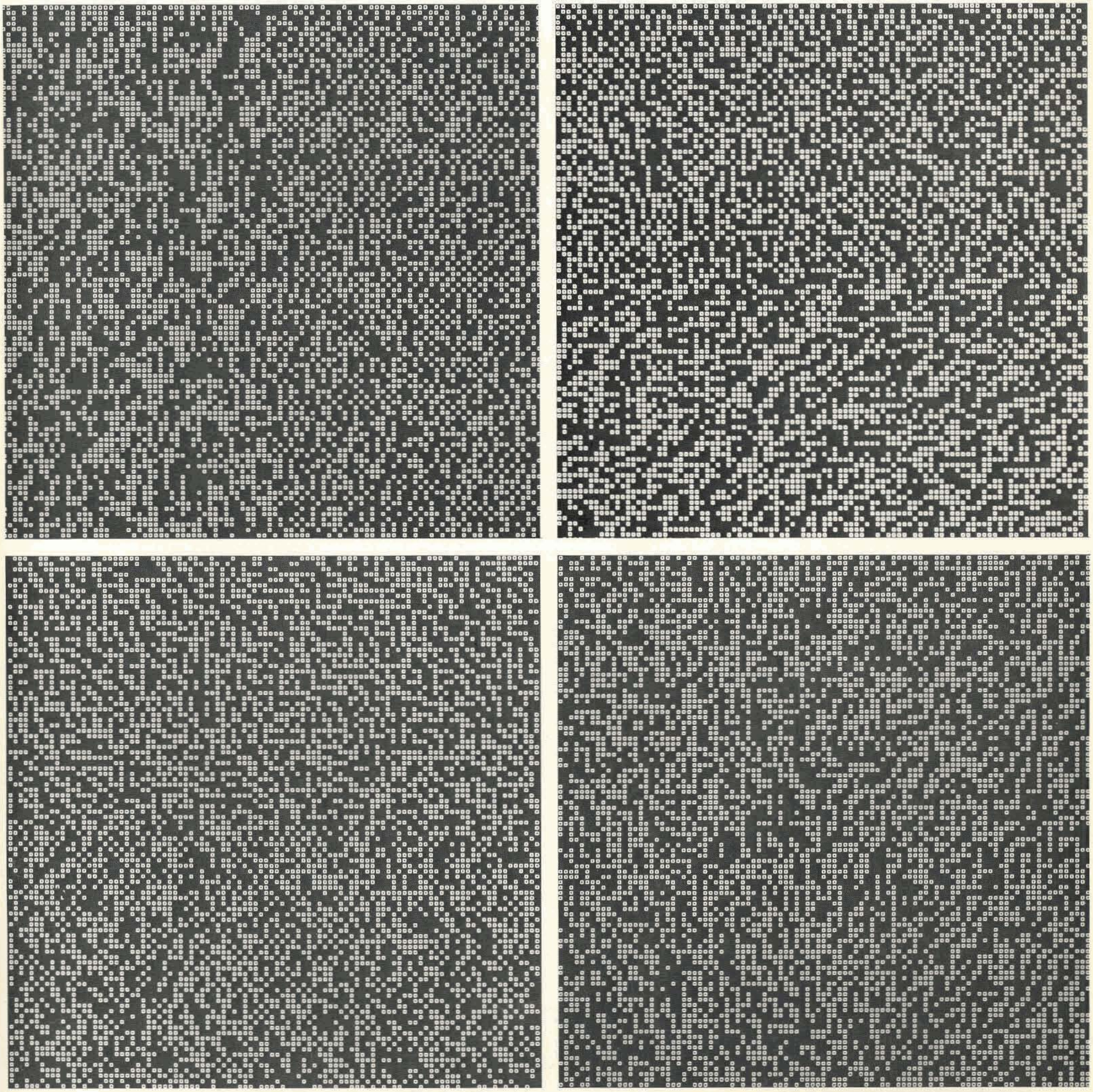
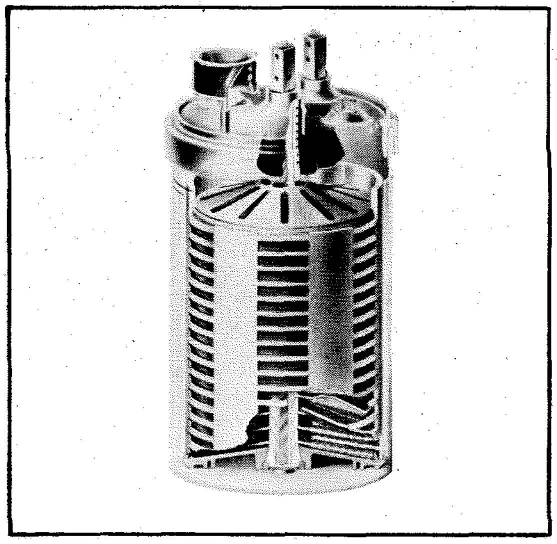
Engineering and Science

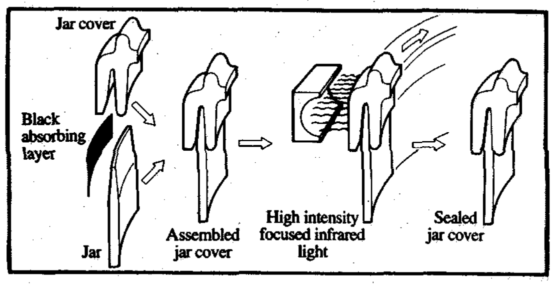


California Institute of Technology/March-April 1974

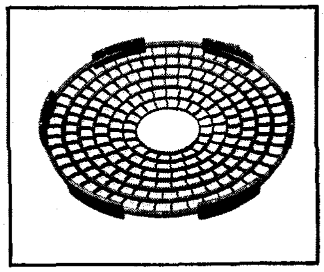
WESTERN ELECTRIC REPORTS



A cutaway view of the new lead-acid battery. For use in the Bell System, four types—each with a different ampere-hour capacity—will replace the 60 configurations currently in use over the same capacity range.



In the sealing process, focused infra-red light is absorbed in a carbon black coating at the jar-cover interface, causing localized melting of the plastic.



The positive grids are designed so that as corrosive growth occurs the space between hoops remains constant. Thus contact with the paste is maintained and electrical capacity actually increases with age as corrosion produces additional lead-dioxide material.

Developing a new lead-acid battery.

Every year, Bell System telephone companies spend over $30 million to buy and maintain the lead-acid batteries they use as intermediate sources of standby power during emergencies.

So they know just how susceptible all lead-acid batteries are to problems caused by corrosion. Problems such as gradual loss of capacity, short- circuits and cracking that could result in acid leaks and occasional fires.

That's why Bell Labs and Western Electric engineers recently undertook the first major improvements on what is essentially a 100-year-old design.

The result: a revolutionary, cylindrical lead-acid battery with a jar and cover fabricated from an improved flame-retardant, impact-resistant polyvinylchloride. The bond between jar and cover is leakproof due to a new infra-red sealing process.

Inside the battery are circular, cone-shaped grids cast of pure lead rather than a lead alloy, then stacked horizontally in a self-supporting structure. Positive grids are cast with large grain-size to minimize corrosion. They're then filled with a paste (tetrabasic lead sulfate) whose rod-like particles interlock for maximum mechanical stability.

These new features required new manufacturing techniques. For example, how could potential suppliers best mass-produce positive plates of the required grain-size and paste the grids rapidly and efficiently, given their conical shape and the new oxide material's crystal structure?

Western Electric's Purchased Product Engineering organization and Bell Labs set up a design capability line at a company subsidiary, Nassau Smelting & Refining.

Using machinery developed at Western Electric's Kearny Works, they refined production methods and materials that made it possible for a supplier to produce the new battery economically, in commercial quantities and to Bell System specifications.

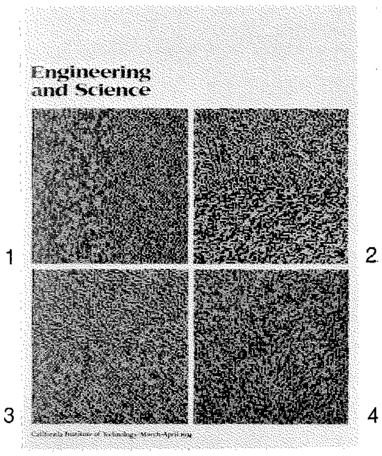
And Western Electric plans to achieve still further savings through a continuing cost-reduction program.

Conclusion: Close cooperation between Bell Labs and Western Electric has resulted in the creation of a superior lead-acid battery. Its expected useful lifetime is at least 30 years—double that of even its best predecessors. It lowers maintenance costs substantially. And its unusual design virtually eliminates the hazard of fire due to mechanical failure.

Western Electric

We make things that bring people closer.

In This Issue



Computerized Science

On the cover—four examples of the textures used in the studies of visual perception carried on in the laboratories of Derek Fender, professor of biology and applied science. Each of these patterns contains two textures generated by different rules. The boundary between them runs through the center and is either horizontal or vertical. Can you detect the orientation of each one? Your score may be better if you look at the patterns from some distance away. (If you're still stumped, the answers are on page 28.)

The *E&S* cover is, of course, more than a game; it is also one example of the kind of service a computer can perform to assist laboratory science. "Computer-Aided Research at Caltech" (page 4) describes Fender's work in more detail, and also that of several other Caltech scientists who are taking advantage of the increasing availability and sophistication of electronic information processing.

In a lot of ways there's really nothing very new about the concept. After all, the Chinese were using the abacus more than 2,000 years ago. But the pace of development of the instruments has certainly accelerated in the 25 years since the first electronic computer was devised. Caltech's Willis H. Booth Computing Center, dedicated just a little more than 10 years ago with two of 1963's most modern computers —an IBM 7090 and a 7040—has moved along with the times. It is now equipped with two late model computers—an IBM 370/158 and a DEC PDP-10—supported by a staff of 40 programmers, analysts, engineers, key-punch operators, and technicians providing computing services to the campus seven days a week.

In Memoriam

Fritz Zwicky, professor of astrophysics emeritus, died in Pasadena on February 8. On March 12 his colleagues and friends held a service at Caltech in his memory. Speakers included Robert Christy, vice president and provost; Robert Leighton, chairman of the Division of Physics, Mathematics and Astronomy, who read a paper prepared by Jesse L. Greenstein; George McRoberts, manager of the electro-acoustic program at Aerojet-General; and Albert G. Wilson (MS '42, PhD '47). "Remembering Zwicky" (page 15) is a selection from the tributes on that occasion —plus a revealing anecdote in Zwicky's own words from an unpublished interview by JPL historian R. Cargill Hall.

Contributions in memory of Dr. Zwicky may be made to the Fritz Zwicky Memorial Fund at the California Institute of Technology.

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Engineering and Science

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Computer-Aided Research at Caltech

One of the most exciting developments in the use of the computer is its application in the laboratory

At Caltech today computers are used in almost every facet of scientific research—to perform tedious mathematical calculations, to collate and catalog experimental results, to control laboratory experiments, to gather data, and to analyze the collected information. But the most exciting new development is in the use of computers in the laboratory.

The development of the mini-computer is probably the most significant addition to laboratory instrumentation since the oscilloscope. These machines are now commercially available, and a number of Caltech research groups own mini-computers, which are used to control experiments and to gather and sometimes also analyze data. The "minis" provide great flexibility and remarkable computing capacity at relatively low cost.

A timesharing system like the PDP-10 in Caltech's Booth Computing Center provides a useful addition to the mini-computer in some cases—and a convenient alternative in others. The expensive high-performance printers, card-readers, volume storage, and other peripherals of the time-sharing computer can be "attached" to a laboratory experiment or a mini-computer by telephone line or private cable. And the Booth Computing Center's powerful IBM 370/158 Batch Processor also becomes accessible to the laboratory via the PDP-10.

On the following pages are just a few Caltech research projects that use the big computers in the Booth Computing Center to directly support their laboratory instrumentation or their mini-computers.

The Gray Group

Harry Gray, professor of chemistry, and his group in Noyes Laboratory use a direct on-line link from their experimental setup to the PDP-10 to help them understand the mechanisms of biological electron transfer reactions.

