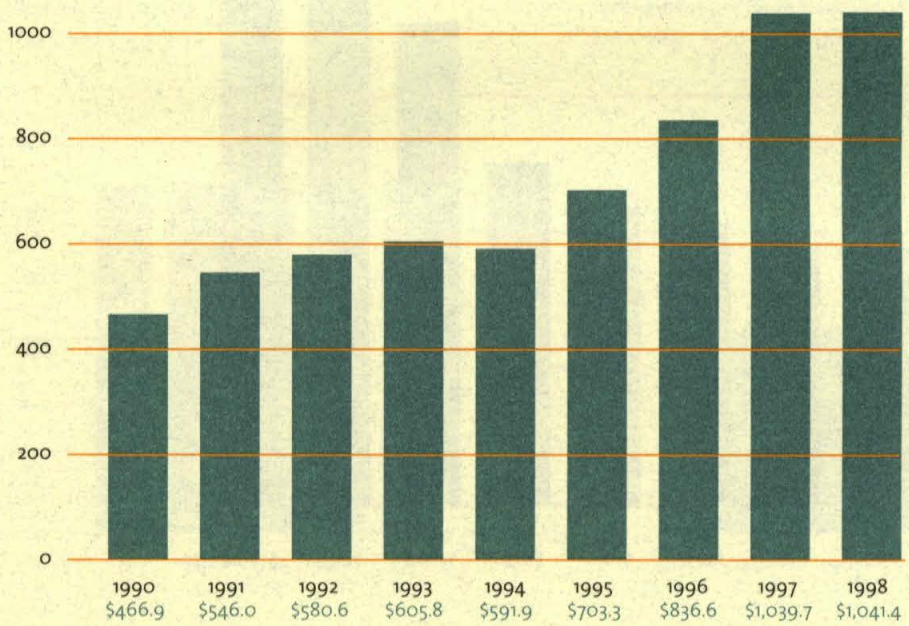
The California Institute of Technology had a modest financial performance in 1998.

Aggregate contributions to the Institute were $91.1 million, and, while the strength of the financial markets at the end of 1998 relative to recent fiscal years was ebbing, Caltech's endowment reached a new high at the fiscal year's end. Net assets increased by $20.9 million during fiscal year 1998.

Statement of Financial Position

The Statement of Financial Position reflects the Institute's healthy financial condition, which is highlighted by the net increase in Campus Properties of $36.9 million. Overall, total assets and total liabilities are approximately the same as they were at the end of last fiscal year.

Endowment Market Value
Fiscal years 1990–98
(in millions)

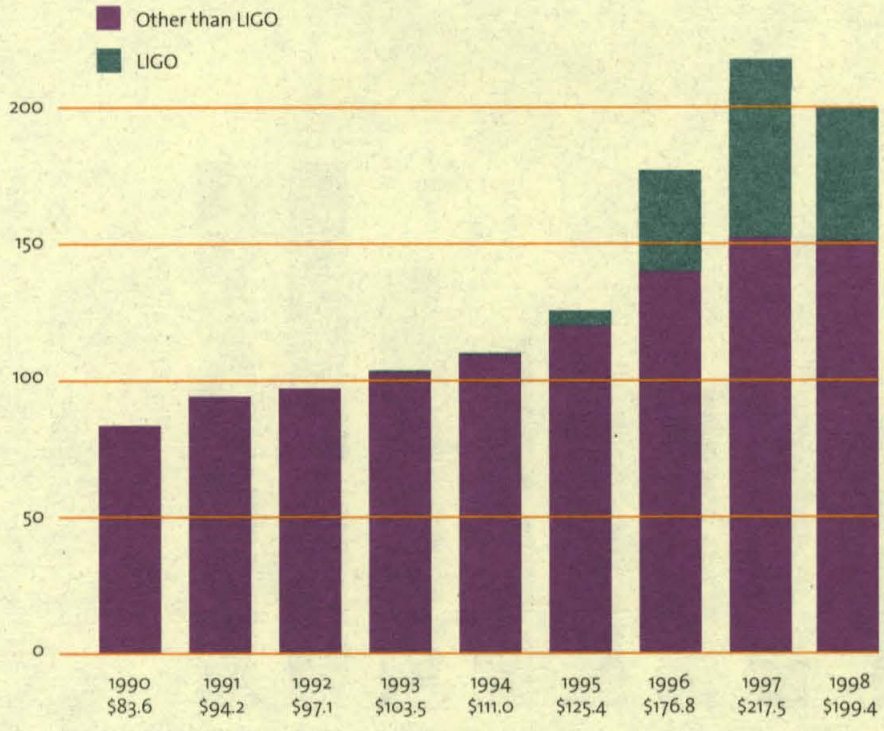


Statement of Activities

The Statement of Activities includes significant realized gains from disposals of investments, the majority of the disposals being a result of the implementation of a new endowment asset allocation policy and five-year investment plan adopted in the latter part of fiscal 1997. Contributions to the Institute were much greater than in fiscal 1997 because of the Biological Sciences Initiative.

