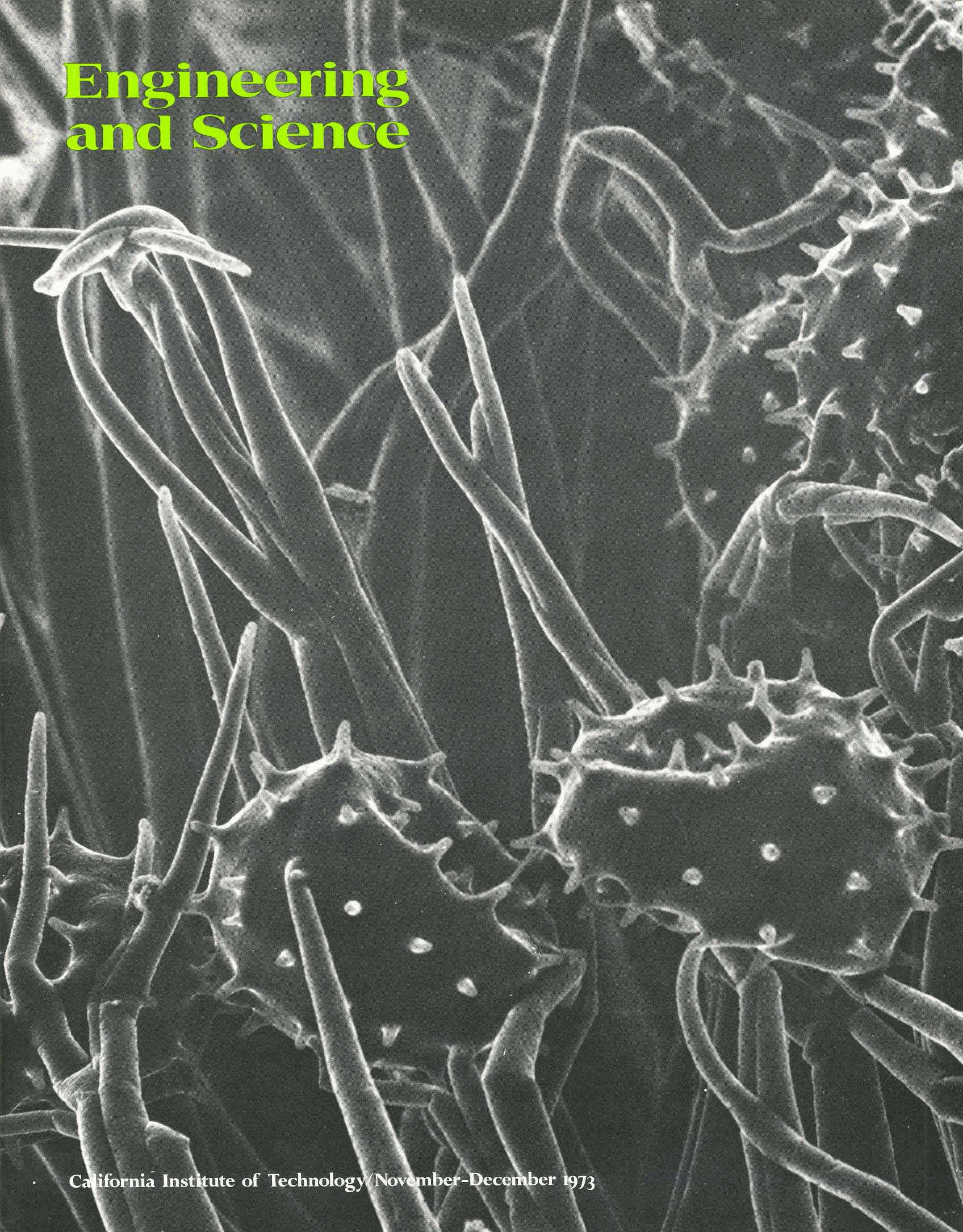
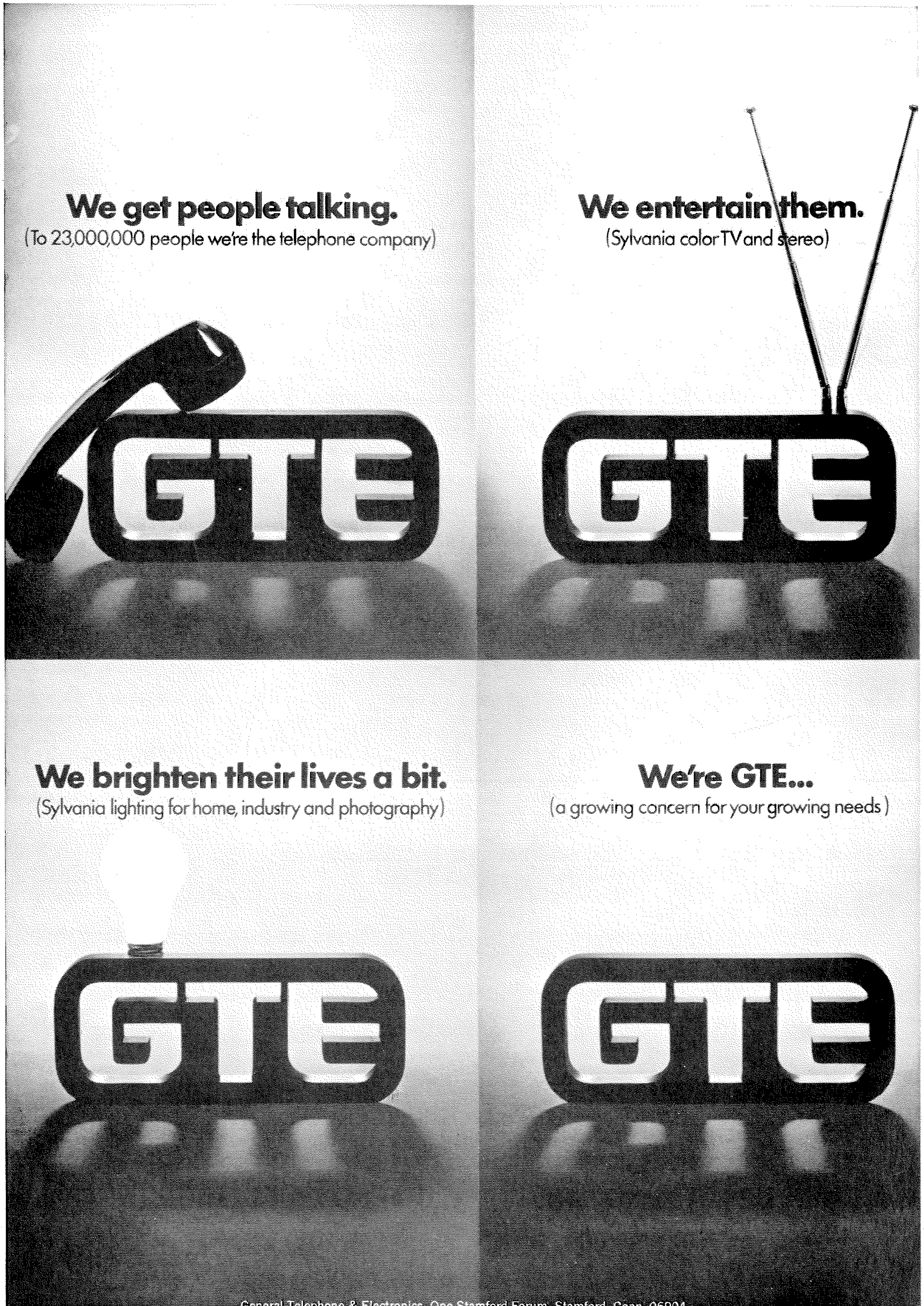
Engineering and Science



California Institute of Technology/November-December 1973

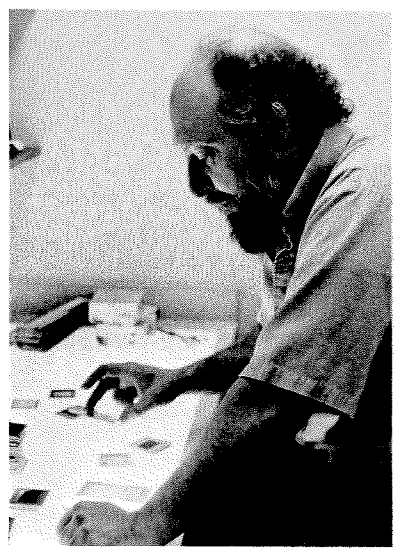

We get people talking.
(To 23,000,000 people we're the telephone company)
We entertain them.
(Sylvania color TV and stereo)
We brighten their lives a bit.
(Sylvania lighting for home, industry and photography)
We're GTE...
(a growing concern for your growing needs)
General Telephone & Electronics, One Stamford Forum, Stamford, Conn. 06904

IN THIS ISSUE

Small World

On the cover—a view through the eye of a scanning electron microscope (SEM) of the pollen on the pistil of a hibiscus flower. At a magnification of about 150 times and in the full splendor of three dimensions, this surpassingly beautiful picture reveals an aspect of the flower never observed by the naked eye, or by the light microscope. What the ordinary camera would see is a cluster of bright objects on the pistil of the blossom (below).

For the cover photo, the SEM was operated by Jean-Paul Revel, professor of biology (right), who was testing it out before going into the more serious matters of photographing cell membrane surface interactions, which are his chief research interest. Among the other oddments he used for tryouts of the SEM's capabilities were a razor's edge, a bee's eye, the head of a bug, and the anther of a knotweed flower. "Ruffles and Flourishes" (page 4) includes examples of the latter two, along with views of single cells caught in the act of ruffling along their edges.



Revel is a native of Strasbourg, France, where he earned a BSc at the university in 1949. He came to the United States in 1953, expecting to stay two or three years while he earned a PhD at Harvard. The PhD was granted in 1957. He returned in 1959 as a faculty member and remained until he came to Caltech in 1971.

Active Chemist

Aron Kuppermann, professor of chemical physics, is a native of Brazil. He received a chemical engineering degree in 1948 from the University of Sao Paulo, and a civil engineering degree in 1952—when he was already an assistant professor of chemistry at Sao Paulo's Aeronautic Technological Institute. Deciding that he wanted to know more about modern physical chemistry in general and radiation chemistry in particular, he went to the University of Edinburgh for a year as a British Council Scholar and then came to the United States. He was awarded a PhD at Notre Dame in 1956 and taught at the University of Illinois until he came to Caltech in 1963. Since then he has done major research on electron scattering and the dynamics of chemical reactions. "An Insight into Chemical Reactions" (page 16) describes some of his latest work.