Gray's approach to the question of electron transfer in biology is unique. As an inorganic chemist he is applying standard techniques of inorganic chemistry to a problem in biochemistry. Knowledge of the reactivity of simple metal ions is applied to the understanding of reactions involving more complex species such as the mitochondrial electron transfer protein cytochrome *c*. Cytochrome *c* reacts within a chain of closely coupled redox catalysts involved in the breakdown of carbohydrates by molecular oxygen.

The experiment is designed to measure changes in the amount of light absorbed by a solution of two rapidly mixed species undergoing a reaction. In addition to cytochrome *c* many other iron- and copper-containing metallo-enzymes are under investigation.

While the study of electron transfer is vitally important, it is also tedious. Rates of absorbance change must be calculated for a wide range of conditions, and the experiment must be performed repeatedly for each set of solutions. Before the advent of the computer in Gray's laboratory, the decay curves of these solutions were constructed by manually plotting one point after another, adjusting the results, and drawing a new graph. Now the PDP-10 collects the information directly from a data storage unit attached to the spectrophotometer recording the absorbance changes, does the necessary calculations, and automatically prints an adjusted plot on the laboratory console.

The Gray group is now able to handle a great deal more data at a much faster pace. And, while storage requirements once limited the speed of the reactions that were studied to tenths of a second, the group is now analyzing reactions as short as a thousandth of a second.

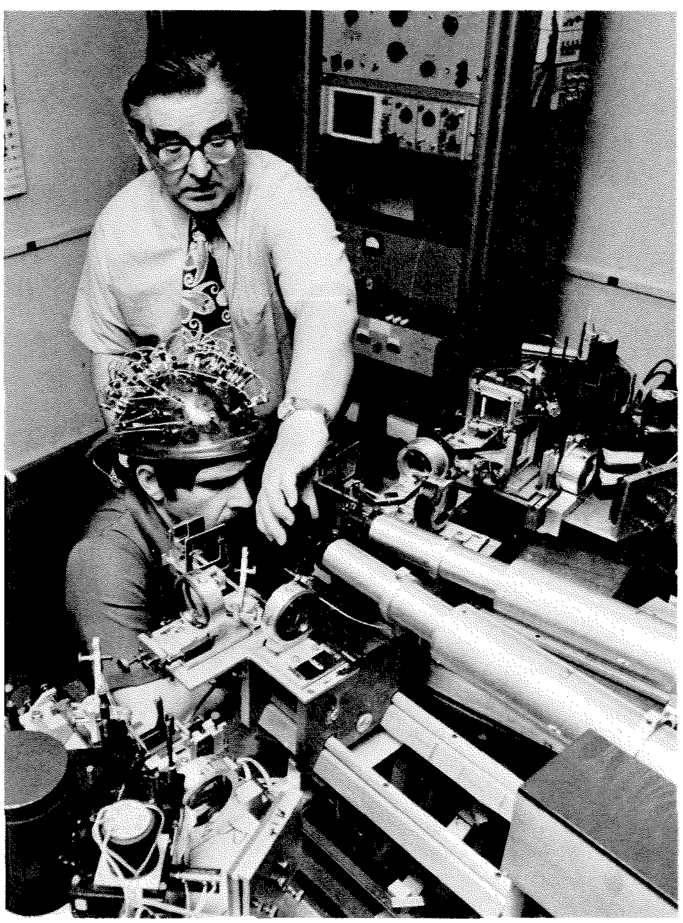
The console in Harry Gray's electron transfer laboratory is receiving reaction results calculated by the PDP-10 in Booth. With Gray are research fellows Bob Holwerda and Leslie Hodges, and graduate student Jim McArdle.

Derek Fender and Eye Movements

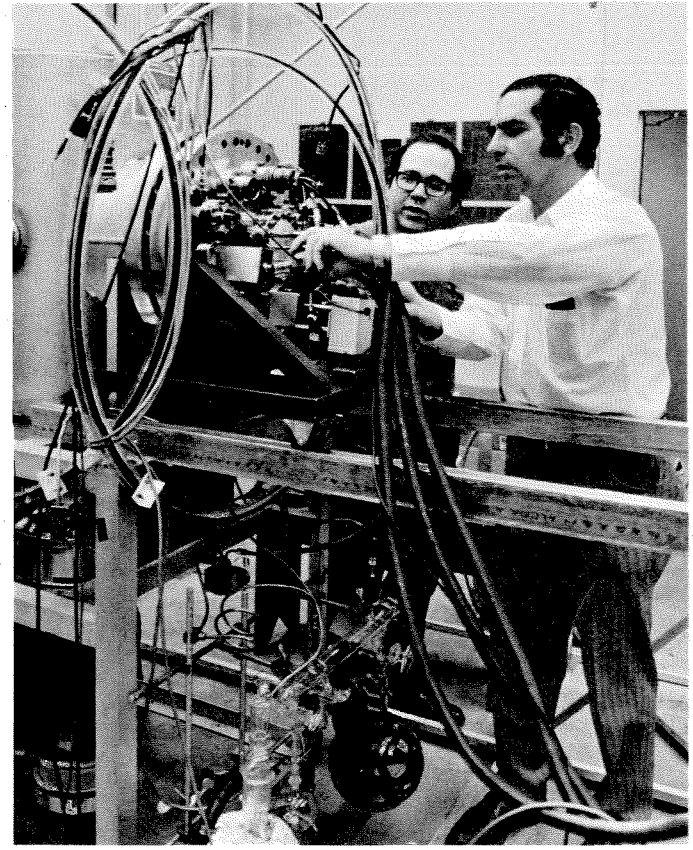
Derek Fender, professor of biology and applied science, has a different approach to computerization in his laboratory. In his studies of why and how the eye moves as it does, he uses a mini-computer both by itself and as an intermediary with the PDP-10.

In experiments on what causes the eye to focus on an object first detected by peripheral (side) vision, Fender uses a PDP-11 mini-computer to monitor a subject's eye movements. Graphs of this movement are kept on a regular basis. The subjects must quickly discriminate between nearly identical targets, separated by distances proportional to the level of visual sharpness being measured. The graphs show that in every case decisions are related to a very jerky motion of the eye called a saccade.

Fender's current experiments deal with the way the brain-eye visual system discriminates between objects of different texture. A random number generator in the 158 in Booth produces cards containing two distinct arrays of dots, each with a unique design. The subject's task is to decide where the boundary lies. The responses are recorded by Fender's mini and then passed on to the 158, which analyzes the data and relays back a new set of dots.



The apparatus Derek Fender is adjusting is used to work out the mapping of connections between the subject's retina and brain. It fixes an image on the retina (one that does not move, even if the subject moves), and the resultant activity in the brain is monitored by a special helmet, worn here by graduate student Tom Santoro.



Graduate student Don Mintz and Aron Kuppermann study the fundamental electronic structure of molecules with this variable-angle photoelectron spectrometer, which is directed by a PDP-8e mini-computer connected to Booth's PDP-10.

The problem posed is: What are the criteria for distinguishing textures between collections of dots of varying visual texture? Fender and the computer are working on it.

Kuppermann Research

With the assistance of a PDP-8e mini-computer and the PDP-10 in Booth, Aron Kuppermann, professor of chemical physics, is studying the fundamental electronic structure of molecules. He does this by shooting photons at the molecules, then measuring the energy of the ejected electrons over a range of detection angles.

Although the experiment is relatively simple, handling the data is not so easy. Hundreds of runs of the experiment are necessary to pick out the real signals from background, extraneous signals, or noise. Automation is almost mandatory, especially in the data reduction processes.

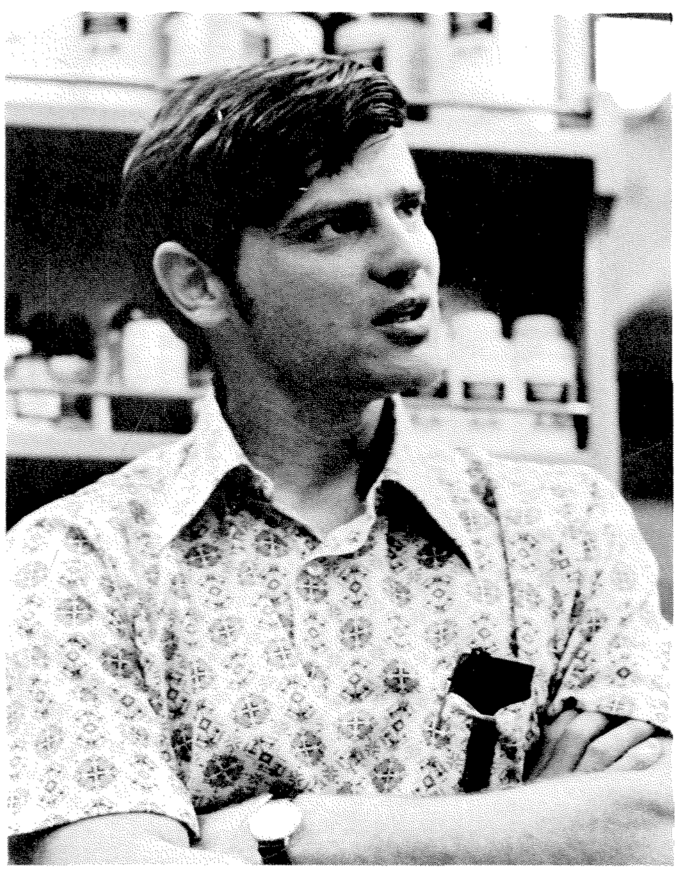
The principal apparatus used in this work is a variable-angle photoelectron spectrometer. The mini-computer functions as a link with this instrument. It receives and stores the already digitized data and issues control commands back to the spectrometer. The computer automatically scans a range of energies as the situation demands and also changes the angle of detection. A direct line with the PDP-10 is used to develop programs for the PDP-8e.

Dreyer, Hood, and Antibodies

William Dreyer, professor of biology, and Leroy Hood, associate professor of biology, in separate but similar research projects, are trying to find out exactly how cells synthesize antibodies.

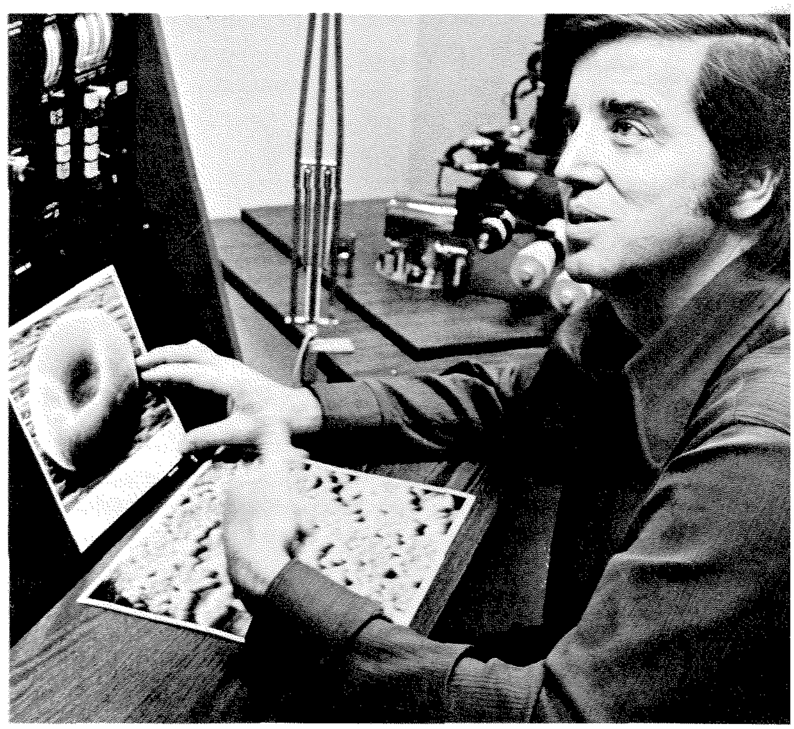
To understand how antibodies are created and how they attack disease organisms requires a complete understanding of the molecules themselves. But there are at least a million different kinds of antibody molecules. And each molecule is an extremely complex protein chain which must be perfectly made to accomplish its mission of annihilation. The phenomenal ordering process in the protein chains is analogous to perfect spelling: not only must each letter be correct, but it must appear in the proper place as well.

