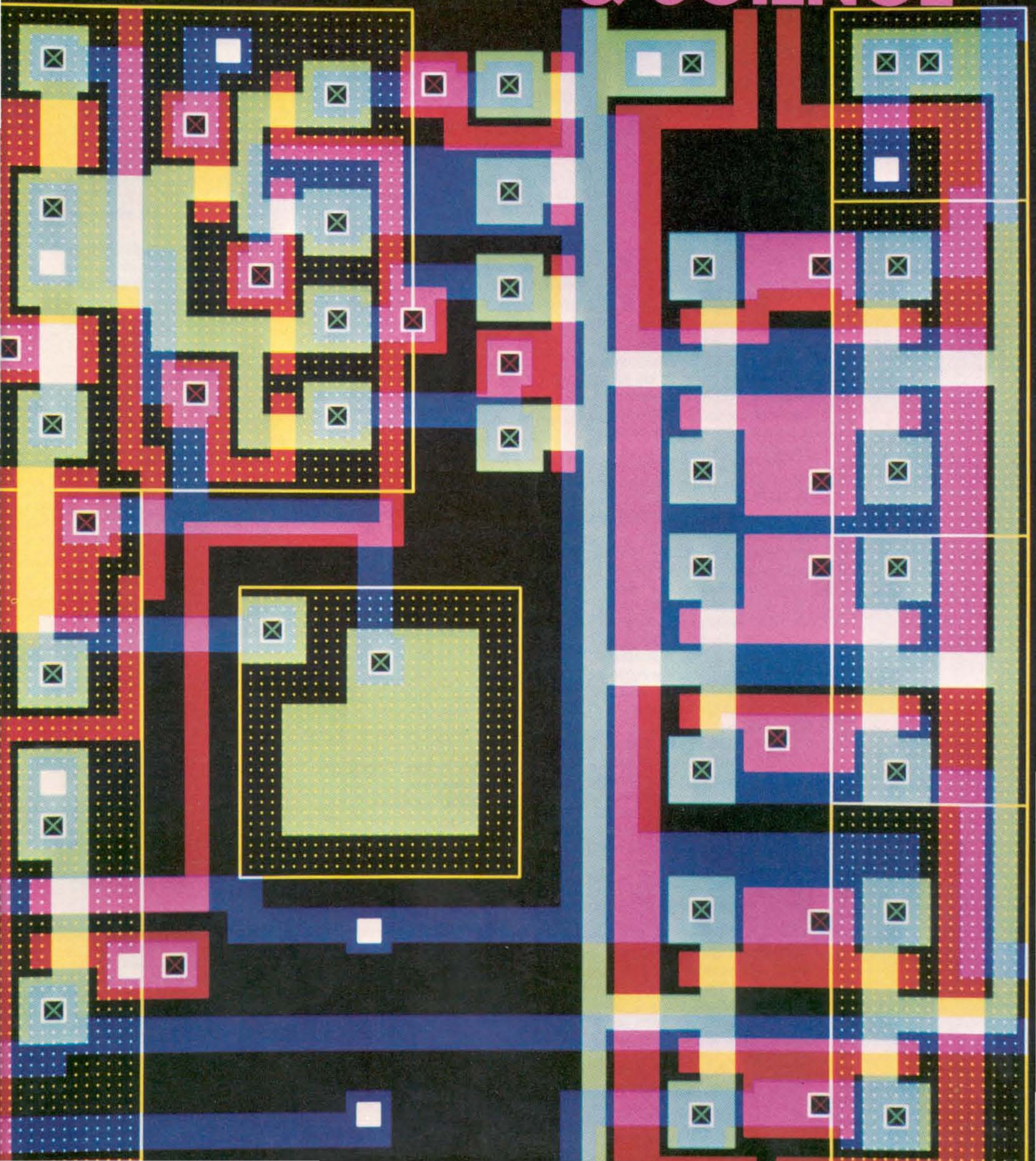
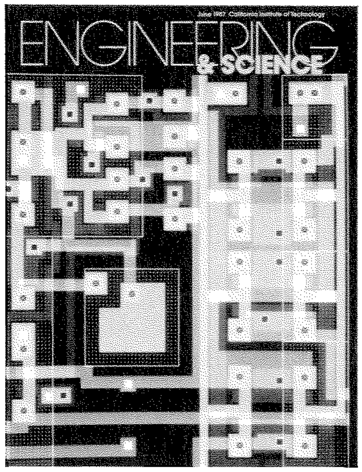
June 1987 California Institute of Technology

ENGINEERING & SCIENCE



In This Issue



Silicon Eye
On the cover — a computer drawing of one pixel from a retina constructed on a tiny silicon wafer that mimics the neural processes in the eye. The pixel is about 100 microns from top to bottom, and the entire chip is composed of about 2,500 such pixels. The colors represent the layers of the semiconductor: red is poly-silicon, green is diffusion, and blue is metal.

The large green square is the photoreceptor. To the right of it are the resistor circuits, to the left the logarithmic feedback elements, and at the top the differentiator — all designed to perform the functions of the biological retina's layers of cells. How this works is explained in "Neural Hardware for Vision," by Carver Mead, beginning on page 2. The article is adapted from his talk to the Research Directors Conference sponsored by the Office for Industrial Associates.

Carver Mead, the Gordon and Betty Moore Professor of Computer Science, is an interna-

tionally known innovator in VLSI design. Mead earned all of his degrees at Caltech (BS '56, MS '57, and PhD '60) and has been on the faculty ever since. His current research interests are focused on computation and neural systems, one elegant example of which is his retina. He's also got an ear in the works. . . .

Managing Science
When the prestigious Commonwealth Club of California invited Marvin ("Murph") Goldberger to San Francisco to speak on the subject of U.S. science, he was "flattered" to be asked to do so in the "backyard of two of America's centers of excellence in academic science" — UC's Berkeley campus and Stanford.

But Caltech, as he pointed out, "enjoys productive relationships" with both those campuses: The Keck Observatory is a cooperative undertaking with UC, and Caltech's high-energy physicists have long enjoyed the hospitality of the Stanford Linear Accelerator Center. And the three institutions will work together as a team in the national competition to try to bring the Superconducting Supercollider to California. Goldberger's speech in the hospitable northern part of the state, "What's Right, What's Wrong with U. S. Science?" begins on page 8.

Goldberger, who earned his BS from Carnegie Institute of Technology in 1943 and PhD from the University of Chicago in 1948, has been president of Caltech, as well as professor of theoretical physics, since 1978, when he succeeded Harold Brown. On September 1 he will return to Princeton, where he spent the two decades before coming to Caltech, to become director of the Institute for Advanced Study.

Uncensored
John Sutherland's Watson Lecture, "Prohibited Words," drew a lot of people to Beckman Auditorium, including some probably expecting something rather more titillating than the usual scientific fare. They may have been disappointed; Sutherland labeled his talk PG13.

His current interest is censorship (his most recent book is *Offensive Literature: Censorship in Britain, 1960-1982*) and on this occasion chose to trace the portrayal of syphilis in art and literature and make some interesting comparisons with the current AIDS epidemic. An article adapted from that talk begins on page 20.

Sutherland came to Caltech as professor of literature in 1984 from previous posts at University College London and the

University of Edinburgh. His PhD is also from Edinburgh (1973) and his BA (1964) and MA (1966) from Leicester University. He has written several books and edited volumes of Thackeray and Trollope. A longtime, regular reviewer for *The London Review of Books* and *The Times Literary Supplement,* he has also more recently become a regular reviewer for the *Los Angeles Times.*

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PICTURE CREDITS: Cover, 5 — Carver Mead; cover, 5, 14, 15, 19, 31, 32 — Bob Paz; 3 — Scientific American, Inc.; 6 — Melgar Photography, Inc.; 8 — Clemens of Copenhagen.

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 | JUNE 1987 — VOLUME L, NUMBER 5

Neural Hardware for Vision

by Carver A. Mead

BIOLOGY HAS ALWAYS BEEN the inspiration for computational metaphor. In the mid-1930s Alan Turing's original model for computation, which we call the sequential process, was based on the way mathematicians proved theorems. Because mathematicians are biological entities, we can say that even Turing's sequential process was inspired by the way biological systems work. But I will be discussing some biological systems that are simpler than mathematicians, since nobody, including mathematicians, can understand the way mathematicians work.

In the last decade or so the knowledge of what goes on in the brain has increased tremendously. When Max Delbrück first interested me in biology 20 years ago, the picture we had of the brain at that time was much more simplistic and much less analog in nature. At the time, neurobiologists were completely preoccupied with nerve impulses and the way they were generated in neurons. Now they are looking more deeply at the principles on which neural computation is based. And there are some surprises here. Nerve impulses, which are quasi-digital, play a surprisingly small role in the actual computation process. Most of the computation is analog, and it's done at the very tips of the dendritic tree of the neuron. Throughout the brain there is distributed feedback from these dendritic tips to the nerves that are driving them.

These new discoveries prompted us to take a fresh look at neural computation to see whether we might be able to synthesize systems that have some of the properties of real neural systems. It turns out that it's probably just the right time to be doing this. What's different today from attempts in the last 30 years to build neurocircuits is that now we have a technology that makes it possible to put a billion transistors on a six-inch wafer and interconnect them all. Conventional digital technology has difficulty using a full wafer, since many transistors are inoperative. Re-creating the brain's distributed analog computation gives us inherent redundancy and robustness under failure. We can actually use a substantial fraction of these billion transistors. So, the technology that was developed for microprocessors and memories has provided us a base on which we can build neural computing systems. These computing systems are based on very different principles from any of the conventional computing engines, analog or digital, that were built in the past.

The particular system we have been working on is a very simple model of the part of the brain wrapped up behind the eyeball. Although it's quite simple by brain standards, it does a level of computation that even our most powerful computers today can't handle. The lens of the eye focuses an image on the surface of the retina, where the first levels of visual processing occur. When we want to see details of shapes, such as letters, the image gets focused on the fovea, a small area of the retina with tightly packed photoreceptors. But the fovea is responsible for only a fraction of the retina's activity. Most of the action happens at the periphery, where movement of the image produces signals that are transformed into nerve pulses that are transmitted over the optic nerve "cable" to the higher centers in the brain.

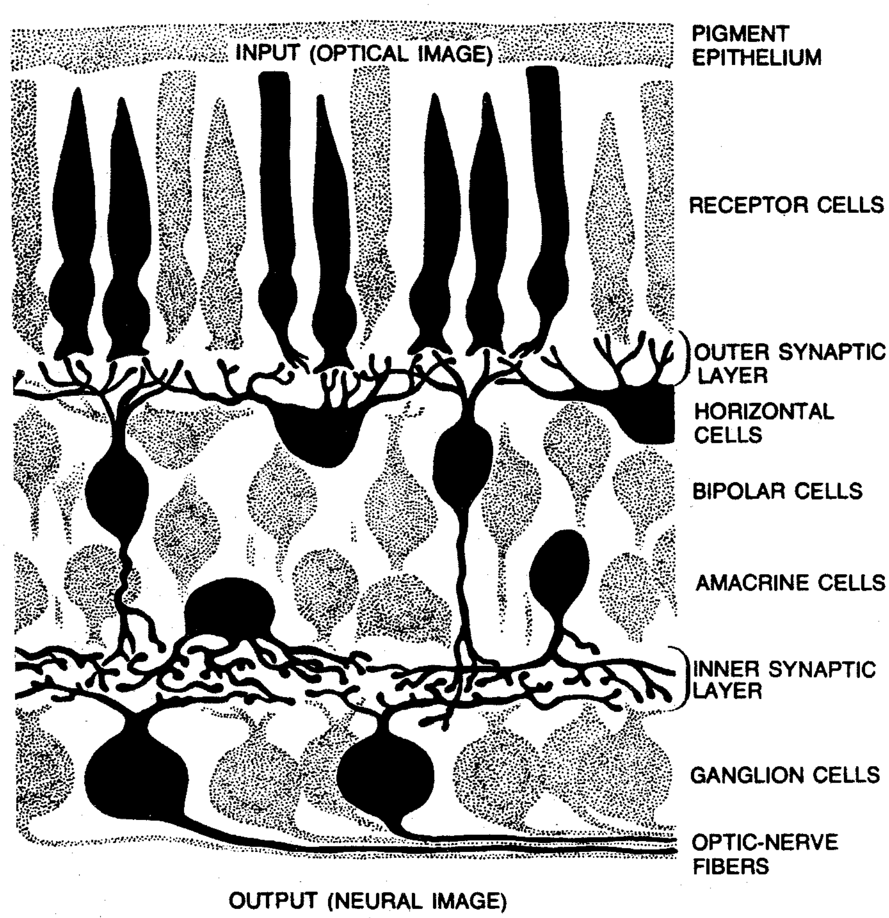
In a cross section through the retina one can see on the surface a layer of photoreceptors, below which lie layers of three different kinds of cells— bipolar, horizontal, and amacrine. Below these cells are the ganglion cells, whose axons form the fibers of the optic nerve. The principal signal flow in the retina runs from the receptors down through the bipolar cells (the horizontal and amacrine cells spread across a large area of the retina in layers transverse to the signal flow) and into the ganglion cells, which turn the signal into nerve pulses. In engineering terms we can say that the process starts by transducing the light energy into an electrical signal. We send that signal on to an amplifier and then off through a cable. The signals in the retina are all analog until they go out the cable as nerve pulses, which are quasi-digital (digital in amplitude but analog in time).

This basic structure (with some diversity in the details) is universal throughout the vertebrates. We can assume that the animals that evolved this eye structure ate any that did not. It is characteristic of biological systems that they are here because they work. An animal didn't live long if it couldn't see the predators that were about to jump on it, and its genes did not have a chance to get represented in the next generation. Because evolution has such a ruthless way of dealing with bad designs, we can view surviving biological structures as highly engineered systems.

The visual system is there to see things about the world. The scene coming into the eye, however, is not the world. It's a bunch of photons that arrive because there is some light somewhere that shines on objects in the world and gets reflected off them into the eye. The light that falls on the image surface is the product of an illumination function multiplied by the reflectance of the object. But we don't want to see the illumination function; we want to see the object. Nobody ever got jumped on by an illumination function. So we take the logarithm of the intensity, and that factors the problem into the log of the illumination function, which is often a smooth function (except for shadows), plus the log of the reflectance of the object. The computation of the logarithm is done in the receptors or in their interactions with each other.

