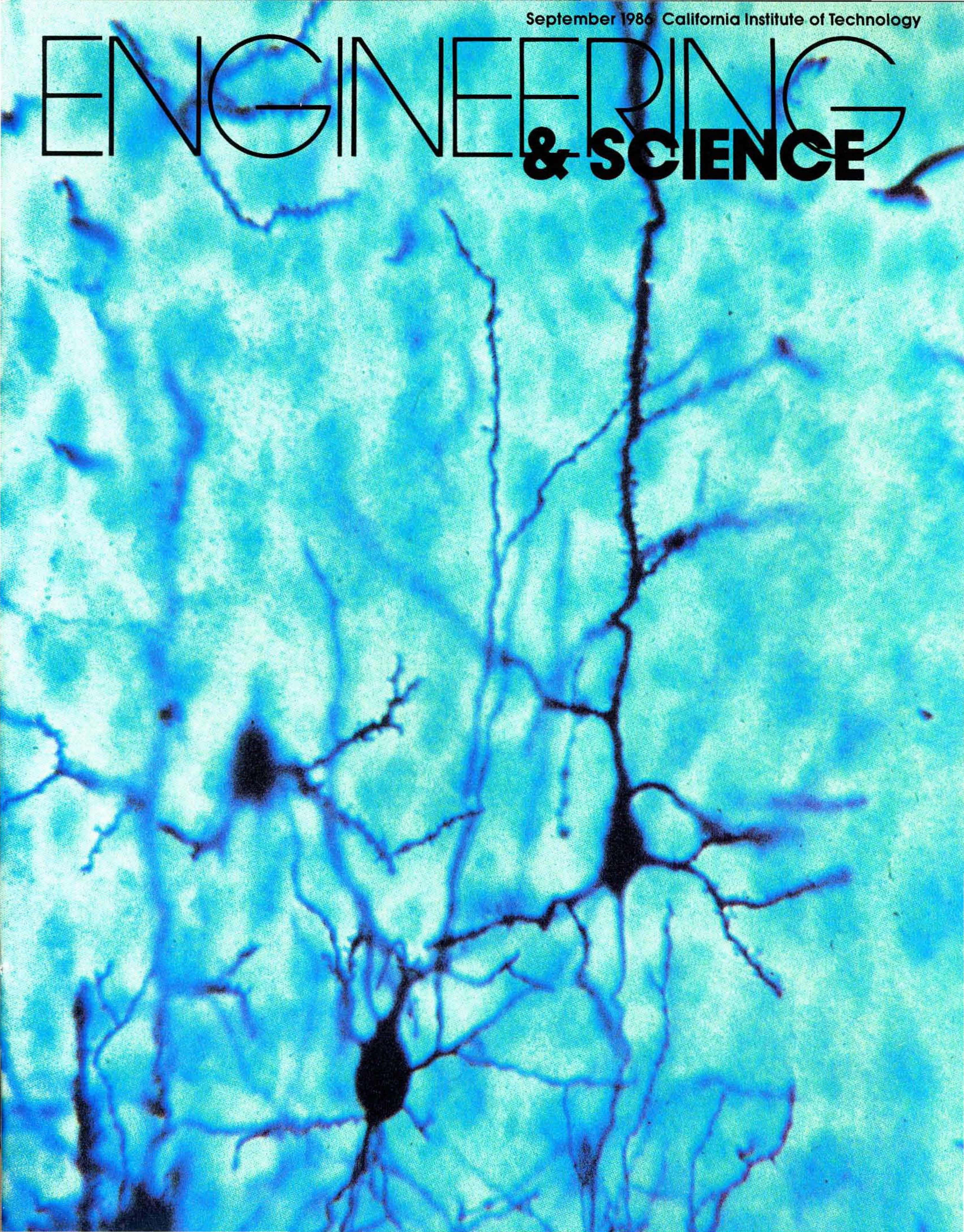
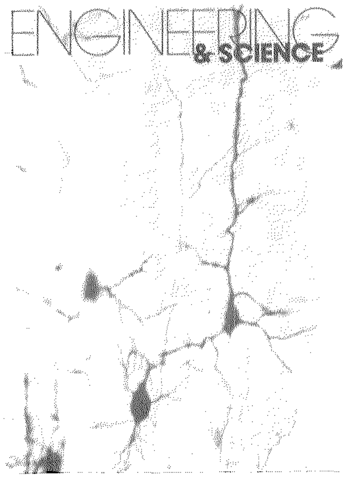
September 1986 California Institute of Technology

ENGINEERING & SCIENCE



In This Issue



Brain Stain
On the cover — neurons of the cerebral cortex. The largest cell, in right center, is a pyramidal cell, the main type of output neuron in the cortex and hippocampus. In this photograph, taken by Edward G. Jones, chairman of the Department of Anatomy and Neurobiology at the University of California, Irvine, less than 1 percent of neurons are fully stained. The rest, whose cell bodies appear as ghostly blue circles, are partially stained.

The dendritic spines — tiny protuberances along the pyramidal cell's dendrites that are the principal sites for synaptic contacts from other neurons— show up unusually well in this photograph. Mary Kennedy is interested in the biochemical structure of these synapses and, in particular, some intriguing reactions that may be related to the biochemistry of learning. Her work is explained in "How Does the Brain Learn? A Molecular View," beginning on page 4.

Kennedy came to Caltech as an assistant professor in 1981 and has been associate professor of biology since 1984. Her BS in chemistry is from St. Mary's College and her PhD in biochemistry from the Johns Hopkins University School of Medicine. She was a postdoctoral fellow in the Department of Neurobiology at Harvard Medical School from 1975 to 1978 and in the Department of Pharmacology at Yale Medical School from 1978 to 1981. In 1986 she was named associate editor of the *Journal of Neuroscience*, a member of the editorial board of *Trends in Neuroscience*, and chairperson of the Scientific Advisory Board of the Hereditary Disease Foundation.

Minority Politics
Two years ago Bruce Cain and Rod Kiewiet, both associate professors of political science, began a study of California's minority groups, a rapidly increasing proportion of the state's population. They wanted to investigate minority attitudes toward political and social issues to determine how they might affect California's political and economic future. One particular emphasis of the study was the potential for coalition politics. The results of the full study were released last March on the occasion of a conference on "Minorities in California" held in Ramo Auditorium. Three panels of the state's minority leaders discussed the Caltech findings and their own views of some of the issues.

Cain and Kiewiet are not minorities; both are blue-eyed with northern European ancestry. (Cain thinks that one of his aunts married a Greek, and that's about the closest he comes to ethnicity.)

His interest in ethnic politics comes from his experience with redistricting and issues of representation. In 1981, on leave of absence from Caltech, he served as chief consultant to the California Assembly Committee on Reapportionment and currently still acts as a consultant to that body. Cain joined the Caltech faculty in 1976 and has been associate professor of political science since 1983. He holds a BA from Bowdoin College (1970) and PhD from Harvard (1976). As a Rhodes Scholar, he attended Trinity College at Oxford University, earning a B.Phil. in 1972.

D. Roderick Kiewiet came to Caltech in 1979 and has been associate professor of political science since 1982.

He earned his BA from the University of Iowa in 1974 and PhD from Yale in 1980. His book "Macroeconomics and Micropolitics," published in 1983, examined the influence of the economy on voter behavior; other recent research has concerned fluctuations in party preferences. "Minorities in California," based on the Cain/Kiewiet report and the conference, begins on page 10.

STAFF: *Editor* — Jane Dietrich
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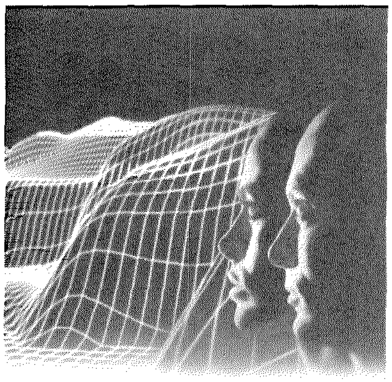
PICTURE CREDITS: Cover — E. G. Jones; 6, 7 — Mary Kennedy; 11, 12, 15, 16, 19, 26-28, 30 — Bob Paz; 21, 23 — Caltech Archives; 23 — Howard A. Nielsen, Jr.; 28-31 — Chris Tschoegl; 31 — Richard Kee; 32 — Martyn Cowley

Engineering & Science (ISSN 0013-7812) is published five times a year, September, November, January, March, and May, at the California Institute of Technology, 1201 East California Boulevard, Pasadena, California 91125. Annual Subscription $7.50 domestic, $20.00 foreign air mail, single copies, $1.50. Third class postage paid at Pasadena, California. Published by the California Institute of Technology and the Alumni Association. Telephone: 818-356-3630.
Postmaster: Send change of address to Caltech, 1-71, Pasadena, CA 91125.

ENGINEERING & SCIENCE

CALIFORNIA INSTITUTE OF TECHNOLOGY | SEPTEMBER 1986 — VOLUME L, NUMBER 1



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How Does the Brain Learn? A Molecular View

by Mary B. Kennedy

THE BRAIN IS a remarkable organ; one of its most remarkable and least understood functions is its ability to learn and remember, to adapt to changes in the environment. Neuroscientists have been studying the brain for 100 years or more, but it is only within the last decade that we have begun to establish some basic facts about how it learns.

It is clear that learning must involve physical changes within the neuron — the cell that is the basic signaling and processing unit of the brain (Figure 1 and cover). Neurons have three main parts: the cell body, the dendrites, and the axon. The cell body forms the center of the neuron, the place where proteins and other structural components are synthesized. Radiating from the cell body are the dendrites — fine, dense, branching processes that receive information transmitted from other neurons. Each neuron also has an axon, a long, often branched cable that carries information to many other neurons. The axon branches end in tiny bulbs called synapses, which are the crucial points of contact with the dendrites of other neurons. They are also active information processing sites.

Billions of neurons, each one making contact with an average of 10,000 others, make up the brain. Although the brain is a soft, almost buttery tissue, the neurons are highly organized. Deep within the brain, neurons cluster in "nuclei." Some of the nuclei send axons to the surface of the brain, which is covered by the cerebral cortex, a highly folded and convoluted sheet of neurons. This cortex is important for most of the brain's higher functions.

Specific, highly organized areas within the brain perform many of its specialized functions. For instance, a part of the cerebral cortex called the motor cortex is contained in a narrow band over the top of the brain. Neurons there send axons directly to the spinal cord, where they signal spinal neurons that in turn activate our muscles. At the back of the brain lies the primary visual cortex, which receives signals starting in the retina. Cells in the visual cortex process information from the retina to produce our concept of the visual world. Figure 2 shows a cross section

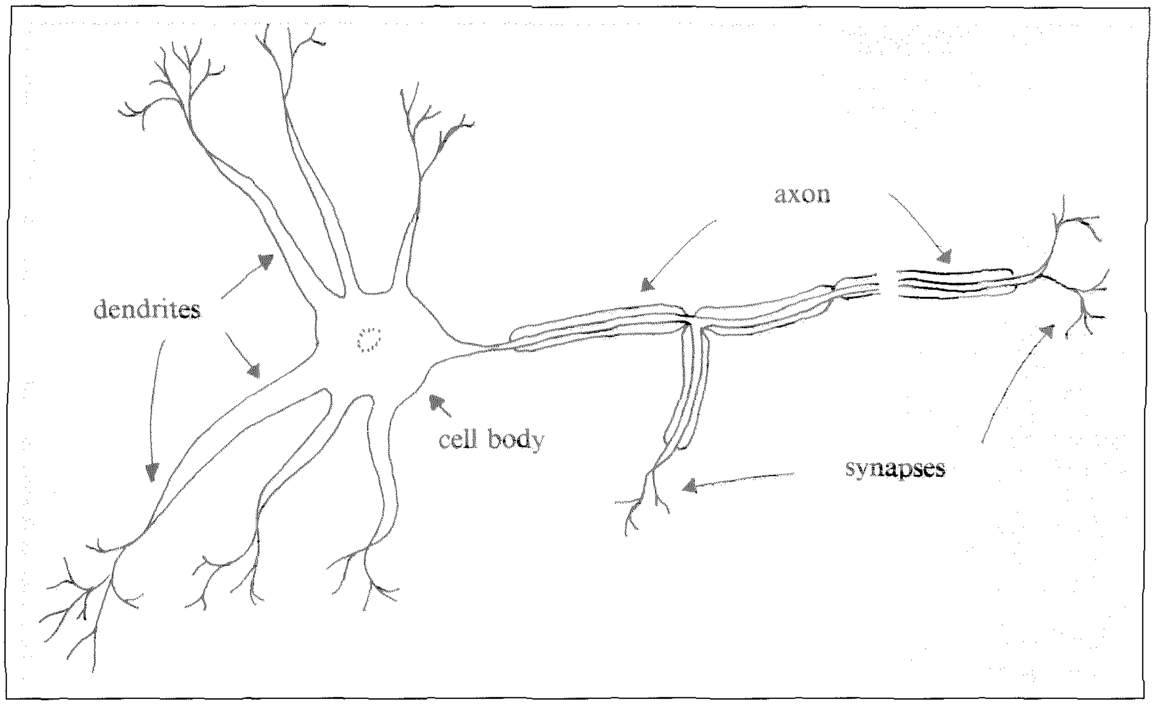


Figure 1. The typical neuron has three main parts — the cell body, the dendrites, and the axon.

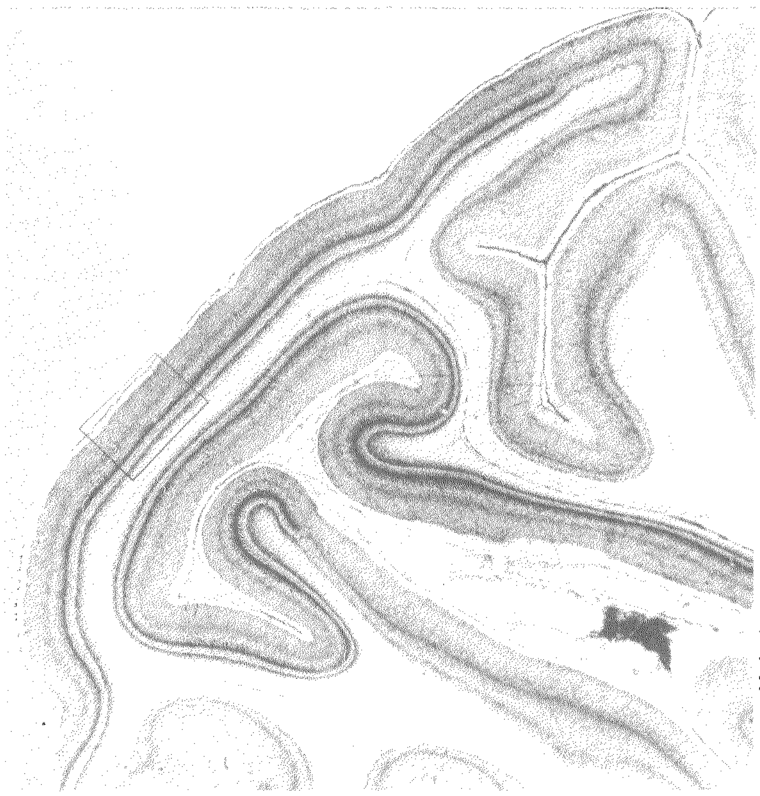


Figure 2. A cross section through the visual cortex of a Macaque monkey reveals its highly organized structure.

through the visual cortex of a macaque monkey revealing its highly organized structure. The stripes indicate specialized layers of cells that interconnect in a regular way.

Where in the brain are memories stored? The most correct answer to this difficult question is that memories seem to be stored in many different places, both in the cortex and in deeper structures. Different kinds of memories are apparently stored in different places — visual memories in the brain's visual areas, motor memories in motor areas, and so on. Complex memories may well be stored dispersed throughout areas of the brain called "association cortex." However, one brain structure, which lies just beneath the cortex, seems to play a particularly important role in the formation of memories. Its name, the hippocampus, comes from the Greek word for sea horse, which some early anatomists thought it resembled.