To simplify the problem, Hood and his group have concentrated on a special class of antibody proteins, the immunoglobulins, which are specifically responsible for providing immunity to diseases. The experiments of this group are directed toward determining the sequence and relative quantities of the amino acids that make up these proteins. An amino acid analyzer measures proteins as they are degraded in sequence by chemically separating off one acid at a time. Each run on the analyzer corresponds to a particular amino acid. An understanding of the entire chain involves comparing series of analyses.



The large number of molecules that are studied by Hood's group requires an automated system. Hood records the data with a PDP-8 mini-computer. These are stored on a magnetic tape and played into the PDP-10, where they are sifted and arranged into meaningful information. The results from each run are displayed either numerically or graphically by the computer.

Dreyer is now developing an automated mass spectrometer to do essentially the same research. In his experiments, data will be produced at a much faster rate, and the PDP-10 will be used to control and record the data until industry comes out with a mini-computer designed to operate the mass spectrometer.



Biologists Leroy Hood and William Dreyer, in separate but similar research projects, are trying to find out exactly how cells synthesize antibodies.

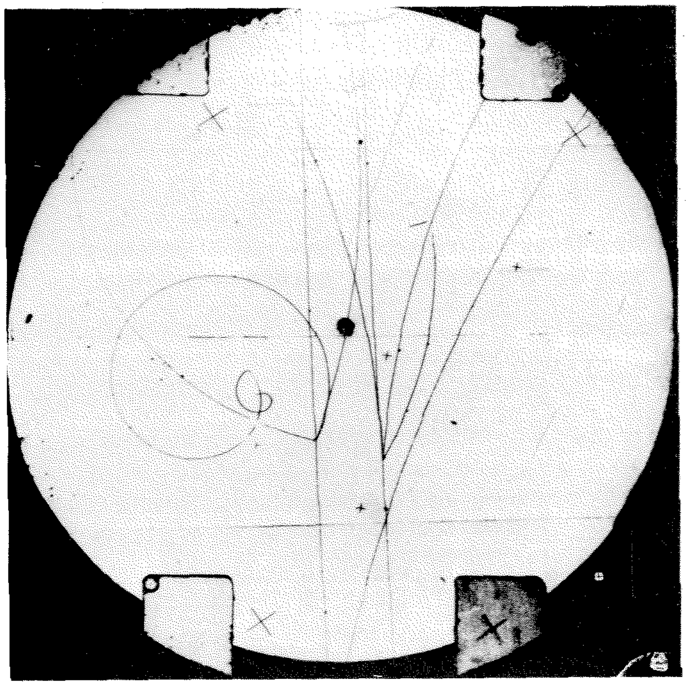
POLLY

A group of high-energy physicists are using the PDP-10 to control a film-measuring machine called POLLY. Their research is aimed at understanding the strongest force known, the one that binds the atomic nucleus together. POLLY's Caltech contingent, including Alex Dzierba, Charles Peck, Ricardo Gomez, and Alexander Firestone, is analyzing the results of experiments done two years ago at the Stanford Linear Accelerator Center.

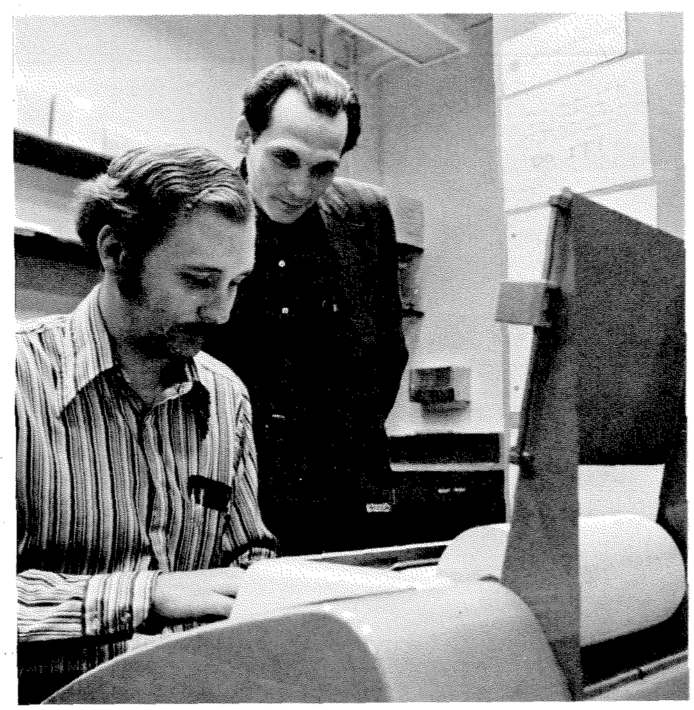
The goal of the research is to measure the diffraction dissociation of protons by pions. To do this, high-energy pions bombard protons in a bubble chamber. This device contains a highly compressed volume of liquid hydrogen. Just before the pions enter, a large piston retracts, allowing the hydrogen to expand and to become superheated in the process. The paths of the particles then show up as tracks of bubbles in the chamber.

During the experiment, three cameras, at different angles, simultaneously photograph the bubble chamber events on 70-millimeter film. POLLY's job is to measure the coordinates of bubbles on this film. From this information, the momenta of all the particles involved in a collision can be determined. The Caltech group, and their collaborators at UC Berkeley and Stanford, are now deciphering the information from more than a million pictures.

Each track must be measured rapidly and precisely. To satisfy this requirement, POLLY uses a complex computer-operated instrumentation system—in this case a PDP-11 mini-computer linked to Booth's PDP-10. An operator initiates the measurement of a track by pointing to it on an optical display of the picture. The computers then drive the spot on a precision cathode ray tube (CRT) so that its image falls on the film where the operator indicated. The CRT spot then executes a series of short sweeps, and, by observing where light is transmitted through the film, POLLY makes a precise measurement of one point on the track. The computers are programmed to make intelligent searches for other track points, so that, from a single, relatively crude, manual measurement, precise coordinates are quickly obtained along its full length. This is repeated for all tracks in an event, and finally, the computer's image of its track analysis is displayed on a terminal screen and compared with the original picture for accuracy and completeness.



An example of the type of picture being measured by POLLY, showing the materialization of particles from the energy of the incident pion. The pion beam enters from the bottom. Here, two of the incident pions have collided with protons in the bubble chamber and, in the process, two new charged particles have been created. In the event on the left, one of the outgoing pions has undergone radioactive decay, and the track shows an apparent sharp change in direction. By measuring the coordinates of points on these tracks with POLLY and the PDP-10, it is possible to determine the momentum of each particle. By studying many such events, physicists hope to learn more about the mysterious inner workings of the strongest interactions in nature.



Tom Garrard (PhD '72), staff scientist, and Edward Stone study some of the features of the program that controls communication between their mini-computer and the PDP-10.

Searching for relatively rare oxygen nuclei in cosmic rays, graduate student Solomon Vidor checks out a tape from the SRL library. Browsing in this library of 7,000 tapes is economically feasible only with the aid of mini-computers and the PDP-10.

The communications link between the two computers is such that the PDP-10 issues commands for the operations, the PDP-11 performs them, and then returns data to the PDP-10. The track measurements are eventually sent to UC Berkeley where three-dimensional stereo views are reconstructed from the data, and the momentum of each track deduced.

Space Radiation Laboratory

Caltech's Space Radiation Lab (SRL) is using the PDP-10 to display processed information collected over the past decade in numerous satellite and balloon-borne experiments.

SRL's current studies are based on information from five NASA-supported satellites orbiting the earth within half the distance of the moon. These high-flying laboratories were designed by physicists Ed Stone and Rochus Vogt to analyze the composition of solar and galactic cosmic rays.

The satellite data are received and stored on magnetic tapes by the Goddard Space Flight Center—and the tapes are eventually added to SRL's enormous tape library housed in the Downs-Lauritsen laboratories at Caltech. It is the volume of information on these tapes that prompted a link with the PDP-10.

Plans now call for the creation of a condensed, problem-oriented data library available for student use. For example, except during periods of solar flare activity the detection rate of oxygen nuclei in cosmic rays is very low. With the current setup, dozens of tapes must be sorted, and scattered data gathered, before calculations of any kind can be done. The condensed tapes will have all the necessary information in one place.

The link between SRL's mini-computer and the PDP-10 facilitates the display of information from this library.

—Gary Prohaska, '73

A Serious Chemist –with a Light Touch

Whatever the game–research, teaching, tennis, or tomfoolery– Harry Gray has always played to win

"Gray's Stable" in Noyes Lab isn't what it used to be. It's been almost a year now since Harry came back from a year's study in Europe, and nobody's been spraying his office with plastic cobwebs or stuffing it full of computer cards. Even Harry hasn't appeared in any costume more exotic than sport shirt and slacks. What's up? Well, everybody—and especially Harry Barkus Gray, professor of chemistry—is concentrating on research.

Of course, even in the heydey of the hijinks, plenty of hard work was going on. Whatever the game—research, teaching, tennis, bridge, Monopoly, or tomfoolery—Harry Gray has always played to win. And at 38, the list of his accolades reads like a what's what in chemistry: numerous awards (election to the National Academy of Sciences at a mere 35, the American Chemical Society Award in Pure Chemistry, and the Harrison Howe and Fresenius awards for research achievement, for example); ten books at the latest count (his publishers feted him with a special award four years ago when sales approached 100,000 copies); and more than 175 scientific papers. His energy, drive, zest—and accomplishments—are the envy and despair of a lot of his colleagues.

"If I knew what motivates him," says John Roberts, Institute Professor of Chemistry and no mean achiever himself, "I'd try to buy a quart."

Nevertheless, in the past a lot of Harry's high visibility on the campus has been due less to his 6′ 3″ height than to his ways of expressing his exuberance. His taste for fast cars, breezy language, and joyous conviviality are justly famous. For instance, his office was named "Gray's Stable" after he retaliated for a student prank by wearing a horse costume to one of his classes. And he was christened "Harry the Horse" at the same time. Once he imported a drum-beating Hari Krishna group to stir up a class full of sleepers. Not too long ago, bored with being a spectator, he impulsively jumped into the middle of the Mudeo with a Caltech coed on his shoulders. And more recently, when a group of belly dancers finished their act by offering instruction in the ancient art, who was the first volunteer to bound onto the floor?

Harry has been the butt of some outstanding student pranks too, most of which he's enjoyed as much as the students. For publication, his comment about finding his smiling face pasted onto a centerfold-nude photo slipped into several thousand of Caltech's current catalogs was a tongue-in-cheek, "I wish they'd used my body too."

The fact that students delight in hazing Harry is a measure of his rapport with them. "We work *with* him," say the students in his research group—"not *for* him." He has a straightforward way of making that relationship clear from the beginning. "Dr. Gray?" he says incredulously. "Call me Harry."

Informality is as much a part of Harry Gray's personality as his sense of humor—but it also serves a very basic purpose. "What I'm trying to do," he says, "is to teach more chemistry, to keep them coming back to class, to drill a little science into their heads."

Doing chemistry has been Harry's pleasure as well as his vocation for a long time. Deciding at age ten that the subject looked interesting, he promoted a shopping trip with his father for the materials to do some experiments he had in mind. After three or four weeks, he emerged from his basement lab and announced his intention to become a chemist. It is probably significant that nobody doubted him, though his mother admitted later that it was a little hard in those years to explain to his friends why Harry didn't come out and play.

Even then, Harry's energy and motivation belied the classic stereotypes of both "only child" and "Southerner" that he had a right to claim. There are a fair number of Gray kinfolk, but his immediate family consisted of his mother and father. And though his home state of Kentucky is usually referred to as a border state, Harry points out that Bowling Green, where he grew up, is in *southern* Kentucky. Being a Southerner may, in fact, account for some of his strongly competitive nature. "I hate to be anything but the best," he says, "and if you're from the South, people tend to assume that you're a little backward. So I learned early to try harder."