The Jet Propulsion Laboratory expended and was reimbursed for $1,236.9 million for fiscal 1998.

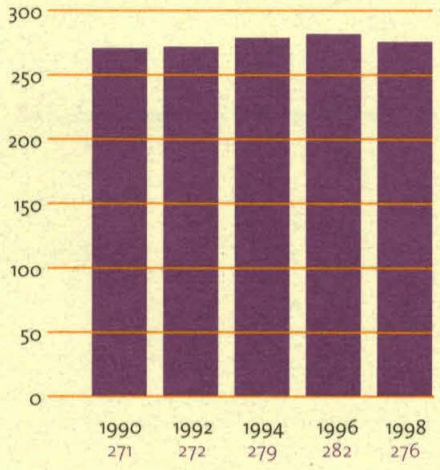
United States Government Grants and Contracts
Fiscal years 1990–98
(in millions)



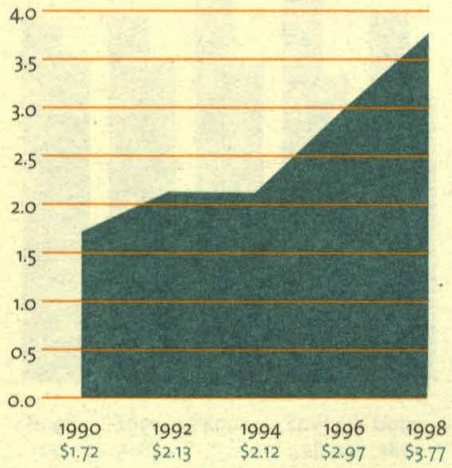
Statement of Cash Flows

A Statement of Cash Flows follows the Statement of Activities. This statement, in three prescribed categories, reflects those adjustments necessary to convert the increase in net assets reported in the Statement of Activities to the net change in cash for the fiscal years reported.

Professorial Faculty
Fiscal years 1990–98



Endowment per Professorial Faculty
Fiscal years 1990–98 (in millions)



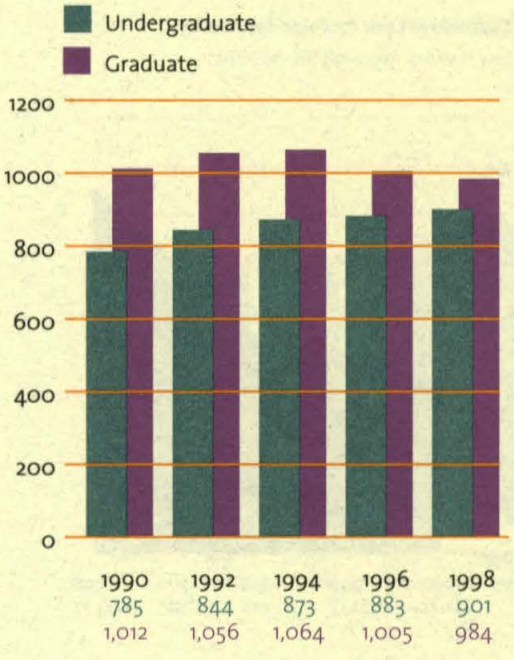
Commentary

The extraordinary performances of fiscal years 1996 and 1997 did not continue through fiscal 1998 because of declines in the financial markets that, for the most part, coincided with the end of our fiscal year. Subsequent to year's end, however, the financial markets had strengthened again, and the Institute's endowments on December 31, 1998, were, in the aggregate, 15 percent greater than on September 30, 1998.