Several circumstantial lines of evidence suggest that the hippocampus plays a role in forming memories. The most dramatic evidence is clinical. It comes from a small set of

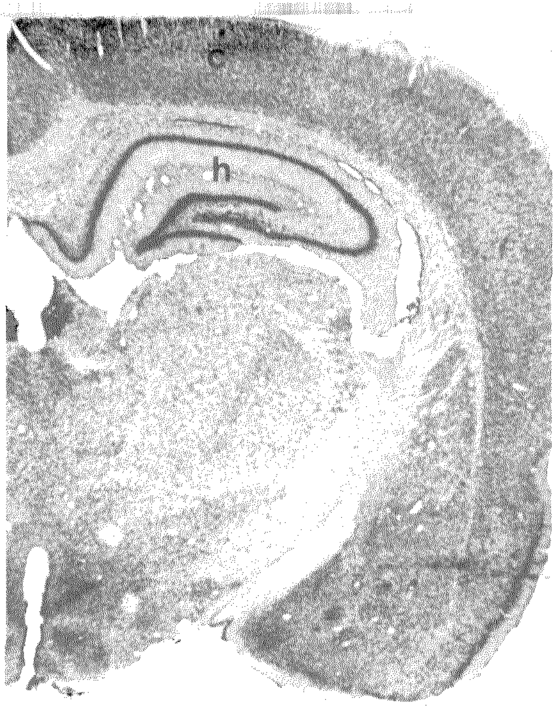
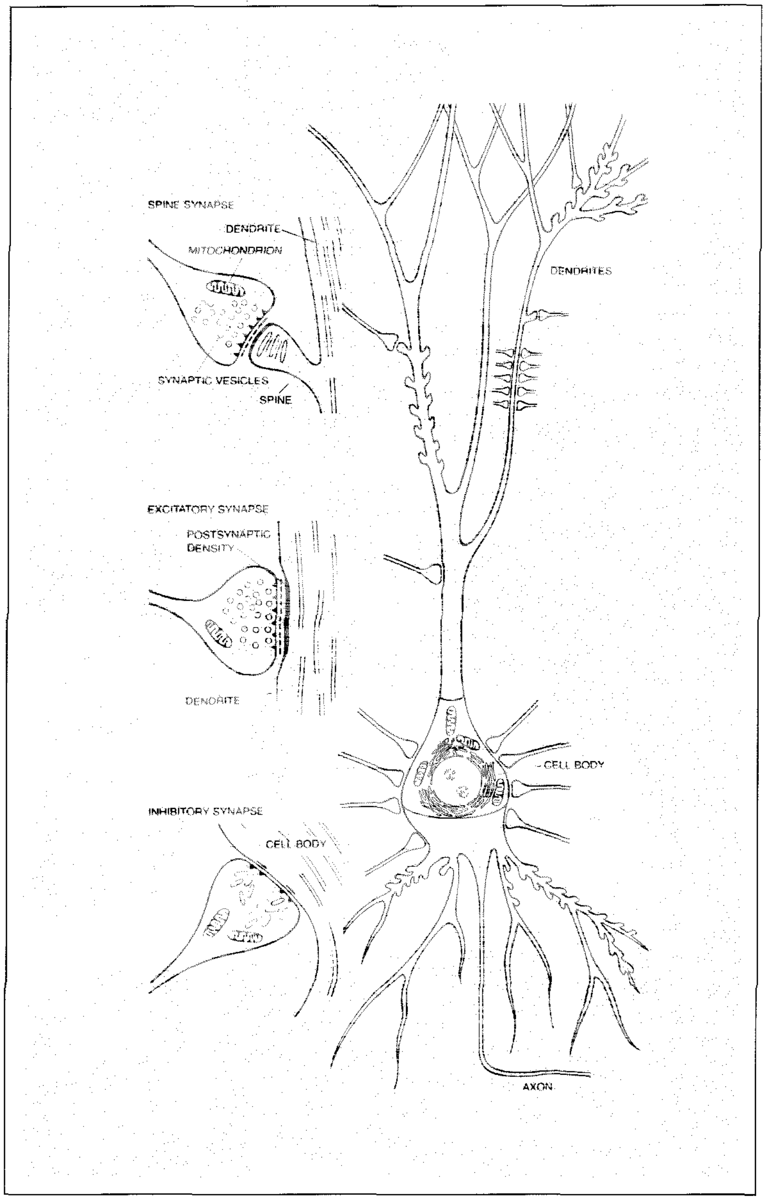


Figure 3. The hippocampus (h) lies just beneath the cortex (c) in this cross section through one hemisphere of a rat brain. The dark lines in the hippocampus are densely packed cell bodies.

Figure 4. The pyramidal cell is the main type of output neuron in the cortex and hippocampus.



patients who, for one reason or another, have suffered damage to the hippocampus and nearby areas. Sometimes the damage is due to disease or accident and sometimes to neurosurgical procedures. These patients often appear reasonably healthy except for one problem — they are unable to form new memories. They remember what has happened to them for just a few minutes, and then these memories disappear. In some cases, such a patient must be reintroduced to his doctors every day. But these people retain most of their memories from times before their hippocampal damage. Such evidence suggests to neuroscientists that the hippocampus may be involved in the formation, but not the permanent storage, of conscious memories. This has prompted several researchers to study synaptic connections within the hippocampus to see how they may be altered during learning.

The hippocampus can be seen in Figure 3, a cross section through one hemisphere of a rat's brain. For several reasons, biochemists like myself rarely study primate brains. Instead, we use the the rat brain. The rat cortex has about the same thickness as the cortex of a human brain, but it is much simpler and smaller. Just beneath the cortex lies the hippocampus. The neurons of the hippocampus receive information from many brain regions, both cortical and subcortical. They also interconnect with each other.

Neurobiologists have found that the strength of synapses within the hippocampus can be changed in a particular way as a result of their previous electrical activity ("previous experience"). To explain how this works, I must first explain more about the structure of synapses. Figure 4 depicts a major type of output neuron in the hippocampus and in the cortex, called a pyramidal neuron because of the triangular shape of its cell body. The diagram shows small protuberances along the dendrites, called dendritic spines. Although they are barely visible in the light microscope, they are the principal sites on the dendrites for synaptic contacts from other neurons.

Under the electron microscope, the detailed structure of the synapse becomes visible (Figure 5). The presynaptic terminal, the transmitting part of the synapse that comes from a distant neuron's axon, contains hundreds of small membranous vesicles filled with a particular chemical neurotransmitter (inset, Figure 4). The spine of the postsynaptic neuron contains a darkly staining fibrous

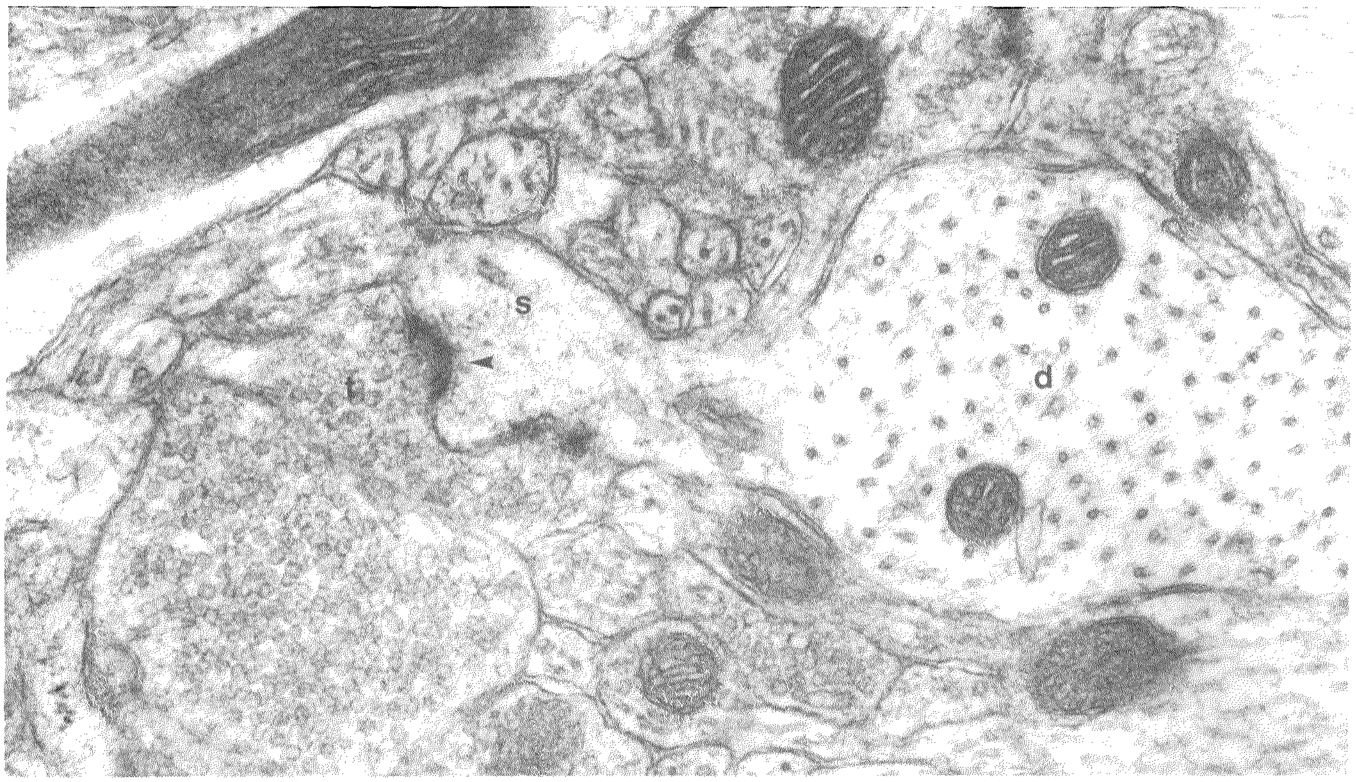


Figure 5. This electron micrograph of a hippocampal synapse shows a cross section of a dendrite (d), its spine (s), and the presynaptic terminal (t), which contains many synaptic vesicles. The arrow points to a postsynaptic density.

structure under its membrane, called by anatomists the postsynaptic density. Its function is not known, but, as you will see, we think that it may play a role in the storage of information by the synapse.

When the axon of a neuron is activated, calcium flows into the terminals at the ends of the axon, causing many of the synaptic vesicles to fuse with the outer membrane of the terminal and release their transmitter into the extracellular space. Protein receptors on the postsynaptic cell then bind this transmitter and initiate transmission of the signal.

The mechanism by which the presynaptic terminal excites the postsynaptic spine relies on its electrical properties. Neurons are tiny batteries. Neurophysiologists are able to poke microelectrodes into them and find that there is a difference in voltage between the inside of a neuron and the outside. At rest, the potential difference between the inside and the outside is between -80 and -50 millivolts (mV). But when a synapse ending on a neuron is activated, the postsynaptic receptors open little channels in the membrane, allowing sodium, potassium, and calcium ions to enter the postsynaptic cell. This flow of ions produces a small, brief depolarization (postsynaptic potential) in the neuron; that is, the resting potential may go from -80 mV to -75 mV or so for a few milliseconds. The neuron integrates information coming from its many

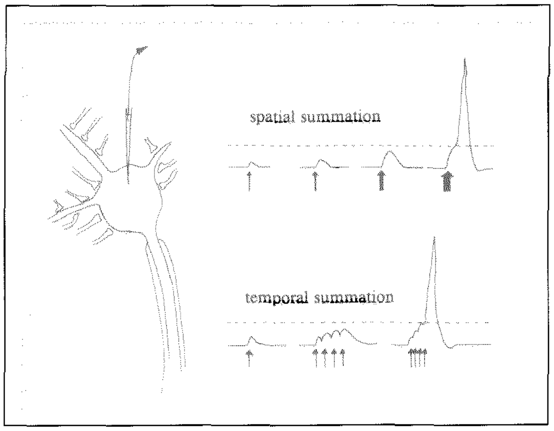


Figure 6. Subthreshold postsynaptic potentials can add together to produce an action potential through spatial or temporal summation. (After Aidley, 1971.)

synapses by summing the potential changes produced by each of them (Figure 6). If the summed depolarization becomes large enough, either because many synapses fire at once (spatial summation) or because one or two synapses fire many times very rapidly (temporal summation), a threshold will be reached. At the threshold, a large change in potential, called the action potential, is initiated. It is self-regenerating and it travels down the axon, ultimately activating presynaptic terminals, which in turn signal other neurons.

You can see that if the postsynaptic potential produced by a particular synapse were suddenly to become larger, it would have a greater influence on the total depolarization of the postsynaptic cell. Changes in synaptic strength probably occur frequently in the brain. They can be produced either by local chemical changes in the brain or by previous electrical activity in the synapse itself. Some of these changes last for only short periods of time, but a certain class of changes appears to last for a very long time indeed — several hours in the laboratory. In the animal these changes may last as long as several weeks and perhaps for an animal's lifetime if they are sufficiently reinforced. Neuroscientists think that these very long-lasting changes in synaptic efficacy, collectively called long-term potentiation (LTP), may underlie part of the process of memory formation.

The hippocampus provides a particularly good place to study long-term potentiation, although it is by no means the only place in the brain that displays the phenomenon. To produce LTP in the laboratory, a neurophysiologist stimulates a group of presynaptic terminals at a high frequency for a short time — say 100 times per second for a few seconds. After this rapid burst of stimulation, whenever one of the synapses is again activated at a more usual low frequency, it will produce a larger postsynaptic potential than it had previously. The larger potential can be observed for hours after the burst. This long-lasting change in the synapse produced by a brief strong stimulus is what one might expect of a memory mechanism. Furthermore, long-term potentiation contains a possible mechanism for the association of one stimulus with another. It is produced more easily (that is, by lower frequency stimulation) in one set of synapses in the hippocampus if another set ending on the same neurons is stimulated simultaneously.

In my laboratory, we have been studying the biochemical structure of synapses in an effort to understand how they are regulated. As I described earlier, synapses transmit signals from the presynaptic side to the postsynaptic side by releasing molecules of neurotransmitter. When an action potential reaches the presynaptic terminal, it causes a rapid influx of calcium ions. The calcium triggers a series of events that causes many of the synaptic vesicles to fuse with the presynaptic membrane and dump their content of neurotransmitter into the synaptic cleft. When the molecules of neurotransmitter bind to their postsynaptic receptors, they initiate a flow of ions across the membrane, producing the brief postsynaptic potential change.

Within this sequence of events there are several ways that the strength of synapses could be modified in order to store information. For example, it is possible to increase the strength of a synapse by increasing the amount of neurotransmitter released from the presynaptic terminal during each impulse. Such an increase actually happens in long-term potentiation, but it does not seem to account for all of its properties. It is also possible to increase the strength of a synapse by increasing either the number or the sensitivity of the transmitter receptor molecules. This would lead to an increased flow of ions and a greater potential change. Another way of changing synaptic strength might be to change the shape of the postsynaptic spines. Many spines have very narrow necks, and if the necks were widened, the potential change produced in the spine might travel out into the rest of the cell more effectively.

This is where biochemistry merges with neurophysiology, because the biochemist would like to determine the chemical mechanisms that cause physiological changes. We have determined that one particularly interesting molecule found in synapses is regulated in a way that suggests that it may be a crucial link in some of the chains of events involved in alterations of synaptic efficacy. This molecule is an enzyme called a calcium-dependent protein kinase.

Most of the proteins that make up cells are enzymes — catalysts that facilitate biochemical reactions important to the life of the cell. A protein is a long chain of amino acids that folds up into a characteristic three-dimensional shape, which is important to the protein's function. Protein kinases regulate the activity of other proteins by altering their shapes. To be specific, protein kinases catalyze the transfer of a phosphate group from ATP (adenosine triphosphate, the cell's energy currency) to specific sites on other proteins (Figure 7) — a process known as phos-

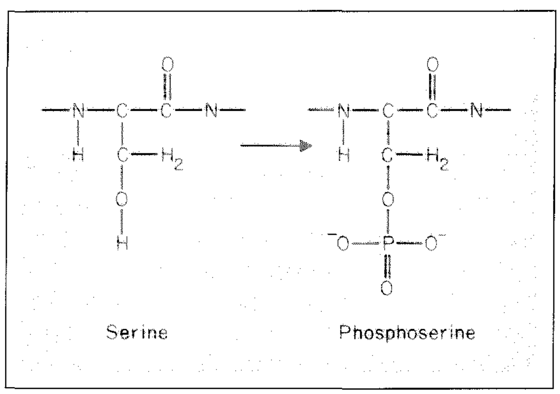


Figure 7. Within a protein, the amino acid serine can be modified by phosphorylation to form phosphoserine.

phorylation. When a big, negatively charged, phosphate group is added to a protein, it often forces the protein to assume a different shape and thus alters its function.

Protein kinases are not turned on all the time but are themselves regulated in a variety of ways by signals external to the cell. One of the signals that can switch on a certain group of protein kinases is an increase in calcium concentration. As I mentioned, calcium levels rise when an action potential invades an axon terminal. My laboratory group is investigating a particular calcium-activated protein kinase that occurs in very high concentration in the brain. We call it brain type II calcium/calmodulin-dependent protein kinase (type II CaM kinase, for short), a name that indicates that it is activated by calcium ions in combination with another small protein called calmodulin. Ngozi Erondu and I have found that this kinase constitutes fully two percent of all the protein in the hippocampus, an extraordinarily high level for a regulatory molecule. It accounts for one percent of the protein in the cortex, and its concentration becomes progressively smaller in lower brain regions. This suggests that it is synthesized at high levels within the cortex and hippocampus in order to be used for some specialized function in those regions.

Mark Bennett, Venise Jennings, and I have also demonstrated that within the neuron this kinase appears to be concentrated in the synapse. Although it is present throughout the neuron — in the cell body and at both pre- and postsynaptic sites — it is especially abundant in the postsynaptic density underneath the postsynaptic membrane where the transmitter receptors are located. It makes up about 20 percent of the total protein in the postsynaptic density; thus the density can be thought of as a cluster of kinase molecules sitting under the synaptic membrane and waiting for a calcium signal.

An important property of type II CaM kinase is its ability to add phosphate groups to itself — a process called autophosphorylation. Steve Miller and I showed the significance of autophosphorylation in an experiment in which we measured the ability of the kinase to phosphorylate other proteins. In the absence of calcium, the kinase has virtually no ability to phosphorylate itself or other proteins; when we add calcium, the kinase begins to phosphorylate both. But if we first allow the enzyme to autophosphorylate for a few seconds before mixing it with the other proteins, the dependence on calcium looks very different. After autophosphorylation, the enzyme has a high catalytic rate in the *absence* of calcium, and adding calcium stimulates this rate only about two-fold. We say that the kinase has been switched by autophosphorylation from State 1, in which its activity depends completely on calcium, to State 2, in which it has a significant calcium-independent activity (Figure 8). In solution, the type II CaM kinase is a cluster of 12 individual catalytic subunits. Autophosphorylation of only a few of these subunits changes the calcium requirement of all of them. So it seems that these few phosphate groups can have a dramatic effect on the shape and function of the whole kinase molecule.