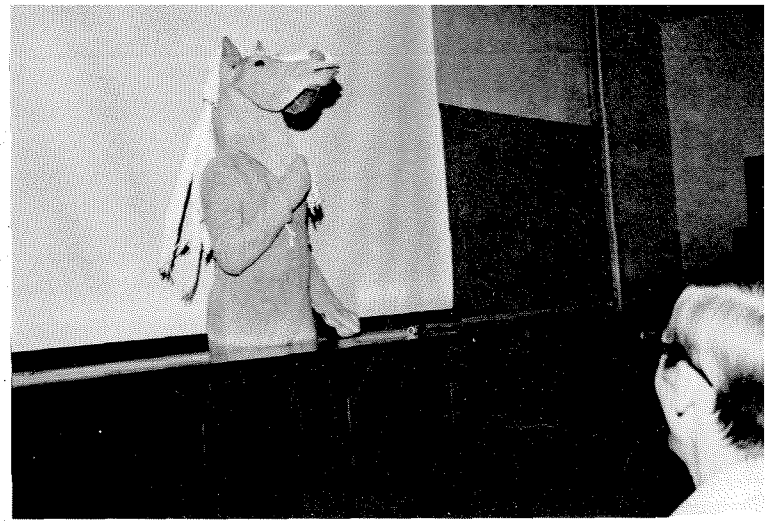
Trying could have sprung from other factors too. Myopic from birth, bantam-sized until late adolescence (he's still referred to as "little Harry Gray" in Bowling Green), and studious by choice, he worried about being accepted by his peers. Once, in the eighth grade, he deliberately flunked a test to remove the stigma of straight A's—and found the experience so painful that he worked twice as hard to make up for it.

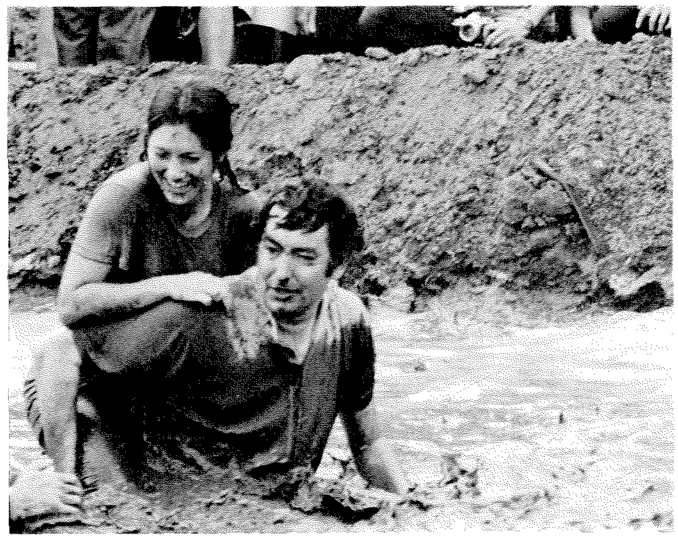
At age 11, Harry got a job as a newspaper carrier, and by the time he was 17, he was assistant circulation manager (and occasional sports writer) for a paper with a press run of about 20,000. His job entailed doing all the circulation accounting, handling subscriptions, dealing with customer complaints, and supervising the carriers. In addition to a daily 4-hour stint, he worked a straight 20- to 24-hour shift on weekends, during which time he had to assemble the Sunday paper—slipping the comics inside the magazine, the magazine into the social section, and so on until the whole edition was together. He was, he recalls with some pride, an expert at it.

He also became an expert at juggling his time. He held the newspaper job through high school and college, went to school, played tennis (he was college conference champion at age 19), and led an active social life. It all added up to a week of 60 or 70 hours of frenetic activity.

Harry is the first to point out that he couldn't have done it if Western Kentucky University, in which he enrolled in 1953, had been a really tough school. Fortunately for someone who had to earn his way, it wasn't "an academic crunch like Caltech," and—typically—Harry made a good thing of the situation. He graduated in 1957, second in his class, with three majors—chemistry, physics, and mathematics—and a surplus of credits. He also had some money in the bank, a scholarship, admission to the graduate school of his choice, and a fiancée.

Shirley Barnes was a mathematics major at WKU, and she finished college in three years in order to graduate (with honors) along with Harry. They were married that summer and set out for Illinois in the fall—Harry to do graduate work at Northwestern University and Shirley to teach mathematics in a Chicago school. Harry looks back on





Northwestern as a "terrific, fantastic place." The conjunction of its small, friendly graduate group in chemistry, the exciting things opening up in Harry's chosen field of inorganic chemistry, and the stimulation of two extraordinary professors—Fred Basolo and Ralph Pearson—added up to what he calls a lucky break for him.

Enthusiasm, ability, and the financial pressure of a growing family got Harry through graduate school in record time. In just three years he was able to take his new PhD, Shirley, and one-year-old Vicki to Copenhagen where as a National Science Foundation Postdoctoral Fellow he studied for a year with Dr. Carl J. Ballhausen.

In 1961, the Grays—now including Andrew—returned to the United States and a teaching job at Columbia University. In the next five years Harry made both a place and a name for himself there. At the age of 29, in 1965 he became the youngest full professor in the 200-year history of the university, and when he left in 1966 to come to Caltech, the student newspaper announced his departure in a black-bordered story.

Harry still feels some compunctions about the rightness of his decision to leave Columbia. ("They took me in when I didn't have any reputation.") But he also recognizes that Caltech was much the best place for his scientific progress. In those terms, he says, the move has paid off beyond his wildest dreams.

Harry Gray's dream for the eventual outcome of his research is to understand completely how at least one catalytic process in nature works—and then design a better one with simpler chemicals. Chemistry in general, he believes, should try to put itself in a position to improve on nature.

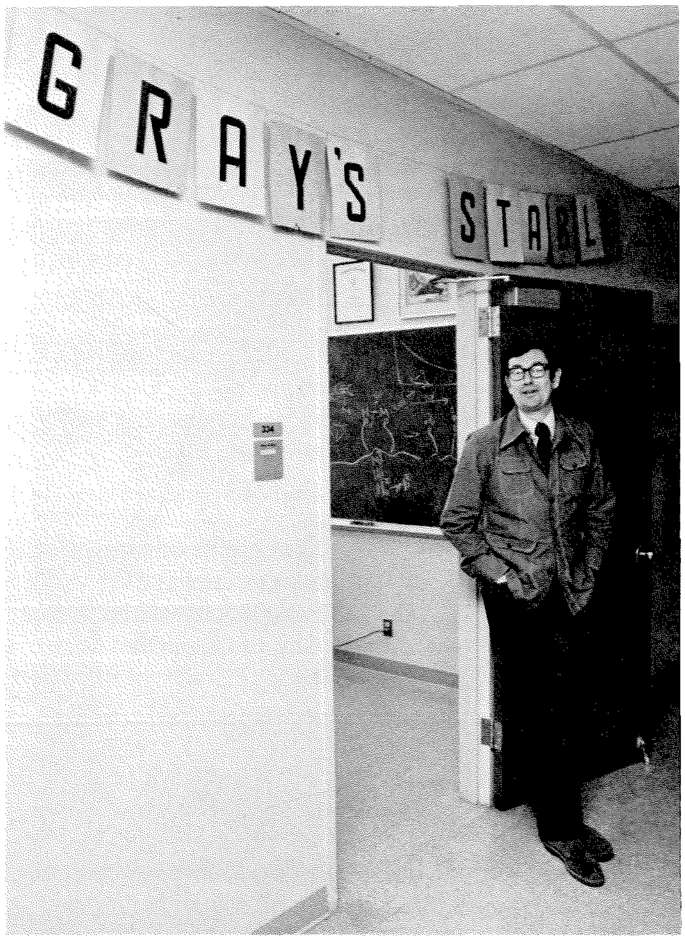
He began his part of this grand design as a graduate student, studying the reaction mechanisms of such transition metals as platinum, palladium, and gold. This research has now become the authoritative work in the field. In fact, at a research conference recently, he asked to have a point clarified and was rather briskly referred to the "classic" literature on the subject—his own.

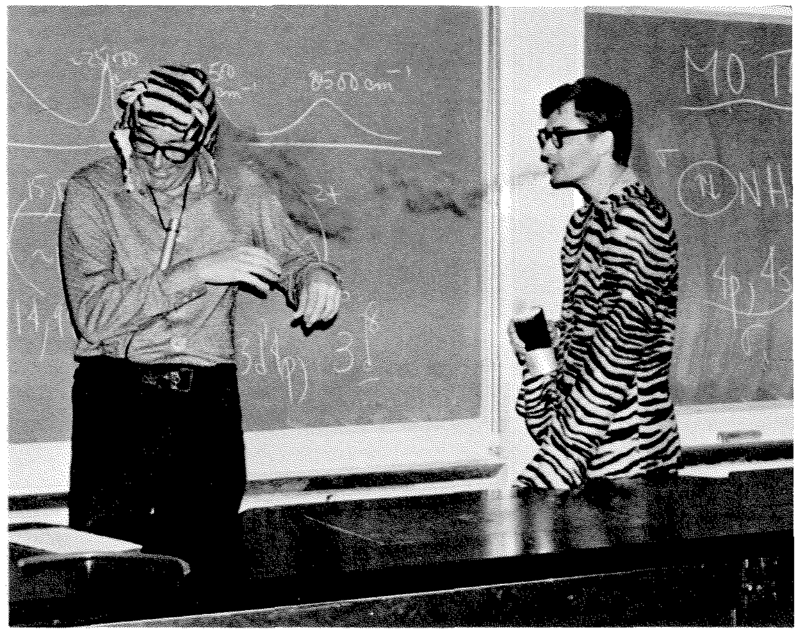
In his postdoctoral year at Copenhagen and later at Columbia, Harry dug more deeply into the theoretical aspects of transition metal chemistry by working out the quantum mechanical descriptions of the electronic structures of a number of these metals and metal-containing compounds. And he developed a method for doing the necessary calculations that is still in use.

His other work at Columbia involved the investigation of compounds containing transition metals bonded to sulfur atoms. In trying to understand their reactions and electronic arrangements, he and his group designed a whole new class of molecules with metal atoms carrying charges that do not exist in nature—and thus synthesized materials with properties that do not occur naturally.

This was all basic research, and the manufactured molecules were pretty much curiosities. Harry was happy to be able to predict that these new electron arrangements could be made—and then make them—but he had no idea that any part of it would ever have practical applications. In the serendipitous way that basic research has often been transmuted into applied science, however, his discoveries may become the basis for new technology. Some of the transition metals that are naturally either too reactive or too inert to be used in the body for cancer therapy are being tested now in the intermediate forms that he and his group developed. And a recent physics seminar seriously discussed the possibility of using his synthetic materials for raising the temperature of superconductors.

Harry's philosophy for choosing his research emphasis has always been based less on what to do next than on what to stop doing. This attitude was particularly appropriate when he decided to come to Caltech in 1966. By then, he





What I'm trying to do is teach more chemistry, to keep them coming back to class, to drill a little science into their heads

felt that he had contributed most of what he had to offer in the chemistry of simple transition metal compounds, and it seemed a natural time to shift directions. He disclaims ever having abandoned thinking about those problems, though. In fact, he still has one group of students who are working on the electronic structures of inorganic compounds. But two new research problems have claimed most of his attention at the Institute: (1) How metals function in the proteins of living systems (metallo-enzyme catalysis), and (2) What happens to transition metal compounds when light is shined on them.

The first of these research areas is described as biological inorganic chemistry, which may sound like a contradiction in terms. But some of the best examples of efficient chemical reactions occur in biological systems—in the naturally occurring complexes of the transition metals. Harry and his group are trying to find out what is the role of metals (chiefly iron and copper) in large protein molecules and why these molecules are so important in nature.

More specifically, Gray's group is working to discover the mechanisms by which energy is stored to run biological systems. The fixation reduction of oxygen, for example, is one of the most important problems for chemistry to solve, and the group is attacking it by trying to understand the reactions of metals with oxygen in living systems. In the body, for instance, oxygen is picked up in the lungs by an iron protein—hemoglobin—and carried to another iron protein—myoglobin—in the muscles. The myoglobin delivers the oxygen to a third iron protein—cytochrome oxidase—where it reacts with electrons passed down another elaborate chain of proteins from the ingestion of food. The result is the reduction of the oxygen to water and the storage of energy in key molecules in the body's cells. What Harry is trying for is to understand this efficient molecular engine—and then improve on it.