Student Works

It's a pleasure for *E&S* to present three stories in this issue either by or about Caltech students. "A New Look at Our Restless Earth" (page 9) reports on the research of Bernard Minster, graduate student in geophysics. Gary Prohaska, who wrote "An Insight into Chemical Reactions" (page 16), graduated last June with a BS in astronomy. And Bob Kieckhefer, a senior in geophysics, tells of his summer work in "Project Oldstone—Greenland 1973" (page 26).

STAFF: *Editor and Business Manager*—Edward Hutchings Jr.
Managing Editor—Jacquelyn Bonner
Associate Editor—Bernard Cole
Art Director—Kathleen Marcum
Photographer—Floyd Clark

PICTURE CREDITS: Cover, 4-8—Jean-Paul Revel/12, 14, 28-30—James and Ingelore Bonner/21—NASA/22—Associated Press/26-27—Bob Kieckhefer/All others—Floyd Clark.

Published seven times each year, in October, November-December, January, February, March-April, May, and June, at the California Institute of Technology, 1201 East California Boulevard, Pasadena, California 91109. Annual subscription $4.50 domestic, $5.50 foreign, single copies 65 cents. Second class postage paid at Pasadena, California, under the Act of August 24, 1912. Published by the California Institute of Technology and the Alumni Association.

Engineering and Science

November-December 1973/Volume XXXVII/Number 2

Ruffles and Flourishes

Each living organism has a characteristic way of moving. A man walks, a child toddles, a horse trots, a snake slithers, a bear shuffles. What about smaller organisms? Well, it seems that a cell "ruffles."

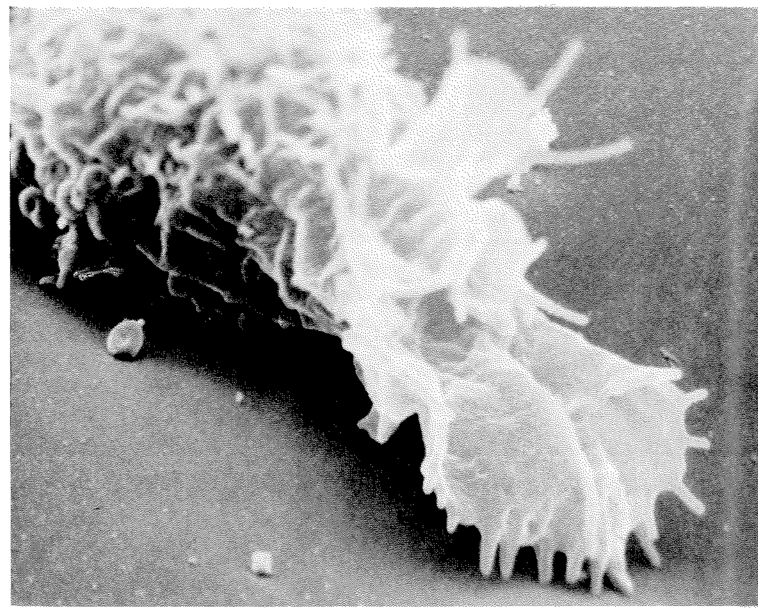
At least this is how Jean-Paul Revel, professor of biology, describes the carefully orchestrated process by which a cell uses a thin ruffled line of veil-like folds along its "front" edge to pull itself across a surface.

Our understanding of cell movement has been based on indirect evidence only. But Revel, using the newly acquired scanning electron microscope (SEM), has produced a series of detailed photographs that gives him a direct look at the ruffles. His spectacular close-ups are also among the first high-quality, high-resolution photographs ever taken of the ruffling mechanism in operation.

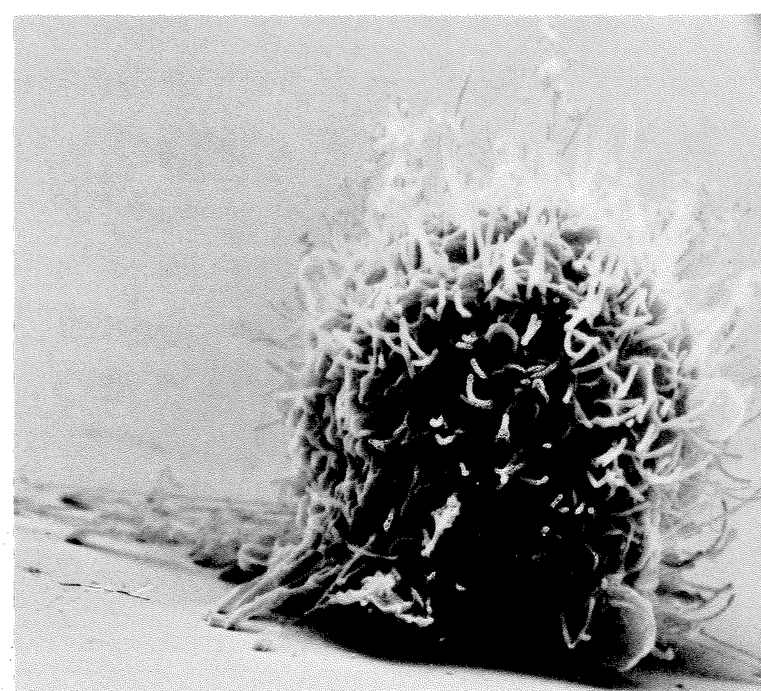
What seems to happen is that as a cell moves across a surface, ruffles can be seen on its forward edge. These ruffles grow upward, extend outward, and then drop to the surface, where they stick. The rest of the cell then flows into and over the ruffles at these attachment points. As the body of the cell moves over the first set of ruffles, another set appears near the new front edge. This second set attaches to the surface in turn, and the first set—now at the rear of the cell—disconnects.

The exact mechanism by which this ruffling takes place —or even if it is involved at all in cell movement—is not clearly understood, and two other possibilities are being examined. One is that the ruffles are the way the cell forms new membrane. The fact that this occurs while the cell is moving is coincidental. The other possibility is that the primary movement mechanism of the cell is internal and that the ruffles are just portions of the external cell surface that have been distorted by this process.

The key to the ruffling mechanism appears to lie in the nature of the cell membrane surface, so Revel and his co-investigators are looking at its detailed structure for useful information.

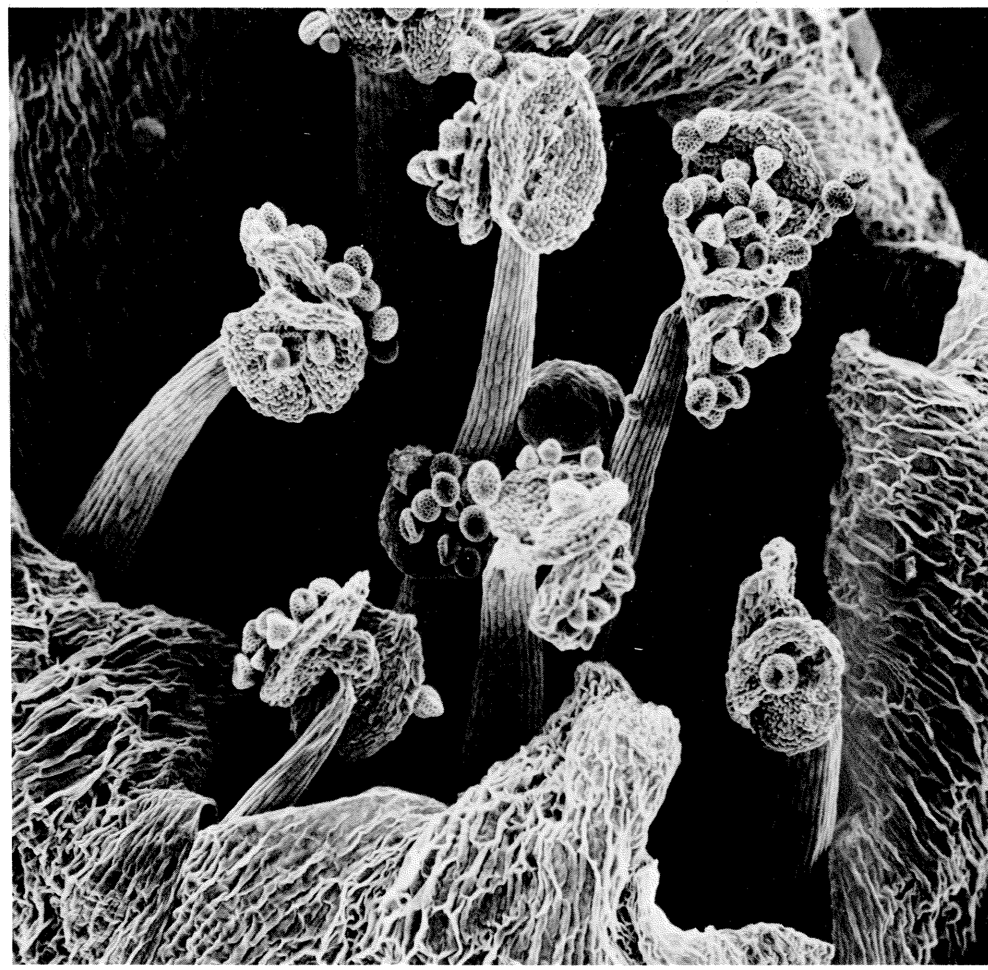


The SEM enables Jean-Paul Revel to record cell movements in 3-D, at 50 times greater magnification and with 10 to 20 times finer detail than is possible with a light microscope. Magnified 15,000 times, a fibroblast cell from the connective tissue of a mouse (above) unfolds an elaborate ruffle on its "forward" edge, which appears to serve as a kind of leg for moving across surfaces. When treated with the enzyme trypsin to detach it from the substrate, the cell contracts into a ball (below), and bubbles develop on its membrane. The magnification is 10,000 times actual size.



The scanning electron microscope reveals how a cell moves

Dried, thinly coated with gold, and photographed by an SEM, a baby hamster's kidney cell is caught in the act of ruffling its way across a petri dish. The magnification—15,000 times actual size—makes it possible to show the cell's newest set of ruffles forming and moving over an older set. The ruffling mechanism seems to be triggered by the proximity of the cell membrane to the surface it is traversing and by the movement of older sets of ruffles toward the back of the cell.