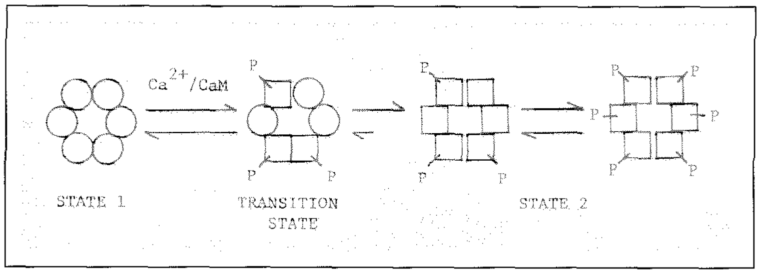


Figure 8. This schematic diagram shows the changes produced by autophosphorylation in the individual subunits of type II CaM kinase.

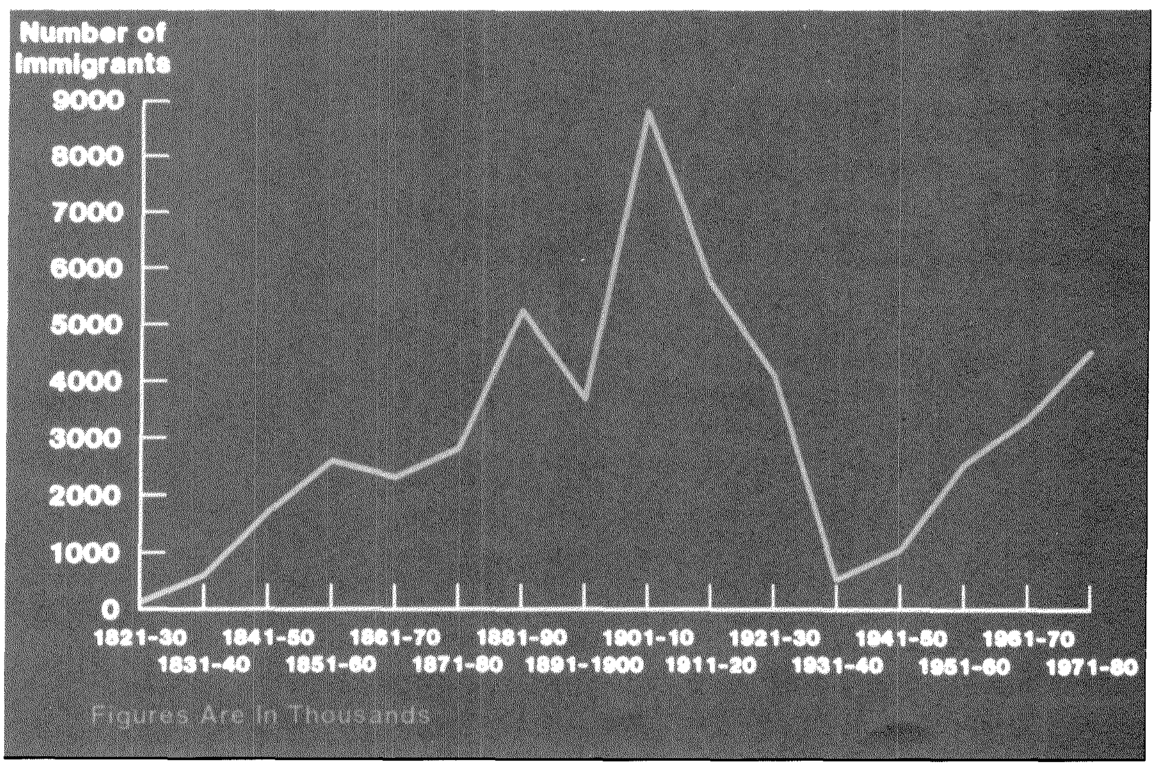
What does this mean? It means that, given a calcium signal lasting a few seconds, the CaM kinase can modify itself so that the effects of calcium persist even after the calcium levels have fallen. If nothing happens to remove the phosphate from the kinase, the enzyme's increased activity can last for a very long time. This kind of molecular switch is intriguing from the point of view of synaptic regulation. It is a mechanism one might imagine for an enzyme whose job is to produce a long-lasting signal from a very brief change in the chemical environment of the synapse.

At the moment, this model of a molecular switch within the synapse is really only that — a model. We are just beginning to test whether the autophosphorylation of the kinase actually occurs in the hippocampus during the generation of long-term potentiation. It may well be that this property of the molecule serves some other purpose entirely. Another question we must address is the nature and function of the other synaptic proteins that the kinase phosphorylates in addition to itself. But we cannot help being intrigued by the interesting properties of this molecule that appears to be positioned at a strategic location within neurons in areas of the brain thought to control learning and memory. □

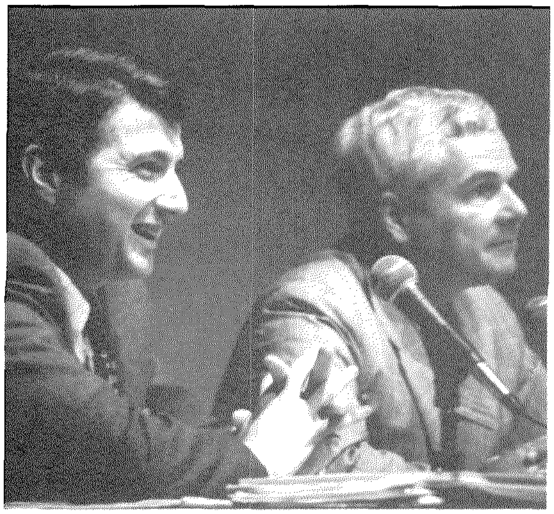
Minorities in California

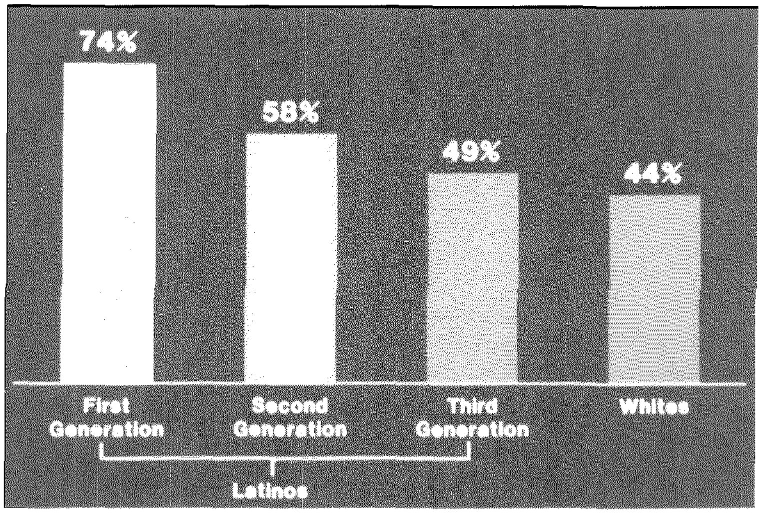
NEW WAVES OF IMMIGRATION hitting the shores of the West Coast are rapidly changing California's demography. These new waves compare to the great influx of different cultures and languages from Europe between 1840 and 1920 but with one main difference: In 1965 the United States rescinded its racial quotas and the population groups arriving now come mostly from East Asia and Latin America. How will their presence, mingled with the minorities who were already here, affect political and economic trends in California, where whites now make up about 60 percent of the population? In what ways are all these minority groups — and different generations of minority groups — similar to and different from each other?

Some of the answers come from Bruce Cain and Rod Kiewiet, associate professors of political science, who two years ago undertook a study of California's minorities. With a grant from the Seaver Institute they surveyed 1,646 blacks, Latinos, Asian-Americans, and non-Latino whites on their attitudes toward political and social issues, their party



When the total number of immigrants to the United States peaked in the early 20th century, most were from European countries. The increase after 1965, when the U.S. rescinded its racial quotas, is mostly due to immigration from East Asia and Latin America.





Left: Bruce Cain (left) and panel moderator Robert Abernethy.

Cain's study showed that, among Latinos, support for amnesty for undocumented aliens decreases with each generation. Such generational tensions could create problems for Latino representatives.

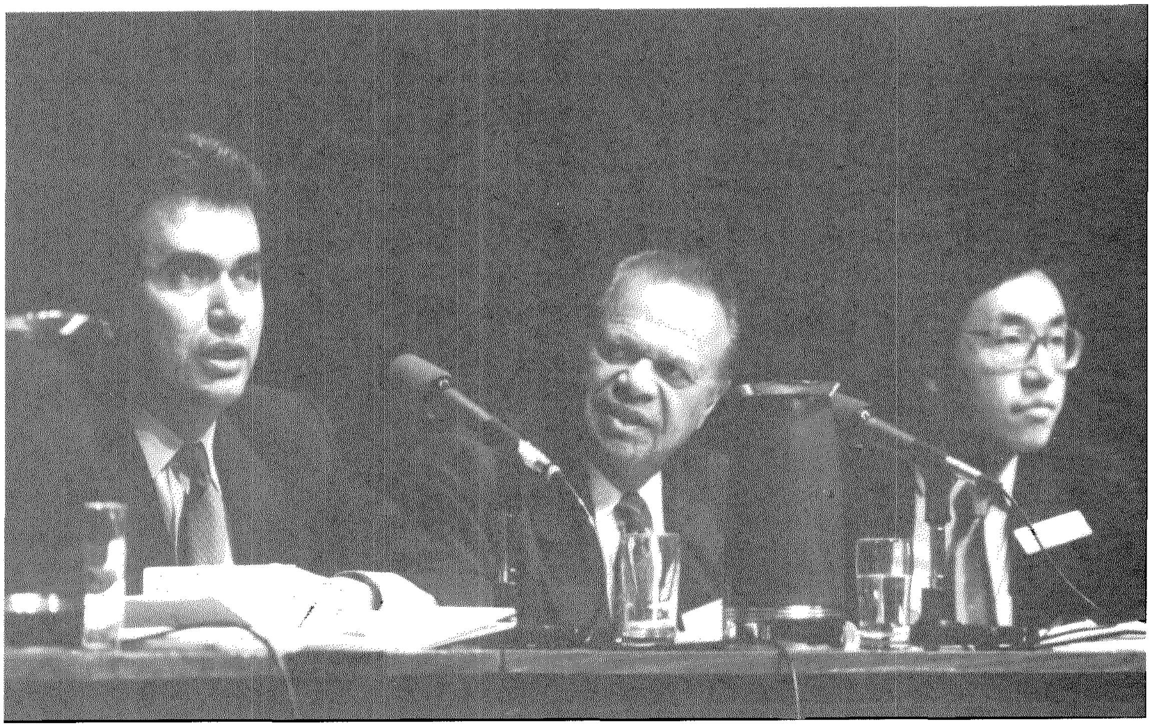
affiliation and political activity. After analyzing all the data from these interviews, Cain and Kiewiet presented their findings at a March 5 conference at Caltech, which included three panels of business, political, and community leaders — mostly minorities. Some of the study's surprising (and some not-so-surprising) results provoked lively debate among the participants. Robert Abernethy, NBC News Washington correspondent, moderated the panels.

The researchers were particularly interested in ethnic politics; they wondered to what extent they might find common interests among minorities that would make for political coalitions — the prophesied "rainbow" scenario of the 1984 campaign. What Cain and Kiewiet found was sharp diversity among the different groups (and, within those groups, differences between generations and income levels) and thus much reason to expect shifting, fluid alliances rather than permanent minority coalitions.

Latinos stood out in their support of bilingual education (65 percent) and amnesty for undocumented aliens (61 percent), and in their opposition to sanctions against employers for hiring undocumenteds (42 percent). In contrast, 41 percent of whites and 51 percent of Asian-Americans support bilingual education, while 44 percent of whites and 43 percent of Asian-Americans support amnesty. Differences exist, however, within the Latino community — for example, differences between citizens and noncitizens on bilingual education and sanctions, between Mexicans and non-Mexicans on arms expenditures, and between higher- and lower-income Latinos on welfare expenditures.

Blacks tended to be the most liberal and loyally Democratic. They also supported bilingual education (63 percent) and amnesty (41 percent) and constituted the biggest group supporting increased spending on welfare (84 percent) and the equal rights amendment (81 percent). But the researchers found a streak of social conservatism running through the black responses. Blacks were the strongest of the minority groups in favor of prayer in the public schools and considered crime and drugs the biggest problems facing the country — stands usually associated with the political right.

Attitudes of Asian-Americans in the Cain-Kiewiet study turned out to be much more conservative than those of the other minority groups. They made up the largest group sympathetic to increased military spending (38 percent — larger than whites), and at 73 percent, second only to whites (75 percent) in favoring the death penalty for murder. (Only 47 percent of blacks and 52 percent of Latinos supported the death penalty.) Asian-Americans voted for Reagan in 1984 and are registering Republican in large numbers. But the Asian community,



Political directions of California's minorities were discussed by Los Angeles City Councilmen Richard Alatorre (left) and Michael Woo (right) and Oakland Mayor Lionel Wilson.

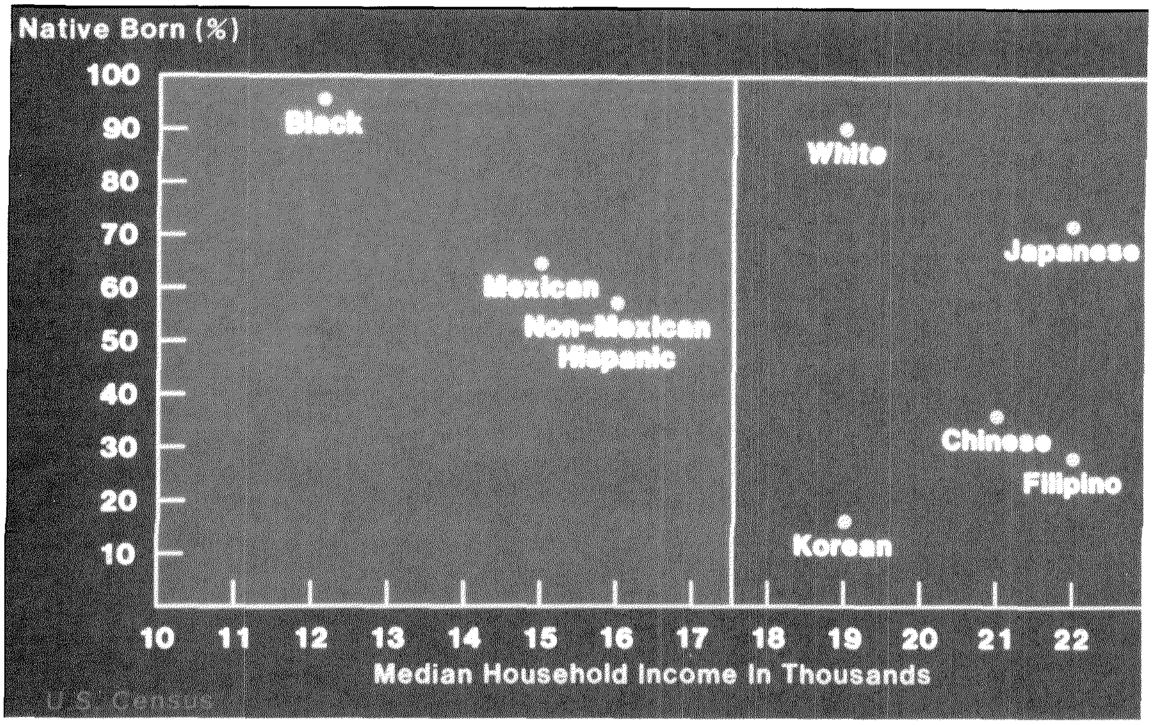
like the Hispanic, is far from being a monolithic block. The Japanese approximated whites in their political attitudes, while Koreans resembled Latinos on language and immigration issues. The Chinese remained difficult to categorize because of the great division between generations.

Cain and Kiewiet also studied minority political power, which depends critically on participation in the political process. They found that the large number of noncitizens substantially suppresses both Latino and Asian-American participation rates, but the latter appears low even after adjusting for noncitizens. Asian-American politicians, however, have been relatively successful at the city and state level, many having run as nonethnic candidates. Blacks and Latinos have had their greatest successes in legislative seats.

Three examples of minority successes at the polls were on hand at the March conference to discuss the study's findings on the political directions of California's minorities: Los Angeles City Councilman Richard Alatorre, the first Latino elected to that body in two decades (and a veteran of 13 years in the State Assembly); Michael Woo, the first Asian-American member of the Los Angeles City Council; and Lionel Wilson, the first black mayor of Oakland.

All three panelists took exception to some of the conclusions of the study, which Woo termed "provocative." Alatorre claimed that the Latino positions on bilingual programs and amnesty seemed in his experience to be just the opposite — most recent immigrants *want* their children to learn English and much of the Hispanic community actually fears amnesty, partially because of the political activism of many of the illegal immigrants. Wilson did not find surprising the social conservatism evident in black responses to the survey given the strength of the black church. But he thought that the younger Asian-Americans (at least in Oakland) were far more liberal than the older generation. Woo also didn't quite buy the extreme conservatism ascribed to the Asian community and thought that the Democratic Party shouldn't write them off. "It's a matter of how the ideological labels are defined," he said. "If different questions had been asked — for example, how much money should be spent on schools — the answers might have pointed in a different direction." Woo also noted ambivalence in the Asian community on bilingual education. Traditionally, he said, Asians have not demanded such programs but have urged their children into areas such as mathematics and science, where language is not so important.

The three were much more sanguine on the possibility of coalitions across groups than the Cain/Kiewiet study would seem to warrant. Although they agreed that differences exist among the groups, "we're not going to form coalitions on differences," says Alatorre.



Variation in minority economic circumstances does not depend on the percentage of native born. Asian-Americans, although many more of them are recent immigrants, are better off economically than blacks or Mexicans, who as groups have been in California much longer.