The second aspect of Harry's current work has to do with photochemistry: adding one new ingredient—light—to transition metal compounds to make them more reactive. At present, energizing a catalytic reaction often involves using a lot of heat and high pressure; Gray's group hopes to be able to substitute light—possibly sunlight—for part of those requirements. The results have been encouraging; they can do several kinds of reactions that can't be done any other way.

The photochemical project is now at about the same point that Harry's first work was 15 years ago, with, he feels, even more potential for great impact in the next two decades. Certainly converting light into other kinds of energy is relevant to today's problems. And the work is not too divorced from that of the metallo-enzyme group either, because plants that contain iron and copper can absorb light and convert it by photosynthesis. So the Gray biological and photochemistry groups may eventually merge, and then perhaps complete the circle back to inorganic chemistry and the simple transition metals. "Once back to GO with our new understanding," says Harry, "maybe we can redesign the catalysts."

Understanding the special role of metal ions in chemistry is the thread that has run all through his work, and in that sense he has worked on one problem for 15 years.

Harry hasn't confined his experimentation to the laboratories at Caltech; he's also logged a lot of classroom time. Between 1966 and 1969 he and George Hammond, former chairman of the Division of Chemistry and Chemical Engineering, made a valiant and time-consuming attempt to restructure the chemistry curriculum. It turned out to be a larger bite than they should have tried to chew.

In the first place, their ideas were fairly extreme; and in the second, too much of the implementation depended on the two of them—their colleagues mostly reacting with a mixture of interest in the logic of the concept and doubt of the wisdom of the pedagogy. Students were wildly enthusiastic, though possibly as much because of the personalities of the professors as the content of the ideas. It might have been wiser to propose small changes in the existing courses, but the two crusaders thought that would be a sellout. Harry is philosophical about it now. "Even though all that effort resulted in almost imperceptible changes," he says, "I've never regretted any part of it. If you have a lot of what you think are brilliant ideas, you might as well face it—you're going to have to do most of the hard work yourself, and that's impossible if your scope is too broad. In terms of our 1966 goals, we blew it; but as I look at it now, I see that we got the most we could have hoped for—we stirred people up to think about what they were doing."

The impact of the effort was not by any means lost on the wider educational world either. In 1972 Harry, age 36, was the youngest person ever to receive the Manufacturing Chemists Association award for teaching college chemistry.

His temperate attitude about the possibility of being on the wrong track now and then is part of the maturing Harry feels he's doing these days. He still gives everything he has to following out his own creative ideas, but he tries to be scientifically honest about admitting the validity of contrary evidence.

This is important to him in aspects of his life other than the scientific. For example, he doesn't want to be known as a driver of fast cars any more. The simplicity of his car-free life in Europe last year impressed him so much that he is thinking about moving within walking distance of the campus. Since he often puts in a seven-day week—being constitutionally unable to pigeonhole Friday's ideas until Monday—he could thus spend time at home with his family more easily. The family, which now includes 18-month-old Noah, is a very high-priority item on his agenda.

Another high-priority item—for approximately the next ten years, Harry estimates—is time for concentrated work on research. He feels the need for long quiet periods to study problems from all angles, and he has deliberately cut the size of his research group so that he can give more attention to each of his students. The way he helps them most, they say, is in developing the strategy to attack a research problem, though he leaves it up to them to initiate the investigation and work out the details. But, one graduate student says, "Harry's so full of ideas these days, we practically have to use a filter to figure out which ones will be useful to us."

Since his research group is divided into three sections, Harry probably has to use a filter too—to shut out distractions and concentrate on the student or problem at hand. But he's pretty good at it. And if he is outwardly happy-go-lucky, he is also something of a perfectionist. No sloppy work, no loosely written paper, no incompletely thought-out conclusions—his own or his students'—get past him.

Harry Gray imparts a light touch to chemistry, but no one should assume that he is not also deadly serious about it. In this game, too, he plays to win. If "Gray's Stable" is not what it once was, it is, nevertheless, what Harry wants it to be.

—*Jacquelyn Bonner*

Remembering Zwicky

Fritz Zwicky–Scientific Eagle

An active and extraordinary scientist, still full of ideas and personal drive, Fritz Zwicky, professor of astrophysics emeritus, died suddenly on February 8. It is difficult to write a brief, conventional memoir about so unconventional a man. Fritz classified scientists into two categories, eagles and low-fliers; a low-flier like myself recognized clearly that Fritz was the high-flier. He pursued an extraordinary range of personal interests: international charities, city-planning, mountain climbing, new explosives, exploding stars, crystals and dying stars, and, especially galaxies. He always saw the Universe in his own original way; he loved the extraordinary objects it contained, and he explained them in his own fashion, sometimes wrong but never dull. He leaves, after nearly 50 years at Caltech, many loyal friends, scientists and public figures; his wife since 1947, Anna Margaritha; daughters Margrit and Barbara (of Berne and Pasadena) and a married daughter, Franziska Pfenninger (of Zurich).

Born in Varna, Bulgaria, a Swiss national all his life, he received his PhD from the Federal Institute of Technology in Zurich in 1922. He came to work at Caltech on the theoretical physics of crystals as a research fellow of the (Rockefeller) International Education Board, served as assistant and then associate professor of physics 1927-1941, and became a professor of astrophysics in 1942. He was a member of the staff of the Mount Wilson and Palomar Observatories till his retirement in 1968, and a pioneer observer on Palomar where he realized the importance of, and exploited, the wide-angle schmidt telescopes for discovery of unusual types of stars and galaxies.

Caltech graduates will remember his course in Analytical Mechanics, required for the PhD in physics.* Astronomers

*See *E&S*, February 1974, p. 29. I can vouch for a further part of the story—explosive events occurring in the Registrar's Office when Fritz wished to record his first perfect grade for a non-existent student.

He climbed many scientific mountains, some with great success, many for the first time

will remember his advanced seminar, which covered the Universe and admitted "only students, assistants, faculty and visiting research personnel . . . who have the time, inclination and ability to engage in active, constructive work. . . . " Faculty wives and secretaries will remember his charitable activities, including an annual display in our board room of children's knitwear destined for schools for war-orphaned children. Although Zwicky had few formal students in later years, he retained a strong influence on recent scientific developments.

He became one of the founders (with Theodore von Karman, Clark Millikan, and others) of Aerojet Engineering, where he served as director of research 1943-49; he was research consultant at Aerojet-General and Hycon till 1960. He held many patents on unusual concepts and devices in jet propulsion—air, water, and earth-borne. When he visited Japan and Germany for the U.S. Air Force, his strong interest in human causes led him to individual acts of charity long remembered. He had a strong interest in the Pestalozzi Foundation, was trustee and president of the American branch, and received its gold medal in 1955. He organized a lengthy project for reconstruction of war-stricken libraries; for years I struggled with Zwicky (always an administrator-baiter) to remove the many tons of books on their way to the Orient or Europe. For many technical services, and for his good works, he received the Medal for Freedom in 1949 from President Truman.

He was awarded the Gold Medal of the Royal Astronomical Society in 1973 for "his many distinguished contributions to the understanding of the constituents of the Galaxy and the Universe." The medal carries the motto *Quicquid Nitet Notandum* [Whatever shines is to be noticed], a phrase peculiarly suited to Zwicky's approach to astronomy. Zwicky's response was equally apt—"I heard as a boy that there will always be an England, a place where debatable gentlemen will be recognized. I hope you have not made a mistake this time."

Zwicky wrote over 300 articles, 10 books, and held 25 patents. From 1933 on he had a philosophical interest in morphological research, a systematic approach to science and technology; he was founder and president of the Society for Morphological Research, and recently a Zwicky Foundation was established in Glarus. He had a strong classical background in thermodynamics and statistical physics. These two threads, combined with a strong personality and bold mind, led him to contribute to astrophysics in a unique way. Lacking the repressions of many, he felt that if a "morphological box"—i.e., a possibility—existed, nature would have filled it and scientists should discover it. This characteristic pattern is found in many of his fields of study.

From 1921 to 1937 he studied secondary structure in crystals, cooperative phenomena, and the theory of cosmic rays; by 1928 he was interested in, and doubtful about, relativity; in 1934 he cooperated with Walter Baade of the Mount Wilson Observatory staff in the discovery of supernovae. He attempted to explain them as a collapse to the neutron-star state (1934), and as producing cosmic rays (1934). Both the discovery of the supernovae and the theoretical links to neutron stars (only two years after the neutron was discovered) are extraordinary feats. A supernova explosion releases energy close to what the sun radiates in 10^{10} years! Neutron-star physics was, in fact, put on a sound theoretical basis by 1937 by Oppenheimer and Volkoff. And rotating neutron stars probably do accelerate cosmic rays; the Baade-Zwicky mechanism used electrostatic fields. With many collaborators, Zwicky started a supernova patrol which discovered most of those now known, finding 100 himself. Baade and Rudolph Minkowski explored and classified their spectra, still an active topic of study and debate. Zwicky carried the idea of collapse under gravity much further, contemplating "pygmy stars" (which do not exist) and "object Hades" (black holes, which probably do exist). Several threads of his work thus appear—interest in extreme types of objects; speculative, approximate theory based largely on classical models; and willingness to undertake systematic, very large, and long observing programs.

In studies of galaxies, which he began in 1929 with a note on the possibility of a gravitational drag on light, Zwicky combined a serious devotion to discovery and cataloging their properties with criticism of the expanding universe theory. He was constructively concerned about the applicability of the conventional definition of a galaxy as a large, closed system of a hundred billion stars—why not a billion or a million or ten stars? Why should not very dense galaxies exist? Could they be found? Look with the schmidt telescope! He studied interacting galaxies of strange shape, the forms of clusters of galaxies, searched for intergalactic matter and intergalactic stars.

One important result was the six-volume catalog of galaxies and clusters of galaxies, prepared with collaborators, which will be of permanent importance to extragalactic astronomy. The "compact"—i.e., relatively dense, high-surface brightness—galaxies have become of special importance with the discovery by Sandage, Schmidt, and others of the quasars, and of their large redshift; Zwicky made lists of compact galaxies, published a large, useful catalog, and had another in preparation.

Violent events in the nuclei of galaxies (which may vary in light in a few days) and explosive phenomena in Seyfert nuclei have been a major concern of astronomers and observers of the last decade. The trend of recent studies of galactic nuclei has been to reinforce our knowledge of high-energy events of still mysterious nature. It is clear that Zwicky's intuition of the importance of implosion-explosion events was a valuable one. In a sense he was a pioneer of high-energy astrophysics. The strange shapes of interacting galaxies interested Zwicky in his search for intergalactic matter. Here, the recent discovery of X-rays from clusters of galaxies suggests that he had an early insight into still another important field.

With Milton Humason, he found the first "faint blue stars," 48 hot objects far from the galactic plane—objects on which I have worked, with pleasure, for many years. Closer to home, Zwicky was interested in research in space by 1946; he attempted to launch artificial meteors from a rocket, and claimed to have shot the first object out of the gravitational field of the earth; he helped found the International Academy of Astronautics and lectured on legal problems of the use of space.

Zwicky, as a young man, was a good mountain climber. He was an extraordinarily live person. He climbed many scientific mountains, some with great success, many for the first time.

—Jesse L. Greenstein
Lee A. DuBridge Professor of Astrophysics

Zwicky: Humanist and Philosopher

The great majority of Fritz Zwicky's publications were in the field of astronomy. Most of the remainder were about his researches in solid state physics and jet propulsion technology. But Zwicky himself always felt that his greatest contributions were in philosophy, specifically in epistemology—in the development of new methods of thought and action. He wrote in 1971: "I feel that I have finally found the philosopher's stone in what I call the *morphological outlook and method.*"

Giving us an insight into how he came to feel this way, Zwicky said in addressing the Pestalozzi Foundation of America, of which he served as president of the board of trustees: "After pursuing a dozen or so various activities ranging from mountain climbing and professional shorthand to physics, astronomy, engineering, languages, higher education, national and international politics, and mutual aid with fair success, I still did not feel satisfied. . . . It was difficult to account for the lack of satisfaction until it occurred to me . . . that no stereotype activity in the books of the past corresponds to my personal genius. Its nature is such that it could become fully alive only through the creation of a new profession—the morphologist."