The visual system also has to make sure that the signals are within range. If they're not, you get blanked out. You have probably noticed this phenomenon, say, watching a baseball game on television. When someone hits a ball up into the stands, the television camera pans from the brightly lit field over to

In this cross section of a vertebrate retina, the main signal flow travels downward from the photoreceptors through the bipolar cells to the ganglion cells, which connect to the optic nerve. The layers of horizontal cells and amacrine cells lie transverse to the signal path. (From "The Control of Sensitivity in the Retina" by Frank S. Werblin. © January 1973 Scientific American, Inc. All rights reserved.)



the stands in the shade. The camera has an elaborate automatic gain control system, but in such a mixed scene you see a pure white field and pure black stands; one signal is above range, and the other is below range, so you don't see anything at all. If an animal did that, its visual system would not be around in the next generation because the predators would simply jump from places that were half in the shade and half in sunlight.

But in the visual system, unlike the television camera, there is a measure of the local average intensity of the light; this value is used as the midpoint for the acceptable range of input levels. Basically this is a mechanism for deciding whether the pixel we are looking at is sufficiently different from the pixels around it to be reported. This level-normalization computation is performed by the horizontal cells. The horizontal cells look at the potentials on a bunch of photoreceptors and then take a spatial average. Then the difference between that spatial average and the local receptor is computed in the synaptic complex in the foot of the receptor. The resulting spatial derivative gets shipped on to the bipolar cells.

The outputs of the bipolar cells feed the amacrine layer, which is responsible for computing the time derivative of the signal. Rising edges of the bipolar waveform are turned into peaks, which in turn cause ganglion cells to fire. In rough terms, the amacrine layer is extracting motion information from the incoming retinal image. In some animals, like the frog, very elaborate motion computations are performed. A visual scene of the frog's natural habitat moving as a whole elicits no response. When a small, dark spot is moved relative to the background, however, a large response results. In higher vertebrates, much of this kind of complex motion calculation has migrated to visual cortex, and the retina computes a simple time derivative.

How much does something have to be moving for us to see it? The answer depends on how much the rest of the image is moving. Another level of gain control mechanism makes sure that, if we are going to report a derivative event, that event is significant relative to the rest of the scene. If we are looking at a tree, and the leaves are all blowing in the wind, something has to move significantly before we will report it. Otherwise, our higher levels of information processing would get overloaded by reports about all those little fluttering leaves. For a primate it usually takes something bigger than a leaf to jump on you and hurt you very much.

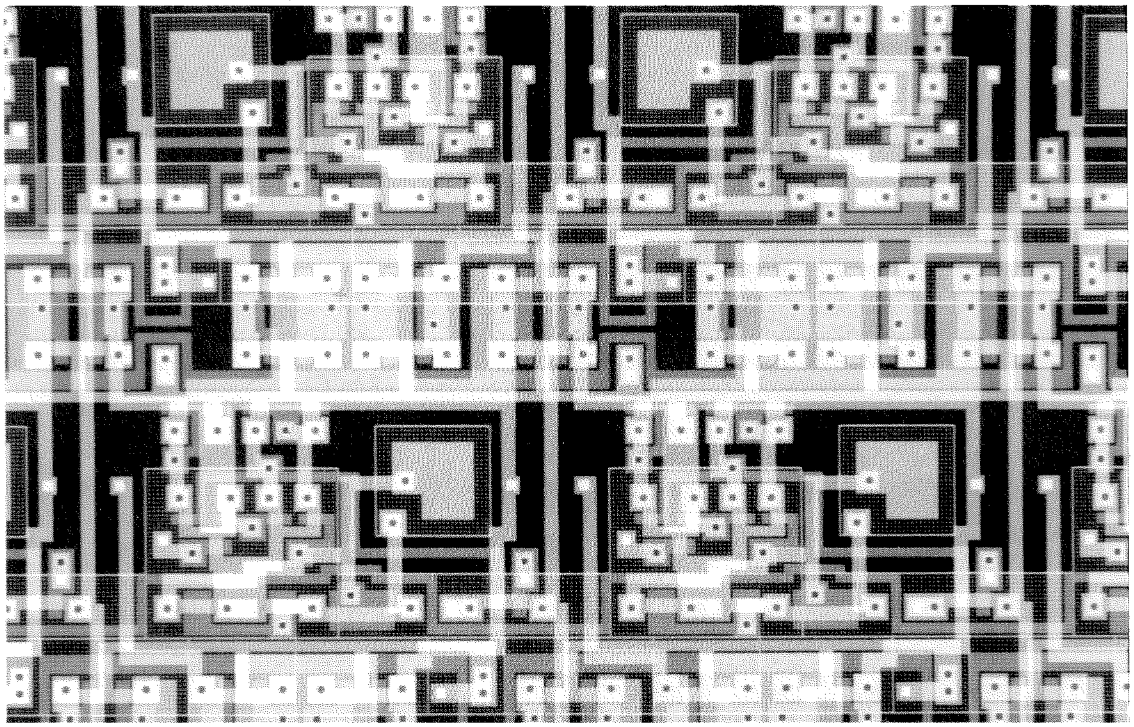
A derivative signal with respect to time is taken by the interaction of the bipolar, amacrine, and ganglion cells. Exactly how biological systems do this is not known. The local derivative with respect to time is compared to the derivatives that are being taken in the surrounding area. If the local signal is significantly larger, it gets reported.

We might wonder why so much of the information in the optic nerve is derivative. After all, we could just ship all the intensity information about the scene up the optic nerve. The optic nerve has a bandwidth approaching that of a television signal. People who design machine vision systems usually start with a television signal; they take one frame and compare it with the succeeding frame, and so on. Motion is characterized as something in one position in the first frame that is in a different position in the second frame.

It would be easy for a living system to do gain control in the camera, like television does, and then send the intensity information up to the brain to extract the motion information where there is a lot more horsepower to do so. So why go to all the trouble of building this elaborate derivative processing machinery down at the camera level? The answer is a straightforward one: A television camera samples every point on the image once every 1/30 of a second. But a predator in the visual field can move a distance of many pixels in 1/30 of a second. So what we have done is to take a simple problem — taking a directional derivative with respect to time — and transformed it into a complicated one. Now we have an image at time t and an image at $t + 1/30$, and we have to decide what point in the first image corresponds to what point in the succeeding image. So sampling transforms the processing task into the extremely difficult *correspondence problem*. People use supercomputers to try to solve that problem. Living systems didn't have supercomputers; they solved the problem the easy way and just took the derivative.

So when we built our rudimentary electronic retina, we built it to just take the derivative also. We based our system on the following four insights from biology:

1. It's important to take a logarithm of the signal, because logarithms factor the scene into the illumination function and the prop-



This computer drawing of a small group of pixels (one pixel appears on the cover) from the center of the retina shows how the individual cells are composed to form the processing array. The entire chip, shown on the following page, contains a 48 × 48 array of these pixels.

erties of the objects.

2. It's important to keep the signals in range.

3. Normalization should be done on a local basis; there is information in the shade and in the sunlight.

4. It's important to take time derivatives before we have sampled the image with respect to time. Otherwise, we would be throwing away the single most important piece of information in the image.

We have designed a simple retina and have implemented it on silicon in a standard, off-the-shelf CMOS (complementary metal-oxide semiconductor) process. The basic component is a photoreceptor, for which we use a bipolar transistor. In a CMOS process this is a parasitic device, that is, it's responsible for some problems in conventional digital circuits. But in our retina we take advantage of the gain of this excellent phototransistor.

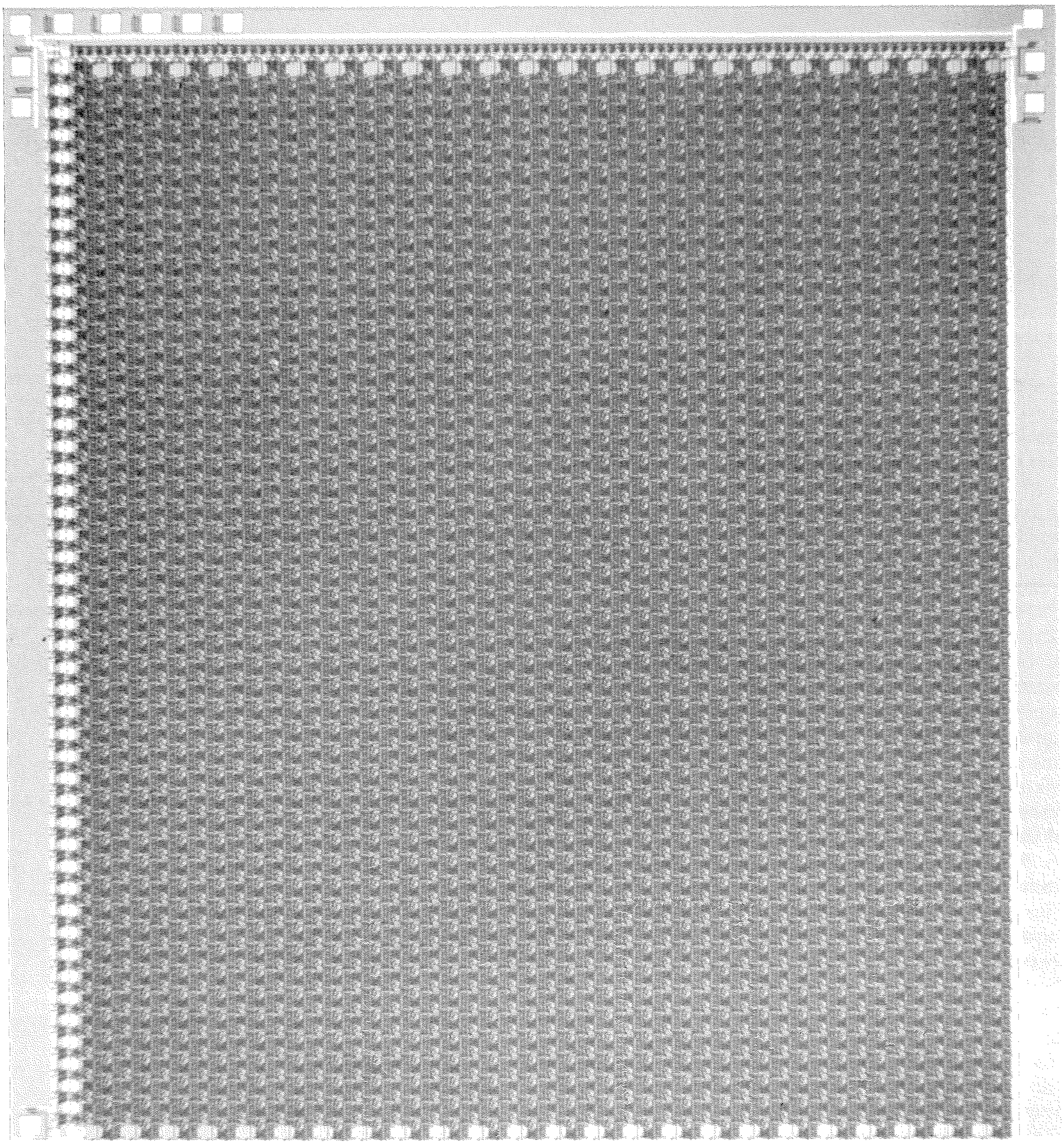
There's nothing special about this fabrication process, and it's not exactly desirable from an analog point of view. Neurons in the brain don't have anything special about them either; they have limited dynamic range, they're noisy, and they have all kinds of garbage. But if we're going to build neural systems, we'd better not start off with a better process (with, say, a dynamic range of 10^5), because we'd simply be kidding ourselves that we had the right organizing principles. If we build a system that is organized on neural principles, we can stand a lot of garbage in the individual components and still get good information out. The nervous system does that, and if we're going to learn how it works, we'd better subject ourselves to the same discipline.

As in a biological eye, the first step is to take the logarithm of the signal arriving at the photoreceptor. To do this, we use the standard trick of electrical engineers, that is, to use an exponential element in a feedback loop. The voltage that comes out is the logarithm of the current that goes in. We think this operation is similar to the way living systems do it, although that is not proven. The element that we use to make this exponential consists of two MOS transistors stacked up. A nice property of this element is that the voltage range of the output is appropriate for subsequent processing by the kinds of amplifiers we can build in this technology. When we use the element to build a photoreceptor, the voltage out of the photoreceptor is logarithmic over four or five orders of magnitude of incoming light intensity. The lowest photocurrent is about 10^{-14} amps, which translates to a light level of 10^5 photons per second. This level corresponds approximately to moonlight, which is about the lowest level of light you can see with your cones.

There are two kinds of receptors in the eye — cones and rods. We use the cones under all normal circumstances and the rods only in very low-illumination conditions. The rods are more sensitive, but they don't have good contrast sensitivity. Our silicon photoreceptor can't compete with the rods, but its intensity range is approximately that of the cones. It's a good photoreceptor, and it's logarithmic over the right range.

Now we can build a network of resistive elements patterned after the horizontal cells in the eye. The horizontal cells take the outputs of all the receptors and average them spatially. They take a weighted average that is a function of distance from the local receptor; the farther away an input is, the less weight it is given. It's an extremely simple mechanism, and it's used in many places in peripheral sensory systems. We want to have something to compare our signal to, but we don't want that something to be global. A television camera blanks out because it compares each

The retina chip enlarged below is 5.4 millimeters by 4.8 millimeters in size and contains about 100,000 transistors.



local signal with the average level over the entire scene. A biological visual system is more intelligent. It takes a local average, which gives progressively less weight to inputs that are farther away.

Our resistive networks turn out to be extremely good at calculating the spatial average. CMOS technology does not have a resistor of sufficiently high value as an inherent part of the process. All of our circuit components — resistors, capacitors, etc.— are made out of transistors. We have to build a little circuit that functions like a resistor, except that it has a mechanism to control the resistance. Each photoreceptor is hooked up to six neighbors in a hexagonal array linked by the resistive network that calculates the spatial average. The circuit is actually better than a regular resistor because, if the voltage between the two sides gets too big, the current that can go through it is limited. So, for example, if one of our pixels gets stuck, it doesn't take down the whole network. In a network of linear resistors, one stuck input could create damage for a large distance.

We made our amacrine cells out of a couple of amplifiers and a capacitor — again, all made out of transistors. Analogous to the amacrine cells' task in the visual system, this little circuit takes the derivative with respect to time. What it does is take the input signal, which corresponds to that coming out of the bipolar cell in the retina, compares it with a temporally smoothed version of the signal, and reports the difference as a finite time constant derivative circuit. The output represents the difference between the local signal and the time average of the surrounding signals. You can think about the computation that's done locally as taking the amplified difference between the local input and the space-and-time-averaged input, which is weighted over the surround in some way that dies off as it gets to farther neighbors. What our circuit does not have, which the amacrine cells do have, is a motion gain control. It will not turn down the gain if an object in the surround is moving. We have not yet evolved that level of processing.