Paul C. Jennings

Acting Vice President for Business and Finance

Undergraduate and Graduate Student Enrollment
Fiscal years 1990–98



STATEMENT OF FINANCIAL POSITION

September 30, 1998 and 1997

(in thousands)

	1998	1997
ASSETS		
Cash	$ 447	$ 29,184
Accounts Receivable		
United States Government	198,441	217,263
Pledges	46,541	38,160
Other	3,897	4,821
Student and Employee Accounts	18,663	18,475
Investments	1,187,686	1,175,167
Deferred United States Government Billings	136,914	124,039
Prepaid Expenses and Other Assets	90,323	88,302
Campus Properties	562,618	525,760
Total Assets	$ 2,245,530	$ 2,221,171
LIABILITIES		
Accounts Payable and Accrued Expenses		
United States Government	$ 338,408	$ 350,082
Other	34,624	29,718
Deferred Compensation	31,320	33,809
Deferred Student Revenue and Refundable Advances	20,926	20,526
Revocable Trust Funds and Agency Funds	18,845	19,561
Annuities Payable and Trust Agreement Liabilities	60,268	61,763
Revenue Bonds Payable and Revolving Line of Credit	89,075	74,575
Total Liabilities	$ 593,466	$ 590,034
NET ASSETS		
Unrestricted	$ 1,235,631	$ 1,252,549
Temporarily Restricted	105,198	84,048
Permanently Restricted	311,235	294,540
Total Net Assets	$ 1,652,064	$ 1,631,137
Total Liabilities and Net Assets	$ 2,245,530	$ 2,221,171

See Accompanying Notes to Financial Statements.

STATEMENT OF ACTIVITIES

Fiscal Year Ended September 30, 1998
with Summarized Information for the Fiscal Year Ended September 30, 1997
(in thousands)

GENERAL CAMPUS OPERATIONS

Revenues, Gains, and Other Support

- Student Tuition and Fees
- Less Scholarship Allowances
- Student Tuition and Fees, Net
- Investment Income
- Realized Gain on Disposal of Investments
- Unrealized (Depreciation) Appreciation in Investments
- Contributions
- United States Government Grants and Contracts
  - Reimbursement of Direct Costs
  - Recovery of Indirect Costs and Management Allowance
- Other Grants and Contracts
- Auxiliary Enterprises
- Other
- Total Revenues and Gains
- Net Assets Released from Restrictions
- Total Revenues, Gains, and Other Support

Expenses

- Campus Operating Expenses
  - Instruction and Departmental Research
  - Organized Research
  - Other Student Aid
  - Institutional and Student Support
  - Plant Operation, Maintenance, and Utilities
  - Auxiliary Enterprises
- Total Campus Operating Expenses
- Interest on Revenue Bonds Payable
- Other
- Total Expenses

JET PROPULSION LABORATORY

- Reimbursement of Direct Costs
- Direct Costs of Organized Research

Total Increase in Net Assets

- Net Assets at Beginning of Fiscal Year
- Net Assets at End of Fiscal Year

See Accompanying Notes to Financial Statements.

	1998			1997
Unrestricted	*Temporarily Restricted*	*Permanently Restricted*	*Total*	*Total*
$ 33,787			$ 33,787	$ 33,207
(18,132)			(18,132)	(14,794)
15,655			15,655	18,413
25,473		$ 396	25,869	30,432
184,579	$ 9,199	6,779	200,557	180,398
(179,310)	(7,550)	(7,512)	(194,372)	47,707
29,471	44,560	17,032	91,063	55,460
160,930			160,930	178,677
65,989			65,989	65,937
8,510			8,510	6,485
14,681			14,681	13,073
18,370			18,370	13,772
$ 344,348	$ 46,209	$ 16,695	$ 407,252	$ 610,354
25,059	(25,059)			
$ 369,407	$ 21,150	$ 16,695	$ 407,252	$ 610,354
$ 107,933			$ 107,933	$ 109,612
167,705			167,705	214,326
296			296	284
55,026			55,026	55,095
25,635			25,635	21,936
14,712			14,712	13,092
$ 371,307			$ 371,307	$ 414,345
3,580			3,580	3,733
11,438			11,438	20,036
$ 386,325			$ 386,325	$ 438,114
$1,236,901			$ 1,236,901	$1,249,527
$1,236,901			$ 1,236,901	$1,249,527
$ (16,918)	***$ 21,150***	***$ 16,695***	***$ 20,927***	***$ 172,240***
1,252,549	84,048	294,540	1,631,137	1,458,897
$1,235,631	$ 105,198	$ 311,235	$ 1,652,064	$1,631,137

STATEMENT OF CASH FLOWS

Fiscal Years Ended September 30, 1998 and 1997
(in thousands)