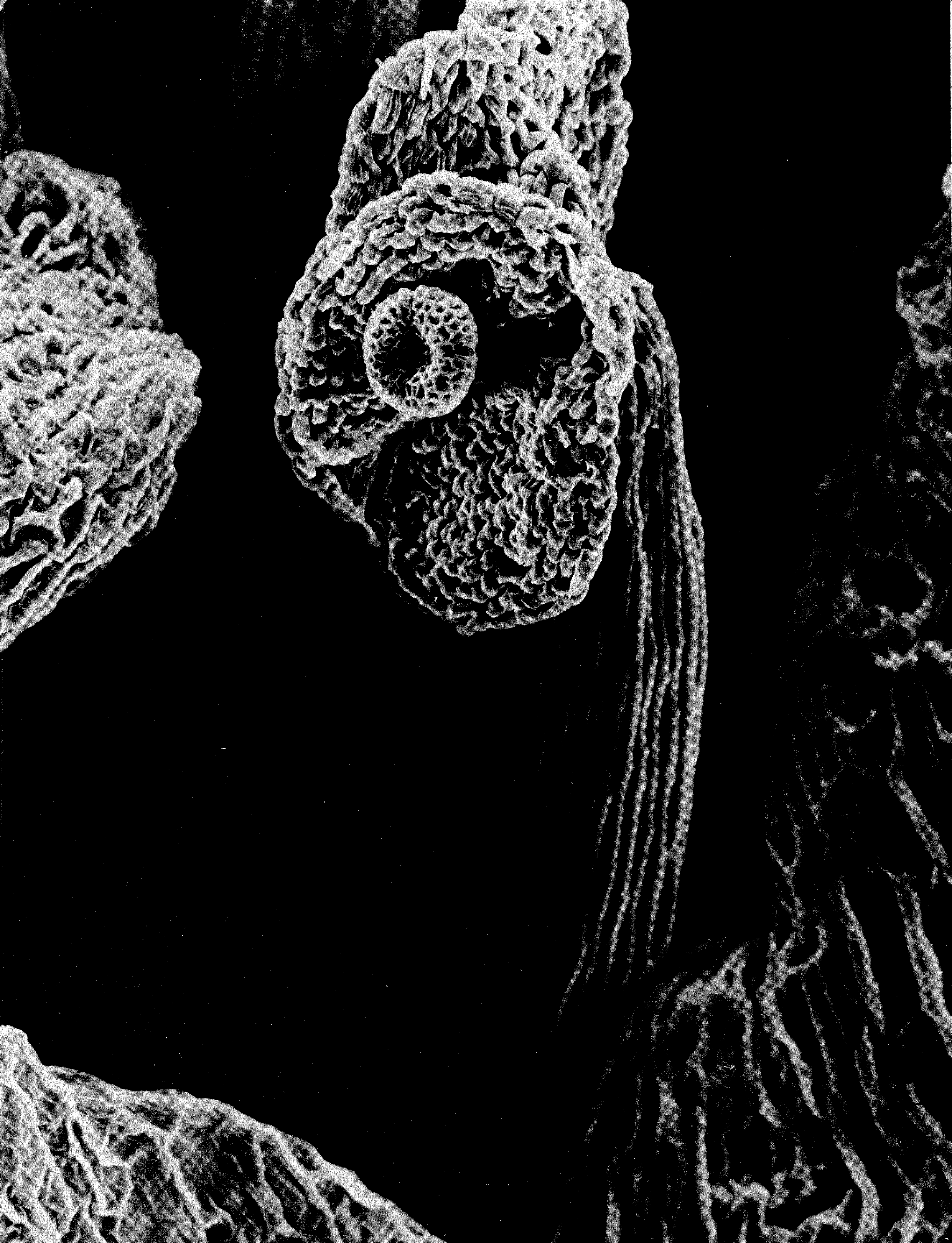


The SEM Looks into a Flower

With an eye for beauty, a natural curiosity, and an SEM, Jean-Paul Revel made these spectacular photographs of an insignificant-looking plant that grows at the main entrance of the Church Laboratory of Chemical Biology. An ordinary photograph (top) of the polygonum, or knotweed, shows the sturdy structure of the fingernail-sized flower. But increasingly powerful magnification reveals a hidden beauty. The SEM photographs of the anther and pollen grains of *one* blossoms are—from left to right—magnified 38, 145, and 650 times.

The instrument that allows them to do this, the scanning electron microscope, is rapidly becoming at least as useful as the standard transmission electron microscope (TEM), which for years has been an invaluable tool in genetics, molecular biology, and virology. While the TEM allows magnification up to 250,000 times, it is only able to record two-dimensional "shadowgraphs" of three-dimensional objects through which electrons are passed. Scientists try to overcome this drawback by slicing their specimens very thin, taking TEM "shadowgraphs" of each of them, and then reconstructing a three-dimensional image from the slices.

The SEM makes this tedious process unnecessary by bouncing electrons off—rather than passing them through—specimens under observation. The secondary electrons that are bounced back are collected and accelerated against a scintillator, which transforms them into bursts of light. These light impulses are amplified to provide a display that can either be viewed directly like television, or photographed. Caltech's SEM can magnify objects up to 100,000 times, and has attachments that allow manipulation of a specimen so that it can be viewed from almost every direction—that is, in three dimensions.



This nightmare is a Hemipteran (alias "bug") magnified 400 times. Revel found it on one of his African violet plants. The honeycombed objects on its antennae are pollen grains from the violet's blossoms.

SEMS have been used in industry for about ten years, but only in the last few years have the quality and resolution of imaging improved enough for them to be useful in basic scientific research. The Caltech SEM is about eight months old, and Revel and many of his colleagues are still getting acquainted with its capabilities. In addition to scanning cells, it has been used to look at the way amoebae aggregate to form slime molds, the appearance of normal and cancerous cells, the origin of nerve cells, the development of chicken embryos, the detailed surface structure of fruit-fly mutants, and the microscopic substructure of various materials like rocket propellants, the "teeth" of mollusks, and bits of meteorites.

"With the scanning electron microscope we can 'fly' around a specimen at high altitude and look at it from all angles," Revel says. "If we find something interesting, we can swoop down for a closer look. If there is something *really* interesting, we can 'land,' walk up to it, and stick our noses inside to see what's going on. □

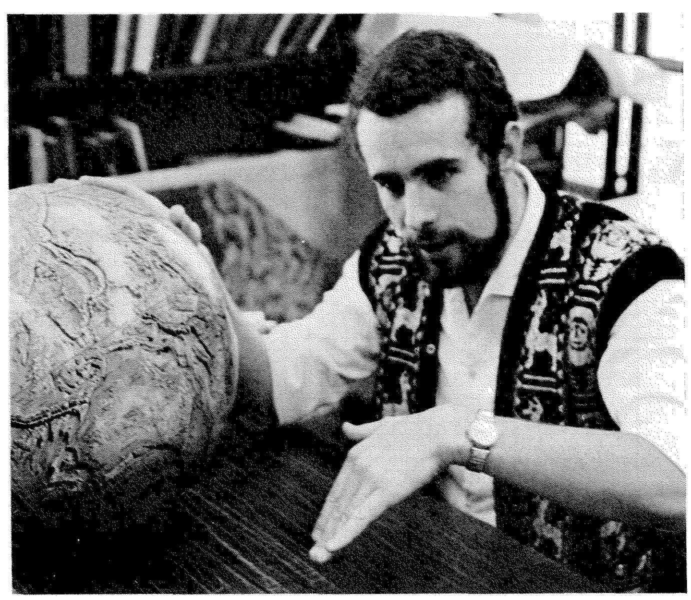
A New Look at Our Restless Earth

Every now and then a revolution occurs in scientific thinking, and the result is an about-face in our understanding of an idea or a phenomenon. The classic example, of course, is the upheaval caused by the Copernican view that we do not live in an earth-centered planetary system but rather in a sun-centered one. Of almost equal impact is the relatively new geological concept of "plate tectonics," which explains the evolution of continents and oceans in dynamic rather than static terms. It proposes that the earth's surface down to a depth of about 45 miles (the lithosphere) is composed of a mosaic of massive, rigid plates that float on an 80-mile-thick layer of plastic rock (the asthenosphere).

The speeds at which two or three of these plates are moving relative to each other have been measured in the past, but now Bernard Minster, graduate research assistant in geophysics, has calculated the velocities of ten of the plates at the same time. Working with Thomas Jordan, a Caltech alumnus (BS '69, MS '70, PhD '73) now at Princeton; Eldon Haines, visiting associate in nuclear geochemistry; and Peter Molnar of the University of California at San Diego, Minster used a computer to figure the speeds and directions of the motion of the plates. Earthquake data and the orientation of large fracture zones observed on the ocean floors gave them local directions of plate motions. Data from magnetic alignments of rocks along the ocean floors provided them with clues to the velocity of the movements over long periods of time.

The computer's analysis of these data shows that the plates move in a complexly choreographed slow-motion dance with respect to each other. Each rotates around an imaginary axis that passes through the earth's center (not necessarily coinciding with the earth's rotational axis). At their boundaries, the plates exhibit any one of three types of motion relative to each other: divergent, convergent, or simple shear. And each type of motion results in characteristic alterations of the earth's total surface. For example, along mid-oceanic ridges, plates move away from each other as molten rock rises to form new ocean floor; in zones such as at the border between the Pacific and South American plates or along the Japanese Trench, one plate is consumed as it slides under the leading edge of the other; and along transform faults like California's San Andreas, plates slide horizontally past each other, and surface area is neither created nor destroyed.