This is not the occasion to review the details of the morphological method. Suffice it to say that the morphological approach sought to be integrative, systematic, and trans-scientific, pushing consciousness to the limits of the conceivable. Zwicky believed that if only we could free ourselves from our pedestrian patterns of thought and learn to think morphologically, the future could be shaped by our images—however bold—rather than by the inertias of existing institutions and investments. For Zwicky, the really revolutionary paradigm of morphology consisted in the replacement of *one* solution by *all* solutions, *one* path by *all* paths, *one* system by *all* systems. Only after the complete spectrum of possible solutions, theories, or systems is developed can the full energies of their mutual tensions become available to us.

Zwicky's "method of morphological construction" passed William James's test for great innovative ideas: "First the new idea is mocked as ridiculous and absurd, then it is admitted to be valid but overrated and of no particular significance, finally it is decided that the idea had been known long ago and that everybody had thought of it himself." So it was with morphology.

Zwicky possessed that necessary concomitant of greatness, the generation in others of a strong positive or negative response. Very few people were merely indifferent to him. His evocation of bi-modal responses was in part due to his phenomenal percipience. Those who see further or deeper are not universally admired.

Another cause was Zwicky's frequent distrust of those in the upper echelons: "Unfortunately many people, and in particular professional men, are impressed only by specific accomplishments in science, engineering, finance, politics and so on, which lead to fame or to material and spiritual 'success' of one kind or another. Such men are a great obstacle to humanity in its march toward the realization of its inherent genius."

Zwicky felt that it was important to unhorse the pompous. He felt that all professors and executives should stay in touch with reality by periodically cleaning the wash rooms. He set the example by doing this himself. It would please Zwicky to say that "that bastard Chairman Mao" stole this aspect of the cultural revolution from him.

One of Zwicky's humanitarian activities was his organization of the Committee for Aid to War-Stricken Scientific Libraries. In order to establish closer scientific human relations, together with a small handful of volunteer assistants, Zwicky collected and distributed over a million dollars worth of scientific periodicals and books, sending them to university and other libraries that had been destroyed in the war—first to allied countries, later to former enemy countries. Zwicky devoted his weekends for several years to this task, personally carrying the heavy cartons of journals, cataloging, wrapping, and mailing.

But Zwicky had a second purpose in mind in organizing the Library Aid Committee. He said, "A common supposition is that activities of this kind require for their successful realization large organizations and considerable funds." Zwicky wanted to disprove this. He felt that the revitalization of democracy depended on "more initiative on the part of every individual as such." The book project was completed "without recourse to any funds except for a few dollars for wrapping paper, a card index, and some expenses for driving a car for the purposes of collecting the material."

Zwicky's point was that there are enough men and women of good will to make such projects a success if only they are pushed with determination. Availability of funds is not a prerequisite. He felt that such projects as the book distribution do more for establishing ties of confidence between different nations and races than can be achieved by speechmaking, legislation, or high-sounding efforts at international cooperation.

Zwicky was concerned with a second type of energy crisis, the drying up of spiritual energy: "There exists today no subject which would excite the imagination of men in a positive way, stimulating a constructive and happy life. The universal appeals of religion, art, political freedom, and science have faded to the vanishing point."

Zwicky's perception of the collapse of imaging power and its import for the Western World came two decades before other futurists finally woke up to its significance. In 1946, he wrote: "The world of today is in a state of disorder which is in conspicuous contrast to the avowed purposes of man . . . the teachings of science, of education, and of religion seem to have become lost in an elaborate system of hypocrisy in which there is little relation between words and actions."

This was one of the earliest recognitions of the corruption of our culture through the distortion of language.

If a single theme dominates Zwicky's humanistic writings, it is the importance of unfettered individual creativity and effort. This viewpoint may not be shared by those who feel everything worthwhile that remains to be discovered or developed will require sizable federal appropriations. Zwicky briefly went the grant and contract route but decided that the loss of the essence of creativity that was implicit in the federal funding system precluded its ever leading to any really basic discoveries. He returned to his original premise: The world's hopes lie in individual free agents, men and women of good will who can come together and work when the need be, but who form no permanent organizations or institutions.

One might wonder why a person of Zwicky's creative stature never attracted large numbers of followers. Discipleship was inconsistent with Zwicky's basic views. He held that everyone was a genius and that each person's life task was to find his own genius, not to follow some other genius. "Most individuals just never seem to realize that they possess unique potentialities and capabilities not to be matched by anybody else and that the penalty for not realizing one's genius is frustration and unhappiness."

Our present civilization is built on, and for, only a few types of geniuses. This is why so many are frustrated and unhappy. This malignancy will remain at the core of society until some way is found of restructuring so as to allow each person to discover his own innate genius.

Whether Zwicky's genius was to hear the beat of different drummers or whether it was the acuity to hear the fainter drummings of the same cosmic drummer that we all hear in part, his passing removes from our midst a creative source of great originality. With his departure the world becomes more homogenized and more mediocre; humankind loses a portion of its freedom and its dignity.

All who knew Zwicky would agree in the appropriateness of applying to him that eloquent eulogy first uttered by Winston Churchill on learning of the death of Rupert Brooke, which was later used at Churchill's own funeral: Certainly, *we shall not see his like again*, and these are times when this world has a desperate need for Zwicky's particular type of genius.

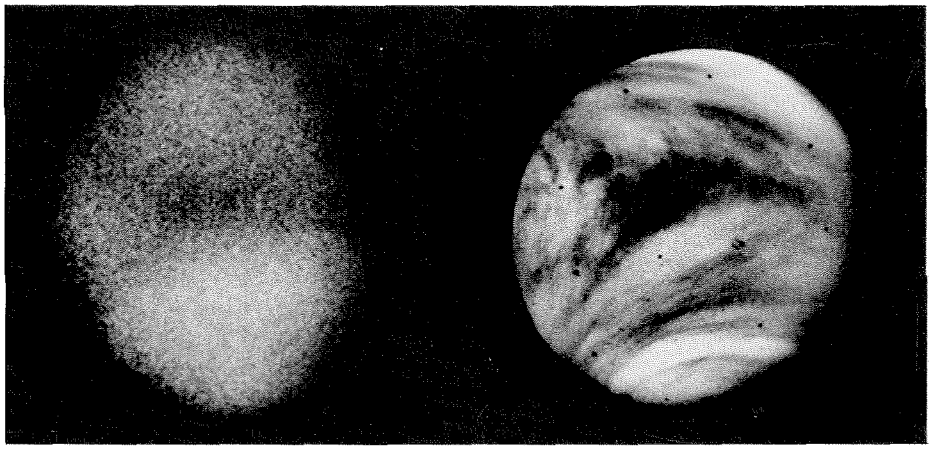
—Albert G. Wilson
Director
Society for Morphological Research

Zwicky on Zwicky

Theodore von Karman was not only a brilliant scientist; he was also a man who knew his Zwicky, as indicated in this brief excerpt from a 1971 interview with Zwicky by R. Cargill Hall, historian at the Jet Propulsion Laboratory.

I think I was instrumental in talking Millikan into getting Von Karman here permanently in 1931-32 or so, and we were really old friends. In all my attempts to get physics over into astronomy, engineering over into astronomy, and so on, he supported me heavily. While he was Director of the Scientific Advisory Board on the Air Force (on my standing with my colleagues I would have never been on that), he insisted that I too should be on it. So, he pushed that through, and I am indebted to him for that, and also later on for having pushed me into the International Academy of Astronautics, and so on. And it would have been quite impossible if all the hierarchy in power would have had their say, because they can not really admit a non-conformist like myself. On the other hand, he had his little jokes with me. He thought I was treating people too abruptly, too roughly, and it would be better not to be that rough; but to commemorate this abrasiveness, he said, "Now we have an occasion to get you into history, and we must devise a unit for the roughness of airplane wings, the surfaces of missiles, and so on. The proper thing will be to name this unit a Zwicky." But then on second thought, he said, "There is no such thing as a whole Zwicky except you—that's far too excessive—so the practical unit will be a micro-Zwicky!"

Payoff from Venus



The ultraviolet markings in the atmosphere of Venus present a dramatically different appearance as seen from an Earth-based telescope (left) and from Mariner 10.

As Mariner 10 flew by Venus at a distance of 453,000 miles, it snapped this picture of the entire planet, computer-enhanced here to bring out the details.

For Bruce Murray, professor of planetary science, and for his co-workers in the Space Photography Laboratory and at Caltech's Jet Propulsion Laboratory, the more than 3,000 close-up photographs of Venus taken by Mariner 10 in February represent the payoff on a long-shot gamble. The emphasis early in the U.S. space program was on radio probing of Venus rather than photographic reconnaissance, so it was a gamble he almost didn't have a chance to take.

The reluctance of the National Aeronautics and Space Administration to commit a spacecraft to a photographic mission to Venus is understandable, for Venus is obscured by an atmosphere almost 100 times as dense as Earth's. In the early 1960's even the best Earth-based pictures of the planet revealed practically no detail in visible light; however, faint markings were discernible when Venus was photographed in ultraviolet light. There was considerable controversy over the nature of these markings—whether they were signs of large-scale atmospheric activity, atmospheric waves, or just chance groupings of stratospheric clouds with no significance at all.

Murray became convinced about that same time that the markings were significant, and he tried twice to get photographic experiments aboard Venus probes before finally succeeding with the 1973 Mercury-Venus flyby. The first time was in 1964 on Mariner 5, which was originally designed as a photographic spacecraft. But NASA decided to remove the television cameras and related equipment to make room for another experiment.

Murray's second attempt came in late 1967, when NASA was considering redesigning a Mariner-Mars spacecraft for a flight to Mercury via Venus in 1970. But this mission had to compete for funding with the 1971 Mars orbiter and was eventually passed over.

Finally, the current Mercury-Venus flyby was approved, and Murray, as head of the television experiment team, talked NASA into altering the cameras to photograph in the invisible ultraviolet region of the spectrum on the chance that the faint Venusian cloud markings were a significant and relatively stable phenomenon. Furthermore, he persuaded them to make changes in the spacecraft radio system so that thousands, not hundreds, of pictures could be returned, resulting in recording the time variation of the atmosphere.

Murray's expectations as to the scientific importance of the markings seem to be verified. The markings are stable and recurring and may be caused by clouds moving high in Venus's atmosphere, where the pressure is 10 to 20 percent that of Earth. The patterns are unlike those of Earth. It is exactly these differences (plus a few similarities) that excite Murray and his fellow Venus-watchers. What will interest them even more will be finding out why the features show up only in ultraviolet light; nothing but a haze appears under normal light.

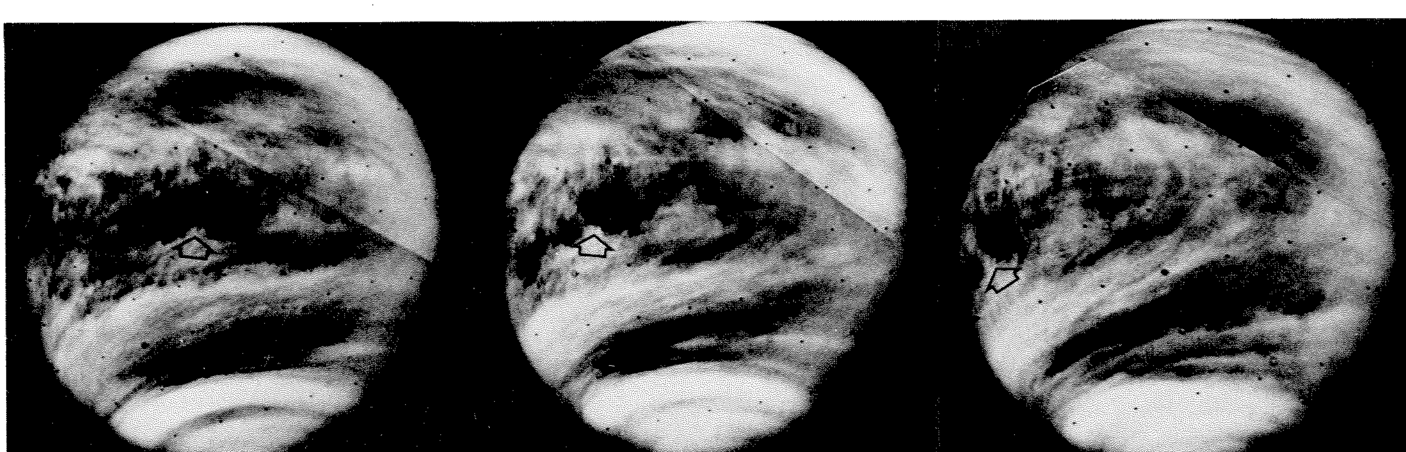
One member of the television team, Verner E. Suomi, a meteorologist from the University of Wisconsin and a visiting professor of atmospheric sciences at Caltech, has speculated that the clouds are formed from streams of hot air that spiral out from the equator, move in flat layers toward the planet's north and south poles, and then sink to the surface. Suomi feels that, oddly enough, these cloud patterns resemble those of a theory of atmospheric circulation first suggested in 1735 by the British meteorologist George Hadley to explain phenomena observed on Earth. However, Earth rotates too fast to produce the simple cloud patterns he predicted, but Venus, which rotates just about once every 243 days, demonstrates Hadley's ideas to perfection.