	1998	*1997*
Cash Flows from Operating Activities		
Total Increase in Net Assets	$ 20,927	$ 172,240
Adjustments to Reconcile Total Increase in Net Assets to Net Cash Provided By Operating Activities		
Depreciation	40,718	39,348
Decrease (increase) in Accounts Receivable	11,365	(49,366)
(Decrease) increase in Accounts Payable and Accrued Expenses	(6,768)	79,827
Contributions Restricted for Long-Term Investment	(17,032)	(29,823)
Realized Gain on Disposal of Investments	(200,557)	(180,398)
Unrealized Depreciation (Appreciation) in Investments	194,372	(47,707)
Other	(19,382)	42,756
Net Cash Provided By Operating Activities	$ 23,643	$ 26,877
Cash Flows from Investing Activities		
Proceeds From Disposal and Other Uses of Investments	$ 641,030	$ 809,918
Purchases of Investments	(647,365)	(791,769)
Purchases of Campus Properties	(77,577)	(46,755)
Net Cash Used In Investing Activities	$ (83,912)	$ (28,606)
Cash Flows from Financing Activities		
Contributions Restricted for Long-Term Investment	$ 17,032	$ 29,823
Repayment of Revenue Bonds	(1,500)	(1,425)
Draw on Line of Credit	16,000	
Net Cash Provided By Financing Activities	$ 31,532	$ 28,398
Net (Decrease) Increase in Cash	$ (28,737)	$ 26,669
Cash at Beginning of Fiscal Year	29,184	2,515
Cash at End of Fiscal Year	$ 447	$ 29,184

See Accompanying Notes to Financial Statements.

NOTE A — SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

General — The California Institute of Technology (the Institute) is a private, not-for-profit institution of higher education based in Pasadena, California. 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. The Institute is a tax-exempt organization under federal and state income, gift, estate, and inheritance tax laws.

Basis of Accounting and Reporting — The financial statements of the Institute have been prepared on the accrual basis of accounting.

Pledges (unconditional promises to give) from donors are recorded as receivables and revenues in the fiscal year such pledges are received. Net assets are classified for accounting and reporting purposes into three categories according to donor-imposed restrictions: permanently restricted, temporarily restricted, and unrestricted. Investments in equity securities with readily determinable fair values and all debt securities are reported at fair value.

Permanently restricted net assets include gifts, charitable remainder unitrusts, pooled income funds, gift annuities, other split-interest agreements, and pledges receivable which require by donor restriction that the corpus be invested in perpetuity. Income generated from these assets may be used in accordance with donor restrictions.

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 pledges receivable for which the ultimate purpose of the proceeds is not permanently restricted.

Unrestricted net assets are those not subject to donor-imposed restrictions.

Gains and losses on investments are reported as unrestricted revenue unless their use is restricted by donor-imposed stipulations or by law.

Donor-restricted gifts which are received and utilized 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.

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.

The Statement of Activities includes certain prior-year summarized comparative information that has not been detailed as to net asset category. Such information does not include sufficient detail to constitute a presentation in conformity with generally accepted accounting principles. Accordingly, such information should be read in conjunction with the Institute's financial statements for the fiscal year ended September 30, 1997, from which the summarized financial information was derived.

Investments — Investments are stated at fair value (Note B). The fair value of marketable 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.

Campus Properties — 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 C). 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 and operates the Jet Propulsion Laboratory (JPL) under a cost reimbursable contract which includes a management allowance with the National Aeronautics and Space Administration (NASA). 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.

Student Tuition and Fees — The Institute maintains a policy of offering qualified applicants admission without regard to financial circumstances as well as a policy of meeting in full the demonstrated financial need of those admitted. Student need in all programs throughout the Institute is generally fulfilled through a combination of scholarships and fellowships, loans, and employment during the academic year. In accordance with preferred industry practice, student tuition and fees have been reduced by scholarship allowances in the amounts of $18.1 million and $14.8 million for the fiscal years ended September 30, 1998 and 1997, respectively. Scholarship allowances are defined as the differences between the stated charges for goods and services provided by the Institute and the amounts that are billed to the students and/or third parties making payments on behalf of the students.