Compared to an animal's eye, this is all very low-level. It's not the kind of thing that could recognize your grandmother or even locate tanks on a battlefield. But it's the first step in simulating the computation that your brain does to process a visual image. It's done in a smooth analog manner completely analogous to the way the eye does it. And it does indeed have tremendous advantages in the preservation of information compared with any kind of system that starts with a standard TV-type front end.

In a small way, we have embarked upon a second evolutionary path — that of a silicon nervous system. As in any evolutionary endeavor, we must start at the beginning. Our first systems have been simple and stupid. But they are, no doubt, smarter than the first animals were. We are, after all, endowed with the product of a few billion years of evolution with which to study them.

The constraints on our silicon systems are very similar to those on neural systems: Wire is limited, power is precious, robustness and reliability are essential. We may therefore expect the results of our second evolution to bear fruits of biological relevance. The effectivenesss of our approach will be in direct proportion to the attention we pay to the guiding biological metaphor. We use the term metaphor in a very deliberate and well-defined way. We are in no better position to "copy" biological nervous systems than we are to create a flying machine with feathers and flapping wings. But we can use biological organizing principles as a basis for our silicon systems in the same way that a soaring bird is an excellent model of a glider.

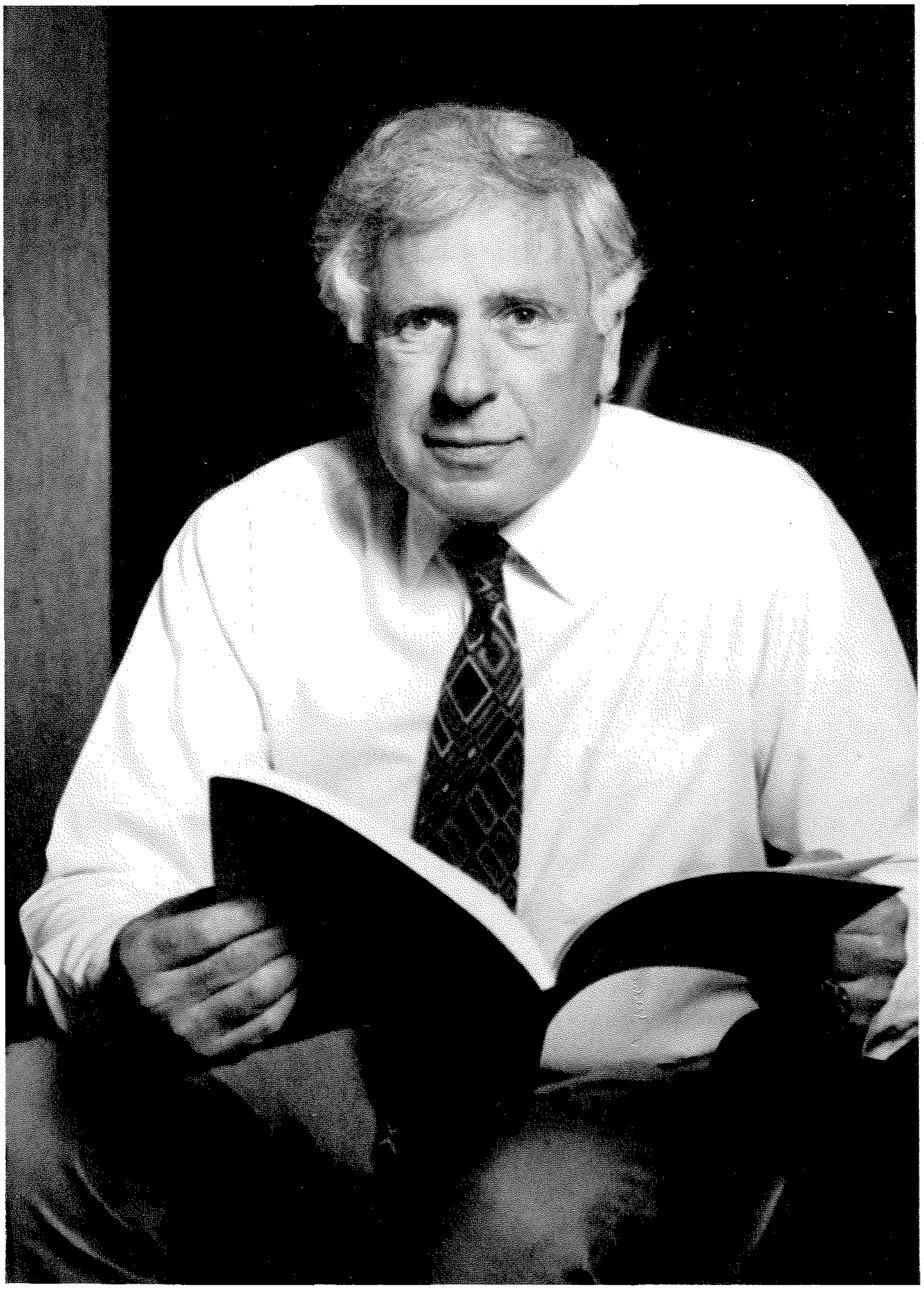
It is my conviction that our ability to realize simple neural functions is strictly limited by our understanding of their organizing principles and not by difficulties in realization. If we *really* understand a system, we will be able to build it. Conversely, we can be sure that a system is not fully understood until a working model has been synthesized and successfully demonstrated.

The silicon medium can thus be seen to serve two complementary but inseparable roles:

1. To give computational neuroscience a synthetic element allowing hypotheses concerning neural organization to be tested.

2. To develop an engineering discipline by which real-time collective systems can be designed for specific computations.

The success of this venture will create a bridge between neurobiology and the information sciences and bring us a much deeper view of computation as a physical process. It will also bring us a fresh new view of information processing and the enormous power of collective systems to solve problems that are completely intractable by traditional computer techniques. □



President Goldberger, who delivered this address to the Commonwealth Club of California in San Francisco March 13, will become director of the Institute for Advanced Study at Princeton in September. He has been president of Caltech since 1978.

What's Right,

by Marvin L. Goldberger

THERE IS A WIDESPREAD CONFIDENCE in our country today about the contributions of science to the nation's well-being. Yet despite examples at every hand of a sustained commitment to American science, important issues of public science policy remain unresolved — problems that must be faced and solved if science is to meet these high expectations.

The present mood of scientific exuberance is easy to read. One example is the recent announcement of administration support for plans to proceed with the Superconducting Supercollider. This $5- to $6-billion project would create the world's largest and most powerful particle accelerator, designed to study interactions among elementary particles at energies never approached before.

Why should we undertake this project? Will it improve our economic comptetitiveness? Will it help our national security? Will the effort impoverish the rest of science? The answers to these questions are not easy to come by, but basically the answer to all of them is "no."

Indeed, there surely will be technological spin-offs that will be important in industry and defense. The real reason for the enormous investment is the drive to understand the fundamental forces of nature and the particles of which the whole universe is built. Must we, the United States, make this great expenditure? We are the richest country in the world. The field of high-energy physics is the most fundamental in all of science. As a nation, we cannot settle for anything less than the very best in all major scientific endeavors. We can, we should, we must take this giant step in the human endeavor to solve the mysteries of the universe.

The Superconducting Supercollider is not

What's Wrong with U.S. Science?

the only evidence of national confidence in science. Although the bulk of funding for U.S. science comes from the federal government, private sector support of academic research in science and engineering is strong — from corporations, foundations, and individuals. At Caltech, we have been exceedingly fortunate to receive two recent major gifts for needed research facilities. The first, for the Keck Observatory, with the largest optical telescope in the world, totals $70 million from the W.M. Keck Foundation. The second, a gift from the Arnold and Mabel Beckman Foundation, will supply $50 million for the creation and operation of the Beckman Institute on our campus, where scientists will attack problems at the interface of biology and chemistry.

Such huge contributions are the exceptions, of course. Nevertheless there is an important role being played by a few foundations and individuals in providing the crucial seed money for areas of science not sufficiently well developed to attract the attention of the federal funding agencies.

For example, at Caltech the research group led by Leroy Hood, the Ethel Wilson Bowles and Robert Bowles Professor of Biology, wanted to build a family of microchemical machines to analyze and sequence DNA and proteins. The National Institutes of Health and the National Science Foundation wouldn't touch the project. But a local Los Angeles foundation, the Weingart Foundation, provided about $1.5 million over five years, to get the program successfully off the ground. Now NIH and NSF money is available for this research. These machines and their lineal descendants will make the widely discussed program to sequence the human genome a realistic project in the foreseeable future. This kind of involvement in research by private foundations is a peculiarly American phenomenon.

Another increasingly important source of scientific research funding in universities is provided by corporations — sometimes in the form of general unrestricted contributions, but more frequently in the establishment of specific research relationships. About 15 to 20 percent of all research support at Caltech comes from industry. The relationships range from corporate funding for specific research projects of interest to the particular firms (and to us) all the way to broad involvements with several companies — who may even be commercial competitors — in generic research areas of interest to all the partners.

Having industry and the universities working together in these different ways has obvious benefits for both parties. The academic community — faculty and students — learns about the real world; and the industries involved are in an improved position to capitalize on innovative research that they may not be able to carry out in their own laboratories. It is entirely a win-win situation with only two caveats: Both sides must be diligent to ensure that the academic enterprise is not skewed by sponsor pressures, and adequate attention has to be paid to industry's ultimate need to show a profit — broadly interpreted — from its investment.

What can industry realistically expect from academic research? Basic research is, of course, the necessary underpinning of all our technological industries. The familiar examples of the transistor, the laser, and integrated circuits began as pure research endeavors. But much of what is troubling the country right now depends far more heavily on rather more mundane factors like management, systems engineering, and the quality of work life. We must be careful not to allow the research universities to be diverted toward short-range goals and away from what they do best: educating first-rate scientists and expanding scientific knowledge. The payoff from these "products" is hard to quantify, but if history is any guide, they are a good investment for both public and private funds.

Although science is obviously flourishing in America and public support is strong, there are some worrisome problems on the horizon that could pose long-term threats. One such problem that has received a great deal of attention lately is the pre-college preparation of our future scientists and engineers. Three recent studies compare mathematics teaching in the U.S. to that in other countries. They all show that our students lag far behind the students in other developed countries, particularly in Japan. Some of the gap can be explained by the difference between the teaching of math in the U.S. and elsewhere, but the greater involvement of parents in other countries with their children's education is also an important part of the explanation.

The organization of scientific research in the U.S. is the key. The co-location of research and teaching in our universities enables the scientific enterprise to flourish.

The teaching of science in our elementary schools ranges from nonexistent to execrable. Two Caltech professors, appalled at what their children were being taught, are developing a kindergarten-through-fifth-grade curriculum in collaboration with the Pasadena school system, and some 30 other faculty and Jet Propulsion Laboratory employees have volunteered to help. This is something universities everywhere must do. Science and math teaching in high schools is not much better; there are many high schools in the country where only one year of science is available.

One reason for the general decline in the quality of our elementary schools and high schools, and particularly in the quantity and quality of science there, is a shortage of qualified teachers. People who used to choose teaching as a profession can find less harrowing, more satisfying, and more lucrative careers elsewhere. People with mathematical and scientific training are in tremendous demand in technology-based industries. It is vital for the country that the investment be made — however it has to be made — to get good teachers back into the schools. As academic fundraisers always say: If you think education is expensive, consider the cost of ignorance. What is so unfortunate about the poverty of good science instruction in the schools is that so many of the potential Lawrences, Alvarezes, Panofskys, Einsteins, and Fermis never get turned on and never try to become scientists. What a loss; many of them become lawyers!

There is another and perhaps even more important consequence of the problem. Almost all the serious issues before this country have a strong scientific and technical component: energy, nuclear power, the environment, food, drugs, AIDS, national security, to name only a few. To make the decisions on such critical questions we rely on our elected representatives, who ordinarily have almost no scientific training to give them a basis for sound judgment. I am not advocating that everyone including our lawmakers should be a theoretical physicist. But we must have an educational system that will at the very least produce a population with a modest degree of scientific literacy.

Public policy toward pre-college education is inconsistent. On the federal level, there were severe cutbacks in the National Science Foundation's pre-college programs in the early years of the current administration. Under the leadership of director Erich Bloch, the NSF has worked to have some cuts restored — the adaptation for high school use of Caltech's video course in physics, "The Mechanical Universe," is an example. But the studies I cited show how much more needs to be done — in and out of school.

These things having been said, you may wonder why the United States has been able to become the best in the world in almost every area of science. How can this be when our schools are so bad? There are a number of reasons: We have a large and diverse population. The success of the scientific enterprise depends heavily on the contributions of a relatively small number of spectacular individuals. We have had and continue to have an enormous infusion of foreign talent, beginning with those who fled European tyrannies before World War II. We didn't have much competition for a very long time. It took western Europe, the Soviet Union, and Japan quite a while to recover from the war.

But our real secret weapon is something else. The organization of scientific research in the U.S. is the key. The co-location of research and teaching in our universities enables the scientific enterprise to flourish. This is what allows us to take college undergraduates who may have an educational history inferior in every respect to that of their foreign counterparts and turn them into the world's greatest, most productive, and most creative graduate students and scientists.

Other countries have created research institutions that do no teaching and universities that do little or no research — a system fundamentally flawed in my opinion, one poorly positioned to keep up with today's rate of scientific progress. I'm absolutely convinced that it is the concentration of roughly 75 percent of our basic research establishment in the universities that provides the explanation for U.S. science to which I now turn.

American academic science since World War II has become increasingly dependent on the fluctuating financial support of the federal government. Caltech and MIT, heavily research-oriented universities, derive more than one-half of their income from the federal treasury. I have several concerns about that relationship.

While the overall dollar amounts devoted to research and development have consistently reflected the confidence in science of the current administration, those budgets also have been increasingly skewed toward defense applications. For 15 years, from the mid-1960s to 1980, there was rough funding parity between civilian and military R&D efforts. Since then the balance has shifted heavily toward the defense side. At present, only a little more than a quarter of the federal R&D effort goes into what is primarily civilian research. And even the proportion of military R&D funding devoted to basic research has been declining since 1971. Outside of the Innovative Science and Technology Office of the Strategic Defense Initiative organization, much of the military R&D effort is focused on fairly short-range development efforts.

Another worrisome point: Federal tax reform, while overdue and no doubt on balance good for the country, in its present form will have a strong negative impact on research universities. Taxing our students' scholarships and fellowships appears to those of us in higher education to be especially counterproductive. At the same time, the revised tax law also lessens for some people the appeal of charitable contributions to higher education — and to other worthy non-profit organizations. Finally, the new law places severe restrictions on the use, by private but not public institutions, of tax-exempt bonds to finance construction of needed research, education, and support facilities.