As if all this were not complex enough, the relative velocities between plates vary widely. The European Plate, for example, is moving away from the North American Plate in the North Atlantic at a rate of three-quarters of an inch a year, but the East Pacific Rise at Easter Island is spreading at a rate of about eight inches a year. The research has also shown—contrary to what had previously been assumed—that North and South



Bernard Minster

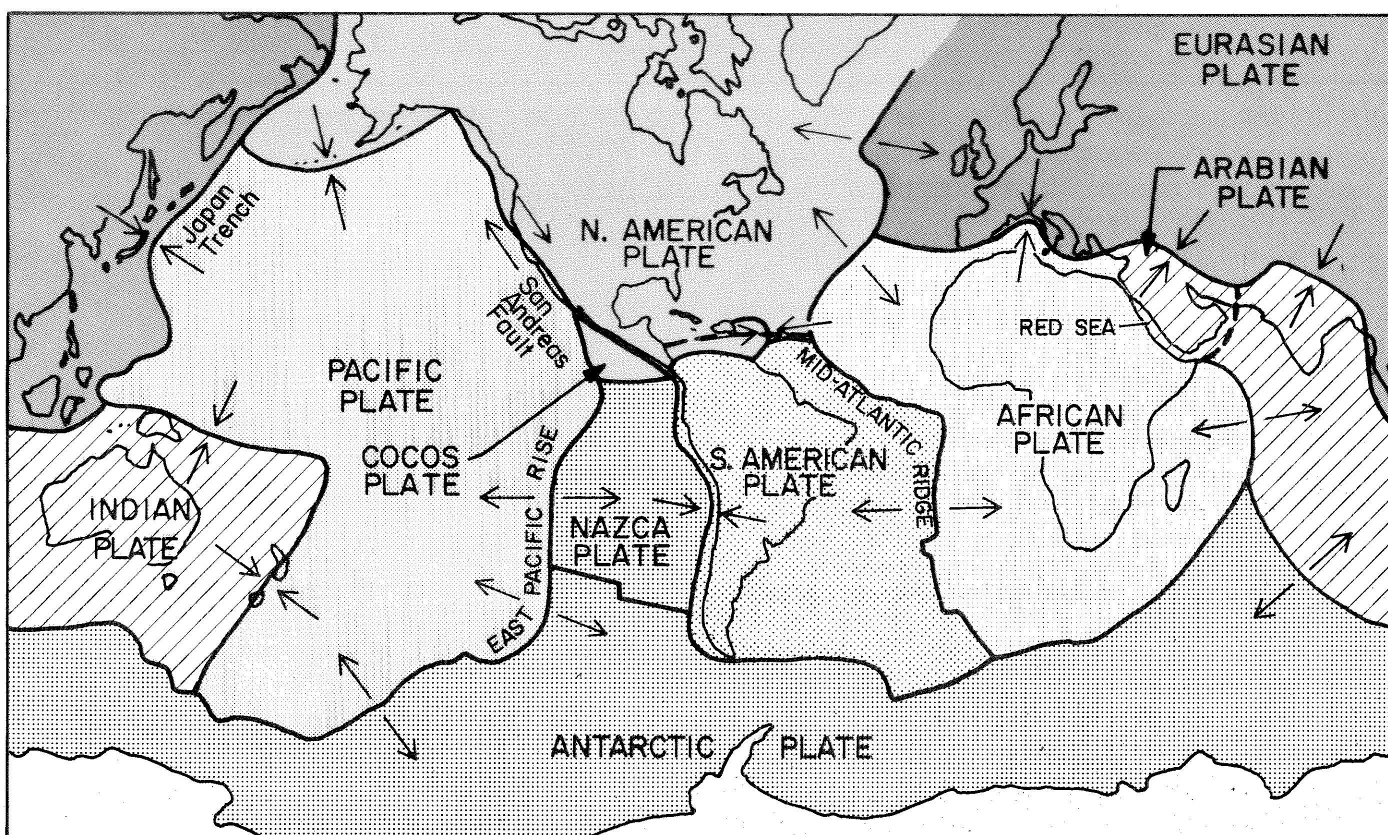
America do not behave as one plate; relative to South America, North America is moving westward at a quarter of an inch a year.

Baja California, along with a slice of western California, belongs to the Pacific Plate. The rest of Mexico, California, and the continental United States are part of the North American Plate. The Pacific Plate is moving northwesterly at a rate of a little more than an inch a year in relation to the North American Plate—a movement that caused Baja to break away from the Mexican mainland about five million years ago. As a result, the Gulf of California was formed and is widening about two inches a year. Eventually it will open at its northern end, because the North American Plate will break somewhere in that area. Most scientists consider the San Andreas fault to be the current plate boundary.

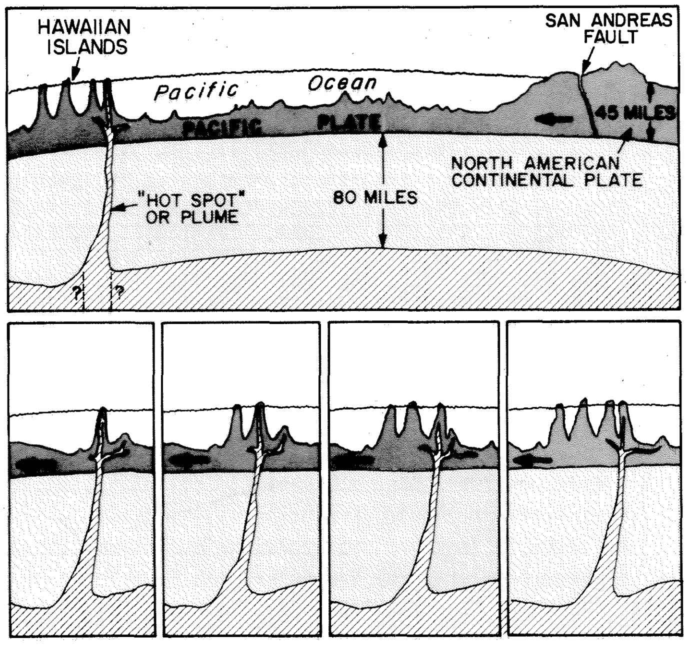
The boundaries of plates often coincide with the most active seismic areas of the earth, but they are sometimes difficult to determine precisely. The boundaries do not always correspond to the margins of continents, since most plates are partly oceanic and partly continental. And the plates vary greatly in size. The great Pacific Plate, for example, reaches from California to Japan and from Alaska to the South Seas. On the other hand, one of the small plates is essentially coextensive with Turkey.

Obtaining the relative motions of the plates gave the Minster group the opportunity to test the Wilson-Morgan "hot spot" hypothesis for the formation of chains of volcanic islands. This theory was formulated by J. Tuzo Wilson, professor of geophysics at the University of Toronto (who will be a Sherman Fairchild Distinguished Scholar at Caltech in 1975); and W. J. Morgan, professor of geophysics at Princeton. According to their theory, there are hot spots in the earth's crust which may be fixed with respect to each other and may represent plumes of molten material rising from the outer core of the earth

The principal tectonic plates of the lithosphere are outlined on this world map. The paired arrows indicate whether—in that particular area of its boundary—the movement of a plate is convergent or divergent to that of the adjacent plate.



In the last ten million years the Pacific Plate appears to have drifted about 500 miles to the northwest



A cross-section cut of about 150 miles down through the Pacific Plate would reveal a hot spot currently below the southernmost Hawaiian Islands. Assuming that the hot spot is fixed, the northern end of the island chain may represent "finished" islands, carried beyond the hot spot by the drifting of the plate to the northwest. The exact structure of the "plume" is still the subject of speculations.

through the mantle. If they are fixed, it should be possible to determine motions of the plates over them that explain the formation of island chains and are consistent with the relative motions of the plates.

Minster and his colleagues have found evidence to support this explanation of island formation. They have studied a ten-million-year period during which the Pacific Plate appears to have drifted about 500 miles to the northwest. As it glided over the hot spot that is now beneath the Hawaiian Islands, molten plate material expanded upward as volcanoes. When this material reached the surface of the ocean, it solidified and an island was born. The process repeated itself as the plate continued to drift, forming a chain of islands—from the island of Hawaii in the southeast in an almost straight line to Midway in the northwest.

Assuming that the hot-spot theory is correct, the researchers found that the plates do not move at the same rates with respect to the earth's interior. On the average, oceanic plates move about four inches a year, and continental plates less than three-quarters of an inch. In addition, it appears that the entire lithosphere may be drifting westward at a maximum of four-tenths of an inch per year—with respect to the earth's interior.

The group is now attempting to extend its studies back another ten million years in order to test further the fixed hot-spot theory. It is important to determine what has happened to these spots—whether they have moved a little, a lot, or not at all. If they are fixed, it places strong constraints on various theories of planetary formation.

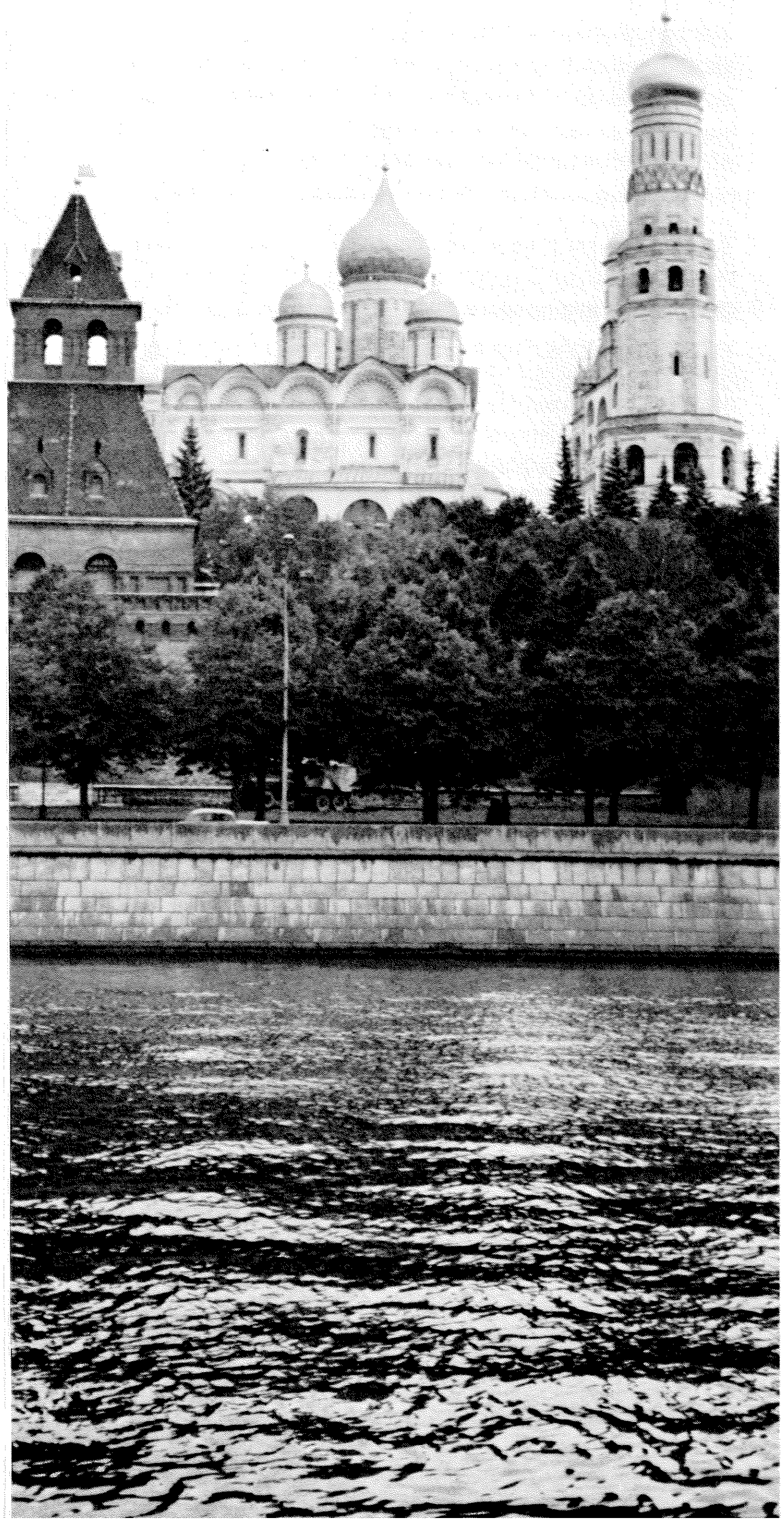
Working to understand the reasons for the motions of the plates, the researchers are looking at three basic but competitive mechanisms: that the plates are being pulled down by the deep oceanic trenches; that they are "gravity sliding" off bulges in the configuration of the earth; or that the motion is closely linked to the fixed hot spots. It may be that the chemistry of the asthenosphere—that mushy layer on which the plates slide—is not the same below the continents as it is below the oceans. Greater friction between the continental plates and the asthenosphere than between the oceanic plates and the asthenosphere would slow the movement of the continents appreciably.