"You don't have to love each other. You have to define the issues that bring you together; that's how politics operates." The most explosive issue in Los Angeles, according to Alatorre, is how to accommodate the large number of third-world people.

Woo did not think that there would be a big explosion but perhaps "lots of small ethnic explosions" over certain issues. He didn't think the split between racial and ethnic groups was inevitable and envisioned a number of "cross-majority-minority linkages" evolving. In Oakland, according to Wilson, no explosion ever occurred, and blacks and Hispanics coalesced around the need to develop power. That city, which is 62 percent minority, has been found by a University of Wisonsin study to be the most integrated city in the United States because, according to Wilson, people there have learned to live and work together.

Economic, as well as political, assimilation interested the Caltech researchers, and the second section of their report concerned business opportunities for California's minorities, in particular the effects that government assistance programs have had on those opportunities. This crucial area of public policy has not received much attention, said Cain. It's difficult enough to start a business, but minorities have some additional problems as well. As many as 75 percent of minority businesses are sole proprietorships, and many go under.

According to the report, although Asian-Americans are generally wealthier and better educated than other minority groups, and have large stable families from which to draw capital and cheap labor, their businesses concentrate on retail and service, in which they have difficulty reaching out to English-speaking markets. Latinos also have large, stable families, but generally come from an economically and educationally disadvantaged background. The language problem also works against Latinos trying to break into other markets. Blacks don't have the language problem, but they do generally come from disadvantaged backgrounds. They have less recourse to family resources and probably experience greater prejudice.

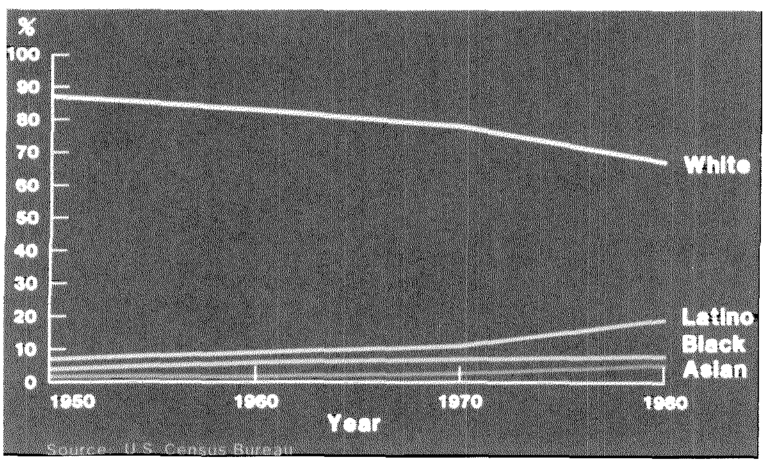
Government involvement can be justified, said Cain in his introduction to the panel discussion, by increasing prosperity, creating a class of minority entrepreneurs, and bringing more jobs to the minority communities. Three government strategies aim at accomplishing this: SBA (Small Business Administration) loans, MESBICs (Minority Enterprise Small Business Investment Corporation), and procurement preferences. If the Gramm-Rudman-Hollings bill forces cuts in these programs, not only will a number of small, marginal minority businesses suffer, but a group of younger, better educated entrepreneurs who have used the loans to create profitable businesses will be in trouble as well, the study concluded.

The second group of panelists differed in their reactions to this segment of the report. Harold Yee, president of Asian Incorporated, took strong exception to Cain's statement that Asian-Americans are reluctant to utilize government assistance programs. "Asians don't use government programs because they're shut out. They came in later and couldn't crack entrenched interests," he said. And since government programs touch only about 3 percent of Asian-American businesses, Yee didn't think it would matter to his community if the funds were cut.

Elbert Hudson, president of Broadway Federal Savings and Loan, was also "willing to live with the cutoff because the programs are not solving the problem anyway." He would let marginal businesses die rather than pumping money into them. He remarked on the "feeling that those businesses that are funded are doomed to failure. The black community has to help itself and can't do it from outside sources." Hudson estimated that there's $350 million in black savings and loans, but the funds are actually controlled by nonminorities. David Lizarraga, president and chief executive officer of the East Los Angeles Community Union, a federally funded organization, expressed unwillingness to give up government assistance programs and depend on local resources. He claimed that government programs have had a positive effect on the Hispanic business community. "I'm still convinced that Horatio Alger would not have made it if his name was Horacio Garcia," he said.

The panel also split on the report's conclusion that both business skills and education are crucial to the success of minority businesses. David Horn, president of South Bay College, a Los Angeles business college, agreed, not surprisingly, with that conclusion.

Immigration is dramatically changing the racial/ethnic composition of California.

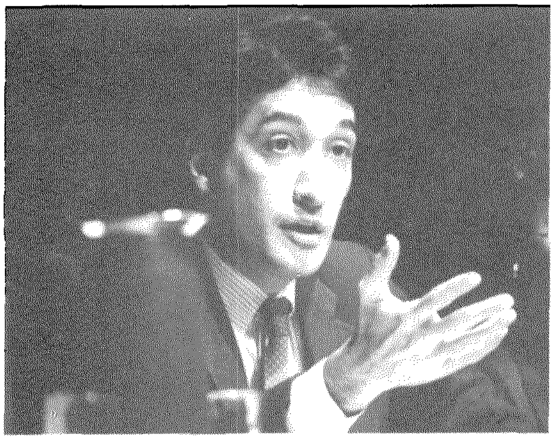
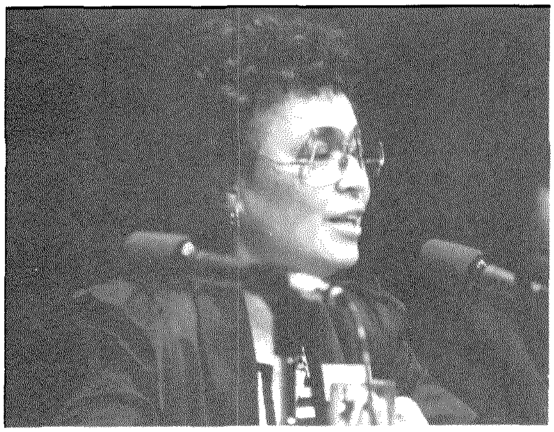


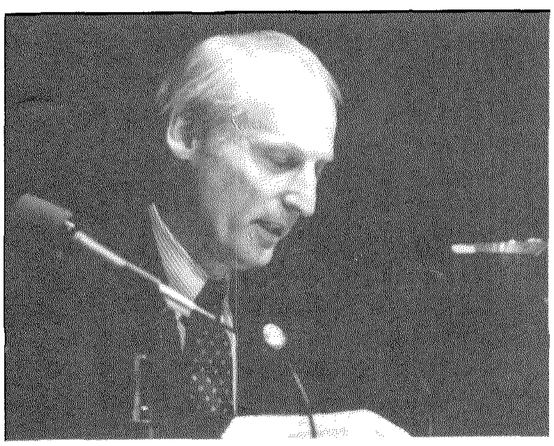
He claimed that education was the most important element for successful entrepreneurs, and that well-intentioned government agencies often supplied funds to persons unqualified to receive them. Others disagreed, Hudson insisting that "education alone can't solve the problems of black kids," and Lizarraga questioning the number of well-educated people who would want to run a business in a minority community anyway. And Asian-Americans, said Yee, *are* well educated ("we put our money into our kids") but don't get the return on human investment that whites get.

The third panel concerned issues of how minorities perceive discrimination and the opportunity structure of society. Cain and Kiewiet wanted to investigate the phenomenon of backlash against immigrants, which also has historical precedent. They hypothesized that minority groups might come together politically in response to a shared experience of discrimination and perceived inequities of opportunity. According to their study, 42 percent of blacks felt that their race limited their deserved opportunities (compared to 23 percent of Latinos and only 8 percent of Asian-Americans). In addition, blacks were far more likely than any other group to have personally experienced discrimination; blacks experienced more economic discrimination, while for Asian-Americans it was much more likely to be social.

Second-generation Latinos and Asian-Americans were more likely to perceive discrimination against them, as were college-educated blacks. Those who felt discriminated against were more likely to be politically active locally, but not nationally, so this issue may not be a likely candidate for producing consensus on national policy. One particularly interesting finding indicated that not only did blacks consider themselves the group most discriminated against in the country, but whites and Asian-Americans agreed with them. As Kiewiet put it in his introduction, "The battleground on these issues will be in the hearts and minds of *white* voters."

On the panel, Henry Cisneros, mayor of San Antonio, Texas, (elected with 94.2 percent of the vote) appeared optimistic about coalitions among minorities. "But what it depends on," he said, "is not a perception of discrimination but who is in a power position and how badly the groups need each other." He compared northern cities, such as Chicago, where blacks in power cooperate with



Hispanics, with Houston (and probably Los Angeles), where personalities and egos pull in opposite directions and groups don't communicate. And in Miami there is open hostility between Hispanics and blacks. Cisneros thought the most pragmatic approach would be to make "floating alliances" to deal with one issue at a time. Minorities might also coalesce around a particular personality (one obvious example being Cisneros himself, although he didn't say so), and the "dynamics of leadership" could overcome ideology. Most mayors of major cities in the United States are black, Hispanic, or female, he pointed out.

Edith Nealey, chairwoman of the South Central Organizing Committee, cited her group as an example of blacks and Hispanics working together in their own self-interest. The community (65 percent black and 30 percent Hispanic) had organized around the issue of the high crime rate, which was stalling economic development.

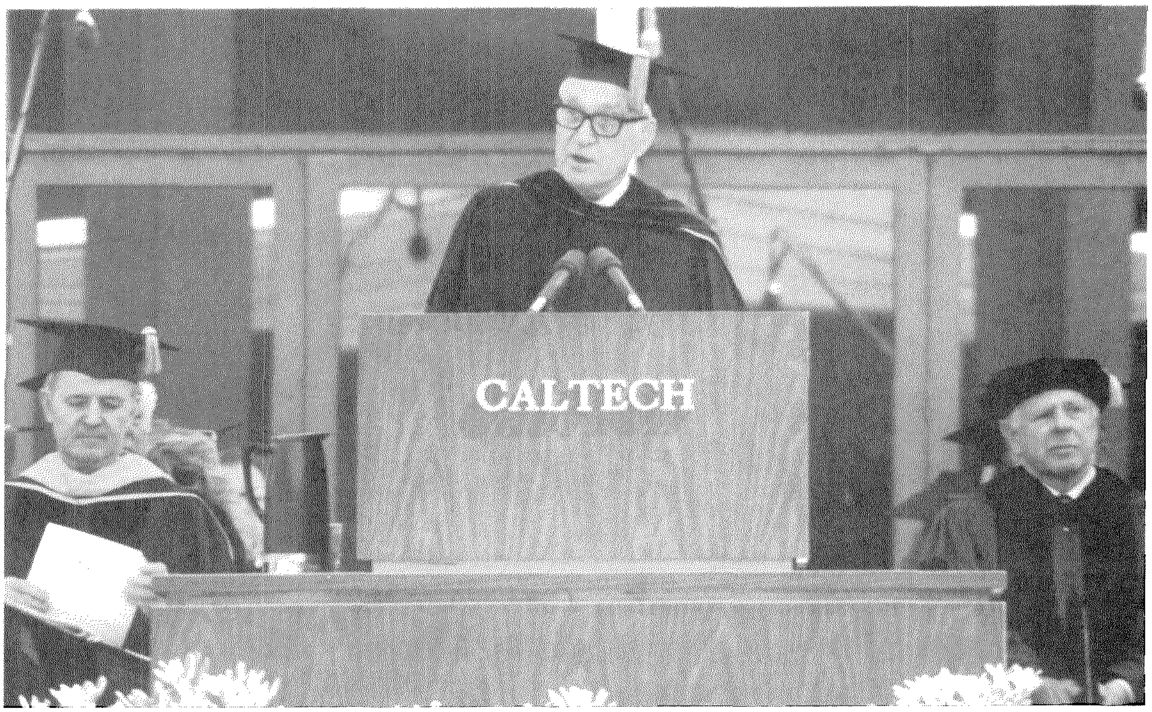
Monterey Park in Los Angeles County has a population of white, Hispanic, and Asian — approximately one-third each. Lily Chen, a Monterey Park city councilwoman, was interested in the study for its implications for a culturally diverse community, since the city has become known for the growing intolerance of English speakers toward immigrants. She hoped that what was happening in Monterey Park was not symptomatic of a growing backlash.

The fourth panel member, Roger Stanton, president of the Orange County Board of Supervisors, attacked the implied "natural place" of minorities in the Democratic Party. He also pointed out that Orange County, which is one of two Republican majority counties out of 58 in California, is not as homogeneous as is commonly thought. One of every four members of the population belongs to an ethnic minority.

Cisneros ended with the remark that there are "tough days ahead" for minorities, but he is optimistic that there is a "recognition on the part of the general public that new immigrants want what immigrants have always wanted — a meritocracy, which America has always claimed to be."

Cain concluded the conference on a similar note of optimism and a pluralist vision of America. The very fact of the great diversity among California's minorities may lead to easing of tensions among the many different groups making up the population. □ — *JD*

Panel members discussing community relations between racial/ethnic groups included (from top): Henry Cisneros, mayor of San Antonio, Texas; Edith Nealey, chairwoman of the South Central Organizing Committee; Lily Chen, Monterey Park City Councilwoman; and Roger Stanton, president of the Orange County Board of Supervisors.



Flanked by Ruben F. Mettler, chairman of the Board of Trustees (left) and President Marvin L. Goldberger, Arnold Beckman speaks to the Class of 1986.

Commencement 1986
Arnold Beckman

Arnold O. Beckman delivered the address at Caltech's 92nd commencement on June 13, 1986. Excerpts from that talk are presented on the following pages.

Beckman did more than just speak. At the end of the ceremonies President Marvin L. Goldberger announced a $50 million gift from the Arnold and Mabel Beckman Foundation, the largest single gift ever made by that foundation. It will be used to create the Beckman Institute at Caltech, which will be devoted to interdisciplinary research in biology and chemistry. It has since been announced that Harry B. Gray, who is the Arnold O. Beckman Professor of Chemistry, will be the director of the new institute.

The initial $40 million is contingent on Caltech raising $10 million in capital funds from private sources. The Beckman Foundation will provide the other $10 million if the Institute can raise an equal amount from members of the Board of Trustees for the general endowment.

IT HAS BEEN MY GOOD FORTUNE to have had a long and rewarding association with Caltech. This fact underlies my remarks today. Rather than state my views on some subject of national or international significance, as is often done by commencement speakers, I shall speak to you in a rather personal vein. We are all members of the Caltech family even though a wide generation gap separates us.

To emphasize the breadth of the generation gap, let me remind you that when I enrolled as a graduate student at Caltech in 1923, none of you had yet been born, nor probably had your parents. My remarks, therefore, will span two generations.

Your role at Caltech has been that of student. I have been a student also, but over the past six decades I have played additional roles: a member of the faculty and a member of the Board of Trustees, culminating in my present position as chairman emeritus. I am a life member of the Alumni Association and of The Caltech Associates. Also, I have grown much older. All of these facts comprise the background for my comments.

. . .

Over the years students have often asked me how they should select the field for their professional careers. My answer has been: "If there is one overriding criterion, it is enthusiasm. If you are enthusiastic, the field in which you work is probably a good one for you. If you are not enthusiastic, perhaps you should look for another field."

Don't worry about whether you have chosen the best professional field for your career; you can always change. Some of the most exciting scientific and technological developments have arisen from interdisciplinary cooperation — electrical engineers becoming biologists, for example, and from persons who have changed their professional fields in mid-life. I started out as a chemical engineer, switched to photochemistry, and ended up an instrument maker!

. . .

On the matter of pride over your accomplishments, may I delicately suggest that you ask yourself: "Did I achieve my success solely on my own, or did others help me?" I think you will find that you have received a great deal of help from many sources, . . . [including] your parents and your professors.

There is another category of Caltech people whom you might well thank — the trustees. . . . It would be a pity for you to graduate without knowing something about trustees, so I'll give you a brief description of them and their duties. . . .

The Board of Trustees is the top level of authority at Caltech. It owns all of Caltech's assets and has overall responsibility for Caltech's well-being. If you have lived on the campus, the Board of Trustees has been your landlord. The trustees must see to it that the Institute has adequate funds for operations and for capital expenditures. They are responsible for the budget, for approving salaries, for wisely investing nearly $400 million of endowment funds. The trustees indeed carry a heavy load of responsibilities, a fact of which you should be fully aware and appreciative.

Who are the trustees? They are 45 distinguished men and women, selected nationwide for their accomplishments and competence. They bring to Caltech an invaluable wealth of experience and expertise. They are dedicated to making Caltech the leading institution of its kind in the world. To this end, each contributes his or her time, energy, expertise, and resources.

. . .

Your years at Caltech have been costly. There is no such thing as a free education. Someone has to pay. Who paid for your education?

Most of you probably have borrowed money from one source or another. Now the painful period of repayment begins. I have full confidence that all Caltech students will pay off their financial obligations in an honorable manner. It is indeed a comfort to learn from the business office that almost no Caltech loans are in default. Caltech's record is one of the best in the nation. I am saddened when I read that nationally over 30 percent of government student loans are in default. Abuses of the student loan programs appear to be flagrant. . . . One may well question the value of higher education for those who have failed to learn the elementary lessons of honor and integrity. . . .

Many students are subsidized by scholarships funded from private sector contributions or from public sector revenues. Have you given much thought to the source of your scholarships, or have you taken them for granted, as something to which you obviously are entitled because you are bright? . . .