"Hadley's theory was correct," says Suomi. "He just had the wrong planet."

The detail seen in the ultraviolet photographs probably occurs only in the upper 3 to 4 miles of Venus's 40-mile-thick atmosphere, and there is no direct way of telling from photographs what is going on underneath. However, it seems unlikely that there are any Earth-like storms in the Venusian atmosphere.

Instead of towering clouds that hover over the surface, Venus seems to be blanketed with smooth cloud layers covered with haze. Features seen from Earth as bands, or streaks, are revealed by Mariner 10's ultraviolet television cameras to have the wispy, elongated quality of terrestrial cirrus clouds. They probably circulate above the planet at about 200 miles an hour and in the same direction as the planet but much faster.

The results of an infrared radiometer experiment designed and built by Guido Münch, professor of astronomy, confirm that the massive Venusian atmosphere stores so much heat that in spite of its long night (124 days) its dark side is essentially as hot as the side facing the Sun. The experiment also reveals that the difference in cloud-top temperature



This series of mosaics shows the rotation of the ultraviolet markings that appear in the Venusian atmosphere (arrows). These markings circle the planet every four days, even though the planet itself rotates only once every 243 days.

Research Notes

between the equator and the poles is small compared to that on Earth.

Other experiments aboard Mariner 10 indicate that planetary Venus is more nearly round than the Earth, the Moon, or Mars; has an electrically charged upper atmosphere but practically no magnetic field; and is possessed of a comet-like tail of protons and electrons that extends away from the Sun.

Mariner 10 has also radioed back measurements that confirm the presence of hydrogen in the Venusian atmosphere. Some of that element is locked into sulfuric acid and water molecules in the clouds, but its presence as a gas in greater-than-predicted amounts may challenge one theory that the hydrogen was released by comets colliding with the surface of the planet. Another theory suggests that the hydrogen was swept into the atmosphere by the solar wind—particles "blowing" out from the sun. It also seems clear that this hydrogen prevents solar radiation from breaking down the carbon dioxide atmosphere of Venus into a more Earth-like one.

Important as it is, the information transmitted from Mariner 10 in its brief encounter with Venus is only a minor by-product of the mission's prime target—Mercury. The innermost planet of the solar system, Mercury is not much larger than the Moon, yet it is denser than Earth. Because of its position in relation to the Sun, it cannot be observed in detail by Earth-based telescopes; in fact, the 750-km-resolution (about 500 miles) observed from Earth is worse than that of the Moon seen by the naked eye. Mariner 10 is scheduled to execute a week-long picture-taking mission in which the spacecraft and its cameras will zoom in closer and closer to Mercury, until the final pictures are at a resolution of 0.1 km (about 350 feet). That is just as good as the best Mariner 9 photos of Mars.

Earthquake Side Effects

The days are slightly longer during periods of intense earthquake activity around the world. Also, during these periods, the earth's poles wander faster.

Don Anderson, professor of geophysics and director of Caltech's Seismological Laboratory, made this surprising correlation after studying three periods in history when giant earthquakes were prevalent—1835 to 1847, 1896 to 1911, and 1933 to 1942. (A giant earthquake is one of magnitude 8.5 or greater—or one that causes a large tsunami or seismic sea wave.) In addition to the giant earthquakes, the general level of seismic activity was also greater during those periods.

Don Anderson

During these seismically active periods the earth's rotation rate was abnormally slow, meaning that the days were slightly longer. During the 1896-1911 period the length of the day increased by about eight milliseconds. The rate is known back for many centuries from astronomical studies of the motions of the stars, sun, moon, and planets.

It is not yet clear whether the earthquakes slow the earth's rotation rate, or whether the slowdown activates great earthquakes. But earthquakes are only part of the story. The much larger movements involving the shifting of mass near the earth's surface are probably responsible for both the earthquakes and changes in the rotation rate. This motion is provided by the activities of the huge tectonic plates that make up the lithosphere, the outer 45 miles of the earth.

Most geologists believe that the earth's entire surface down to a depth of 45 miles is made up of a mosaic of massive plates that move in relation to each other, riding and sliding on a layer of plastic rock about 80 miles thick. The largest of these is the Pacific Plate, which extends from Japan to the west coast of the United States and from Alaska southward many thousands of miles.

The Pacific Plate is moving faster than the others and seems to dominate the earth-rotation effect among the plates. It is diving under the Aleutian Islands and Japan and is scraping past California along the San Andreas Fault. A piece of the Pacific crust is diving under Chile. Nearly all the largest of the earthquakes during the "great earthquake years" occurred around the edge of the Pacific Basin—in South America, Japan, and the Aleutians.

When an edge of the Pacific Plate dives under the Aleutians or Japan, the lithosphere bends until big chunks of it crack and break, causing earthquakes. Anderson believes that this "decoupling" at plate boundaries leads to accelerated plate motions, and this is the major process affecting the earth's rotation. Plate motions occur in jerks, lasting some five to ten years rather than being continuous.

In the past 70 years the lithosphere has been diving under Japan about 10 times faster than in the past 1,500 years. The present rate is about eight inches a year, much greater than the average rate over the past several million years. After certain large "decoupling" earthquakes—given this name by Hiroo Kanamori, professor of geophysics—the plate rates can be faster still.

Anderson developed his conclusions from studies of the earthquake records of Japan, China, and Chile. Quakes have been recorded on seismological instruments since 1900, and a fairly complete record of giant quakes is available back to the year 1800. Japan and China have adequate records back to the year 400 A.D.

Anderson's theory is not yet useful in predicting specific earthquakes at a particular place. But by monitoring the location of the pole of rotation and the length of the day very precisely, particularly after large earthquakes, he believes it might be possible to determine when conditions are getting ripe for major seismological activity elsewhere on the globe.

He's chairman of the committee on research with warm-blooded animals, but Jean-Paul Revel also works with cold-blooded specimens like this whelk.

Creature Comforts

When the Kerckhoff Animal Care Facility was built at Caltech 25 years ago, it was as carefully designed and up to date as a hard-working committee could devise. But if the animals haven't changed very much, standards for their care have; and the time has come for large-scale renovations and remodeling.

A major portion of this work will be funded by a $195,000 grant from the National Institutes of Health. Caltech will provide another $75,000. Jean-Paul Revel, professor of biology and chairman of the committee on research involving warm-blooded animals, is in charge of the project, which is slated to start this month.

The 7,500-square-foot facility now houses about 2,600 animals used by 15 investigators in the Divisions of Biology, Chemistry and Chemical Engineering, and Engineering and Applied Science.

With the installation of modern cages and sterilization equipment, the animals will have even better care than they have had in the past—and operating costs should be reduced.

The Month at Caltech

Visiting Scholars

For the last 18 years the Phi Beta Kappa Visiting Scholar Program has sent off ten distinguished scholars a year to visit universities and colleges that have Phi Beta Kappa chapters. Caltech, which does not have a chapter, cannot be on the receiving end of any of these calls, but many Institute faculty members have served as visitors; the two latest are Ray Owen and Eugene Shoemaker, who will be on tour in 1974-75.

Each Visiting Scholar goes to eight campuses over a period of four weeks (not necessarily consecutively) and gives three to six talks, one of which is a public lecture. Most of the time on each campus, however, is spent in meeting informally with faculty and students. Schools outside large urban areas are given priority in scheduling.

Almost all the academic disciplines have had spokesmen on the program over the years. Caltech has been represented by Hallett Smith, professor of English; Wheeler North, professor of environmental science; computations linguist Frederick B. Thompson, professor of applied science and philosophy; and two trustees—the late Henry Dreyfuss, industrial designer; and George Beadle, former professor of biology at Caltech and Nobel prizewinner, and his writer wife, Muriel, who filled a joint appointment.

A current Phi Beta Kappa scholar is Harry B. Gray, professor of chemistry. In October he visited St. Louis University, the University of Missouri, Centre College of Kentucky, and the University of New Mexico. He found the experience "enjoyable, interesting, and exhausting—but you do get to know people."

Ray Owen and Gene Shoemaker are the only two scientists on the 1974-75 panel. Owen, professor of biology, will probably give talks on death and disease; science, politics, and money in the national cancer program (Owen was appointed in 1973 to the President's Cancer Panel); progress toward the conquest of cancer; and a viewpoint from immunogenetics of the causes and cures for cancer. Shoemaker, professor of geology, proposes to talk on the canyons of the Colorado and the consequences of catastrophe—the geological processes that shaped the earth; and on planetesimal accretion—a detailed look at some processes by which the earth was born.

Braun Professorship

George W. Housner, professor of civil engineering and applied mechanics, has now been named Carl F Braun Professor of Engineering. He is the first occupant of this new professorial chair.

A regular visitor to the Baxter Hall fish pond, and the man who keeps the carp supplied with Saltines, is Caltech's new Carl F Braun Professor of Engineering—George Housner.

The endowed chair is made possible by gifts from the Braun family through the Carl F Braun Trust Estate and C F Braun & Co.

Housner received his MS and PhD in civil engineering at Caltech, and has been a member of the Caltech faculty since 1945. Internationally known as an expert on the effects of earthquakes on structures, he has been a leading figure in the design of buildings to resist earthquakes, and in the development of instruments and techniques for measuring the impact of earthquakes on structures.

Housner is chairman of the National Academy of Engineering Committee on Natural Disasters and also of the Earthquake Advisory Board of the California Department of Water Resources. He is a member of the California Governor's Earthquake Council and of the Los Angeles County Earthquake Investigation Commission.

He is a member of both the National Academy of Sciences and the National Academy of Engineering.

The new professorship is named for the late Carl F Braun, founder-president of C F Braun & Co, an engineering and design firm with headquarters in Alhambra. Mr. Braun was a trustee of Caltech and a charter member of the California Institute Associates. He was a director of the Associates from 1937 until his death in 1954. One of his three sons, John G Braun, is now a trustee of Caltech.

The Carl F Braun Trust Estate, established in 1955 to help educational and other organizations in California, and the Braun Company have made a number of contributions to Caltech, including the graduate residence hall, Braun House, and the rehabilitation of Kerckhoff Marine Laboratory at Corona del Mar.

Bombshell

Alfred Hitchcock, the film director, interviewed for *The New York Times* recently by Deirdre Carmody, related and indelible encounter with Caltech's Robert Millikan.

During World War II, Mr. Hitchcock directed *Notorious* with Ingrid Bergman, Cary Grant, and Claude Rains. There is a famous scene in a wine cellar where a valuable substance has been placed in the wine bottles by the Germans. Mr. Hitchcock thought the substance should be Uranium-235, so he and Ben Hecht, who wrote the screenplay, went to consult physicist Millikan.

"We went into his study, and there was this bust of Einstein, and we said to him 'How big would an atom bomb be?' " Mr. Hitchcock recalled.

The year was 1944, when scientists were working in great secrecy to perfect the atomic bomb, but Millikan maintained his composure and emphatically told the two men that such a bomb could not possibly be constructed.