Our students are not only going to be paying taxes on the aid they receive but also getting less of it. Again this year, in its proposed budget for the 1988 fiscal year, the administration recommends severe cutbacks in federal financial aid for students. The higher education community will no doubt turn to the Congress and lobby heavily for the protection of our current and future students. It is important to remember that there is a huge constituency: 12 million students (most with two parents) and 3,000 colleges and universities with interested faculty members.

American academic science since World War II has become increasingly dependent on the fluctuating financial support of the federal government.

When it recruits incoming freshmen, Caltech looks for the very best potential scientists and engineers without regard to their financial need. We're generally pretty successful in our recruiting — typically our freshmen have the highest average combined SAT scores in the nation. But we also find that 70 to 75 percent of our incoming students need financial aid.

We're trying hard to attract scholarship, fellowship, and loan funds from the private sector. But major reductions in federal financial aid programs might well turn Caltech and many other private institutions into places filled with only the children of the wealthy and the very poor; the middle class will not be represented. This is clearly wrong for the students, for the scientific endeavor, and for the country.

Pork-barrel politics has recently entered the halls of academe. In the past two or three years, it has become an all too common practice to hire a Washington lobbyist to present an institution's well-intentioned case for needed campus facilities. Such a practice, it is claimed, permits the "have nots" to play catch-up with the "haves." Although the needs for research facilities and instrumentation are very real on both "have" and "have-not" campuses, in my view pork-barrel politics is not the way to produce the kind of science this country requires.

To build a wall around our laboratories may serve to preserve the present — but only at the expense of the future.

With regard to needs for up-to-date instrumentation on campuses, let me give an example. About two years ago the Department of Defense asked the universities to make proposals for instrumentation in connection with potential DOD-supported projects. The department got back requests for $645 million; there was only $30 million to disperse. Quite a descrepancy. People have estimated a need throughout the country for about $2 billion to truly modernize university laboratories.

I'd also like to address, admittedly from a partisan point of view, the problems confronting one specific area of science, the unmanned exploration of space. My duties at Caltech happily include supervision of the Jet Propulsion Laboratory, which is operated by our institution on behalf of NASA. JPL and the other NASA centers involved in unmanned space exploration have compiled an impressive record since the orbiting of the first American satellite, Explorer 1, in 1958.

Even before the tragic Challenger accident, the competition for resources with manned spaceflight and military applications had placed major limitations on unmanned, scientific missions. The Challenger accident has, of course, compounded the problem. I cannot minimize the fact that our space science program is in very serious trouble — and was even before the Challenger disaster. Overemphasis on manned space flight, total reliance on the shuttle, the enormous cost of the space station, and the absence of a clear commitment to science has threatened our pre-eminent position.

Finally, I want to touch on the need for continued freedom in scientific communication. The trend toward placing an increased percentage of federal support of science within the defense budget has led to increased pressure to restrict the academic tradition of open communication. Again, that is certainly not the way to assure America's role as a productive source of high-quality science. To build a wall around our laboratories may serve to preserve the present — but only at the expense of the future. The real answer in science is to run faster.

"Competitiveness" is the magic word in Washington these days. Commenting on the importance of science and technology in a competitive society, Erich Bloch said: "We depend, for economic progress, on what we call the engineering and science base— the collection of people, institutions, equipment, and facilities that enable us to do fundamental research in the sciences and engineering. This dependence is real. So it is surprising that the United States is still not doing a very good job of taking care of the science and engineering base: We aren't training enough young scientists and engineers, we aren't investing sufficiently in research equipment and facilities, and we aren't supporting adequately the activities of our basic researchers."

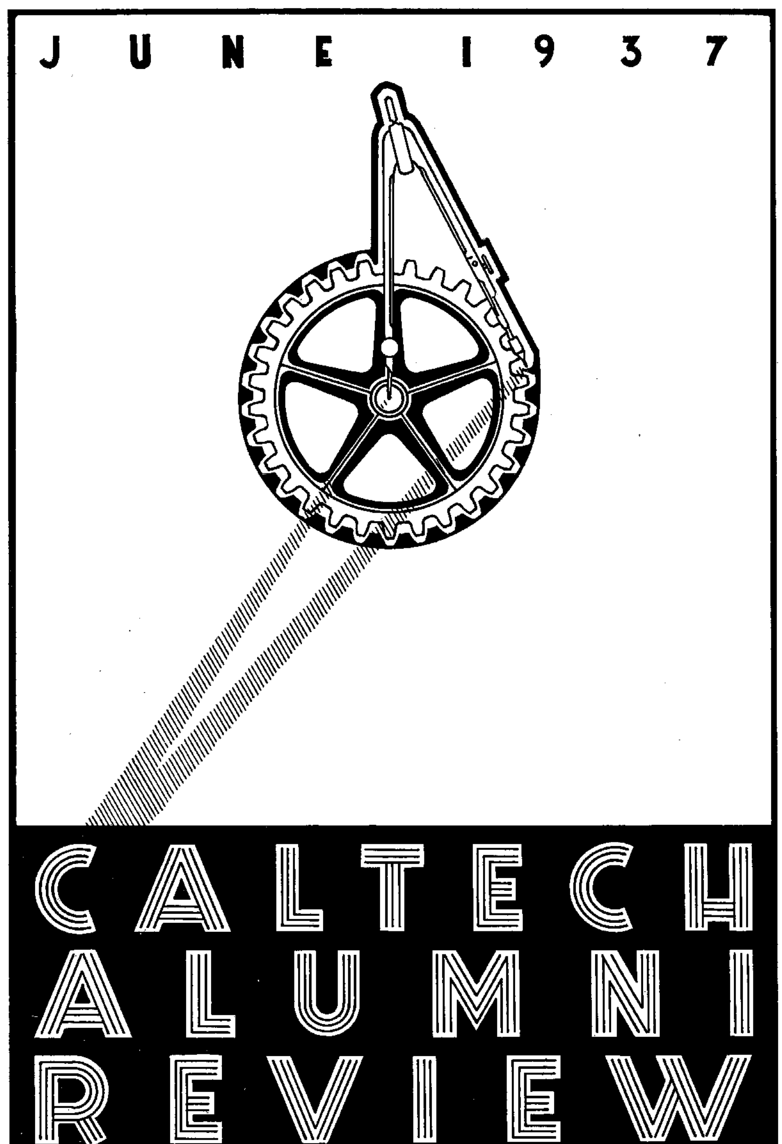
American science is doing great things, but it does need increased support. This point was succinctly stated last year by the White House Science Council's Panel on the Health of U.S. Colleges and Universities: "One conclusion is clear: Our universities today simply cannot respond to society's expectations for them or discharge their national responsibilities in research and education without substantially increased support."

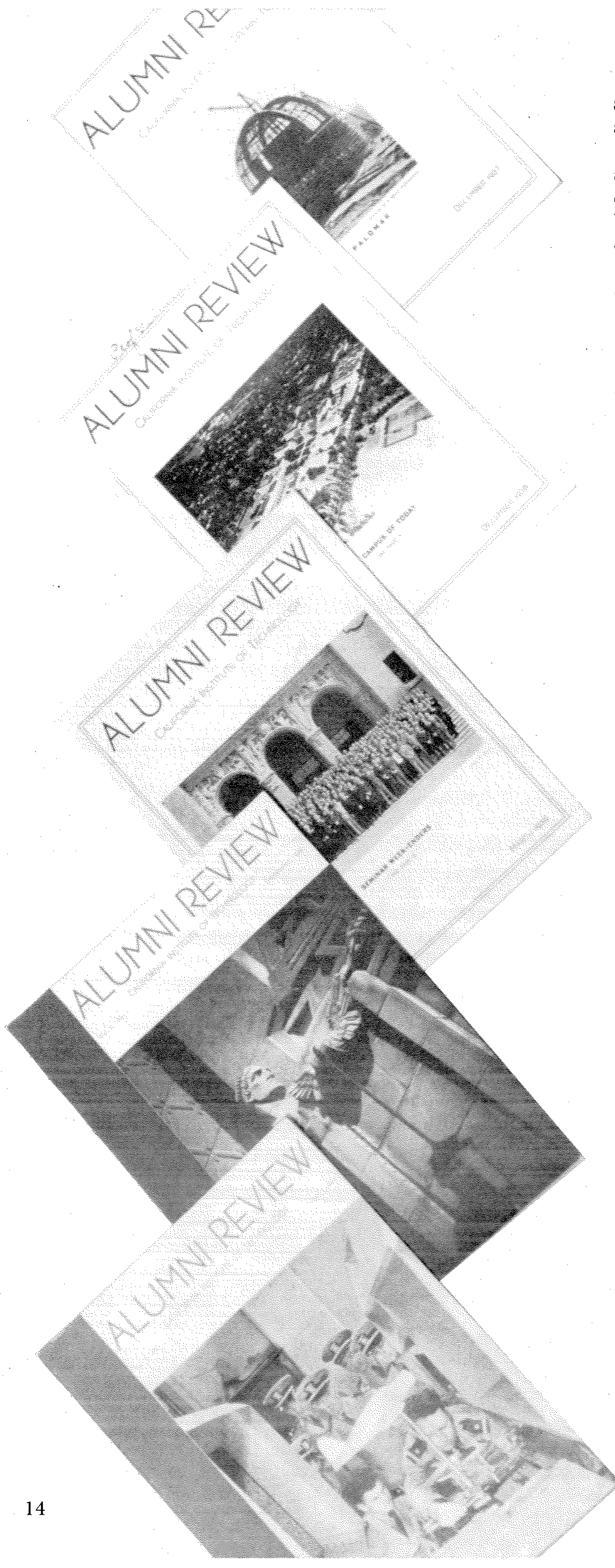
What's right about U.S. science plays a major factor in America's success, today and tomorrow. Let's continue to address what's wrong — or, perhaps more accurately, what can be improved — in the way we encourage and support scientific research. □

Golden Anniversary for E&S

THE LIST OF ALUMNI HONORS that year was impressive: Carl Anderson won the Nobel Prize, Frank Capra won an Oscar (for *Mr. Deeds Goes to Town*), and Linus Pauling was appointed chairman of the Division of Chemistry. It was June 1937, and these were among the achievements reported in the first issue of the *Caltech Alumni Review*, which a few years later became *Engineering and Science*. In the 50 years since, the magazine has grown from a circulation of a few hundred to 16,000, which includes not only the members of the Alumni Association but also faculty and students, The Associates and other friends of Caltech, corporations, media, libraries, high schools, and even some subscribers.

Al Atwood, BS '32, MS '33, first editor of the *Caltech Alumni Review*, put out that original issue on a $150 grant from the Alumni Association ("actually, I think I went $45 over budget," he says). Atwood, whose field was electrical engineering, inherited, sometimes reluctantly, a publishing reputation. His father's status as a well-known writer for the *Saturday Evening Post* and *National Geographic* was the "bane of my life all through school. English teachers would expect me to be a writer too, and I wasn't." But he didn't escape his presumed destiny easily. He was editor of the *Big T*, Caltech's yearbook, and when the Alumni Association decided to start a magazine to bring news of Caltech to





alumni all over the country, the editorial task, as usual, fell to Atwood.

Atwood found other creative talents among the alumni. The first cover was designed by Harold Graham, ex '24, who had become a noted local artist and industrial designer, associated with painter Millard Sheets in Claremont. Among the assistant editors was George S. Rice III, '31, whose family owned a printing firm. George Rice and Sons (which today is still a well-known press in Los Angeles) printed the first *Alumni Review*. Two hundred copies of the first issue were run off and handed out at the Alumni Association's annual meeting. It was a such a success that the board approved its continuation; so it was enlarged to a full-size quarterly magazine and mailed out to members of the Association.

At the time Atwood was back on campus working as the resident engineer at the Caltech Pump Lab for the Metropolitan Water District. Because the Pump Lab tests could be performed only when the wind tunnel wasn't running (they shared the same big motors), most of Atwood's work was done late at night, and he often had time during the days to work on the magazine. He enjoyed the task "because I was able to persuade a lot of people to write for it. I was lucky I knew so many people. It was a lot of fun but still an awful lot of work trying to contact all those people and keep my job going too."

Among the regular contributors was Atwood's friend and classmate, Bill Pickering, later to become director of the Jet Propulsion Laboratory. The first issue carried an article by Pickering on research on atoms and cosmic rays. Other articles in the magazine's first year chronicled the construction on Palomar Mountain and the building of the telescope; construction on the Colorado River Aqueduct, "the largest water supply system in the history of the world" (as the man in charge of measuring the aqueduct's water flow, Atwood threw the switch that let the first water through); and progress on the new technology of "Cinematography in Colors." ("Without fear of contradiction, it may be said that the production of a three-color motion picture print with sound track draws more liberally upon the physical sciences than does any other form of art.")

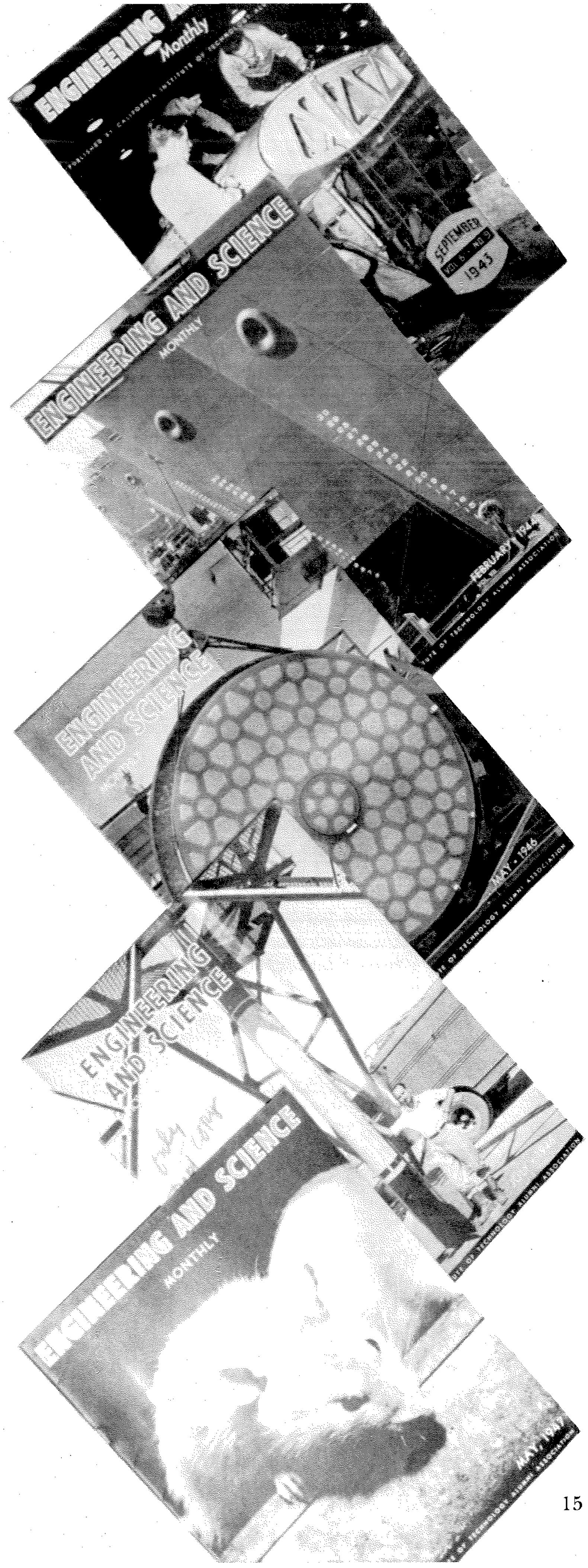
In September 1938 Atwood passed the editorship on to Ted Combs, '27. Combs had also been editor of the Big T for his class and, because engineers weren't being hired at any great rate in those days, went into the publishing business briefly. After the Long Beach earthquake in 1933, he became an engineer with the lumber industry, doing research on building code problems and helping rebuild schools but was willing to take over the task of getting out the *Alumni Review* in his spare time.