NOTE B — INVESTMENTS

Institute investments consisted of the following (in thousands):

	September 30,	
	1998	*1997*
Marketable securities		
Debt securities	$ 265,330	$ 220,385
Equity securities	823,684	851,388
Total marketable securities	$ 1,089,014	$1,071,773
Short-term commercial obligations	27,784	31,694
Real estate mortgages, notes, and other	70,888	71,700
Total investments	$ 1,187,686	$1,175,167

Institute assets include endowments as follows (in thousands):

Consolidated endowment pool	$ 948,287	$ 950,514
Separately invested endowments	93,143	89,155
Total	$ 1,041,430	$1,039,669

NOTE C — CAMPUS PROPERTIES

Campus properties consist of the following (in thousands):

	September 30, 1998	1997
Land and land improvements	$ 23,627	$ 22,476
Buildings, including construction in progress	356,759	339,327
Equipment	493,051	437,561
Campus Properties – cost	$ 873,437	$ 799,364
Less accumulated depreciation	(310,819)	(273,604)
Campus Properties – net	$ 562,618	$ 525,760

Depreciation has been calculated, using the straight-line method, with life years of 20, 40, and a range of 3 to 50 for land improvements, buildings, and equipment, respectively.

NOTE D — PLEDGES RECEIVABLE

Pledges receivable consist of unconditional promises to contribute to the Institute in the future and are recorded after discounting the present value of the future cash flows.

At September 30, 1998, pledges receivable are expected to be realized in the following periods (in thousands):

Within one year	$ 17,819
Between one year and five years	31,037
More than five years	2,617
Subtotal	$ 51,473
Less allowance for uncollectible pledges	(1,439)
Less discount	(3,493)
Total	$ 46,541

NOTE E — REVENUE BONDS PAYABLE

On October 27, 1994, the Institute issued $30 million in CEFA bonds for the purpose of financing and refinancing the acquisition, construction, and completion of certain educational facilities. The Series 1994 bonds are variable rate bonds maturing on January 1, 2024, repayable with interest from the general revenues of the Institute. Principal of and premium, if any, on the bonds is payable upon presentation. The applicable interest rate on these bonds is adjusted weekly by the trustee, and as of September 30, 1998, was 3.50%. The rates are determined by the Remarketing Agent. Subsequent to fiscal year end in October 1998, the Institute issued $103.9 million in California Educational Facilities Authority (CEFA) Revenue Bonds for the purpose of financing and refinancing the acquisition, construction, and completion of additional educational facilities, and to defease the $43.1 million outstanding principal amount of the Institute's Series 1991 bonds. The Series 1998 bonds are repayable with interest from the general revenues of the Institute over a 30-year period. Interest rates are fixed and range from 4.25% to 4.50% per annum. Required principal and interest payments are approximately $2.0 million for fiscal year 1999, approximately $4.5 million per year for fiscal years 2000 through 2027, approximately $56.6 million for fiscal year 2028, and approximately $51.6 million for fiscal year 2029, when the bonds will be fully redeemed. Principal and interest payments on the Series 1991 bonds were approximately $4 million per year for fiscal years 1992 through 1998 with interest rates fixed from 4.8% to 6.4%.

NOTE F — REVOLVING LINE OF CREDIT

The Institute has a revolving bank credit facility which provides maximum borrowing of up to $50 million which expires in June 2001. The unsecured borrowings under this facility bears interest at LIBOR plus 0.2% per annum. At September 30, 1998, there was $16 million outstanding under this facility.

NOTE G — CAMPUS OPERATING EXPENSES

Campus operating expenses for the fiscal years ended September 30, 1998 and 1997, consisted of the following (in thousands):

	Instruction and Departmental Research	*Organized Research*	*Other Student Aid*	*Institutional and Student Support*
Salaries	$ 58,063	$ 48,760		$ 25,462
Staff Benefits	13,593	8,464		5,442
Materials and Supplies	23,956	57,588		22,679
Travel	3,278	3,086		774
Other Student Aid			$ 296	
Utilities				
Depreciation	9,043	26,520		669
Construction Costs of Government Assets and Other		23,287		
Total	$ 107,933	$ 167,705	$ 296	$ 55,026

NOTE H — COMPONENTS OF NET ASSETS

The following presents the net asset categories by purpose as of September 30, 1998 and 1997 (in thousands):

	Unrestricted	*Temporarily Restricted*	*Permanently Restricted*
Operating Funds	$ 44,034		
Pledges Receivable		$ 41,384	$ 5,157
Student Loan Funds			10,552
Invested in Plant	449,627	6,292	
Life Income and Annuity Funds		26,502	27,445
Endowment and Other Funds Functioning as Endowment	741,970	31,020	268,081
Total	$ 1,235,631	$ 105,198	$ 311,235