If your scholarships derived from public funds, federal or state, has your elation over getting the awards ever been tempered by an awareness that so-called public funds are taxpayers' money? Does it bother you that part of your education was paid for with funds that otherwise could have been used to feed the hungry or provide health care for the poor? . . .

Society does indeed have an obligation to care for the indigent. It also has an obligation, however, to see that the oncoming generations are educated so that there will be an adequate supply of competent and skilled persons to carry on the great multiplicity of human activities essential for the continuing well-being of the nation. To this end government agencies invest taxpayers' money in support of education, with the hope and expectation that society will ultimately receive significant benefits from the investment. Whether or not its investment in your education will prove to be a sound investment remains to be seen. It is up to you to see that it is.

The point I wish to make is that, in addition to whatever legal and financial obligations you may have incurred to fund your education, you also have a *moral* obligation to put back into society at least as much as society has given to you, preferably more.

When I enrolled as a student at Caltech, it never occurred to me to wonder: "How does it happen that right at the time I am ready for higher education, Caltech is ready for me? It exists, with excellent laboratories, classrooms, and a superb faculty. How did that happen?"

When I became older, I realized that it was not happenstance that Caltech was in existence, ready for me. Caltech was the product of the vision, dedication, and generosity of many persons. . . .

You, members of the Class of 1986, have benefited, as did I, from the foresight and generosity of many predecessors who paved the way for your education at Caltech. I respectfully suggest that you consider what obligation you have to take your turn in paving the way for your successors — to help Caltech meet its needs for the training of future generations.

. . .

Your continuing education will include not only ever-expanding comprehension of existing knowledge, but also — and this is probably more important — an awareness and understanding of *new* knowledge that no one has today, a body of knowledge to which you, the Class of 1986, unquestionably will make significant contributions. . . .

I speak confidently on this point because of my own personal experience. In June 1928 I received my coveted PhD degree a few hundred feet from here, on the steps of the Gates Chemistry Laboratory. As you are today, I was then, very proud and happy. I faced the future with joyful anticipation.

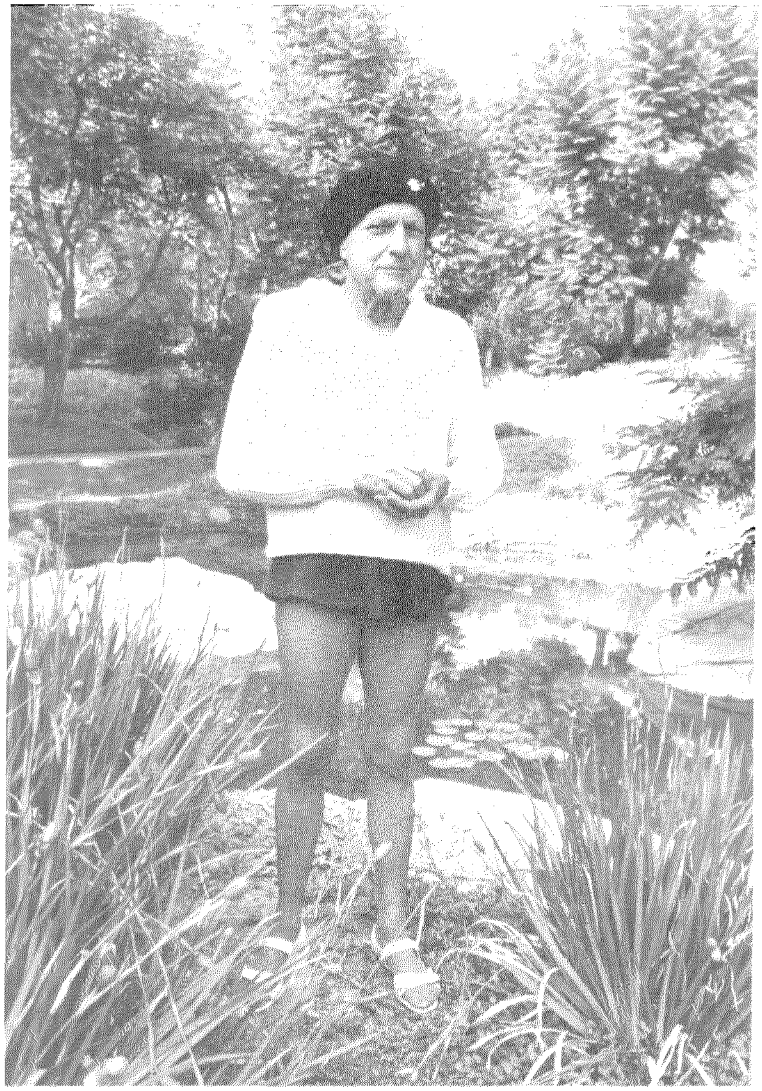
Fortunately, I was not then aware that the time-honored adage "ignorance is bliss" applied to my happiness. I was blissfully unaware of the extent of my ignorance. For example, despite three degrees in chemistry, I had never heard of such things as the antibiotics that have revolutionized medicine, of DNA, or of electronics, or computers.

Without wishing to diminish in any way your pride on this happy, eventful day, let me suggest politely that there are some things about which you are ignorant today, but which will become realities within your lifetimes. What are they? Let your imagination run wild. Judging from what actually happened in my lifetime, your wildest fantasies will fall far short of what will become realities in your lifetimes. Discoveries of the next half-century probably will be more numerous and at least as astounding as those made during my lifetime.

. . .

If I have induced any of you to look at your Caltech experiences in a new light, or if I have added to your feeling of excitement, hope, and anticipation over what the future holds for you, I've accomplished my goal. You are indeed fortunate to have had the privilege of studying at Caltech, a fact that will become more meaningful to you as time goes on. □

Simmons and the Strain Gage



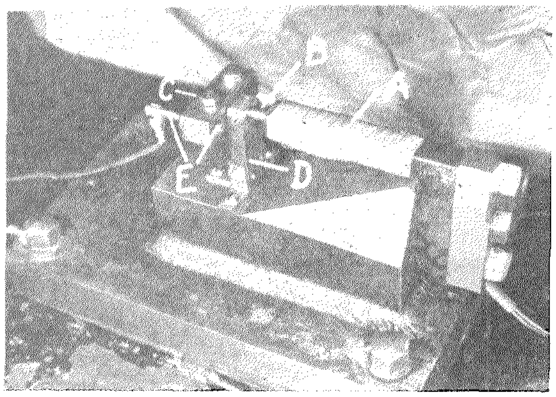
Edward Simmons stands on the spot where he invented the strain gage 50 years ago. It was then a cubbyhole office on the first floor of Throop Hall.

FIFTY YEARS AGO this month a former Caltech graduate student invented, almost casually, a device that caused an engineering revolution. Although some date the birth of the bonded wire resistance strain gage to 1938, Edward E. Simmons, Jr., actually first conceived it in 1936. When the outside world discovered its existence three years later, the versatile instrument found immediate, enthusiastic acceptance, first in an aircraft industry hard-pressed by the demands of World War II and eventually in all industries where stress analysis is crucial. Strain gages based on Simmons's prototype are still in widespread use today. Simmons (BS '34, MS '36 in electrical engineering), although offered research jobs elsewhere, determined to be a free-lance operator and chose to remain in Pasadena in the house he has inhabited since 1934. He's a familiar figure around the Caltech campus, which he considers a "suitable local amusement park."

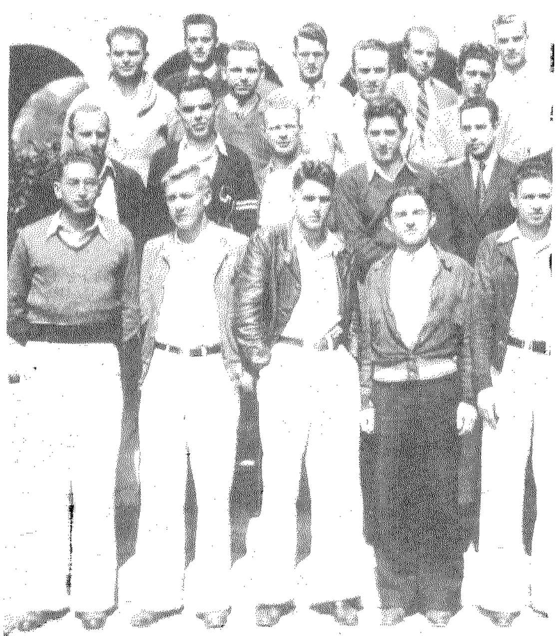
Components of all machines and structures are subject to strain that can deform them — tension, compression, bending, and twisting. Ever since the time of Robert Hooke and Isaac Newton, scientists and engineers had been trying with only limited success to devise ways to measure this strain accurately and conveniently. Even in the first third of the 20th century experimental stress analysis was in a relatively crude state. Design engineers had to compensate for the lack of accurate information by providing extra strength and sometimes extra weight to, say, airplane propellers or bridge girders, to insure against failure.

"Engineers had wanted something like this since the pyramids were built," wrote Francis G. Tatnall, who first recognized the commercial potential of Simmons's innovation and who, rightly or wrongly, is known as the "father of the strain gage." Tatnall, then testing-machine sales manager and later research director of Baldwin Southwark Division of the Baldwin Locomotive Works in Philadelphia, had long been prowling universities in search of the perfect strain gage — "zero length, zero thickness and . . . almost zero price."

Howard A. Nielsen, Jr., in his history of Baldwin, *From Locomotives to Strain Gages* (Vantage Press, 1985), describes Tatnall's "bootleg research": "He would ferret out the testing-equipment innovators, hidden in cluttered offices in remote corners, conceiving equipment they needed to do their daily jobs. Then he would promptly sign them up for Baldwin to market their product worldwide, leaving the dazzled inventor breathless." Nielsen's book describes how Baldwin, the leading manufacturer of steam locomotives, opportunely and without investing a dime (thanks to Tatnall's "research"), fell into the testing-equipment business just as locomotives were dying out. Nielsen, who worked for Baldwin from 1946 to 1957, admits that there exist "certain aspects of early strain-gage history that are fuzzy in the mists of time, memory, and legalisms." But most accounts agree on the actual discovery. Tatnall's own book, *Tatnall on Testing* (American Society for Metals, 1966), contains lengthy passages devoted to his joy at unearthing Ed Simmons at Caltech in August 1939.



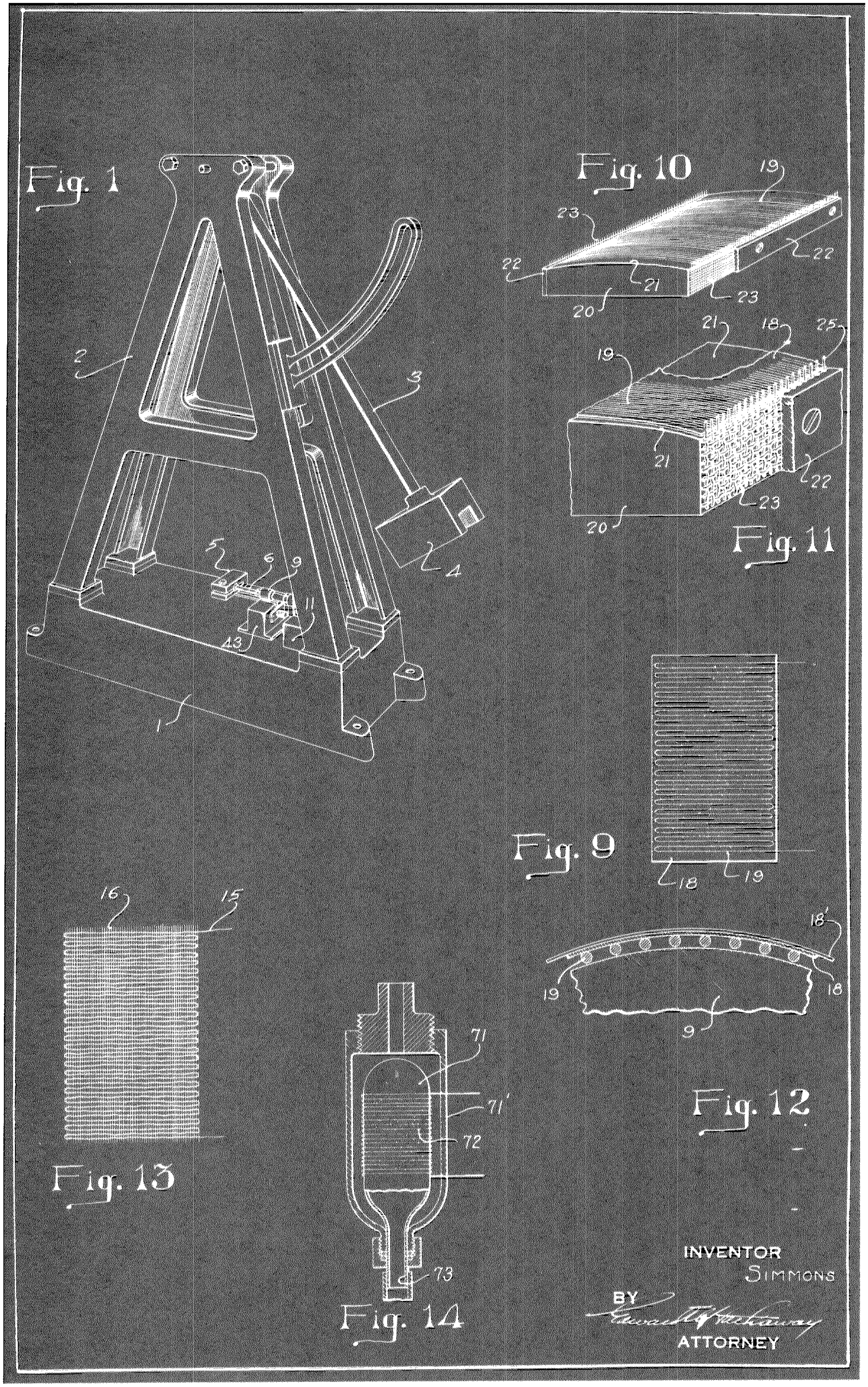
Simmons's original invention — "a new type of tension dynamometer" — was described in a paper by Clark and Dätwyler published in the Proceedings of the American Society for Testing Materials annual meeting in 1938.



In the 1933-34 California Tech *Simmons is standing third from left in the front row of the student branch of the American Institute of Electrical Engineers.*

Simmons was then occupied part time constructing electrical equipment for Donald S. Clark, assistant professor of mechanical engineering, in his Impact Research Lab, a program sponsored by several commercial firms starting in the fall of 1936. At that time his campus reputation for ingenuity had already made him a magnet for problems that required creative solutions. So Clark and Gottfried Dätwyler, research fellow in aeronautics, asked Simmons to construct an impact dynamometer — "a device for translating instantaneous forces into instantaneous electrical impulses which could be recorded on an oscillograph" — basically a strain gage. Within the first few days of September, Simmons conceived and designed it. "It was a flash-of-genius sort of thing," says Simmons, "and it turned out astoundingly well." He told Tatnall that since he hadn't known it couldn't be done, he just did it.

What Simmons did was to take advantage of Lord Kelvin's 1856 discovery that electrical resistance in a metal wire changes when it is stretched and its length and diameter change. This can be expressed as a ratio; for example, stretching a wire 0.1 percent might produce a change in resistance of 0.17 percent. Strain or distortion in a structure would stretch a thin wire attached to it, and the change in resistance could be measured. Simmons was not the first to exploit this idea for a deformation gage; Roy Carlson, a Caltech student in the early 1920s, had invented a gage that found use primarily on dams. In Carlson's instrument each end of a wire was attached to a separate point on the structure to be tested, a procedure that measured the average strain over a relatively large gage length. Simmons's solution was to attach the entire length of a fine wire (smaller in diameter than a human hair) to the test object by first zigzagging the filament into a grid a fraction of an inch long and then cementing it down with glue. Lead wires then connected it to a device, such as a Wheatstone bridge, to measure the electrical resistance, which could



Filed with the 1944 patent application for a "Material Testing Apparatus," this drawing shows the impact testing device and several versions of Simmons's wire gage.

be recorded. It came close to measuring the strain at a point. And it was elegant and simple.

Tatnall admired elegant thinking. When, after hearing rumors and pursuing Clark for a couple of years, he finally tracked down Simmons in his garage, he could appreciate the beautiful simplicity of the device amid its chaotic surroundings. "He [Simmons] picked up from a rough tabletop a most amazing collection of wire gages in various configurations, bonded and unbonded, some like Lilliputian stringed instruments . . . others laid down on old Christmas cards. . . . When I extracted patiently from Simmons a description of what he had done I could hardly contain my enthusiasm."

Tatnall had earlier discovered Arthur Ruge of MIT, who had invented a similar device sandwiched between two pieces of paper the size of a postage stamp, and the Baldwin Locomotive Works had already applied for a patent in Ruge's name. When Tatnall brought the Caltech and MIT groups together, it became clear that Simmons had done it first. Tatnall suggested naming the new strain gage SR-4 (S for Simmons, R for Ruge, and 4 for the four men involved, including Clark of Caltech and A. V. deForest of MIT). Baldwin Southwark changed its application to a basic patent for Simmons and a string of improvement patents for Ruge. Each remained protective of his piece of the pie, according to Nielsen, whose job it was to keep track of the patents, and he had Simmons and Ruge "both breathing hotly down my neck."