The comparatively high speed of the oceanic plates may reflect the fact that they are, in effect, taking a dive. They are growing in some places, as material oozes up from below. But they are disintegrating in others, as one edge of an oceanic plate shatters against another plate (usually a continent) and is forced back down into the lower layers of the earth. Once it begins to slide, it may go rather quickly.

No one knows just how long this kind of plate tectonics has been operating, but it surely has been going on for at least 200 million years—and possibly for 2 billion years. There is evidence that 200 million years ago the major land masses were assembled into one single supercontinent that has been splitting into pieces and moving into new alignments ever since. The results have already led to some rather strange associations, and the end is not in sight. Given enough time, it even seems likely that the relentless northwesterly movement of the Pacific Plate will make Los Angeles and San Francisco across-the-channel neighbors.

Minster's research is sponsored by Caltech's Jet Propulsion Laboratory, the National Science Foundation, and the National Aeronautics and Space Administration. □

A scenic symbol of Russia—
the Kremlin from across the Moskva River.



Notes on a Trip to the Soviet Union

BY JAMES AND INGELORE BONNER

When Academician Keldysh, president of the Soviet Academy of Sciences, visited Caltech with a group of Russian scientists in October 1972, he expressed the hope that a group of Caltech people would be able to visit his country as guests of the Soviet Academy. That hope soon became a formal invitation, and this fall 16 members of the Caltech community took a two-week trip to Russia. The party included 9 trustees and faculty, and 7 wives—Arnold and Mabel Beckman, James and Nancy Glanville, William Keck, Lawrence Williams, Harold and Colene Brown, John and Ellen Pierce, John and Edith Roberts, Gerald and Naomi Wasserburg, and James and Ingelore Bonner. "Notes on a Trip to the Soviet Union" is adapted from the Bonners' travel diary.

FRIDAY, SEPTEMBER 14

Up at 8 a.m., Ingelore and I pack, pack, pack and are off to the airport by 11:30. We are to catch TWA flight 760. It is very full, but Harold Brown scuttles around and gets us all seats—in the very rear, to be sure. The plane is full, crowded, noisy, but it's only ten hours nonstop to London, where we arrive at 7 a.m. On our plane are Harold and Colene Brown, Jerry and Naomi Wasserburg, the John Pierces, and us. In London we get off at airport 3—the foreign flights airport—and are transported to airport 1—the one for European flights. Then we wait for several hours.

We buy Russian phrase books, etc. Trustees Larry Williams and Bill Keck meet us there. They have cleverly come the day before to London and have spent the night there. We are also joined by Jack and Ethel Roberts. Then we go on to Moscow by British European Airlines, which has now been renamed British Airlines. This flight—on a British Trident, which is their analog of a Boeing 727—is also full. The plane is delayed in take-off for one hour by fuel spilled on the tarmac around the plane. ("We have to soak up the spilled gasoline before we can start the engines.") Then 3.25 hours to Moscow.

It is raining in Moscow. Our group is picked up in a special bus, taken to a VIP lounge by a committee consisting of a vast number of notables, including varied officers of the Soviet Academy of Sciences. Here too we meet our interpreter, protector, guide, and constant companion, Mr. Yuriy Reznikof. Yuriy is totally bilingual in Russian and English, can make jokes in English (and does all the time), and is furthermore a nice guy. He is an employee of the Soviet Academy of Sciences, not of Intourist.

From the airport we proceed to the Hotel Rossia; this is the largest hotel in Russia and is said to be the largest in the world. It has 3,000 rooms, 6,000 beds. It is adjacent to the Kremlin and has marvelous views. It is a very nice hotel, but it is cold. Our room is only 14°C—about 58° Fahrenheit. In some respects it has good service, but it is only because Yuriy Reznikof and our other Academy helpers order everything ahead of time. Our group has its own table in the restaurant, with a little American flag on it.

Thence to a short sightseeing tour of Moscow. Moscow has changed in the 12 years since I was last there. Many new buildings, everyone better dressed, many more cars on the street. Then to bed.

SUNDAY, SEPTEMBER 16

Up late and to a nice sightseeing tour of Moscow. We go in the evening to a formal reception—dinner in the Praha Restaurant. It is cold as an ice cave—10°C. Little speeches by Keldysh and Harold Brown. Then I talk about differences between females and males. (Females have two X chromosomes, males only one X and a Y . . . Intelligence is not concentrated in the X chromosome, or the Y either; therefore we are all equal but different . . .) It is a great success.

President Keldysh, an aerodynamician, is an important man in the U.S.S.R. As President of the Soviet Academy of Sciences, he is a member of the Presidium of the Supreme Soviet of the Soviet Union. Thus he has a direct input into political, fiscal, and all other aspects of the cutting up of the economic and fiscal pie of the Soviet Union. Science and development is taken seriously in our host country.

MONDAY, SEPTEMBER 17

Our initial duty on this day is a visit to the Presidium of the Academy of Sciences in the U.S.S.R. Our host is Academician M. V. Keldysh. All of our group is present, plus a distinguished group of Soviet Academicians, plus our omnipresent interpreter and aide. Academician Keldysh outlines the organization of the institute and makes a sort of semi-formal speech.

In general the Academy has paid attention to the establishment of institutes and sciences of importance to the development of the Soviet Union. Keldysh mentions in particular chemistry and more recently bioorganic or biochemistry. Also many of the institutes of the U.S.S.R. which have to do with atomic energy were initially born in Lebedev Institute of Physics of the Academy. Academician Keldysh said, "In the last ten years we have pushed forward in molecular biology, particularly in Moscow and Pushino. The results are very successful, both in the study of protein structure and in the study of nucleic acids, peptides, etc.

"The Academy has sent expeditions to each republic to set up permanent scientific bases there. Each republic has been helped to form its own Academy. Some of these have become centers in particular fields for all of the Soviet Union, as has astronomy in Armenia.

"There are four sections of the Academy—Physics and Mathematics, Chemistry and Biology, Earth Sciences, and Social Sciences and Humanities. Each section has a vice president in charge of it—thus Y. R. Ovchinnikov is the vice president of the Academy for Chemistry and Biology. Each section is divided into departments." Finally Keldysh closed by saying, "As is the fashion now, the Academy also has a swarm of scientific councils and committees."

In the p.m. to the Institute of Natural Products Chemistry. I go with Arnold Beckman, Jack Roberts (who is an old friend of Ovchinnikov, the director of the Institute), and Larry Williams. This Institute was established in 1959, as part of the effort to start biology going again in the Soviet Union after its previous hard times. The main directions in the Institute are the study of biopolymers, regulatory biology, protein chemistry, peptide chemistry, synthesis of DNA molecules, and the study of steroid and peptide hormones, the study of antibiotics—especially peptide antibiotics, and the plant-growth hormones. They have two Beckman sequenators, and a Beckman peptide synthesizer—which is present but not yet installed. It is waiting for Majid, the Beckman service engineer, to come from Palo Alto to finish its installation. Majid is a hero in the Soviet Union, a hero of the installation of many, many sequenators—and of many, many wild parties. He is a Beckman service man, and previously a Spinco service engineer in our group at Caltech, a really good guy.

Everyone in the Soviet Union wants a Beckman instrument– a scintillation counter, a Spinco centrifuge

This is a big laboratory. They have 250 professional people, PhD's, and 500 helpers of various kinds, including a few graduate students. It's all broken down into groups of 10 or 12 PhD's per group or lab. It's a first-class place, and the best instrumented biology laboratory that I saw in all of our trip to the Soviet Union.

On our tour, each group explained its work in English, and very well. This is a very impressive place. They are good people and they do good work. Each program is reviewed every three to four years, and each individual's work is assessed. If he doesn't measure up, it is policy to get him a job in industry or in an academy of agriculture or medical sciences—which are of lesser value than the Academy of Sciences itself. Dr. Khoklov, the vice director, says that the Institute is so good because of the vigor and ability of the director, Academician Ovchinnikov.

It is noteworthy that in a land supposed to be full of Women's Lib, and in which we saw many women in construction jobs, etc., we saw very few around this Institute, and these few were concerned with things like hanging up our coats. No women scientists.

In the evening to the ballet, *Swan Lake*. This is the best *Swan Lake* we have ever seen, and entirely different. It has two endings. The first is sad, for the heroine turns back into a swan. Then, after a short intermission, they have a second ending where the hero saves her and turns her back into a human—really neat.

It is interesting that our Soviet hosts don't understand what trustees are, and treat them rather differently from the faculty, but Arnold Beckman is honored in the Soviet Union. Everywhere we go, as soon as our hosts recognize that he is the Beckman of Beckman Instruments, they kowtow to him. Everyone in the Soviet Union wants a Beckman instrument—a scintillation counter, a spectrophotometer, a Spinco centrifuge.