			1998	1997
Plant Operation, Maintenance, and Utilities		*Auxiliary Enterprises*	*Total*	*Total*
$ 7,353		$ 5,072	$ 144,710	$ 133,414
1,594		1,068	30,161	42,781
4,147		7,782	116,152	108,301
25		63	7,226	6,401
			296	284
8,757			8,757	8,708
3,759		727	40,718	39,348
			23,287	75,108
$25,635		$ 14,712	$ 371,307	$ 414,345

1998	1997
Total	*Total*
$ 44,034	$ 42,162
46,541	38,160
10,552	10,004
455,919	441,423
53,947	59,840
1,041,071	1,039,548
$ 1,652,064	$ 1,631,137

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 year ended September 30, 1998, was $171,000. The funded status and projected benefit obligation of the plan at September 30, 1998, were approximately $36.1 million and $36.7 million, respectively.

Pension costs for the defined contribution plan for the fiscal year ended September 30, 1998, were $10.0 million ($9.5 million in fiscal 1997) for the Campus and $33.0 million ($32.0 million in fiscal 1997) 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 (in thousands):

	Campus	*JPL*
Service cost – benefits attributed to service during the year	$ 1,629	$ 4,504
Interest cost on accumulated benefit obligation	2,582	10,321
Amortization of actuarial deferral	791	3,468
Net	$ 5,002	$ 18,293

The reconciliation of unfunded status as of September 30, 1998, was as follows (in thousands):

	Campus	*JPL*
Retirees	$ 18,682	$ 77,646
Fully eligible employees	7,203	30,598
Other active employees	18,277	66,113
Accumulated postretirement benefit obligation	44,162	174,357
Remaining actuarial deferral	(18,097)	(69,234)
Total	$ 26,065	$105,123

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 $105.1 million is included in the Statement of Financial Position 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 $31.8 million 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 6.75% (7.25% in 1997) and a 5.50% (6.50% in 1997) annual rate of increase in the per capita cost of covered health care benefits for retirees were assumed for 1998. This cost trend rate is assumed to decrease to a rate of 4.50% in 1999 and thereafter. The health care cost trend rate has a significant effect on the amounts reported. As of September 30, 1998, a 1% increase in the assumed cost trend rates in each year would increase the accumulated post retirement benefit obligation by $8.0 million and $30.4 million, and the net periodic postretirement benefit cost for the year by $0.9 million and $3.0 million for the Campus and JPL, respectively.

NOTE K — DISCLOSURES ABOUT FAIR VALUE OF FINANCIAL INSTRUMENTS

For those financial instruments for which it is practical, the following methods and assumptions were used to estimate fair value:

Cash and Accounts Receivable — The carrying value approximates fair value.

Student and Employee Accounts — Due to the nature and terms of these financial instruments, which can be subject to significant restrictions, it is not practical to estimate their fair value.

Investments — As described in Note A, the Institute accounts for its investments on a market value basis and, accordingly, the carrying value approximates fair value.

Revenue Bonds Payable — The fair value of revenue bonds payable is estimated based on the quoted market prices for the bonds or similar financial instruments and approximates the carrying value.

NOTE L — CONTINGENCIES

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

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 the Jet Propulsion Laboratory. 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 the Jet Propulsion Laboratory. 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.

REPORT OF INDEPENDENT ACCOUNTANTS

PRICEWATERHOUSECOOPERS

March 22, 1999

To the Board of Trustees of the
California Institute of Technology

In our opinion, the accompanying statement of financial position 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, 1998, and the changes in its net assets and its cash flows for the year 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 audit. We conducted our audit of these statements in accordance with generally accepted auditing standards which require that we plan and perform the audit 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 audit provides a reasonable basis for the opinion expressed above.

PricewaterhouseCoopers LLP

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"...investigat[ing]...the largest and oldest structures in the universe and the tiniest components of matter" — one of four "visual metaphors" created by digital artist John Hersey to suggest the scope and scale of Caltech research. Other drawings by Hersey appear on pages 4, 19, and 32.

1997–98 Annual Report

Produced by the Office of Public Relations

Writer/Editor: Barbara DiPalma
Contributors: Babra Akmal, Michael Farquhar, Douglas Smith, Robert Tindol
Design: Denton Design Associates

Photography and image credits:
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