Although the magazine at that time was strictly for alumni, and alumni contributed most of the articles, from the beginning it stressed research. "We also had very good response from the faculty," says Combs, "who were quite willing to share their research and their findings. Caltech was small enough then that you could practically walk through the corridors of Throop Hall and see everybody you knew, buttonhole them, and make your arrangements."

Combs reported on the first Seminar Day in 1938 (which, he wrote, "marked a new high in alumni-campus relationships"). Among his favorite articles was one by Irving Krick, MS '33, PhD '34, in the December 1938 issue on "A Physical Basis for Long-Range Weather Forecasts." Krick later gained fame for predicting meteorologically favorable conditions for the Normandy landing on D-Day, but he had a local reputation long before then. "Movie companies wouldn't go out on location without his say-so," according to Combs.

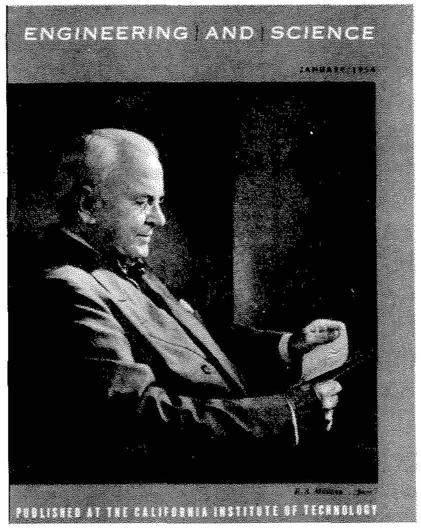
In 1939 Combs was succeeded as editor by George Langsner, '31, who was in turn succeeded a year later by Hugh Colvin, '36, who worked for Union Oil and had become active in Caltech's Industrial Relations Center. Like his predecessors, Colvin had worked on the *Big T* and was also sports editor of the *California Tech*. (His interest in publications also led him to help start a monthly newsletter at Harvard Business School, the Harbus News, which also still survives.) Colvin remained editor until June 1942, when Don Clark '29 (PhD '34) took over. During these years the difficulties of putting out a magazine while holding a full-time job became insurmountable, so the *Alumni Review* editors turned their articles and illustrations over to the Colling Publishing Company in Los Angeles, which then handled everything else — layout, production, printing, and distribution.

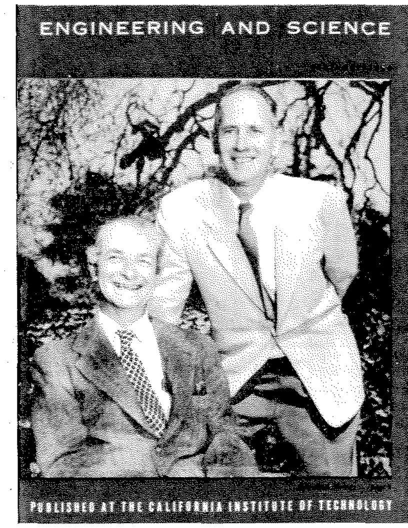
According to Colvin, it was R. C. Colling of that firm who suggested building the *Caltech Alumni Review* into a more important



Yousuf Karsch's portrait of Robert A. Millikan appeared on the cover of the January 1954 issue announcing Millikan's death a month earlier.

The February 1954 cover depicted Linus Pauling, head of chemistry, and George Beadle, head of biology, for an article on "Chemical Biology at Caltech." Both later won Nobel Prizes.





magazine— expanding its scope and audience and issuing it monthly to appeal to advertisers. (All the early editors had problems soliciting enough advertising.) In 1943 Colling hired a young man to sell advertising space in the magazine, and in September the *Alumni Review* was reincarnated as *Engineering and Science Monthly.* Clark remained editor-in-chief, with Colling as managing editor and the Colling Publishing Company in charge of business management.

Colvin, who remained on the magazine's editorial advisory board through most of the 1940s, remembers lengthy (and heated) discussions among the alumni board members, Colling, and himself over all these proposed changes — including the name. He's not sure, but Colvin says, "It sticks in my mind that maybe I came up with *Engineering and Science.*" In his introduction Robert A. Millikan explained the new name with an opening sentence that could have benefited from an editor:

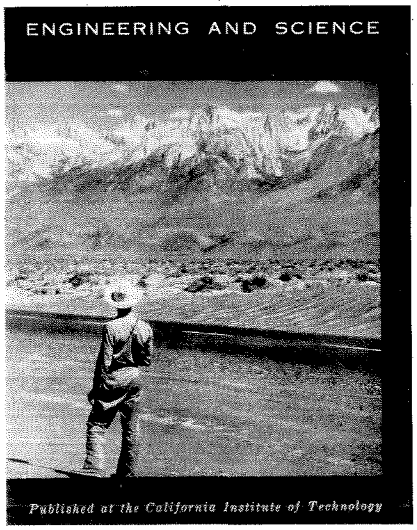
"A name such as 'Engineering and Science' for a magazine that is to be used for the presentation of technical and semi-technical articles by those who have graduated from, and those who are connected with, the California Institute of Technology is very appropriate, for it reflects the very close association that should exist between these fields, an association the creation of which has in fact been one of the most distinctive objectives in the Institute's development."

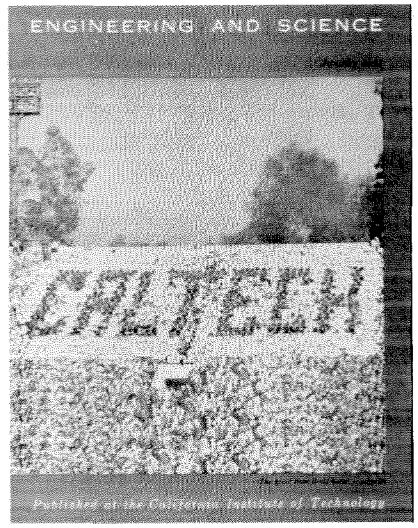
Millikan continued: "It is a familiar but a very true observation that the fundamental science of one generation is the applied science of the next. The solution of the problems associated with the war has furnished very recent and very powerful verification of the correctness of this assertion.

"With the inauguration of this magazine which replaces the 'Alumni Review' a new means has been provided for the dissemination of information on the technical work of Institute graduates in the general field of engineering and science. With the greater circulation anticipated, it is hoped that more people will thus have an opportunity of seeing the high caliber of the work of Tech men. The new magazine will also provide another outlet for interesting information resulting from the developments going on at the Institute itself."

While the newly conceived magazine began to carry more Institute news, many of the articles were still contributed by alumni. And during the war its pages were indeed dominated by "the solution of the problems associated with the war," as Millikan had observed. Common were articles such as "Electronics in a Postwar World" (March 1943), "Oil is Ammunition!" (September 1943), "Engineers for the American Service Forces" (March 1944), "Steel in the War" and "Human Blood: Life Saver 1 in World War II" (February 1945). Leavening the relentless military/industrial focus of the war years were the frequent contributions of Chester Stock, professor of paleontology, who wrote on his numerous fossil discoveries in the western states and Mexico.

Engineering and Science survived the war — with a little help from the Institute — but the desired increase in advertising revenues to support the new expansion never quite materialized, and the advertising representative was let go. When advertising dropped off





When Ed Hutchings intentionally reversed the picture of the Sierra Nevada on the May 1960 cover because he wanted the man looking in the other direction, he "caught hell from every Caltech geology graduate."

The January 1961 E&S *with the story of the great Rose Bowl stunt was one of the most popular issues. But many readers noticed that Hutchings had pulled a stunt of his own. Since the original photograph was horizontal, he lengthened it by recycling some of the crowd at the bottom.*

still further during the early postwar years, another reassessment was in order. But instead of cutting back, Caltech decided in 1948 to try to improve the magazine.

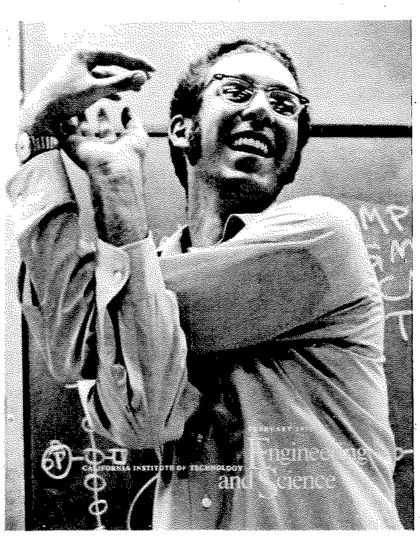
At the June 1948 annual meeting of the Alumni Association it was announced that "we have embryonic plans for expansion of the magazine with greatly increased Institute aid. We plan to make the magazine not only larger, but better. We have engaged a professional journalist of top rank to manage the magazine. . . . We haven't yet definitely determined what the character of the new *Engineering and Science* will be but we expect to have it tell more of what the Institute is doing."

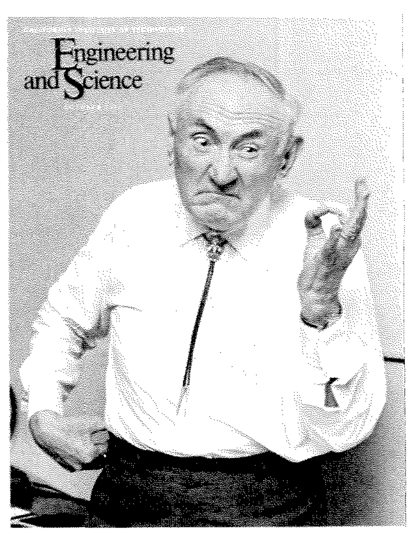
The "professional journalist of top rank" turned out to be Edward Hutchings Jr., who "definitely determined what the character of the new *Engineering and Science*" was to be for the next 31 years. A 1933 graduate of Dartmouth, Hutchings had worked on the *Literary Digest, Tide, Business Week, Look,* and *Liberty.* When Chuck Newton, then assistant to the president, went to New York to recruit an editor, he found Hutchings working on *Science Illustrated,* a magazine published by McGraw-Hill, which folded eventually because, according to Hutchings, it didn't really have a theory about what it wanted to do.

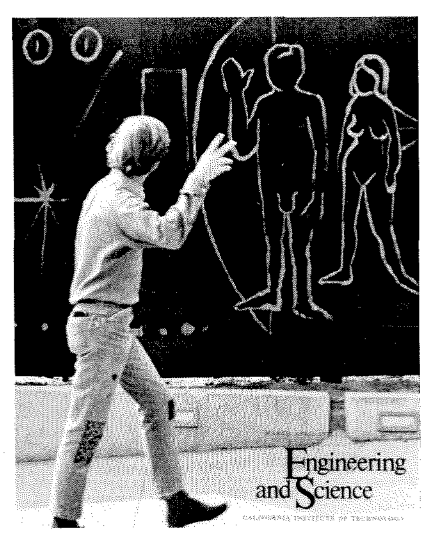
Hutchings *did* have a theory about explaining science, and it was this personal view that came to shape *E&S.* Hutchings puts it simply: "I tried to get people to write so that *I* could understand it."

It was through this goal of making science understandable and the vision of *E&S* as a *Caltech* magazine rather than just another alumni magazine that Hutchings left his mark. "I always figured that what the alumni — from this kind of a place, especially — wanted to read was what everybody wanted to read. Like the science editor of the *New*

Other favorite covers include grad student Bill Beranek impersonating a double helix (February 1971); Professor of Astrophysics Fritz Zwicky impersonating Fritz Zwicky (October 1971); and an anonymous Caltech undergraduate's friendly greeting to the figures (reproduced on a construction fence) that originally graced an etched plate on Pioneer 10 as a message to other possible worlds (March-April 1972).







York Times, they want to know: What are we doing here? How good is it? Who's doing it? How important is it? They don't want to know that Joe Blow had a baby."

For breaking new ground with "this understandable science business," the magazine began to collect a number of awards. In the late 1960s and early 1970s it was rated among the top ten alumni magazines in the country. In 1971 a special *E&S* issue on the environment won the *Newsweek* Award for excellence in presenting public affairs. As the awards rolled in, Hutchings felt obliged to come up with an official statement of purpose for *E&S*. He described it thus:

"*Engineering and Science* is a magazine about the California Institute of Technology — about the people who teach and study here, their research and ideas. The articles in the magazine are written by Caltech faculty, students, alumni, and distinguished visitors to the campus, and they are intended to give a sample of some of the current life, work, and thought at Caltech."

Hutchings credits the magazine's success to a great stable of writers ("who *offered* us articles!") — Arie Haagen-Smit, who introduced smog in *E&S*, James Bonner, Peter Kyropoulos, Bob Sharp, Dick Jahns, and "the earthquake boys" — Hugo Benioff, Beno Gutenberg, and Frank Press — "I just couldn't stop printing them." And "it was an editor's salvation to have someone like [former President] DuBridge. When I had a five-page hole to fill, I would always think, 'Ah, DuBridge!' He saved my life again and again."