Arnold Beckman is full of businesslike activity, he visits everything, he arranges for better ways for Beckman servicemen to come from West Germany or Vienna to service his instruments in the Soviet Union, and he arranges to set up a school to train Soviet engineers to be Beckman servicemen in the Soviet Union.

The Cathedral of St. Basil and a section of the Kremlin wall and Red Square form a backdrop for James Bonner and Yuriy Sivolap, a Russian friend and former Caltech Postdoc.

Beckman is a hero in the Soviet Union. At a meeting at the new science city of Pushino, about 120 kilometers outside Moscow, at a lunch given for us by the director of these institutes, Academician Scryabin, the director of the Institute of Photosynthesis, Professor Ustaniev, got up and gave a toast to Arnold Beckman, saying: "In 1947 I was fortunate enough to come into the possession of a Beckman DU spectrophotometer. With this instrument I made my PhD thesis. With this instrument I made my DSc degree. With this instrument I became a professor and a director of the Institute of Photosynthesis. After 27 years, the instrument is not quite perfect for the last year, but will soon be perfect again. I toast Dr. Arnold Beckman and his instruments."

TUESDAY, SEPTEMBER 18

Today's exercise is a visit by Arnold Beckman, Larry Williams, and myself to Pushino. We drive there in two rather new Volga sedans; the Volga was restyled three years ago and looks pretty good. It has a four-speed, four-on-the-floor transmission, and can go up to 180 kilometers per hour, which we do on the crowded two-lane highway. Spooky! Only thing to do is close your eyes and relax! The drivers are all very good—no catastrophe happens. There are no seat belts.

Pushino has a population of about 15,000 people and is about five years old. It's on top of the hill, overlooking a river, and away out in the country—a very beautiful setting. A mall about 200 yards wide, planted with trees and grass, separates the academic institutes on one side from the apartment buildings which house the scientists and service personnel on the other side. It's a nice sort of setting for people who like this sort of setting—sort of an Oak Ridge-type existence.

Scryabin is apparently the general manager of the whole complex and is also director of the Institute of Biochemistry and Physiology of Micro-Organisms. He explains to us that Pushino is an experiment in a new style of science organization. The whole thing belongs to the Soviet Academy of Sciences and it is divided into groups—molecular biology, biochemistry, and physiology of micro-organisms; a laboratory of bioenergetics, and institutes of biophysics, photosynthesis, and agrochemistry and soil research. There is also a computing center and a department for the development of instrument design.

Academician Scryabin explains that "there was a different situation in biology about 10 to 20 years ago, and when this situation was undone, it was decided to establish several new institutes for modern biology such as those in Pushino." What he is referring to is the end of the Lysenko center and the beginning of the new era. Each of the institutes has of the order of 500 to 1,000 people in it.

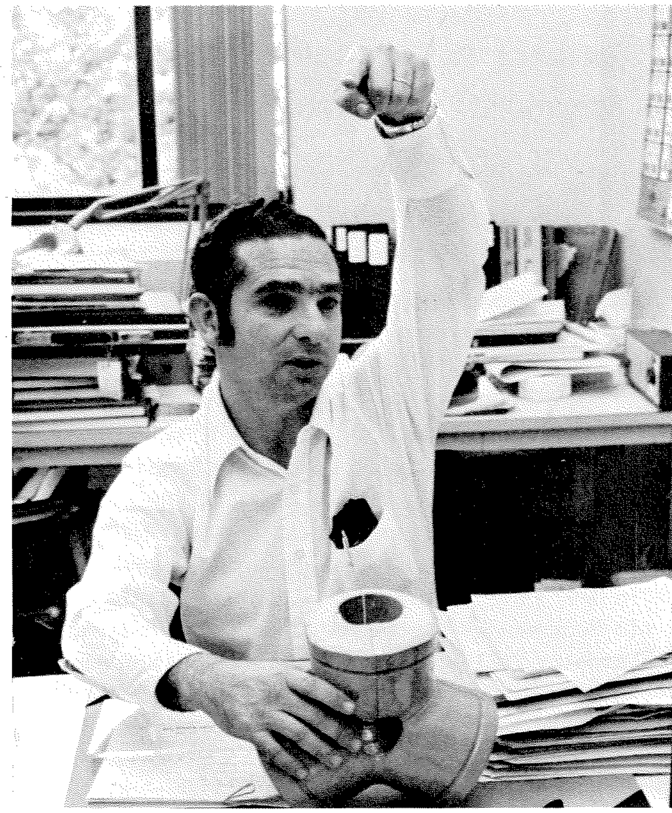
Scryabin tells us about the organization of the institutes and says that he has just been told that he has had five million rubles a year added to his budget, and he doesn't know what to do with it. I suggest to him that he give it to me as a research grant. He replies that this is not possible, but I can move to Pushino. There I can have a big lab—50 people will work with me, and I can buy lots of Beckman instruments. They have a modern European hotel almost finished in which I can live. It is less than two hours drive from Moscow, provided you drive up to 100 kilometers per hour in the Volga sedan.

The organization is typical of that of most research institutions. Each institute is broken up into actual research groups of about 15 to 30 people. The whole place seems to be wide open for growth and work. However, this was a less than totally satisfying visit. It was basically a run-through of labs—led by Scryabin talking, and with little conversation with other people.

The Biophysics Institute of 1,000 people, 300 PhD scientists, is mainly concerned with neurophysiology. Since we had no lab tour, I don't know what they do. We didn't visit the Photosynthesis Institute but the director asked me in an aside to please tell Academician Keldysh how important photosynthesis is to study. He's afraid that it is not properly appreciated either by Keldysh and the upper echelon of the Academy of Sciences or by Scryabin. He is probably right. Even so, the Photosynthesis Institute is a

continued on page 28

An Insight into Chemical Reactions



Historically, chemists have been interested in two fundamental concepts: chemical structure (the arrangement of atoms in molecules) and chemical dynamics (how molecules change due to chemical reactions). In terms of understanding the structure of molecules, chemistry is now a fairly mature field, but the understanding of chemical reactions is still in its infancy. Now research in that field too has begun to boom.

With the aid of theoretical models, Aron Kuppermann, professor of chemical physics, and his co-workers have revealed some new and important aspects of chemical reactions, including the existence of resonances. (Simply defined, a resonance in a chemical reaction is a short-lived intermediate, formed when two molecules in the process of reaction stick together.) The work may have a profound influence on our understanding of chemistry.

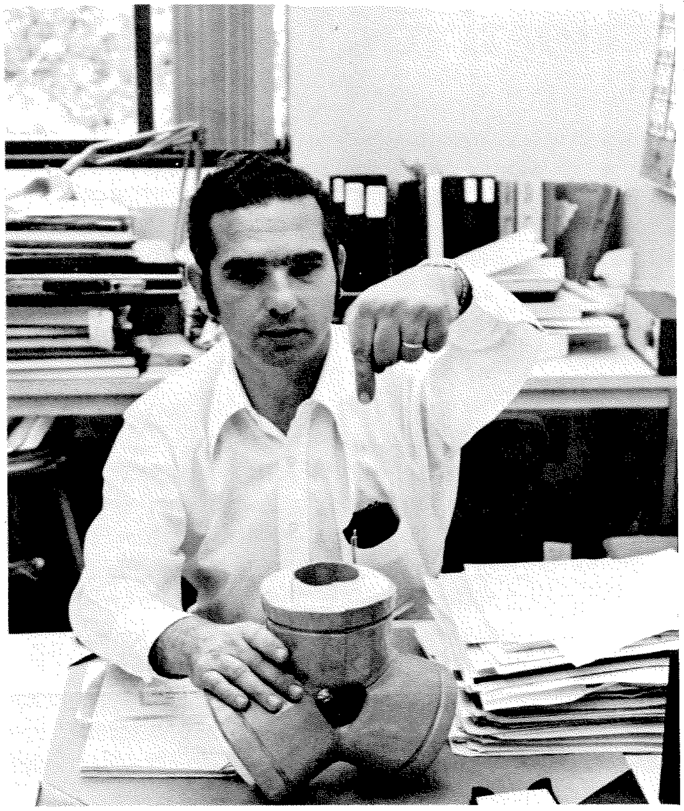
In the past, chemists have been handicapped for lack of sufficiently powerful experimental and theoretical techniques to answer vital questions concerning chemical reactions—questions that deal, for example, with the effectiveness of reactions. How is chemical change most efficiently brought about? What happens to the energy following a reaction? Does it appear in the vibration or in the translation of the resultant products of reaction?

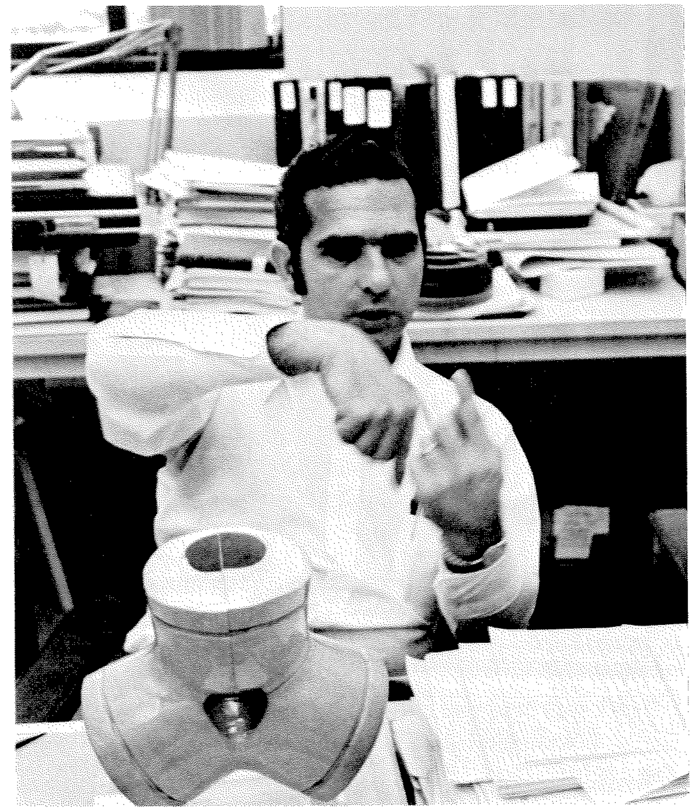
What makes this research important now is that there are new techniques that make the solving of these problems possible. "We can take a ride on top of a molecule and watch what's really going on," Kuppermann says.