The patent problems, unfortunately, did not end there. Although Simmons, at Clark's behest, signed an agreement in 1940 assigning royalties and license approval to Caltech, he claimed later that it was with the understanding, through Clark's promises, that the royalties would be channeled into the Impact Research program and that he would be employed in that program on a regular basis. When first Simmons and then the entire program were terminated in 1941, it turned out that the royalties had gone into the general fund of the Institute, which was apparently unaware of Clark's promises and didn't consider him empowered to make any anyway. The now unemployed Simmons, who had previously lacked interest in the business end of things, hired a couple of young lawyers (a friend he had known in the Boy Scouts and a law school classmate of his) and sued for the rights to all royalties. The case went all the way to the California Supreme Court, which finally decided in Simmons's favor in 1949, enabling him to collect $125,000 in impounded back royalties. Total royalties over the 17-year span of the patent amounted to close to $1 million.

While the wheels of justice were slowly grinding, Simmons had worked as a radar engineer at the Sacramento Air Depot during the war and then returned to Pasadena to work for the Rheem Manufacturing Company. But the court decision changed all that. According to Tatnall's account: "After this, when I was looking for Ed Simmons I would find him dressed like a tennis player in his law library that he had accumulated for study during the trial. While Ruge-deForest pushed ahead with the strain gage and transducer business, Ed Simmons read law, set up a 'Simmons Research Foundation,' went into the oil prospecting business with a friend and came out with two gushers. He took up skin-diving and cave exploring in a quiet, persistent way, became an expert 3-D photographer with Viewmaster equipment. . . . He involved himself successfully in setting up a wire music service for restaurants; he did everything but follow up on the strain gage business."

The strain gage business did, however, apparently leave its mark on Caltech's patent policy. Clark and others at Caltech had been under the impression that the Institute owned the rights to anything developed there, but there had been no formal policy. In 1943 the Board of Trustees adopted a resolution to require a written invention agreement of employees. Current policy stipulates that employees assign to Caltech "inventions made in the line of Institute duty or with the use of Institute facilities."

Under Tatnall's zealous marketing strategy, the SR-4 strain gage went on to fame and fortune. Because of the tiny gage's insignificant cost, testing engineers could plaster them all over a structure and then pitch them out afterwards. Aircraft companies on the West Coast were using the device as soon as news of it got out, even before the patent application. A Lockheed engineer called it "the most sensational advance for aircraft design that had yet appeared" and predicted its use would move like wildfire. It did; Tatnall describes "strain gage fever" spreading eastward. A prominent speaker at the New York annual meeting of the Institute of the

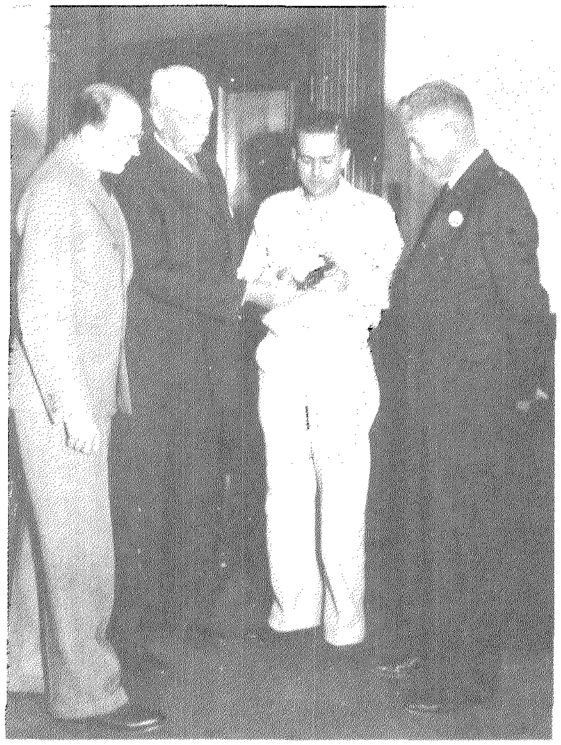
Aeronautical Sciences in 1943 proclaimed: "The SR-4 strain gage has been the greatest single contributor to the present efficient airplane structure, thereby strongly aiding Allied air supremacy."

Since World War II SR-4 strain gages have found application in the automobile and railroad industries, on bridges, buildings, and highways, on all types of machinery, and in the design of almost any new equipment or structure that must undergo stress. They are also an essential component of electronic weighing equipment. Now 150 different types of strain gages are commercially available in a business worth a half-billion dollars per year.

Even though Simmons abandoned the strain gage business after seeing his patent through the courts, his role in its invention did not go unrecognized. Tatnall, who had great admiration for the original thinking of attic inventors like Simmons, nominated him in 1944 for the Edward Longstreth Medal of the Franklin Institute of Philadelphia, which awarded about 15 medals each year for "contributions to the arts and sciences of the world, to the good of mankind and to the advancement of science." The Franklin committee cited Simmons for his "valuable contribution to engineering and research. . . . [his device] has proven essential in engineering design of aircraft and other powerful instruments of war, and will be as valuable in peace."

In his book Tatnall described the ceremony: "Medal Day begins with a formal luncheon at noon followed by meetings with the Medalists, press conferences for them, publicity photographs and other customary formalities. Simmons did not show up, so I just explained that he was embarrassed, knowing that he wasn't at all, he just did not care. Simmons was still absent when we dressed for dinner, Medalists in white tie and tails, others in black tie. When the Medalists filed into their designated places at the head table, I had not the nerve to look to see if my boy was at his place at the table. When I did get up nerve to look my heart jumped with joy. There he was sitting between the great chemist, Dr. Leo Baekeland, inventor of Bakelite, tall, mustached and impressive, and on the other side Dr. Harlow Shapley, famous astronomer, director of the Harvard observatory, both in white tie and tails. Ed Simmons was looking very small, very young and very bored and he was in his familiar tennis clothes, or a slightly enhanced version of them. As each Medalist would receive his medal and scroll from the President of the Franklin Institute, each would graciously acknowledge with a word or two — except Ed Simmons, who said nothing at all and looked tired. I think, but I am not sure, that he got the biggest hand of all from the 450 or more prominent people attending the dinner. Those of the Institute and committee members present seemed to feel that I had done the Institute a favor by letting them see in person an inventor that looked like a traditional, historic type, a Diogenes. After this, let me hear no one criticize the dress or nonconformities or little singularities of E. E. Simmons, Jr., for I am one of his fans." □ — *JD*

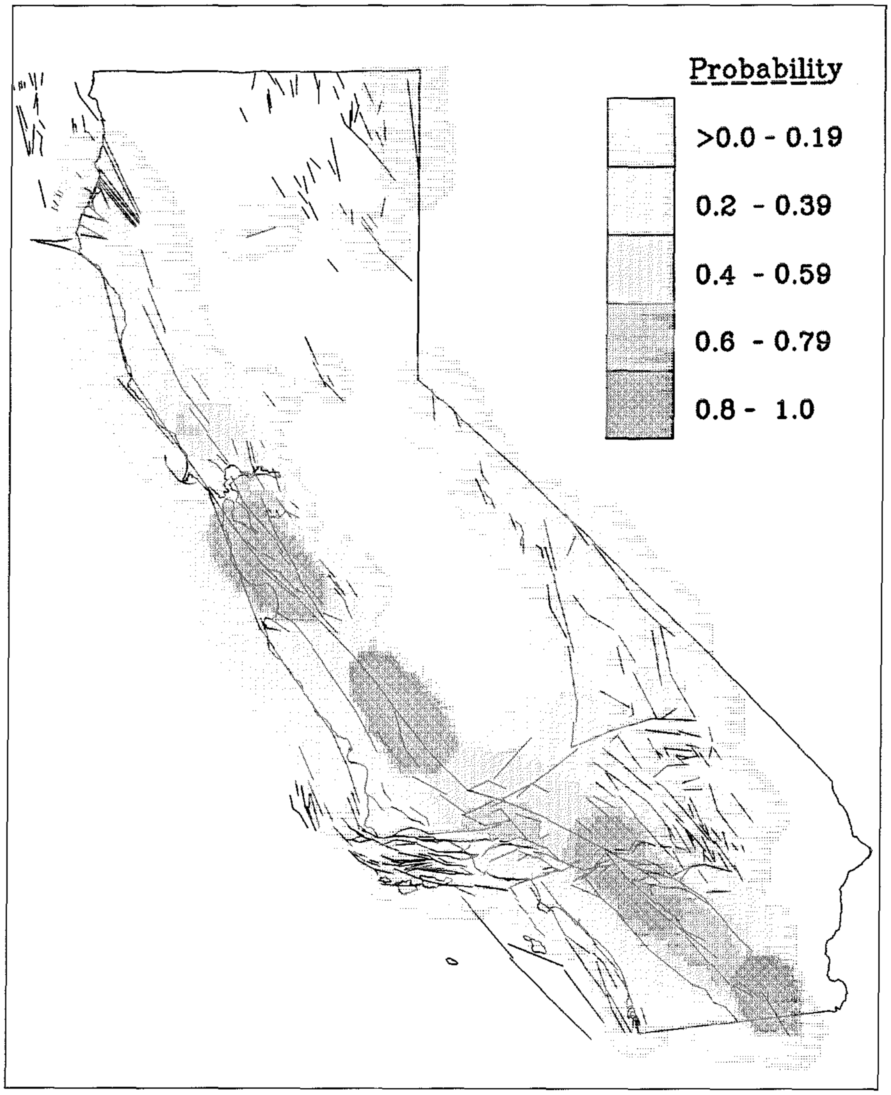
Simmons (left) and Arthur Ruge of MIT, the "S" and the "R" of the SR-4 strain gage, shake hands at the 1964 Los Angeles meeting of the Western Regional Strain Gage Committee. This took place 25 years after the original patent agreement.



Simmons (second from right) displays his 1944 Longstreth Medal to executives of the Baldwin Locomotive Works. Frank Tatnall stands at right.

Research in Progress

Guessing a Hazard



This map shows the probability that any given area in California will suffer damage from an earthquake within the next 50 years.

THE RECENT SPATE of California earthquakes has led to renewed calls by communities around the state for reliable earthquake hazard estimates. While seismologists are still unable to predict individual quakes, they have long recognized that certain areas are more at risk than others. But until Steven G. Wesnousky, a former Caltech research fellow in geophysics, got involved, these risk estimates had a serious flaw — they were almost all based solely on the historic record of earthquakes, a record that is at best only a couple of hundred years old.

Wesnousky, who's now at the Tennessee Earthquake Information Center at Memphis State University, has conducted a detailed study of the geologic record of Quaternary Period faulting. By collating a massive amount of data bearing upon the location and magnitude of prehistoric earthquakes — at least those that have occurred during the last 100,000 years or so — he has produced the first geologically based earthquake hazard maps of the state of California.

In constructing these maps, Wesnousky had to determine both the magnitude and the rate of occurrence of earthquakes that rocked the state in the distant past. Earthquakes occur along faults, and studies of modern earthquakes reveal that larger earthquakes produce longer fault ruptures. The relationship between earthquake magnitude and rupture length is an empirical one, but observations of recent earthquakes have allowed seismologists to state that a rupture of length X is generally produced by a quake of magnitude Y. So by collecting information on fault length, Wesnousky is able to determine quake magnitude.

Wesnousky obtains estimates of the rate of occurrence of prehistoric earthquakes using data derived from two different methods — a direct method and an indirect one. In the direct method researchers examine sediments that are ruptured by a fault. When the ages of those sediments are known, investigators can often determine when prehistoric earthquakes have occurred.

The indirect method involves looking for rock formations on either side of a fault that were once adjacent but have become split and separated by a succession of quakes over the eons. By determining how old the formations are and how much separation there has been, the "slip rate" of the fault can be computed. The slip rate provides a measure of the average rate of strain accumulation on the fault, and from this it's possible to calculate how frequently earthquakes, which release this strain, occur.

Using this sort of information, Wesnousky constructed a series of California maps detailing different aspects of earthquake hazard. One shows the number of faults in a given area that might be expected to produce earthquakes causing peak ground accelerations of greater than one-tenth the force of gravity ($0.1g$). This is the level at which older structures and some modern structures not engineered to withstand earthquake shaking are susceptible to significant damage. Another map shows how frequently, on average, severe shaking can be expected. Still another series of maps shows the locations where the severe shaking is most likely to occur in California during any random 50-year period.

In the map pictured here, all this data has been combined with information on recent quakes. This map shows the estimated probability that mapped on-shore faults will produce ground accelerations of greater than $0.1g$ during the *next* 50 years. Writes Wesnousky in a paper soon to be published in the *Journal of Geophysical Research*, "[This figure] conveys information in a format that may prove useful for decisions regarding the siting of hazard mitigation procedures and the deployment of seismic instrumentation."

Not surprisingly, Wesnousky's maps indicate that the communities most at risk from a major earthquake lie along certain sections of the San Andreas fault. The San Andreas, which extends almost the entire length of the state, accommodates most of the slip as the Pacific plate moves northward relative to the North American plate. The San Jacinto fault, which traverses communities in the San Bernardino area and continues southward to the Mexican border, can also be expected to be the site of a large temblor in the not-too-distant future.

Although two of the most highly populated areas in the state — the Los Angeles and Ventura basins — are *not* traversed by faults the size of the San Andreas or the San Jacinto, they are shot through with a myriad of lesser faults. These faults are subject to only moderate slip rates, but there are so many of them in these regions that the hazard there is relatively high.

While Wesnousky's map highlights areas of high hazard, other areas of high hazard may yet remain unrecognized. On the map, an area can appear to be a low-risk area for two reasons: Either the risk really is low, or there simply haven't been enough geological data collected there to determine the true risk.

But this lack of data can be remedied. Says Wesnousky, "I think the primary result of this work is that it provides a framework for taking an active approach toward assessing seismic hazard. Rather than waiting till an earthquake occurs to modify our understanding of seismic hazard, we can look for faults and the features associated with them and gather information about slip rates and prehistoric earthquakes. I think research agencies should make a conscious effort to acquire those data. A lot of the data that I brought to bear on this problem came together in a rather hodge-podge way, from many investigators working in their separate little areas. It's worked quite well, but I think there's a chance here for a more rigorous approach." □ — *RF*

Tracking Stellar Reactions

THE UNIVERSE CONTAINS roughly equal amounts of carbon and oxygen. All life on our planet relies on this fact, but the carbon/oxygen ratio is also of vital importance to every star in the sky. If a star has too much carbon, an immediate supernova explosion is likely; if there's enough oxygen, on the other hand, the star can progress through several stages of evolution before its inevitable death as a supernova.

A team of physicists at the Kellogg Radiation Laboratory led by Bradley Filippone, assistant professor of physics, is trying to understand how it is that nature has made comparable amounts of carbon and oxygen. Included in the team are Kai Chang and Leon Mitchell, research fellows in physics, graduate student Rick Kremer, former undergraduates Kenneth Hahn and Aaron Roodman, Hugh Evans, visiting associate in physics, and Charles A. Barnes, professor of physics. They have been attacking the problem with Caltech's newest accelerator, nicknamed the Yellow Submarine.

At the heart of the problem are two nuclear reactions that take place in the interior of stars. In the first reaction,

$$3\alpha \rightarrow {}^{12}C$$

the nuclei of three helium atoms

(alpha particles) fuse to form one carbon-12 nucleus. This is called the triple-alpha process, and it is the principal source of carbon in the universe. In the second reaction,

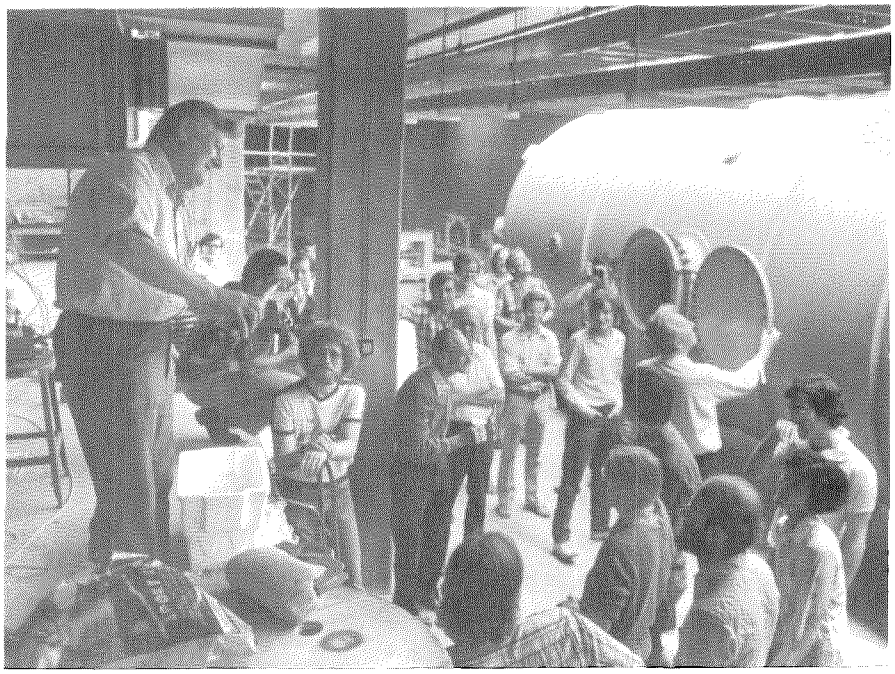
$$^{12}C + \alpha \rightarrow {}^{16}O + \gamma$$

the carbon produced in the triple-alpha process fuses with another alpha particle to form an oxygen-16 nucleus with the emission of a gamma ray.

If the first reaction goes at a much faster rate than the second, there will be an accumulation of carbon in the star, and carbon nuclei will begin fusing with each other. These carbon-burning reactions lead to a whole host of products: ^{23}Na plus a proton, ^{20}Ne plus an alpha particle, and ^{23}Mg plus a neutron, for example. These reactions produce huge amounts of energy, enough to cause a violent carbon-detonation supernova, which would leave no remnant of the star whatsoever. If, on the other hand, the second reaction proceeds faster than the first, then there will be an overabundance of oxygen. This condition, too, would eventually lead to a supernova after further evolution of the star, but in this case the explosion would leave a neutron star or a black hole as a remnant and would, in addition, produce a very different mix of elements in the explosion's ejecta.