Mr. Hitchcock said that he was followed by government agents for the next three months.

Science Fiction Festival

Under the aegis of John R. Pierce, professor of engineering and an old hand at science fiction himself, Caltech held its first Science Fiction Festival on March 7 and 8.

Ushered in by a four-week series of classic films (*The Time Machine, Forbidden Planet, Planet of the Apes*, the two original pilots of the television "Star Trek" series, and two fragrant episodes from the Flash Gordon movie serial), the festival proper opened with a concert in Ramo Auditorium on March 7 by pianist Leo Smit, with verbal embellishments by Sir Fred Hoyle, astronomer, science fiction writer, and visiting associate in physics at Caltech. Smit's program, except for an original composition, was made up of selections mentioned or utilized in

Science meets science fiction—three Feynmans (Gwyneth, Richard, and Carl—who is the only full-fledged science fiction buff in the family) welcome writer Jerry Pournelle to Caltech's first Science Fiction Festival.

the plot of Hoyle's latest book, *October the First Is Too Late.*

Following the concert, a reception in Winnett Lounge, cosponsored by ASCIT and the Caltech Y, gave students and faculty their first opportunity to meet at least some of the science fiction writers scheduled to make a formal appearance on the following day.

Six popular science fiction writers were on hand for the Saturday symposium held in a very crowded Ramo Auditorium—Poul Anderson, Harry Harrison, Robert A. Heinlein, Larry Niven, Jerry Pournelle, and Robert Silverberg. The discussion started off on the announced topic—"The Relation Between Science and Science Fiction"—and the authors agreed that science fiction generally lagged behind scientific advances, so that new discoveries were constantly making their stories obsolete. (For example, said Jerry Pournelle, the discovery of the very intense radiation belts around Jupiter had made the actions described in literally hundreds of stories impossible.)

The discussion quickly broadened out to include the eager audience and any number of new topics—the role of women in science fiction, the relationship between science fiction and "mainstream" literature, the concept of science fiction as a literary ghetto, and the question of the existence of "wormholes" leading to other universes.
After dinner with faculty members in the Athenaeum, the writers came back to Ramo Auditorium for a Saturday night screening of "Lunch with John W. Campbell," a film about the late great editor of *Astounding* and *Analog*, and for more commentary and discussion before the festival finally broke up in an orgy of adulation and autographing.

The Month at Caltech . . . *continued*

Last Word?

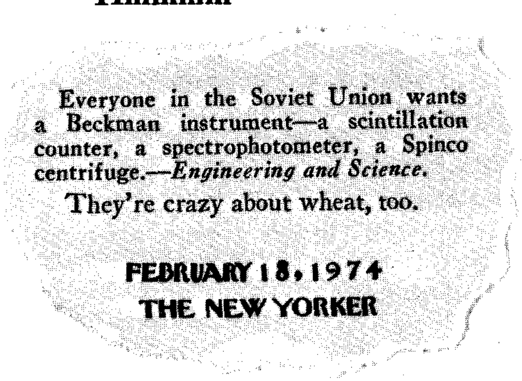
Irwin Nathan, Systems Consultant for Xerox Corporation in Rochester, New York, forwards this final word on the recalcitrant Xerox machine reported on by James and Ingelore Bonner in the November-December issue of E&S—*a memo to him from G. S. Planner, General Manager for Xerox in London:*

You will recall the article in the Caltech magazine recording the trip made to the Soviet Union by the Bonners, and the critical comment that the Xerox machine was not working—"it breaks down and cannot be fixed because Xerox service men do not come."

As we know the user, our office in Moscow contacted them and were informed that the machine does work well, but they had had to make these comments to the visiting delegation from the States, as an explanation of why they could not make copies, which in fact is not allowed because of the censorship rules.

They have sent a letter to us, confirming that the machine was installed in 1972 and has worked correctly according to its specification—and they have no claim in respect of service or quality.

Hmmmm


Everyone in the Soviet Union wants a Beckman instrument—a scintillation counter, a spectrophotometer, a Spinco centrifuge.—*Engineering and Science.*
They're crazy about wheat, too.

FEBRUARY 18, 1974
THE NEW YORKER

Books

Some recent ones by or about Caltech people.

ALMOST ALL ABOUT WAVES
by John R. Pierce
MIT Press $8.95

It is characteristic of John Pierce that he includes an "almost" in his title. Anyone else would have claimed that this book was *all* about waves.

"Modern physics is full of waves," Pierce says at the start of the book, "the earthquake waves which seismologists study; the waves and ripples on oceans, lakes, and ponds; the waves of sound which travel through the air; the mechanical waves in stretched strings and in the quartz crystals that are used to control the frequency of radio transmitters; the electromagnetic waves that constitute light, and that are radiated by radio transmitters and received by radio receivers; and finally, the waves of what?—probability, perhaps—which are used in quantum mechanics to predict the behavior of electrons, atoms, and complex substances."

What Pierce does here is to show how much a physicist or engineer can learn about waves without using a great deal of mathematics.

John Pierce got his BS from Caltech in electrical engineering in 1933, his MS in 1934, and his PhD in 1936. After 35 years with the Bell Telephone Laboratories, he became professor of engineering at Caltech in 1971.

SEISMICITY OF THE SOUTHERN CALIFORNIA REGION
by James A. Hileman, Clarence R. Allen, and John M. Norquist
Seismological Laboratory $14.25

Caltech's Seismological Laboratory has been collecting data on southern California earthquakes for the last 41 years. Now three members of the staff have published a book about 15,340 quakes.

Seismicity of the Southern California Region is a 494-page volume with listings of the earthquakes of magnitude 2 or more. Not an interpretive study of seismic hazard, the book simply presents a maximum amount of fundamental data—the latitude and longitude of the quakes, their location by quadrangle name, the time of their occurrence, their magnitudes and depths, and the accuracy with which they were located.

Clarence R. Allen, professor of geology and geophysics; John M. Norquist, senior research engineer; and James A. Hileman, graduate student in geophysics, are the co-authors. Hileman developed a way to use Caltech's computer to print out maps of the fault distributions, and portions of the book are from his PhD thesis.

The book will, of course, be used by geologists who are interested in seismicity; but it should also be extremely helpful to engineers who are trying to resolve problems like selecting suitable sites for nuclear power plants.

OPERATING SYSTEM PRINCIPLES
by Per Brinch Hansen
Prentice-Hall, Inc. $13.50

The first book to offer in-depth coverage of the common principles of computer operating systems for students and professional programmers. Per Brinch Hansen has been an associate professor of computer science at Caltech since 1972.

THIN-SHELL STRUCTURES
Theory, Experiment, and Design
edited by Y. C. Fung and E. E. Sechler
Prentice-Hall, Inc. $21.95

The edited proceedings of a symposium held at Caltech in June 1972, co-sponsored by the Institute, the Air Force, the Office of Scientific Research, and the U.S. Navy Office of Naval Research.

The editors are both Caltech alumni: Ernest Sechler, now professor of aeronautics at the Institute, got his BS in aeronautics in 1928, MS in 1929, and PhD in 1934; Y. C. Fung got his PhD in aeronautics in 1948, and is now professor of bioengineering and applied mechanics at UC San Diego.

DAILY LIFE IN PEOPLE'S CHINA
by Arthur W. Galston
with Jean S. Savage
Thomas Y. Crowell Company . . . $6.95

Art Galston came to Caltech as a research fellow in 1943, and was associate professor of biology when he left in 1955 to become professor of biology at Yale, where he is Eaton Professor of Botany and director of Yale's Marsh Botanical Garden.

In May 1971 he was the first American scientist to visit the People's Republic of China since its founding in 1949. Intrigued and impressed, he made a second visit in 1972, accompanied by his wife and daughter. This was far from the standard "official" visit; the Galstons even spent a couple of weeks living—and working—on a commune near Peking.

Art came to Caltech last January, on the Caltech Y Leaders of America program, to talk about some of the highlights of his unusual China trip. This is the whole story—and it makes a lively book—illustrated with more than a hundred of Art's own photographs.

THE RESTORATION OF THE EARTH
by Theodore B. Taylor and
Charles C. Humpstone
Harper & Row, Publishers, Inc. . . $7.95

A thoughtful proposal of a plan for dealing with our pollution problems—nationally and internationally. Both authors are associated with the International Research and Technology Corporation in Washington, D.C. Charles Humpstone is a lawyer; Theodore Taylor, a nuclear physicist, received his BS at Caltech in 1945.

REFERENCE GUIDE TO FANTASTIC FILMS
Science Fiction, Fantasy, & Horror
compiled by Walt Lee
Volume 1 (A-F) $9.50
Volume 2 (G-O) $9.95

Walt Lee published the first volume of this index in 1972. Volume 2 has just been issued, and a third volume is due later this year. This monumental guide is, quite simply, a listing of every film ever made anywhere with any science fiction, fantasy, or horror in it. What's more, each film listing includes the date of production, the production company, date of release, running time, and screen credits—with special notes of interest and references on each picture. The three volumes will contain about 20,000 listings in all.

Books ... *continued*

The books are softbound, 8½x11, and illustrated. They are not generally available at bookstores, but can be ordered directly from Mr. Lee (P.O. Box 66273, Los Angeles 90066). Price of the three-volume set is $28.

The man behind this awesome undertaking, Walt Lee, got his BS at Caltech in physics in 1954 and is a member of the technical staff at Hughes Aircraft.

THE BRAIN CHANGERS
Scientists and the New Mind Control
by Maya Pines
Harcourt Brace Jovanovich, Inc. . . $7.95

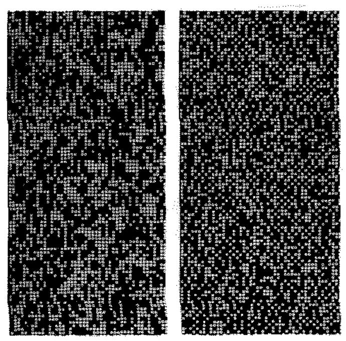
Despite the lurid title, this is a reasonable, rational reporting job on some of the brain research now going on in laboratories around the country. The author includes brief descriptions of the Caltech work of Derek Fender and James Olds, and a more extensive report on the research of Roger Sperry and his graduate student Michael Gazzaniga, PhD '65, now a professor of psychology at New York University.

ALGEBRAIC THEORY OF LATTICES
by Peter Crawley and
Robert P. Dilworth
Prentice-Hall, Inc. $11.95

A graduate-level text covering current developments in lattice theory. Robert Dilworth (BS '36, PhD '39) is professor of mathematics and chairman of the faculty at Caltech. Peter Crawley (BS '57, MS '58, PhD '61) came to Caltech as an assistant professor of mathematics in 1963 and was a professor when he left in 1972 to go to Brigham Young University.

Look Again

If you had trouble determining the orientation of any or all of the four computer-produced patterns on our cover, here they are again with the bisecting boundaries revealed.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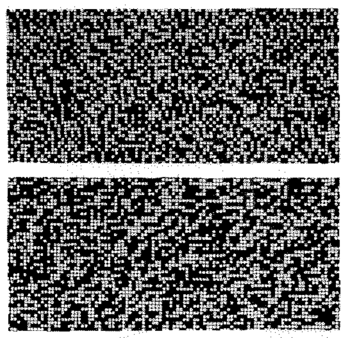
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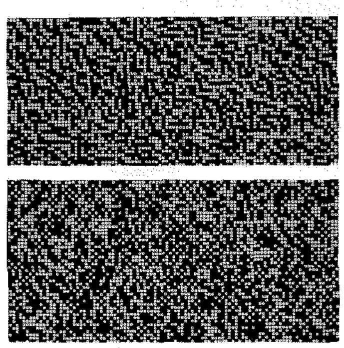
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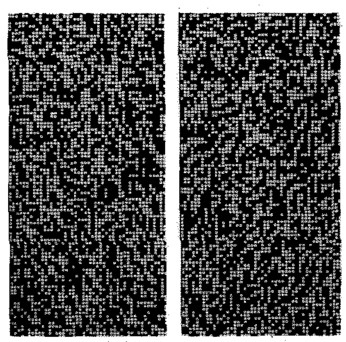
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