The way Kuppermann looks at molecules is to employ a crossed molecular beam apparatus to study molecular collisions. This kind of apparatus was first used successfully 15 years ago at Oak Ridge National Laboratory and has since been markedly improved by investigators at Caltech and elsewhere. The device has the advantage over earlier experimental techniques of permitting a high degree of selectivity of the kind and energy of the molecules which are made to collide. When this energy is made sufficiently high, attention can be focused on reactive events that normally account for an extremely small fraction of the collisions between reactants.

Kuppermann's apparatus, known as "the beast," consists of two sources of molecules enclosed in a vacuum and set at right angles to one another. The molecules are propelled as a beam from each source toward a point of intersection. A mass spectrometer then detects the molecules scattered into different directions of space. The resultant information is fed through cables into a small computer where it is stored and processed. This billiard-ball technique is the most direct way to measure the forces between molecules. These forces determine the bulk properties of gaseous molecular mixtures, including viscosity and heat conduction.

To help his theoretical efforts, Kuppermann recently began building representative models of the potential energy in chemical reactions. The inspiration for his models, which was generated by a particular system of





Aron Kuppermann, professor of chemical physics, conceived, designed, and built this deceptively simple-looking balsa wood model of the potential energy in a chemical reaction. His gestures only hint at its inner complexities—a labyrinth of channels through which the tracks of colliding molecules and their reaction products can be traced.

mathematical coordinates, he says, "came in a flash, but only after many months of intensive work. I have in my briefcase about 250 pages of notes—and on page 250 there's a big 'Eureka'."

The models illustrate to scale all the translational, vibrational, and rotational motions of the colliding molecules and of their reaction products. The internal anatomy of the models determines what chemistry is going on.

Two of the models have proved particularly useful. The first describes geometrically the simplest chemical reaction occurring in nature—the exchange of an atom between a hydrogen molecule and a hydrogen atom. The other model represents a similar process between a hydrogen molecule and a fluorine atom to produce hydrogen fluoride. This product is formed with a large amount of vibrational energy and is one of the key processes in the hydrogen-fluorine chemical laser—one of the most powerful chemical lasers in existence.

Both models are equipped with hinges that allow partial disassembly, thus affording a view of their interiors. The intricate topological structure reveals, through the size and shapes of the holes and passageways, the prominent features of chemical events—giving clues to the probability of the occurrence of various reactions. By simply looking at the hydrogen-fluorine model, Kuppermann has suggested that the deactivation of vibrationally excited hydrogen fluoride molecules by hydrogen atoms may be a very efficient process. Events of this kind are of importance for the understanding and improvement of lasers.

With the aid of the models, he is making an extension from a simplified world of collinear collisions between atoms and diatomic molecules (used in preliminary theoretical studies) to the real three-dimensional world. This transition is the crux of his current theoretical research.

On the experimental side, Kuppermann initially used the crossed molecular beam apparatus but at purposely lower energies than requisite for reaction in order to study exactly how molecules bounce off one another. This work was designed to measure the intermolecular forces first postulated by the Dutch physicist J. D. van der Waals a century ago.

The van der Waals force is a long-range force due to the attraction of the electrons of one molecule by the nuclei of another. When two molecules approach each other, they feel the weak attraction due to this force. For a reaction to occur, the molecules must get much nearer, and a substantially larger degree of energy must be supplied to overcome the strong repulsions that frequently exist between molecules at close distances. Van der Waals forces, which are of crucial importance in nature, are a thousand times weaker than the chemical forces at play during reactions.

The van der Waals force esentially determines the physical state of matter—liquid, solid, or gaseous. It all depends on whether the molecules stay close enough to fall into the little van der Waals traps, corresponding to a minimum in the potential energy. In liquids and solids the molecules have fallen into and remained in these traps. At higher temperatures the molecules get excited and escape to form a gas. The van der Waals force is always present, but whether or not its effect is important depends on the molecular energies.

Before the first experiments were done, the Kuppermann group feared that the molecules' cigar-like shape and wild spinning motions would obscure tiny quantum mechanical oscillations predicted by theory. Instead, they found that the molecules bounced off in such a way that the fact that they were molecules rather than atoms (which are spherical) didn't make much of a difference. They also found that the quantum mechanical diffraction oscillations were, indeed, visible. From these oscillations, which showed that molecules behave like waves, the forces between molecules were precisely measured for the first time.

Kuppermann's study of van der Waals forces was an important milestone in studying molecular collisions. Using the cross-beam technique, he is now planning to shoot molecules at each other with much higher energies. The molecules will be energized to temperatures of about 20,000 degrees Fahrenheit—greater than the surface temperature of the sun—in a device called an arc-heated hypersonic beam source, built with the assistance of graduate student Mike Coggiola, who has also been a major contributor to the intermolecular force work. These very high energies are necessary to overcome strong repulsions and to permit the molecules to get near enough to react chemically.

Perhaps Kuppermann's most significant discovery from his recent calculations, done in collaboration with graduate student George Schatz, is the prediction of high-energy resonances in a chemical reaction—a phenomenon he hopes to find in the laboratory eventually. Theoretical particle physicists have found similar resonances at a billion times greater energies, but chemical resonances have never been observed and should prove technically very difficult to locate.

The implications of the current research are very encouraging. Potentially, it could make a host of related chemical systems better understood. "Chemistry is the source of chemical change," Kuppermann says. "The question we're asking about what happens when two very simple molecules collide and react are questions that pertain to what's happening in the chemical reactions that make you see and smile and breathe. But right now we're only trying to understand what happens when two little molecules bang into one another."

—*Gary Prohaska '73*

Thomas Lauritsen
1915-1973

On October 16 death ended the 41-year association with Caltech that began when Thomas Lauritsen entered the Institute as a freshman in 1932. Even during those undergraduate years he began the close research collaboration with his father, C. C. Lauritsen, and W. A. Fowler that eventually established the W. K. Kellogg Radiation Laboratory as a center for research in nuclear physics, astrophysics, and geophysics.

As a graduate student, Tommy built the first of the pressurized Van de Graaff accelerators at Caltech. This machine is still used for research and is the oldest accelerator of its type in active use. After receiving his PhD in 1939, he held a postdoctoral appointment in what is now the Niels Bohr Institute in Copenhagen. There he built an identical copy of the Kellogg accelerator, and was thus instrumental in starting the program that led to another international center in nuclear physics. The close relationship that has always characterized the association of these two research groups dates from this period.

During the war years Tommy and the Kellogg group were first involved in the development of the proximity fuse, and later in the design and construction of solid-fueled rockets for the Navy. Virtually all of the rockets used on the South Pacific beachheads came from this project. Tommy was also actively engaged in the work at Los Alamos during the last years of the war. In recognition of his wartime contributions, he received a Presidential citation.

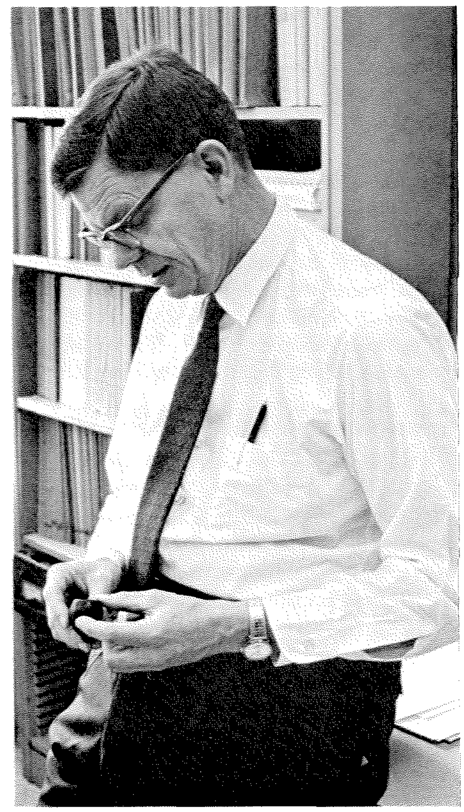
In the postwar period more accelerators were built in Kellogg, and high-precision techniques for the study of nuclear energy levels were invented. The group became the center for the spectroscopy of the light nuclei. Tommy remained interested in this field until his death; his critical reviews (in collaboration with Fay Ajzenberg-Selove) of work in light-element nuclear spectroscopy became world famous, and Caltech became a clearing house for information on the energy levels and systematics of the elements up to neon in the periodic table.

Some of the preoccupation with this range of nuclei was a consequence of the laboratory's expanding interest in the role played by nuclear reactions in stellar energy generation and element formation. This research has become a major specialty of the Kellogg group. Their success in this new field of nuclear astrophysics is directly attributable to the foundation that Tommy Lauritsen provided—an enormous store of knowledge of the systematics of the light nuclei and their reactions in addition to his collaboration in measurements of the rates of nuclear processes thought to be important under astrophysical circumstances.

In the last few years Tommy devoted much of his time to service to the whole physics community. This consisted of membership on many national committees, the chairmanship of the Division of Nuclear Physics of the American Physical Society (1972-73), and a major role in writing the report of the Physics Survey Committee. This report, *Physics in Perspective,* has just appeared and promises to have a substantial impact not only in listing accomplishments in physics for those outside the field but also in giving the physics community a chance to examine its rather diverse goals and try to arrive at a set of priorities for the future development of its sub-fields.

His Caltech colleagues will remember Tommy's contributions to a wide variety of faculty, ad hoc, and departmental committees. He had the unique gift of being able to look at a situation as if from outside, and thus always had a clearer understanding of the implications of a decision. His membership was prized not only because of his wisdom, but also because of his intrinsic humanity.

Over the years he taught many physics courses; all were distinguished by his careful preparation, his thoughtfulness toward his students, and his remarkable sense of humor. Most recently he helped ease the trauma of partially abandoning *The Feynman Lectures on Physics* in Ph 2 by taking over the job of lecturer in the non-Feynman track (track A) of the course. Though everyone had his own idea of what should be done about Ph 2, Tommy managed to keep the show running despite the over-



abundance of divergent viewpoints.

To those of us at Caltech who knew him well, we have lost a loyal friend and a unique source of solutions to the problems we did not hesitate to share with him. We'll deeply miss his wise council and the sense of humor that helped tie us together as a real community.