It's only when the rate of production of oxygen is at least as fast as the rate of production of carbon that a fairly massive star can remain more or less stable. In this case, carbon nuclei still fuse with one another, producing quantities of energy, but the star is able to respond to the increased temperature by increasing in size. This decreases the pressure, cooling off the star and dampening the carbon fusion reactions. A star in this sort of cycle is said to be undergoing quasi-static carbon burning.

To determine whether the two reactions will be in balance, it's important to have precise data on the yields of the reactions as a function of energy and density. If the general shape of such a yield curve is smooth, as in the triple-alpha reaction, the curve's details can be worked out by making just a few measurements at critical points along the curve. But if the shape of the yield curve is complex, as in the reaction of ^{12}C with an alpha particle, a great many more measurements need to be taken for accurate determinations of the reaction's yield. This reaction is dominated by a number of "resonances" — sharp peaks whose locations on the energy scale are known, but whose exact shapes can only be determined by experiment.



In this 1981 photo, Charles A. Barnes toasts the arrival of the "Yellow Submarine," Caltech's newest tandem accelerator.

Working with Peggy Dyer, now of the Los Alamos National Laboratory, Barnes in 1974 determined the shapes of two of these resonances, which peak at 2.4 MeV and -0.045 MeV. But the most astrophysically interesting region of the curve is at about 0.3 MeV — this is where most of a star's heat production takes place. The oxygen yield in this region is dominated by two resonances at negative energies: the one at -0.045 MeV and another at -0.245 MeV.

"You can't get to these resonances even in principle because they're at negative alpha-particle kinetic energies," says Barnes. "But though the resonances themselves are physically inaccessible, nevertheless their effects on the oxygen yield are very real — their tails manifest themselves in the region of positive energies. The 'scents' of these resonances are present at higher energies, and even though it isn't a big effect, if you work hard enough you can 'smell' them, and they do all the things that positive energy resonances do."

One must, however, work very hard indeed. The problem is that the yield curve has an extremely steep slope in the region below 2.4 MeV. This means that as the energies get lower, the yields decrease very rapidly, causing problems in detection. In 1974 Dyer and Barnes were able to determine yields down to 1.4 MeV, but the rate of oxygen production in the region of interest near 0.3 MeV is about 100 million times less.

This job became somewhat easier in 1981 with the delivery of Caltech's newest tandem accelerator — the Pelletron, more commonly called the Yellow Submarine. Designed by Barnes along with engineers from the National Electrostatic Corporation, which built it, the Yellow Submarine has allowed Barnes and his colleagues to extend their measurements down to 0.95 MeV, where the yields are only about 1 percent of what they are at 1.4 MeV.

In these experiments, a beam of ^{12}C ions is accelerated and aimed at a two-inch cylinder filled with helium atoms. Within the cylinder a tiny proportion — maybe one in 100 quadrillion (10^{17}) — of the entering ^{12}C nuclei will fuse with helium nuclei to form ^{16}O, producing a gamma ray in the process. The ^{16}O nuclei streak out of the cylinder with the unreacted ^{12}C, but because of the Law of the Conservation of Momentum, the heavier oxygen nuclei travel 25 percent more slowly than the lighter carbon.

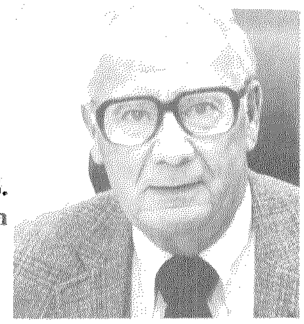
The researchers take advantage of this slower speed in their efforts to separate and detect each fusion event. Immediately after the beam leaves the target cylinder, it passes through a velocity filter that discards most of the faster-moving ^{12}C atoms. This changes the proportion of oxygen from one in 100 quadrillion atoms to a relatively rich one in 100 million. The beam then passes through a large magnet, which performs a further separation based on mass, and then to a counter that measures the charge of each remaining atom. Finally, the exact time of detection (which can be determined with an accuracy of just a few nanoseconds) is correlated with the time of detection of the gamma ray produced at the instant of fusion. If all of these quantities have the right values, the event is presumed to reflect the actual production of a nucleus of oxygen.

In this way the researchers have extended their measurements down to 0.95 MeV. But, Barnes says, "How much further we could go is really an endless question. We could probably get down to 0.90 with an enormous effort, dropping about another factor of 10 in yield." The problem is that even at 0.95 MeV, they are only detecting a few fusion events per day. Although it seems feasible to get the background noise in the detector system down to about 1 count per day, the lower the actual oxygen yield gets, the longer the experiment must be run to achieve a statistically significant number of counts above that background. As Barnes points out, "At some point you're not talking about an experiment that lasts the time it takes a graduate student to get a PhD; you're talking about an experiment that lasts an entire human lifetime — a length of time we cannot afford to spend on a single experiment."

However, the Kellogg team believes that if they can verify their results down to 0.95 MeV, the scent of the negative-energy resonances will be strong enough to reconstruct their shapes quite accurately. In turn, this will give the theorists the data they need to understand how nature has made the concentrations of carbon and oxygen observed in the universe.

Reflecting on the many years he has spent studying stellar helium burning, Barnes remarks, "Isn't it marvelous that nature has contrived to make comparable amounts of carbon and oxygen so we can live? On the other hand, if that were not true, we wouldn't be here to ask the question, 'Isn't it marvelous?'" □ — *RF*

Retirements 1986



Francis S. Buffington

FRANCIS S. BUFFINGTON was educated at MIT, where he received an SB in general engineering in 1938 and a ScD in metallurgy in 1951. His research interests lie in the areas of diffusion and phase transformations in solids.

Buffington came to Caltech in 1951 as an assistant professor of mechanical engineering. He was promoted to associate professor in 1956, and in 1963 his title was changed to associate professor of materials science. In 1983 he was made professor of materials science. He is a registered professional engineer and a member of the American Physical Society and the American Society for Metals.

Buffington has served on the Graduate Studies Committee, on the Membership and Bylaws Committee, and on the Faculty Board. He was chairman of the Curriculum Committee in 1980-1981. The bulk of his service, however, has come about in the following five roles: associate dean of graduate studies; option representative for applied mechanics, civil engineering, engineering science, environmental engineering science, materials science, and mechanical engineering; secretary of the combined faculties in applied mechanics, materials science, and mechanical engineering; and chairman of the committee to monitor first-year PhD students in applied mechanics, civil engineering, materials science, and mechanical engineering.

Buffington's colleagues in the Division of Engineering and Applied Science remark on his ability to recall instantly the special aspects of the academic life of any individual student under discussion. His talents as option representative have proven so valuable that he has been asked to continue in this capacity for several engineering options during the coming year.

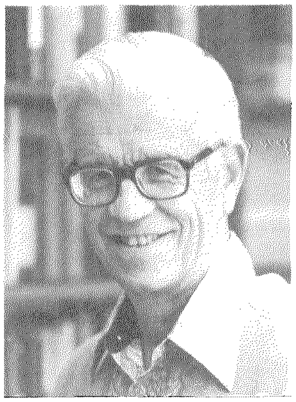
Robert F. Christy

ROBERT F. CHRISTY came to Caltech in 1946, soon after the completion of his work on the Manhattan Project. Charlie Lauritsen and Willy Fowler had been looking for a theoretical physicist for their experimental nuclear physics group, and they asked J. Robert Oppenheimer for a recommendation. He promptly suggested his former student Christy, then on the University of Chicago faculty, calling him "one of the best in the world."

When Christy got here, he immediately gained renown for his theoretical work, but he was also known for his ability to do experimental work and to work with his hands. As one of the members of that old group said, "I wouldn't give most theoretical physicists a paper clip because they'd hurt themselves. But Christy's amazing. He's even built a swimming pool. And he can do all kinds of complicated work around his house — not as a hobby, mind you, but as a challenge. If something breaks down, he'd rather fix it than have to say he can't."

In the early 1960s Christy's interests turned to theoretical astrophysics, and he won the prestigious Eddington Medal of the Royal Astronomical Society of London for his work on variable stars. He is a member of the National Academy of Sciences, and he has served Caltech as executive officer for physics (1968-1970), vice president and provost (1970-1980), and as acting president of the Institute (1977-1978). In 1983 Christy was named Institute Professor of Theoretical Physics by the Board of Trustees.

J. Kent Clark

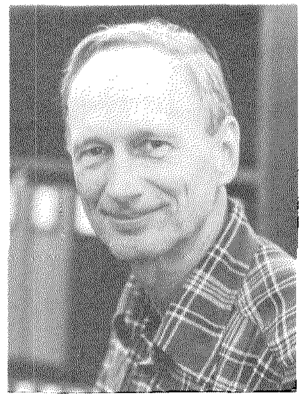


HE'S BEEN CALLED Caltech's unofficial poet laureate and the Bard of Baxter Hall. J. Kent Clark, professor of literature, has for years been best known around campus for writing, acting, and singing numerous Caltech musicals. These have included "The Road to Stockholm" (1954), "This is Science?" (1955), "Who is this Guy DuBridge?" (1956), "The Importance of Being Earnest" (1959), "What Makes Beadle Run?" (1961), "Lee and Sympathy" (1966), "The Bacher File" (1970), and "Beautiful Beckman" (1975). (Clark's musical collaborator has been Elliot Davis, whom Clark describes as a lawyer, business executive, and part-time genius.)

In between musicals Clark has served on many faculty committees and has written three books: *The King's Agent* (1958), a novel; *Dimensions in Drama* (1964); and *Goodwin Wharton* (1985). This last is a delightful biography of a late-17th-century Englishman, Lord of the Admiralty under King William, who must have been the most gullible human being who ever lived.

Clark was born in northern Utah and received his BA from Brigham Young University, majoring in English and history. His graduate work at Stanford University was interrupted by World War II. He served three and a half years in the Air Force as a supply officer in a radar batallion in the Philippines. Shortly after coming to Caltech, Clark completed his dissertation — on Jonathan Swift — at the Huntington Library. He started as an instructor in English in 1947, and was appointed assistant professor in 1950, associate professor in 1954, professor in 1960, and professor of literature in 1980.

Eugene W. Cowan

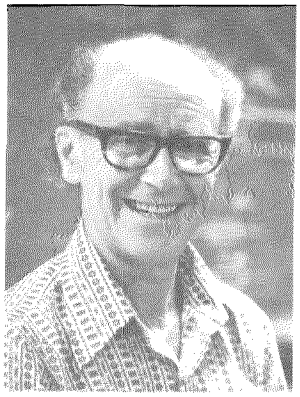


EUGENE W. (BUD) COWAN has been at Caltech for over 40 years. After receiving his BS at the University of Missouri and his MS at MIT, he came to Caltech in 1945. He worked with Carl Anderson (now professor of physics, emeritus), and was awarded his PhD in 1948. He became a research fellow in 1948, an assistant professor in 1950, and an associate professor in 1954. In 1961 he was promoted to professor of physics, the position he has held ever since.

Cowan's research interests have included investigations of high-energy interactions of cosmic rays, air pollution studies, and studies of the earth's magnetism. He is noted for perfecting a cloud chamber capable of operating on a continuous basis. All cloud chambers depend on the condensation of a vapor on the charged ions left by the passage of a speeding particle. Previous cloud chambers required a sudden, large drop in chamber pressure for condensation to occur, and this had to be followed by a rest period during which no observations could be made. Cowan's innovation eliminated the need for the pressure decrease and thus eliminated the rest period.

Long recognized for the quality of his teaching, Cowan was awarded the ASCIT award for teaching excellence this past February for his course on classical electromagnetism. He has been a regular patron of the Caltech pool's noontime lap swim for years, a practice he plans to continue.

Norman Davidson



LIKE LINUS PAULING and Max Delbrück, Norman Davidson belongs to the tradition of physical scientists who have turned their attention to biology. He started out working on the kinetics of fast reactions and for this he was elected to the National Academy of Sciences, and he also received the California Section Award of the American Chemical Society in 1954. But his interests soon turned to molecular biology and the structure and function of DNA.

The California State Museum of Science and Industry described his more recent research when they named him California Scientist of the Year for 1980: "Dr. Davidson has pioneered the development of methods, using the electron microscope, for identifying structures and mapping sequences in nucleic acids. One such method, heteroduplex mapping, is used by virtually every laboratory in the world interested in gene structure. The Davidson laboratory has applied these and other methods in an elegant series of studies of the genes of tumor viruses and the fruit fly."

Davidson received his BS and PhD in chemistry from the University of Chicago. In addition, Oxford University awarded him a BSc when he was there on a Rhodes Scholarship in 1939. During World War II he worked on war-related subjects at USC, Columbia University, and the University of Chicago. In 1946 he came to Caltech as an instructor in chemistry and he was associated with Linus Pauling in the teaching of the freshman chemstry course. He became assistant professor in 1949, associate professor in 1952, and professor in 1957, and in 1982 he was named the Norman Chandler Professor of Chemical Biology. He was executive officer for chemistry from 1967 to 1973.

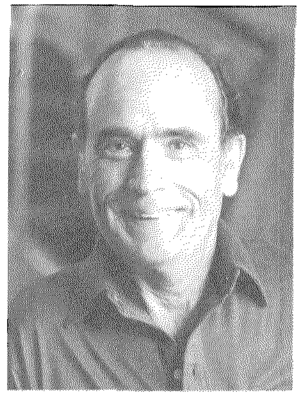
Charles R. De Prima

CHARLES R. DE PRIMA is one of those rare Caltech professors who started his career in one division and is finishing it in another. He was hired as an assistant professor of applied mechanics in 1946 by what was then called the Division of Civil and Mechanical Engineering and Aeronautics (now the Division of Engineering and Applied Science). His area of research was fluid mechanics, and he taught the course in mathematics for engineers originated by Theodore von Kármán. In 1951 he was promoted to associate professor, and he became a full professor in 1956.

But there was a reorganization of responsibilities among the divisions in the early 1960s, and, in addition, De Prima's interests had shifted in the direction of pure mathematics. So in 1964 he became professor of mathematics in the Division of Physics, Mathematics, and Astronomy. His research in recent years has been in the areas of analysis, partial differential equations, and operator theory — the study of abstract spaces and the operators that work on those spaces.

Retirement hasn't stopped his research; only the setting has changed. De Prima has moved to Gualala, California, an isolated community on the Pacific coast in Mendocino County, 120 miles north of San Francisco. He's in good company: several current and former members of the Caltech community have homes there, including David Morrisroe (vice president for business and finance and treasurer) and Clair Patterson (senior research associate in geochemistry).

David C. Elliot



DAVID C. ELLIOT seems to have spent the early part of his academic career collecting master's degrees — he's got three of them. The first came in 1939 from St. Andrews University in his native Scotland. After a few years in the Indian Civil Service during and after World War II, he went to Harvard University, where he obtained a second master's in 1948 and a PhD in 1951. Five years later he received his third master's, this one from Oxford University.

Elliot came to Caltech as an assistant professor of history in 1950. In 1953 he was promoted to associate professor, and he became professor of history in 1960. His research interests have ranged widely: he has studied European organizations, the liberal party in Scotland, London's 1660 Restoration period, and arms control and national defense. He has served as a consultant to the Ford Foundation, the RAND Corporation, NASA, and the Foreign Area Fellowship Program. In 1980 he was awarded a NATO fellowship for a project on European moves for arms control dealing with theater nuclear forces.

Elliot's career has been marked by dedicated service to the Caltech community. He was chairman of the special 75th anniversary celebrations in 1966 and served as vice chairman of the faculty from 1965 to 1967. From 1967 to 1971 he was executive officer for the humanities and social sciences, and from 1973 to 1985 he was secretary of the faculty. His class "Introduction to Europe" has long been popular with Caltech undergraduates, and in 1971 Elliot received an ASCIT award for teaching excellence.

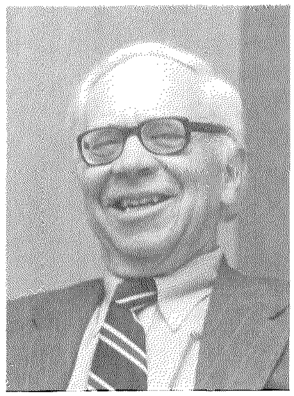
Derek Fender

DURING WORLD WAR II Derek Fender, like so many other British scientists of the period, served in the Royal Corps of Signals, helping to develop radar. The aspect of the problem he worked on involved the interface between man and machine. How, for example, can a gunner be trained to aim not at the point where an enemy aircraft is now, but where it will be in 30 seconds, the time it will take the anti-aircraft shell to arrive?

Fender's research since then has continued more or less in the same vein. He has always been concerned with questions about how human brains interpret signals coming from the world around us. To get at some of these questions, he has had to invent some rather elaborate devices. He's pictured on the cover of the April 1971 issue of *E&S* wearing one of these devices — a custom-fitted, air-conditioned helmet bristling with 49 electrodes that he employed to record his own brain waves. Later, he improved the device to the point where it contained 97 electrodes.

Using these devices, and others as well, he studied subjects such as how the brain interprets textures and localizes objects in space. Fender is also credited with a significant advance in the development of the electoretinogram, an advance that permitted the early detection of retinal disease.

Fender came to Caltech from Reading University in 1961. He started out as a senior research fellow in engineering, and was appointed associate professor of biology and electrical engineering in 1962. In 1966 he became professor of biology and applied science.