Among Hutchings's favorite articles are "anything by Feynman," but especially "There's Plenty of Room at the Bottom" (February 1960) and "Los Alamos From Below" (January- February 1976). These were also frequently requested as reprints. The Rose Bowl stunt (January 1961) was another popular issue, but the all-time winner was Elting Morison's "A Case Study in Innovation" (April 1950). Reprints of Morison's "little talk at the Athenaeum" were requested by the thousands for a couple of decades. (Its popularity has waned, but a few requests for it still come in every year.) Another one of Hutchings's early issues (November 1948) contained an article entitled "Xerography, A Newcomer to the Graphic Arts," by Chester F. Carlson, '30, who invented the now ubiquitous process. "He submitted the article," says Hutchings, "and I thought it was an interesting thing. Damn; I should have bought stock."

The magazine changed its look many times over the decades, and for a brief time in 1967-68 changed its name to just *E&S*. The full name returned, but the ampersand officially replaced the "and" in 1977. Its frequency has ranged from nine to seven to four to the current five times per year. Hutchings retired from *E&S* in 1979, although he still teaches journalism and is adviser for the *California Tech* (and edits an occasional best-seller, such as *Surely You're Joking, Mr. Feynman*). Jacquelyn Bonner, who as associate editor and managing editor had been with the magazine since 1965, succeeded him and remained editor till 1984.

Among Bonner's favorite stories were those on the Apollo missions ("the glamour of that time trickled down even to us") and articles by such articulate writers as Bob Sinsheimer, Jesse Greenstein, and Willy Fowler, "who made scientific concepts almost poetically beautiful." And then there was the April 1970 issue — a special issue on the biological bases of behavior. "The printer thought it was obscene (because of *National Geographic*-like anthropological photographs) and at first refused to print it. Ed insisted, but they gave us a short run, and we never had enough copies." Bonner also remembers as popular articles by Ray Bradbury and Al Hibbs and the recent oral histories.

Probably the most popular article of the current year has been Francis Clauser's "The Boat That Almost Was" (November 1986) about his bold ideas for 12-meter yacht design and his experiences with an America's Cup syndicate (to which he had been recruited by Chuck Newton, who appears to have done a lot of this sort of thing). Clauser has old ties to the magazine. In the June 1937 issue of the *Caltech Alumni Review*, a column of alumni news called "Ye Editor Comments" contained the following notice: "Miss Catherine McMillan, demure blond custodian of Dabney library, has become engaged to one of the famous Clauser twins. Rumor has it that the lucky one is Francis H. Clauser, but being unable to tell them apart we cannot verify this."

It was indeed Francis Clauser, BS '34, PhD '37, former chairman of the Division of Engineering and Applied Sciences and now the Clark Blanchard Millikan Professor of Engineering, Emeritus, whose career has spanned 50 years of *E&S* — so far. □ — *JD*


ENGINEERING AND SCIENCE
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Prohibited Words Literature and AIDS

by John A. Sutherland

CENSORSHIP is evidently universal — like the incest taboo. Despite the promises of the First Amendment of the American Constitution and other declarations of human rights, the ideal of absolutely free speech remains utopian. Only, I think, in the impotent carnivals of the lunatic asylum are inmates entirely free to say what they please, write what they please. Learning what can be said where, to whom, and when is one of the most difficult yet important lessons in social conduct. There are things we say in private that we would not (or cannot) say in public; things permissible with friends that are not permissible with strangers; things that may be said to members of the same sex which are inappropriate in mixed company. In the last stages of a cocktail party, things may be said that would be out of place at a funeral party. And in literary terms, things may be printed under reporting privilege in a newspaper that would provoke immediate libel action if reprinted in a novel.

The list could be extended. But the central element is "prohibition." We are bound by thousands of such situational webs, enforced by law, custom or social code. But if prohibition is one cultural universal, so too is the fact that the targets of prohibition are always changing or shifting in importance. Hence yesterday's prohibited thing becomes today's permitted thing. This is particularly the case with the printed word and the entertainment media. Thus an R-rated movie such as *The Exorcist*, which caused moral panic in 1973, appears in 1987 as family viewing on prime-time network television. In literature, this decensorship can be illustrated by a recent novel, D. M. Thomas's *The White Hotel.* First published in 1981, this has become one of the more acclaimed novels of modern times. Before the liberating Lady Chatterley judgement in 1959, however, it could not have been published without substantial cuts and a century earlier not at all.

This example may suggest that the movement is inexorably towards liberalization. And this bolsters a pervasive myth fondly held by many liberals that historically censorship is always in retreat. The images associated with this myth are well worn: on one side the tide of progressive enlightenment sweeping society ever onward and upward. On the other side, the picture is of floodgates forever opening catastrophically wider, letting in a deluge of filth.

Very simply, this notion of inexorably progressive decensorship is a misapprehension. I would argue that the amount of prohibition, in all its subtle and diffused forms, is probably more or less constant at all periods, assuming one could measure it as a single commodity. What makes this consistency difficult to perceive is that prohibition moves from target to target so quickly and so mutably that it deceives the eye. Take one small topical example to counter the Thomas illustration. In early 1987, the California Bicentennial Committee approved for official distribution a history book which, to their later dismay, they discovered contained slanderous allegations about black Americans; namely, that in the period before the Civil War their condition of slavery was justified by their being "shiftless and lazy." On investigation, this extraordinarily stupid allegation was found to have originated in an article by F. A. Shannon, an authority on American history who died in 1929. The makers of the 1987 book had simply recycled this earlier work without reading it.

It was a gross lapse, and the offending book was duly withdrawn. But the episode reminds us that in one area, what was sayable in 1927 is not sayable in 1987. There is a vast new network of prohibition that has come into existence since the 1960s. What was a perfectly respectable comment a few decades ago is legally actionable today (or at least, as in the case of Al Campanis, may cost you your job). And tomorrow? Which of our cosy prejudices will be banned? It is hard to say, but I imagine that much of our currently acceptable discourse about gender may become either proscribed or bad form.

On a *quid-pro-quo* reckoning, it seems to me that post-1960s freedoms of discourse on sexual matters are at least equaled and possibly outweighed by post-1960s prohibitions, or inhibitions on racial matters. All things considered, it is a fair trade-off. But having made the paradoxical point that liberation in these matters is something of an illusion, I would concede that in one respect the period 1950-85 has been one of remarkable cultural openness and relaxation. We have not had more freedom as such (when all the gains, losses and diffusions are added up), but we have certainly had an unprecedented quantity of discussion and debate on the question of intellectual and artistic freedom. Put bluntly, Western society has, over the last thirty years, been amazingly talkative on the subject of censorship — never more so. That talk, I believe, is coming to an abrupt end. Why? Or to pose the question another way, what emergency could shut us up on this fascinating topic?

There are, I think, two surefire ways of foreclosing open-mindedness about censorship: war and epidemic. We do not (thank God) face imminent war, but the fear of plague is again with us. The fear is somewhat unfamiliar. It is our good fortune as a generation in the West to have become virtual strangers to plague. I can remember, rather dimly now, the polio outbreaks of the 1940s and the unreasoning terror they brought with them — together with mysterious prohibitions as to visiting swimming pools and cinemas or even, in some summer months, any public place. My parents can just remember the Spanish Influenza of 1919. But even this pandemic, which in a year killed more than the Great War in four, pales beside the recurrent devastation brought by the Black Death in the 14th century; the bubonic plagues that ravaged England from the 14th to the 17th century; the mysterious "sweating sickness" of the early 16th century; smallpox in the 18th century; the cholera and typhus epidemics of 19th-century Europe or the yellow fever outbreaks in the U.S. at the same period.

For those in the past whose books we most revere as literature and whose painting as art, plagues and epidemics were as familiar features of the calendar as winter or bad harvests. So out of practice are we that it requires some imaginative effort to recall what plague mentality entails. Typically, one may say, the plague comes quite suddenly and mysteriously from somewhere else. It is a visitation that sharply defines a here and a there. Hence the well-known fact that from its first appearance in the late 15th century syphilis was for each nation another nation's disease. The French called it the Neapolitan Boneache. The Italians called it the Spanish Disease. The English called it the French Pox. The Moslem Turks called it the Disease of the Christians. The Spanish called it the Haitian Disease. And for the whole of the Old World, syphilis was a gift from the New World, via Columbus's crew.

The xenophobic aspect of plague mentality fosters a reflexive herd consciousness and what zoologists call startle reactions (that phenomenon whereby, when one bird suddenly takes off, the whole flock instantaneously and unthinkingly joins it in flight). In terms of human society, epidemics lead routinely to panic, hysteria, mass irrationalisms. For obvious reasons, they are bad times in which to be a foreigner. In 1497, for instance, an order of the Paris Parliament commanded that all "foreigners suffering from syphilis" (a disease for which there was as yet no definite name) should leave the capital within 24 hours on pain of summary hanging — a wonderfully efficient way of spreading the disease beyond the city walls.

Only gradually are plagues seen as domestic social problems that can be solved by human agency. Routinely in the past, epidemics were conceived to be inscrutable acts of a punitive God — that category of disaster against which one can never insure. The favored scientific causation theory before the medical revolutions of the 17th century was astrological. Comets or unusual conjunctions of the planets were thus intimately connected in the public mind with dreaded outbreaks of plague.

There were, however, some epidemic diseases whose causes were more comprehensible to the medieval mind and not simply to be put down to unlucky constellations — diseases, that is, which were acts of God where the Maker's purpose might be clearly discerned. Principal among these rational ailments was leprosy, a disease whose stigmata (as indicated by Biblical writ) were taken as a sign physical of spiritual uncleanness or defilement. Leprosy demonstrated God's displeasure, and as a disease it was very effectively handled by further punishing the victim whom God had already punished. The system was elaborately legalistic, as it was formulated in 12th-14th century Europe. But essentially, the official treatment for leprosy was moral and penological: punish the victim and cast him out, with a righteous sense that by so doing one was going along with God's prescription.

In the first waves of the syphilis epidemic in the early 16th century, the secondary stage with its visible skin lesions was more ravaging that it was in later centuries.

Syphilis was another rational plague in which God's purpose was manifest. It was, as anyone could understand, a punishment for sexual delinquency. Hence it was called venereal, pertaining to Venus, goddess of love. Women were often singled out for punitive medical treatment since syphilis was clearly another infliction by the daughters of Eve on the sons of Adam.

Unlike most epidemics, particularly early epidemics, we have a plausibly precise starting date and source for the European origin of syphilis. Most commentators entertain it as a strong possibility that the ailment returned with Columbus's crew and found its way to Naples in the early 1490s. Following Charles VIII's taking of that city, and the sexual orgy that followed, there was a fearful outbreak of the new disease. The epidemic was terrifying enough to demobilize the army. And the deadly contagion was (it is suggested) disseminated by the homecoming mercenaries throughout Europe. There are those who think this scenario is too neat; and various pre-Columbian or non-Columbian theories have been advanced. But all commentators agree that syphilis broke out with a series of extraordinarily virulent waves of epidemic in the early 16th century. In these ravages (whose ferocity has never been equaled since) the second and most visible stage of the disease was far more destructive than it became in later centuries.

The link between syphilis and gross sexual incontinence was immediately apparent. One awkward early name for the malady was the "lecher's ailment," which puts the epidemiological case clearly enough. Jerome Frascator, a poet-*cum*-physician writing in 1530 bestowed on the *morbus gallicus* the name that has stuck most closely to it during its subsequent career: syphilis. Frascator's was, as it happens, one of the more flagrant misnomers of medical history. In his poetic disquisition

Syphilus is a shepherd swain (traditionally a figure symbolizing careless love) who provokes the anger of Apollo and is consequently afflicted with a mysterious new disease. Frascator's poem (although written in Latin) was very popular, possibly because it ascribed no national origin to the disease; possibly too because it offered useful Galen-derived therapies and a magic bullet, mercury.

As a sexual paying-out, syphilis immediately recruited all the stigma and mythology previously attaching to leprosy, the traditional disease of the unclean. (Leprosy, oddly enough, seems to have largely died back in Europe about the time syphilis arrived.) Job, the patron saint of leprosy, promptly became re-employed as the patron saint of syphilis.

I want to skip forward here to the point at which our serious educational study of English literature normally begins: namely Shakespeare. By the late 16th century, syphilis as a disease had clearly lost some of its early ferocity. It was still frightening and widespread, but it could be lived with. Panic, flight, prayer, self flagellation and sadistic scapegoating were not the only recourses. There were even remedies. Mercury was in general use as a curative agent and despite toxic overprescription was moderately efficacious. (Hence the rueful witticism: "one night of Venus, a lifetime of Mercury.")

In the age of Shakespeare, syphilis was highly unpleasant but essentially a disfiguring and long-term degenerative disease, not a sudden killer. Many of its remote tertiary consequences were largely unregarded. And at a period when life expectancy was low it represented just one life-shortening hazard among many. But it had a blighting or corrosive effect on intercourse generally and sexual intercourse in particular. Shakespeare, like his fellow dramatists, was morbidly aware of the Neapolitan Boneache. It figures centrally as a motif in *Timon* and in *Measure for Measure.* And there are numerous passing references in many of the plays (if only in the expletive "Pox on it!"). *Henry IV* pt. 2 opens with Falstaff anxiously having his urine tested. It emerges that he may have the gout or the pox (gout from drinking, pox from wenching). He's not sure, and remains unsure throughout the play. His diseased condition we understand is a microcosm of a larger illness in England's body politic.

By the end of the 17th century there had emerged two distinct literary strategies for dealing with syphilis; one of which I'll call aestheticization and the other silence. Aestheticization in this context does not mean using the cosmetic resources of literature to make the disease beautiful, but finding a central place for it within the domain of art. To aestheticize it in this sense is to domicile or domesticate it as a fact of life.

Aestheticization of venereal disease is prominent in Restoration Comedy and the most improper of that improper genre, William Wycherley's *The Country Wife* (1672). Wycherley's hero Horner (i.e., cuckolder) hits on one of the witty stratagems that are the essence of the form. He has it put out that a particularly severe dose of VD has rendered him impotent. The news makes him a laughing stock. But more to his purpose, it means that gentlemen entrust their wives to him, as a kind of upper-class eunuch. Horner takes

Treatment of syphilis in the 17th century consisted of infusing mercury into the patient's body in a fumigation tub (foreground). Mercury applied as ointment caused excessive salivation, as the background patient graphically demonstrates.

William Hogarth's series of drawings of The Rake's Progress *(1735) describes the "progress" from high living to syphilitic madness. Plate 5 (left) depicts a "Tavern Scene" and Plate 8 (right) the "Scene at Bedlam."*

full advantage of his privileged intimacy, and notoriously the comic climax of the action is the so-called China scene, in which a foolish husband is cuckolded on stage by his treacherous wife and Horner behind a drawing room screen. Summary cannot do justice to Wycherley's wit and ingenuity. But what I would stress here is its central idea: the syphilitic or pseudo-syphilitic hero. Whatever else, the play indicates an extraordinary willingness to confront a painful social fact and laugh at it.

Aestheticization is similarly apparent in Hogarth's *The Rake's Progress* (1735). Hogarth's narrative series of eight plates tells the story of a young man of mode who runs through several fortunes in dissipation and luxurious living, descending finally into the open ward of Bedlam, where he expires a penniless madman. It is, of course, less a progress than a fall, like Adam's. In the two plates reproduced here the harlots around the rake have so called beauty spots prominently visible on their faces. These are social camouflage, a cosmetic covering of sores. What is a mark of mortal illness is converted by the application of pounce to a coquettish sign of beauty. Compare with the secondary cutaneous lesions of syphilis in the medieval drawing on the previous page. On his part, under his askew wig the befuddled rake is bald. His head is probably shaven. And the 18th-century fashion of the wig (and a bare pate underneath) was probably another social camouflage to hide alopecia, the hair loss associated with secondary syphilis.

In the last plate, the rake is naked. He goes out of the world as he came in. And he is clearly melancholy mad (unlike his raving fellow Bedlamites) and as clearly syphilitic mad. There are visible the telltale lesions on his stripped body. It is a very moralistic conclusion but even in this terrible degradation Hogarth renders his degenerate, disease-raddled hero strangely noble by allusion to conventional and heroic poses.

The effect of Hogarth's series is complex. It evokes pity, terror, scorn, and admiration, allowing none to predominate. The rake is morally contemptible — a wantonly self-destroyed fool, yet strangely heroic. He assumes the image of humanity crucified by temptations and a disease whose afflictions far exceed the just deserts of averagely sinful

mankind. The complex force of Hogarth's design is evident if one compares the last plate with the graphic depiction of a late 17th-century syphilis hospital on the previous page. (Note the fumigation tub, by which mercury was infused into the patient's body. In the far right of the picture another patient is expectorating. One of the side effects of mercury in ointment form was gross expectoration, up to three pints of saliva a day being considered tonic, although the fetid stench of the patient's breath was often unbearable to himself and his attendants.) This anonymous picture is terrible, but wholly inartistic. Its purely documentary effect is as low-keyed as a surgeon general's health warning.

For a number of reasons (many of them to do with the Puritan strain in British ideology) the head-on approach to syphilis practiced by Shakespeare, Wycherley, or Hogarth gave way to the other, less aggressive strategy: artistic silence. Look for venereal disease in the great works of English literature from 1750 to 1880 and you will have a fruitless time of it. There is simply a hole. Venereal disease nevertheless remained a dominant fact of lived life, shortening the span of many of the authors who studiously never mention it publicly. Mention is confined to such secret texts as Boswell's journals, the dirty joke, or, most frequently, the jargonized discourses of medicine.

How was this prohibition enforced? It seems to have been the outcome of a consensual conspiracy of tact, discretion, and good form. The social disease was something one simply did not bring up in society. The conspiracy of decent reticence held firm throughout all the upheavals that otherwise turned the world upside down. Most paradoxically, as literature became self-consciously "realistic" in the 19th century with the rise to dominance of the novel, the silence actually deepens. Between 1820 and 1880 there were probably some 30,000 novels published in England. Not one of them, as far as I know, alludes directly to venereal disease.

Even had they been legally permitted, Dickens, George Eliot, or Thackeray would probably not have wanted the freedom to introduce syphilis frontally into their novels. It would have been a treachery to the sanctities of the sacred English family. Avoidance of reference was universal. The famous Ninth Edition of the *Encyclopaedia Britannica*, for instance, has long and informative separate entries on Leprosy and Smallpox. Look for Syphilis, and you are obscurely directed to a paragraph in the "Surgery" entry. This morbid fear of direct reference explains the violently scandalized response to Ibsen's *Ghosts* when it was first performed in London in the 1880s. The play deals, discreetly enough, with the horrific effects of tertiary and congenital syphilis (effects that were gradually becoming known in their full horror to medical science). But the play was attacked as more contaminatingly dangerous ("an open sewer") than the disease itself. It strikes us as pure Grundyism — a signal instance of Victorian hypocrisy. But the 19th century's self-willed prohibition on reference to syphilis was, in fact, a strategy. Effectively it controlled the fact by controlling the idea, and it controlled the idea by banishing it, by creating an ideal world in which syphilis had no public existence. If the 18th century covered its sores with beautifying aids and cosmetics, the Victorians covered their uncomfortable thoughts with beautiful myths.

I said earlier that we are sadly out of practice in dealing with epidemics. In our inexperience we instinctively reach back to two options, or strategies, from the historical past. One is medieval: a policy of prohibiting the person (as if he were a leper). The other is Victorian: a policy of prohibiting the word (as if it were dirty). Both strategies are evident in America's current encounter with AIDS.

The Victorian option of willed silence in the face of AIDS explains the extreme reluctance of the TV networks to carry condom ads, despite the fact that condoms are agreed to be useful prophylactics. The pretexts ("inappropriate for a significant proportion of our viewers") boil down to a single sovereign fact: the audience does not want to hear about condoms in their living rooms, even if condoms save lives.

There are other revealing instances of willed silence about AIDS. The refusal, for instance, of Liberace's physician to enter the actual cause of death on the entertainer's death certificate; or the automatic use of Strangelovian euphemisms ("exchange of bodily fluids"); or President Reagan's disinclination until very recently to use the dreaded acronym in any public statement.

If the Victorian strategy is evident, so is the even more frightening medieval practice of prohibiting not the word but the person. Vestigial remnants of society's leprosarial procedures are recognizable in the demand that universal testing for AIDS be at once inaugurated; presumably as the prelude to forcible separation. It is only too easy to see AIDS sufferers as victims of *flagellum dei*, the scourge of God: are they not clearly sinners — gays, whores, junkies, guilty because ill, ill because guilty? (Hence the bizarre formulation of haemophiliacs or infected new born babes as "innocent victims" of AIDS.) There has been no serious suggestion that those with AIDS lose all their civil rights. But the increasingly urgent wish of medical insurance companies to deny them coverage (as if they were not legitimately "sick") is a step in that direction.

There is, of course, one factor that makes our situation very different from either Victorian society's dealing with syphilis or Medieval Europe's dealing with leprosy — namely, the extraordinary authority and power of the news media. There has been no shortage of press coverage. Indeed, journalism's attention to AIDS may seem obsessive (recalling the entirely phony panic that was whipped up by herpes three years ago). But for all their fearless confrontation with the clinical and epidemiological facts, newspapers do not (as the idiom goes) bring AIDS home to us. And this, surely, is where literature, film and the arts have a part to play. Their great power is to make the strange thing familiar; to give us an intimate inwardness with otherwise unbearable facts. In Hogarth's prints disease, although graphically horrible, is nevertheless domesticated. It is part of the everyday facts and furniture of 18th-century London life — as English as apple pie is American. Is AIDS as American as apple pie? I don't think so.

It is highly unlikely that Hogarth's art cured anyone, any more than W. H. Auden's pre-war poems (as he candidly admitted) saved a single Jew from the gas chamber. Nevertheless, as a species, we are the better for having had Auden and Hogarth. One must beware that most arrogant and Canute-like error of ordering the artist what to do. But one can, I think, enter a fervent plea or hope that in the present AIDS-related emergency artists of Hogarthian stature may emerge. Not to cure or alleviate what may well be a terrible epidemic. But to help us to confront it with some degree of human dignity and charity. □

Research in Progress

Core Temperature

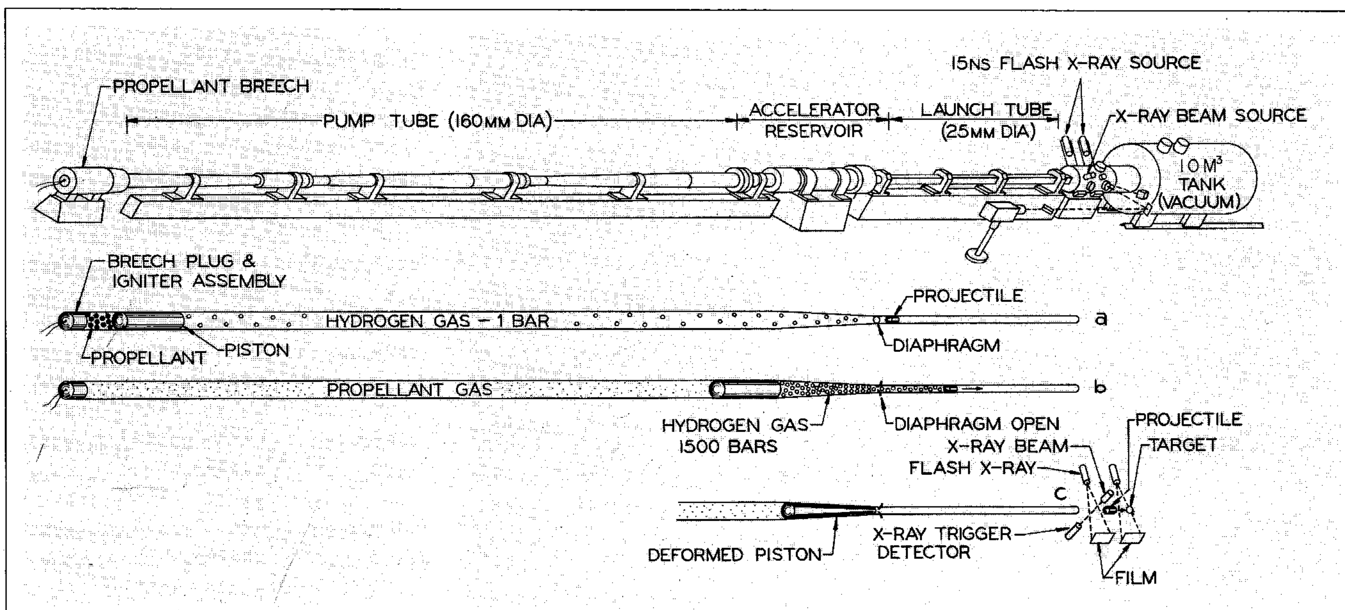
Sometimes one particular scientific instrument or technique proves enormously varied in its applications — far beyond original expectations. Such is the case with the instruments and techniques that Thomas J. Ahrens, professor of geophysics, uses in the Helen and Roland Lindhurst Laboratory of Experimental Geophysics.

In this laboratory are three powerful guns capable of accelerating projectiles to enormous speeds. Firing off one of these guns is not a casual affair. The largest is 106 feet long, weighs 35 tons, and is capable of accelerating one-ounce plastic and tantalum bullets to speeds of 16,000 miles per hour. Before firing it, the researchers have to go through an elaborate and detailed checklist, as well as a NASA-style countdown. And when it finally fires, all of South Mudd shakes.

All this trouble seems to be worth it, though. In past years Ahrens and his group have: compressed the gemstone garnet, altering its crystal structure into a form never before seen (*E&S*, May-June 1971); discovered major phase changes in calcium and iron oxide; fired bullets at targets of solid hydrogen, simulating the environment deep in the interior of Jupiter and Saturn; located the earth's "missing" sulfur in the molten outer core; shed new light on the possible cause of the mysterious Tunguska explosion, which took place in the USSR in 1908; lent credence to the theory that a gigantic meteorite hit the earth 65 million years ago, leading to the extinction of the dinosaurs; illuminated the structure of the ice craters on the surfaces of such satellites as Ganymede and Callisto; and developed a plausible hypothesis explaining how pieces of Mars may have been blasted into space by a meteorite impact, eventually to find their way to earth (*E&S*, March 1985).

These projects all share a common thread, however. Says Ahrens, "We usually think of processes occuring in the solar system as being rather gentle, like wind, for example. But impact turns out to play a far greater role than previously thought."

This year, Ahrens and his group, collaborating with researchers at UC Berkeley, have determined that the earth's core is thousands of degrees hotter than was previously thought. This new value for the core temperature — 6,900 Kelvin (almost 12,000° Fahrenheit) — implies that there may be a non-convecting layer at the core-mantle boundary, or else the rest of the earth would be much hotter than it actually is. The core is even hotter than the surface of the sun.



The largest of the Lindhurst Lab guns is 106 ft. long. When the chemical propellant ignites (a), a 20-kg plastic piston compresses hydrogen in the pump tube. As the projectile enters the high-pressure reservoir section (b), the diaphragm ruptures, and the projectile begins to accelerate down the launch tube. As a result of the deformation of the plastic piston in the high-pressure reservoir (c), gas pressure is maintained on the projectile until it clears the launch tube. A continuous x-ray beam measures the projectile's velocity.

Geophysicists have long known that the earth's core is composed of molten iron (with some impurities) at pressures of over 350 gigapascals (GPa) — 3.5 million atmospheres. What they haven't known, at least not accurately, is the melting point of iron at these great pressures, which provides a lower limit for the temperature of the core. Previous studies were able to measure iron's melting point only to relatively modest pressures. Extrapolations from these low-pressure measurements led to upper estimates of about 3,000 K to 4,000 K for the core's temperature.

In the recent experiments, the melting point of iron was measured using two techniques. In the first, the UC Berkeley researchers — graduate student Quentin Williams and Professor of Geology and Geophysics Raymond Jeanloz — made continuous measurements of iron's melting point up to about 100 GPa in a laser-heated diamond cell. In this novel apparatus, a thin foil, 0.003 inches square, of 99.99 percent pure iron was within a matrix of powdered ruby. Diamond anvils then compress this iron sandwich as it is being heated by a tightly focused laser beam. To determine the temperature, the researchers measured the light radiated by the heated iron. And to determine whether the sample had melted, they used two criteria: the disappearance of the sample's surface texture after heating and the observation of fluid-like motion of the sample when held at high temperature.

For pressures up to about 300 GPa, the Caltech researchers — Ahrens, Visiting Associate Professor in Geophysics Jay Bass, and graduate student Robert Svendsen — used the Lindhurst Lab guns. The bullets were aimed at a target of single crystal aluminum oxide (sapphire) on which a thin film of iron had been deposited. For less than one microsecond, the impact produced the intense pressures required. To measure the temperature during this brief period, the researchers relied on an instrument known as a four-color optical pyrometer in a technique that is quite similar in its details to one astronomers use to measure the temperature of stars.

Taking into account the fact that the core is not made up of pure iron, the researchers arrived at a temperature of about 6,900 K for the solid inner core. The temperature at the boundary between the inner and outer core is about 6,600 K and the temperature of the core-mantle boundary is about 4,800 K.