W. T. Jones

IT WAS ONLY IN 1970, after a long and distinguished career at Pomona College, that W. T. Jones came to Caltech, at first as a visiting professor of philosophy. He decided to stay, and he was appointed Andrew W. Mellon Professor for the year 1972-1973, after which he became professor of philosophy.

Jones's special subject of study has been in the area of world views, and he has published many papers on aspects of this subject. He has also written seven books, including *Morality and Freedom in the Philosophy of Kant* (1940), *Facts and Values* (1961), *The Sciences and the Humanities* (1965), and the five-volume *A History of Western Philosophy* (1969-1975).

Jones has received many honors, and has been, at various times, a Rhodes Scholar, a Guggenheim Fellow, a Lippincott Fellow, a Proctor Fellow, a Ford Faculty Fellow, and a Phi Beta Kappa Visiting Scholar. He is the director of the Wenner-Gren Foundation of Anthropological Research and a member of the Board of Trustees of Pomona College. He has earned honorary doctorates from Ripon College and Pomona College.

In a stimulating article entitled "What's the Use of the Humanities" in the January-February 1977 issue of *E&S*, Jones wrote, "[O]ne of the great aims of education should be to help students learn how to enjoy — *enjoy*, not merely tolerate — cognitive dissonance, cognitive ambiguity. . . .We want an educational system that does not allow its graduates to live within their various competences as in a castle, protected by moat and drawbridge, but one that encourages them to look outside, even on occasion to step outside and view their castle from without."

Lester Lees

LESTER LEES received his bachelor's and master's degrees from MIT, but throughout his long career he never had time to acquire a PhD. But there's a saying in the aeronautics community that goes "One Lees equals ten PhDs," so the lack of a doctorate has apparently been no handicap.

Lees started at Caltech in 1942 as a research fellow and instructor in mathematics. He spent the years from 1946 to 1953 on the faculty of Princeton University, but then returned to Caltech to become associate professor of aeronautics. He was named professor of aeronautics in 1955 and professor of environmental engineering and aeronautics in 1970. In 1971 he was appointed the first director of the Environmental Quality Laboratory, a position he held until 1974.

Lees's research interests have centered on the problems of high-speed flight, including the re-entry of missiles and spacecraft into the earth's atmosphere. Within this area, one of his special research topics involved studies of atmospheric wakes behind re-entry vehicles. Because of his expertise in this area, he was asked to serve on the Space Vehicle Panel, the Space Technology Panel, and the Combined Space Science and Space Technology panels of the President's Science Advisory Committee from 1963 to 1967. He was also a member of NASA's Lunar and Planetary Missions Advisory Board from 1967 to 1969.

Lees's work in aircraft fuel-efficiency led to his interests in issues of environmental quality. He has been the recipient of many honors and awards, including election to the American Academy of Arts and Sciences and the National Academy of Engineering.

Sten Samson

Walter Schroeder

A SWEDISH CITIZEN, Sten Samson has received three degrees from the University of Stockholm: Fil.kand. (1953), Fil.lic.(1957), and Fil.dr.(1968). He first came to Caltech in 1953 at the invitation of Linus Pauling, then chairman of the chemistry division. Except for a brief return to Sweden in 1956-1957 for the purpose of applying for immigrant status, he has been here ever since.

Samson's research interests have focused on the crystal chemistry of highly complex intermetallic compounds, complex minerals, and solid-state related substances of inorganic nature. He has been active in the development of a broad line of x-ray instrumentation, including automated diffractometers, monochromators, and low-temperature devices and, in fact, he was manager of the chemistry division's x-ray diffraction facility in Crellin Laboratory.

Samson is currently trying to discover in detail the processes that occur in the crystal lattice of organic conductors at low temperatures. Samson developed an automated diffractometer for this purpose capable of measuring x-ray reflections down to 16 K. An understanding of these processes is crucial in elucidating mechanisms of solid-state transitions such as conductor-to-insulator and paraelectric-to-ferroelectric.

Samson started at Caltech as a research fellow. He was promoted to senior research fellow in 1961, to research associate in 1973, and to senior research associate in 1980.

WALTER SCHROEDER came to Caltech as a PhD candidate after receiving his bachelor's and master's degrees at the University of Nebraska. He worked in the lab of Laszlo Zechmeister trying to determine the chemical structure of carotenoids. He received his doctorate in 1943 and quickly found himself aiding the war effort — he was a member of a group investigating the chemistry of smokeless powder and other explosives.

After the war Schroeder's interests turned to the biochemistry of proteins and, in particular, their structure and amino acid sequences. In 1969, using techniques far more tedious and cumbersome than those available today, he accomplished the feat of sequencing the enzyme catalase. With a length of 506 amino acids, it was by far the largest protein sequenced up to that time.

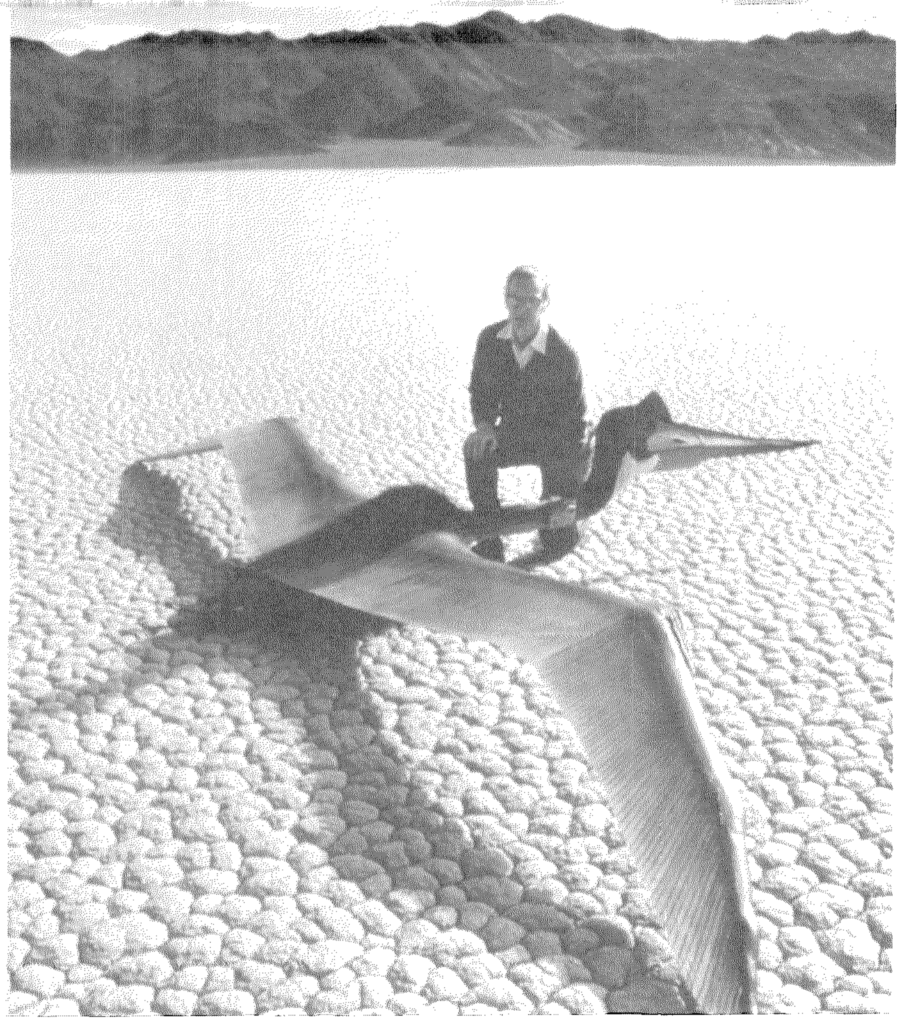
Schroeder has spent most of his career investigating one particular group of proteins — the hemoglobins — which are the oxygen-carrying molecules in blood. He is known for determining the amino acid sequence of fetal hemoglobin and detailing the differences between that molecule and the type of hemoglobin present in adults. Lately, he has begun investigations of sickle-cell anemia, a disease that results when a person has a defective gene for adult hemoglobin. Along with others, he believes that the disease may be ameliorated if a sickle-cell victim's blood cells can be tricked into resuming production of fetal hemoglobin.

Schroeder was a research fellow from 1943 to 1946, a senior research fellow from 1946 to 1956, a research associate from 1956 to 1981, and a senior research associate in chemistry from 1981 until he attained emeritus status this year.

AT THIS YEAR'S faculty dinner at the Athenaeum honoring the 1986 retirees, Kent Clark led the assembled dignitaries in a rousing rendition of one of his songs, written originally for the 1953 show "Take Your Medicine." The noble sentiments expressed in the chorus might well serve as a motto for us all:

Let's grow old disgracefully
I'll chase you and you chase me
What a scandal we can be
As we grow old disgracefully.

Random Walk



Paul MacCready poses with QN last January at Death Valley, where the creature really did fly for the film "On the Wing."

Watson Lecture Schedule

THE EARNEST C. WATSON lecture series for fall-winter 1986 will include: Richard P. Feynman, Nobel Laureate and the Richard Chace Tolman Professor of Theoretical Physics, on "My Experiences on the Challenger Commission" — October 15; Bruce C. Murray, professor of planetary science, on "Man's Future on Mars" — October 29; Jean-Paul Revel, the Albert Billings Ruddock Professor of Biology, on "Heart Attack! Tactics for Sick Tictocs" — November 12; Peter Goldreich, the DuBridge Professor of Astrophysics and Planetary Physics, on "Planetary Rings" — December 3; and John J. Hopfield, the Roscoe G. Dickinson Professor of Chemistry and Biology, on "Brain-like Decisions by New Computing Circuits" — January 14.

The lectures will be held at 8:00 p.m. in Beckman Auditorium and are open to the public without charge.

Faculty Awards

OVER THE SUMMER, Caltech faculty members have harvested a large crop of awards. John D. Roberts, Institute Professor of Chemistry, has been named the recipient of the 1987 Priestley Medal by the American Chemical Society. The Priestley Medal is the nation's highest honor in chemistry.

Charles A. Barnes, professor of physics, has received the Medal of Astrophysics of the Paris Institute of Astrophysics. (See "Tracking Stellar Reactions" on page 25 for a description of Barnes's current research.) Barnes and Wolfgang Knauss, professor of aeronautics and applied mechanics, have both won Senior U.S. Scientist Awards from the Alexander von Humboldt Foundation in West Germany.

The German Society for Clinical Chemistry has named Leroy Hood corecipient of its Biochemical Analysis Prize. Hood is the Ethel Wilson Bowles and Robert Bowles Professor of Biology and chairman of the Division of Biology. Heinz Lowenstam, professor of paleoecology, emeritus, has won the 1986 Medal of The Paleontological Soceity. And Hans W. Liepmann, the Theodore von Kármán Professor of Aeronautics, Emeritus, who earlier this year earned a 1986 National Medal of Science, has been awarded the 1986 Daniel Guggenheim Medal by the United Engineering Trustees.

Record Research

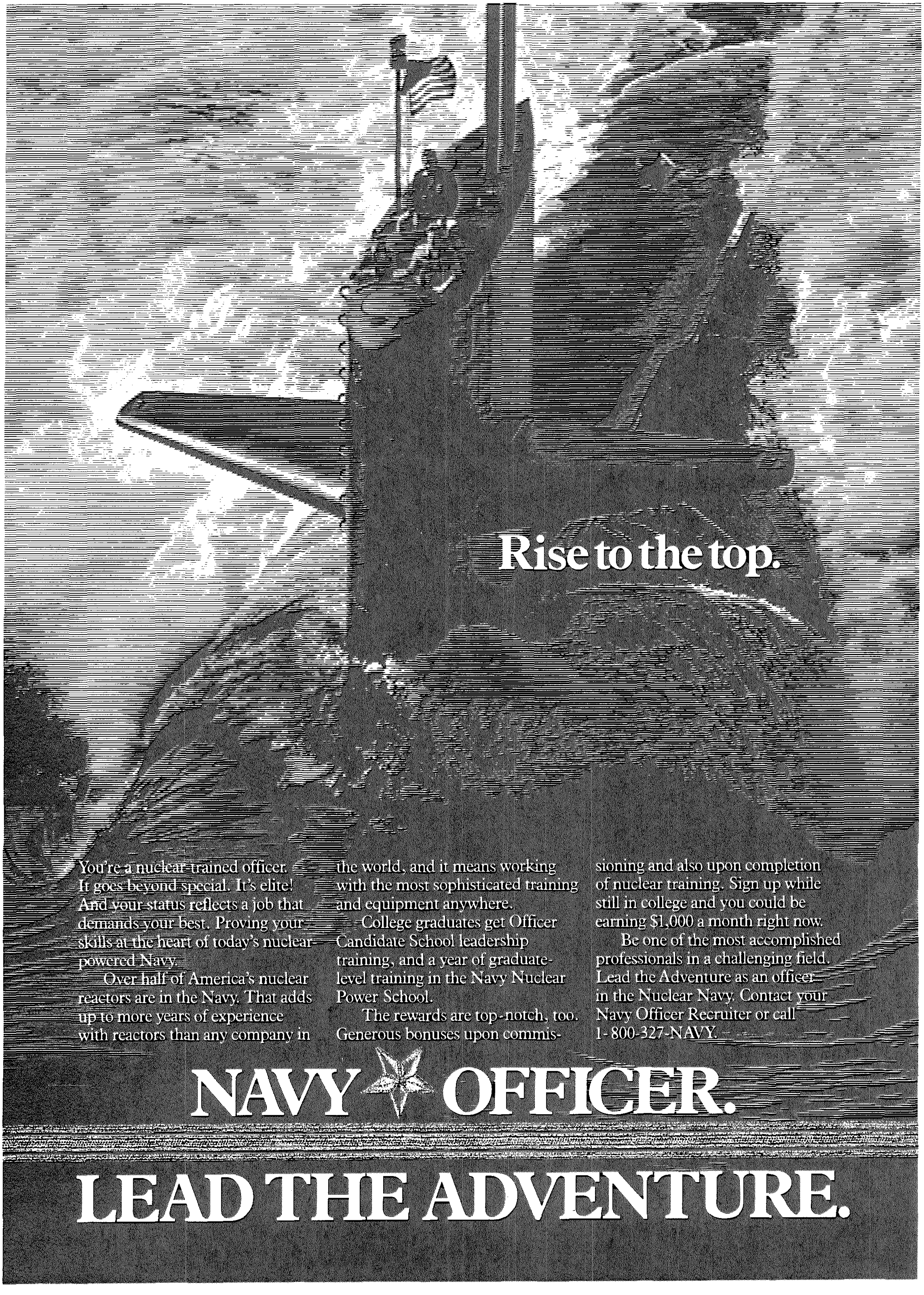
NINE PERCENT of the Caltech undergraduate student body — a national record — became associate members last spring of Sigma Xi, the national honorary research society. The 71 students qualified for the honor by completing an independent research project — an opportunity that has been extended to a large number of undergraduates by the Institute's SURF (Summer Undergraduate Research Fellowship) program.

Return of Pterodactyl

AFTER CRASHING on its first public flight, Paul MacCready's wing-flapping replica of the prehistoric pterodactyl *Quetzalcoatlus northropi* (QN) has been repaired and is hanging with other famous aircraft in the National Air and Space Museum in Washington, D.C. Interference from other radio signals at Andrews Air Force Base last spring released QN's parachute prematurely, sending the model to earth amid great publicity.

QN had, however, flown about 20 times previously, most notably for the film, "On the Wing," which is now opening at IMAX theaters around the country (including Los Angeles and San Diego). A non-flying replica of the pterodactyl with a 36-foot wingspan is accompanying the film on tour.

MacCready, who described QN's creation in the November 1985 *E&S*, is now at work on a version of the flying reptile capable of ascent.



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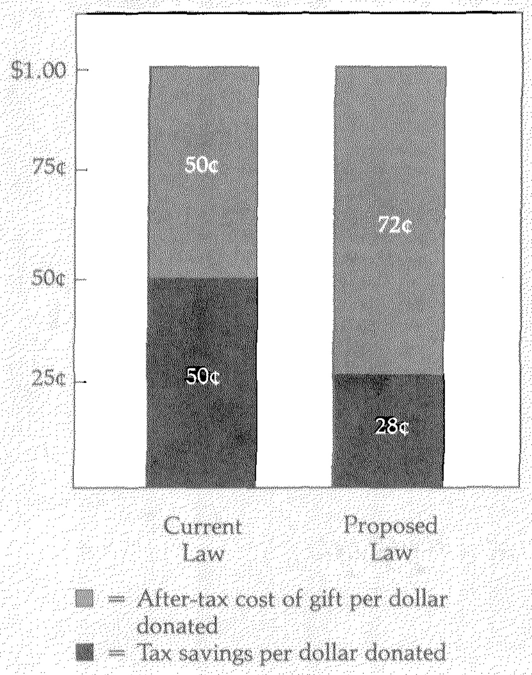
1986 Tax Reform — It Affects Us All



If you are considering making a gift to Caltech, you may be wondering how pending federal tax reform will affect your charitable contribution. The final impact of the tax bill is impossible to predict, but it is virtually certain that one significant change will be the reduction of individual tax rates. It is anticipated that the highest tax bracket of 50% will eventually be reduced to 28%. The accompanying chart illustrates how this reduction in tax rates increases the cost of making a charitable gift.

Caltech's alumni and other friends contribute not just for tax considerations, but because they believe in the Institute. Nonetheless, gifts this year will provide you with greater tax savings than in future years. It will be advantageous, therefore, to make a gift now, before the end of the calendar year and before the new tax law takes effect. This way both you and Caltech benefit.

If you would like more information about ways to benefit yourself and the Institute, write or call:

J. Thomas Gelder, Director
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