These temperatures imply the existence of a major boundary layer at the base of the mantle that acts something like a pressure cooker, holding the heat in. This layer does conduct heat but may not itself be convecting. Therefore, a great deal of the heat generated within the core may remain in the core. If the boundary layer did convect, the core would be cooler and the mantle hotter.

"It will be difficult to settle this issue of the boundary layer," notes Ahrens. "The thermal conductivity of the layer appears to be a factor of five less than previously thought. However, some of my colleagues still believe it is convecting." □ — *RF*

Clouds, Not Comets

Christine Wilson's name is associated with the discovery of a comet, but the second-year Caltech graduate student is really more interested in galaxies — their structure and their history and precisely how far from earth they are. During the past year, while media attention focused on Comet Wilson, Wilson herself was focusing telescopes on the spiral galaxies M33 and M101 to trace the dynamics of star formation there. Her project, done in collaboration with Caltech astronomer Nick Scoville and Carnegie Observatories astronomer Wendy Freedman, is one of the first studies of individual star-forming regions outside the Milky Way. Understanding how stars are born — whether singly or in flocks, as half of a binary system or as the center of a planetary one — is considered crucial to understanding the dynamics and evolution of galaxies. In addition to shedding some light on these topics, Wilson's research could help to determine whether models of star formation proposed for the Milky Way can reliably be applied to similar galaxies in other parts of the universe.

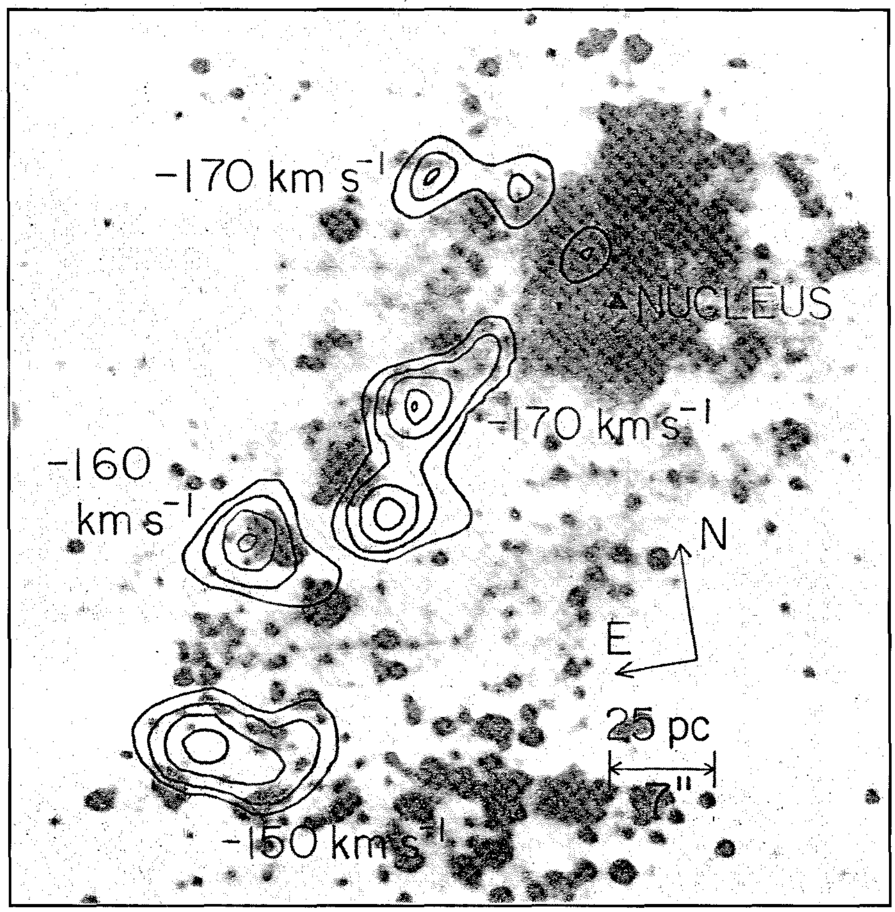
Stars originate inside gigantic clouds of molecular gas and dust that congregate by the thousands in the central regions and pinwheel arms of spiral systems like the Milky Way. Close to 99 percent of this gas is molecular hydrogen. Shielded by dust that absorbs nearly all visible light, molecular hydrogen is also mute in the radio band of the spectrum. Thus, studies of star-forming regions require the use of several tools in the astronomer's kit — optical telescopes that observe the blaze of blue and red light from massive young stars; infrared instruments to study the dust that engulfs stars in the embryonic and newborn phase; and radio dishes that track emissions from the fraction of gas that isn't molecular hydrogen. The most abundant of these compounds, carbon monoxide, radiates strongly at microwave (millimeter and submillimeter) frequencies and is considered a highly dependable tracer of the structure and dynamics of the hydrogen.

Until recently, these properties could not be studied in much detail extragalactically because of the limited resolution of single-dish telescopes. Single-dish studies of the relatively nearby spirals M33 and M101 had detected moderate CO emissions in the galaxies' centers and in one of the spiral arms of M101, roughly corresponding to what has been observed for our own galaxy. But at such distances (current estimates place M33 about 3 million light years from earth, M101 four to seven times as far), the CO emissions that signaled their kinship with the Milky Way were too weak to encourage closer studies of the resemblance.

Wilson's studies make use of the higher resolution provided by the Millimeter Wave Interferometer, a newly constructed three-dish array at Caltech's Owens Valley Radio Observatory. Deployed at designated points along a 100-meter track, the three telescopes can function as a single dish whose diameter equals the greatest extent of their separation. Using the interferometer, Wilson has begun to resolve the gas in the centers of M33 and M101 into individual molecular clouds, ranging from 150 to 200 light years in size. She's also started to measure velocity dispersions for the individual clouds, data that can be used to compute their mass.

Previous optical studies of these galaxies have detected large amounts of blue light in the neighborhood of the CO concentrations, presumably emanating from very hot young stars that have formed from the collapse and condensation of the molecular gas and dust. Using calculations that constrain the distance a star can be from a molecular cloud and still be viewed as a product of that cloud, Wilson would like to extend these observations to see how the number of stars correlates with specific quantities of gas. "Enough single-dish studies have been done so that we now know roughly how much molecular hydrogen there is in a number of external galaxies. But until now, nobody's really looked at these systems on a smaller scale. We'd like to have a much more precise estimate of how much CO in these systems equals how many stars, and then plot that result against data we have for the Milky Way. We do know that gas in our galaxy is being converted into stars much more slowly than theoretical calculations would indicate. It would be interesting to find out if this is occuring in other spirals as well."

Wilson would also like to determine how the masses, size, and numbers of the individual clouds in M33 and M101 compare to the measurements that have been obtained for nearby star-forming regions and the nucleus of the Milky Way. Attempts to study these properties locally can also be impeded by interstellar dust and by the earthbound astronomer's position within the galaxy. "When we look at the center of the Milky Way, we're looking through the galactic disk and seeing the nucleus edge-on," says Wilson. "But we see M33 and M101 in cross section, so we can look directly into the centers of these galaxies to see how the gas and stars are distributed there. We can also pinpoint the position of the clouds relative to the spiral arms, which imposes constraint on theories of how these arms are formed. In the Milky Way, we're sitting in one of the arms, and can't easily make these observations."
□ — *Heidi Aspaturian*



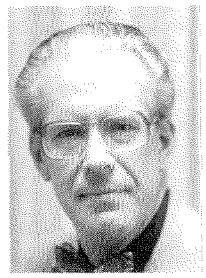
An interferometer map of several molecular clouds in the center of the spiral galaxy M33 is shown superimposed on an optical photo of the same region. The dark patches in the photo are bright young stars believed to have formed from the clouds.

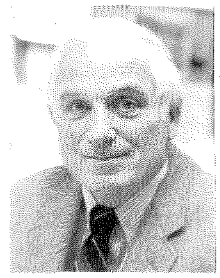
In this Palomar Observatory photo, M33, 3 million light years from earth, displays its spiral structure. The galaxy is thought to resemble the Milky Way, although smaller.

Random Walk

Three Professorships Endowed


Scott


Schmidt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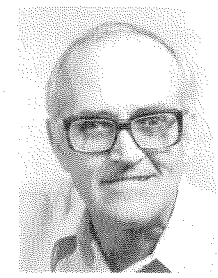
Patterson

THREE PROFESSORS have been appointed to newly established chairs. Ronald F. Scott has been named the Dotty and Dick Hayman Professor of Engineering. Scott, who joined the Caltech faculty in 1958, is known for his work in soil mechanics and dynamics. The professorship was established by a gift from Mr. and Mrs. Richard L. Hayman, who are active members of The Associates and had also previously endowed a chair in mechanical engineering. Mr. Hayman studied mechanical engineering at Caltech.

Astronomer Maarten Schmidt, Institute Professor of Astronomy since 1981, has been appointed the first Francis L. Moseley Professor of Astronomy. The chair was endowed with a grant from the Flintridge Foundation and is named for a pioneering electronics engineer who was a life member of The Associates. Schmidt, a member of the Caltech faculty since 1959, discovered the large red shift of quasars, thus determining that quasars are the brightest and most distant objects in an expanding universe.

Caltech recently established the Marvin L. Goldberger Professorship to honor its departing president. The chair was made possible through a gift from John G Braun, trustee of the Carl F Braun Trust. Members of the Braun family have made numerous major contributions to Caltech since 1926, when the Carl F Brauns were among the charter members of The Associates. John G Braun is former president, chairman and chief executive officer of C F Braun and Company and a life member of the Caltech board of trustees.

James J. Morgan, professor of environmental engineering, whose research is in the field of aquatic pollutants and water purification, has been named the first Goldberger Professor. Morgan joined the Caltech faculty in 1965 and is also currently vice president for student affairs.

Olson Named Trustee

JAMES E. OLSON, chairman and chief executive officer of American Telephone and Telegraph, has been named to Caltech's board of trustees. Olson, who is a graduate of the University of North Dakota, has worked in the telephone and telecommunications business since 1943 when he was hired as a splicer's helper. He became vice president and general manager in Northwestern Bell Telephone Company's Iowa area in 1964 and vice president, operations, for Indiana Bell in 1970. He became president of that company two years later and president of Illinois Bell in 1974. In 1977 he was named executive vice president of AT&T headquarters, vice chairman of the board in 1979, and vice president and chief operating officer in 1985. Olson assumed his current position in September 1986.

Faculty Awards

GEOCHEMIST CLAIR PATTERSON was elected to the National Academy of Sciences. Patterson, who joined Caltech in 1952, is known for establishing the age of the earth and for emphasizing the dangers of industrial lead pollution.

Two Caltech faculty members — Gene Broadwell, senior scientist in aeronautics, and Gary Leal, the Chevron Professor of Chemical Engineering — have been named to the National Academy of Engineering.

Ahmed Zewail, professor of chemical physics, has been awarded a Guggenheim Fellowship. In addition to the two that were announced in the previous issue, Christof Koch, assistant professor of computation and neural systems, has been awarded a fellowship from the Alfred P. Sloan Foundation.

Among faculty members awarded honorary degrees at various commencements are: Harry Gray — University of Chicago and University of Rochester; Jesse Greenstein — University of Arizona; and G.J. Wasserburg — Arizona State University.

Ernest Swift, Mrs. Lauritsen Die

ERNEST HAYWOOD SWIFT, professor of anaytical chemistry, emeritus, died April 26 at the age of 89. He had come to Caltech as a graduate student and teaching fellow in 1919 and had been associated with the Institute longer than any other person.

Swift received his MS in 1920 and PhD in 1924. He served on the faculty as an instructor since 1920, becoming assistant professor in 1928, associate professor in 1939, and professor in 1943. Since 1967 he had been professor emeritus. He was also chairman of the Division of Chemistry and Chemical Engineering from 1958 to 1963 and chairman of the faculty from 1963 to 1965.

Those wishing to make a donation in his memory may send it to Caltech's Division of Chemistry and Chemical Engineering for the Ernest H. Swift Lecture Series.

SIGRID LAURITSEN, widow of Charles Lauritsen, and mother of the late Thomas Lauritsen, died March 11 at the age of 95. Both her husband and son were professors of physics and founders of Caltech's famed Kellogg Radiation Laboratory. She was an MD in her own right.

Friends may make contributions to the Lauritsen Memorial Fund, which supports a guest lecturer every other year.

When the fog lifted May 19, a peculiar sight greeted Monday-morning commuters. In place of the famous HOLLYWOOD sign the name of a well-known institution famous for pranks stood revealed. When E&S *went to press, the perpetrators were still unknown.*

Student Honors

AMONG THE TOP 20 WINNERS of *Time* magazine's annual College Achievement Awards (see inside back cover) was Eric Gaidos. Gaidos, an applied physics major, is one of a group of Caltech students involved in designing an unmanned balloon to explore the Martian surface (*E&S* March 1987). Each award winner, chosen on the basis of academic excellence and exceptional achievement, receives $2,500. Runners-up in the competition included Brian Daniels, an economics major, and Vineer Bhansali, a physics major. All three are juniors.

All four Caltech seniors who submitted creative projects in application for the Thomas J. Watson Foundation's travel/study fellowships were chosen to be among the 80 winners. Each will receive $11,000 for nine months of independent foreign research and travel.

Mark Carlin, an applied physics major, will spend a year in Europe learning the sport of luge and the skills of luge sled design. Joey Francis plans to study the process of rain forest destruction in Borneo, portraying the dynamics of rain forest life through photography and writing. His major is literature and applied science.

Rosemary Macedo, an independent studies major in optics, will spend the year participating in international expeditions to study the physical dynamics of the ocean, and physics major Andrew Tikofsky will travel to Israel, Germany, and Eastern Europe. He is interested in how various political minorities are treated and how that treatment affects their life choices and identification with their minority group.

Distinguished Alumni

AT CALTECH'S 50th Seminar Day May 16, five alumni received Distinguished Alumni Awards. These awards, the Institute's highest honor, are conferred in recognition of achievement in science, engineering, business, or public service. This year the recipients were:

- James E. Lu Valle, director of the Stanford undergraduate chemistry teaching program for many years;
- Morris Muskat, retired technical adviser in the Gulf Oil Corporation and highly regarded for his technical contributions to the petroleum industry;
- Stanley C. Pace, chairman and chief executive officer of General Dynamics Corporation;
- Alvin W. Trivelpiece, executive officer of the American Association for the Advancement of Science and former director of the Office of Energy Research, U.S. Department of Energy;
- John Waugh, the Arthur Amos Noyes Professor of Chemistry at MIT, noted for his pioneering nuclear magnetic resonance techniques.

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