—Tom Tombrello
Professor of Physics

A Thomas Lauritsen Memorial Fund has been established. Tax deductible contributions may be made to the California Institute of Technology with the notation that they are for this fund.

The Month at Caltech

New Course

Caltech students in aeronautics have always had excellent training in the theory of such flight-related topics as fluid and solid mechanics, jet propulsion, and flight dynamics. In fact, their theoretical training has been so thorough that few of them have much understanding of the compromises necessary to develop a functioning system in any large aerospace project.

A new course is being offered for the first time this year to help solve that problem. Ae 207, Case Histories in Aerospace Engineering, is designed to introduce students to the entire management program—financing, customer relations, and long-range planning, as well as interactions between technical groups.

Supervised by aeronautics professors Homer J. Stewart and Ernest E. Sechler, Ae 207 started this fall with an enrollment of 14—2 seniors and 12 graduate students. The subject for the first term is the Mariner 9 mission to Mars, and scientists and engineers from Caltech's Jet Propulsion Laboratory are giving lectures on such subjects as how the project began, how it was organized, designing the spacecraft, development of the instruments, and evaluation of the scientific results.

Development of the DC-10 airliner is the subject for second term, and key men from McDonnell Douglas Corporation will give the lectures. Among the topics for discussion will be the economic analyses made to determine the need for the system, airline and passenger requirements, financing, aerodynamic and structural analyses, wind tunnel and flight testing programs, how materials used in building the plane were chosen, inside and outside acoustic problems, marketing, and planning for advanced or modified models.

The topic of the third term will be announced later, but it too will cover a fairly recent aerospace project.

Theory, of course, continues to be the basis of what is taught at Caltech, but students who have taken Ae 207 will also have learned that more than theory must go into solving production problems.

In Memoriam

Caltech lost two long-time friends and trustees in October—men whose terms of service to the Institute totaled more than 50 years.

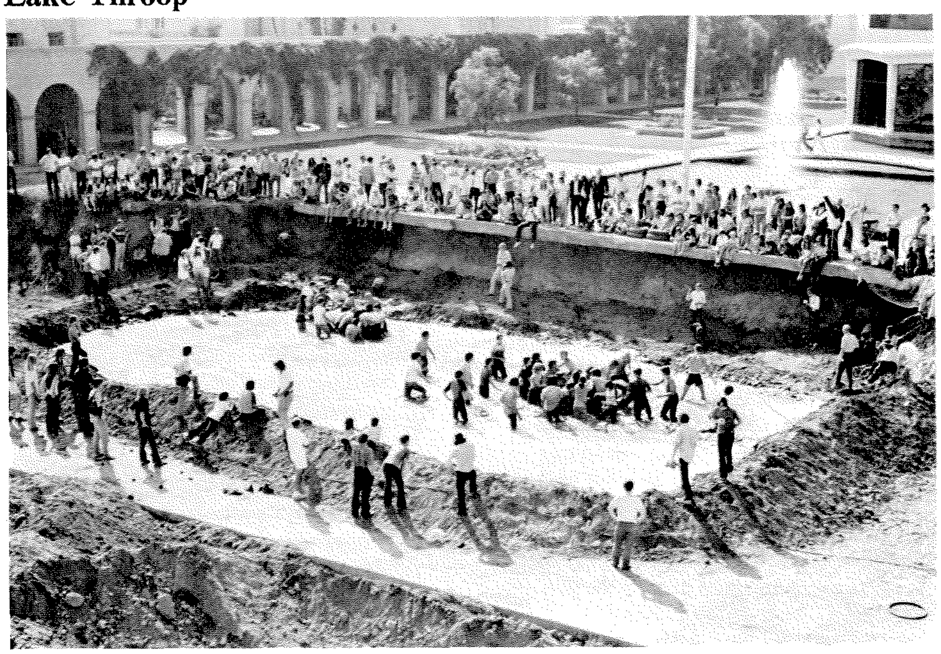
John Barber, 1886-1973

John E. Barber, who died on October 2 at the age of 86, was first elected to the board in 1954 and became a life trustee in 1966. He had served as both vice president and treasurer, and was valued for his counsel in financial affairs. He was also a life member of The Associates, and had served as president, vice president, and secretary of that organization.

Mr. Barber was a native of Toledo, Ohio, and graduated from Yale in 1910 with membership in Phi Beta Kappa. He went into the investment business in New York, and after World War I served with the Dawes Commission on Reparations in Europe. Moving to Pasadena in 1920, he became president of various financial organizations which today are components of Security Pacific National Bank. During the 1930's he headed utility companies in the Middle West, returning to Pasadena during World War II. He was associated with U.S. Steel Corporation, retiring as treasurer of its subsidiary, Columbia-Geneva Corporation. In retirement he was closely associated with Disney Enterprises and was instrumental in arranging the financing of Disneyland.

Mr. Barber is survived by his wife, a son, and two daughters, 14 grandchildren, and one great granddaughter.

Lake Throop



The 59th annual Mudeo on October 21 had a lot of favorable factors: the spacious Throop site for a temporary lake, a warm day, enthusiastic participants—including girls—and the largest audience in years. What wasn't so favorable, for the freshmen at least, was the outcome. For the first time in 11 years the sophomores won. Score 6½ to 2½.

Norman Chandler, 1899-1973

Norman Chandler died on October 20 at the age of 74. He had been a trustee since 1941, continuing a family tradition that began in 1920 when his father was elected to the board. He was also a life member of The Associates.

Mr. Chandler was born in Los Angeles and went to Hollywood High School. He graduated from Stanford University in 1922 and immediately joined the *Los Angeles Times,* becoming assistant general manager in 1934 and, in 1936, vice president and general manager. In 1941, when his father moved up to board chairman, he became president of Times Mirror. In 1944 he was appointed publisher of the *Times,* a post he held until 1960. Since that time he has been board chairman and chief executive officer.

The *Times* editorial of October 23 said of him: "To public service in the ordinary sense of the phrase he was no stranger. He served on many boards. He was a trustee of USC and, for more than 30 devoted years, of Caltech. He worked, often quietly but always powerfully, on many civic enterprises . . . To the thousands of persons here and around the world who knew Norman Chandler in his business and public capacities, he was a man of dignity and gentle forcefulness. Those who knew him more intimately had the great good fortune to know even better his indelible personal qualities—his unfailing thoughtfulness, his natural courtesy, his resolute, unpretentious courage, his steadfast allegiance to family, to friends, to associates and to conscience."

Mr. Chandler leaves his wife, son, a daughter, eight grandchildren, a brother, and two sisters.

A Norman Chandler memorial fund has been established. Tax deductible contributions may be made to the California Institute of Technology with the notation that they are for this fund.

Caltech's Man on Skylab 3

It could be just a coincidence, but the National Aeronautics and Space Administration seems to be developing a taste for putting a Caltech graduate on the final flight of each of its space programs. In December 1972, Harrison Schmitt (BS '57) was pilot-astronaut for Apollo 17, the last of the U.S. manned moon-landing missions. Now, the last of the current series of manned earth-orbiting missions—Skylab 3—has been launched carrying Edward Gibson (MS '60, PhD '64) as its science pilot.

The 37-year-old Gibson graduated from high school in Kenmore, New York, and got a BS in engineering from the University of Rochester in June 1959. He came to Caltech that fall to work toward his MS in mechanical engineering, with a jet propulsion option, and stayed on for his PhD in mechanical engineering, minoring in physics.

For a year following his graduation, Gibson was a senior research scientist at Philco Corporation's Applied Research Laboratories in Newport Beach. While there he did work on lasers and the optical breakdown of gases and published a number of papers on plasma physics.

Ed Gibson

Selected as a scientist-astronaut by NASA in June 1965, Gibson spent 53 weeks in flight training before joining the astronaut group in 1966. He served in a number of backup positions for the manned lunar missions, and in 1969 was selected as a member of the astronaut support crew for Apollo 12. Since the completion of the Apollo program, he has been in training for Skylab.

In the meantime Gibson's scientific interests have shifted slightly—from classical and plasma physics to solar physics. He wrote the training document on solar physics for the Skylab astronauts, which has been published under the title *The Quiet Sun.*

As the science pilot for Skylab 3, Gibson is responsible for all the studies of the earth's resources; investigations of the earth's upper atmosphere, the interplanetary plasma, and the sun; medical experiments; galactic and intergalactic astronomical observations; and an analysis of the possible technological uses of near-earth orbital space—all, of course, with the active collaboration of his fellow astronauts, Mission Commander Gerald Carr and Pilot William Pogue.

If this sounds like a lot, consider also that the three men constitute a rookie crew, none of them having flown in space before. And they are orbiting the earth in a craft that is only partially operating and rapidly deteriorating. Gibson, however, is optimistic about the "advantages of being one of the last in line"—and so another Caltech graduate is doing what he can to wrap up NASA's current program in the great style to which the space agency is becoming accustomed.

Honors, Awards, and Appointments

Nobel laureate Richard Feynman received the Niels Bohr International Gold Medal in Copenhagen last month—directly from Queen Margrethe. The prestigious medal is awarded by the Danish Engineering Society every third year "to an engineer or scientist in recognition of outstanding work for the peaceful utilization of atomic energy." The first of the medals was given in 1955 to one of the founders of modern physics—Niels Bohr himself.

Feynman, who is Richard Chace Tolman Professor of Theoretical Physics at Caltech, has contributed greatly to the understanding of the structure of the atom, particularly in quantum electrodynamics, the field for which he was awarded the Nobel Prize in 1965.

One bow, a gold medal, and two smiles are the order of the day for Denmark's Queen Margrethe and Caltech's Richard Feynman.

A. J. Haagen-Smit, professor of bio-organic chemistry emeritus, received the National Medal of Science in Washington, D.C., on October 10. He was honored "for his discovery of the chemical nature of the source of smog, and for the successful efforts he carried through in smog abatement."

For over 25 years Haagen-Smit has been a protagonist in the battle against smog at all levels of industry and government. He is currently both chairman of the California Air Resources Board and head of the President's task force on air pollution.

Established in 1963, the National Medal of Science is awarded to prominent scientists who "in the judgment of the President are deserving of special recognition for their outstanding contributions to knowledge in the physical, biological, mathematical, and engineering sciences." The very first medal was given to Theodore von Karman in 1963. Since then three other members of Caltech's faculty have received it: A. H. Sturtevant in 1967, and John Pierce and Allan Sandage in 1971.

The national professional fraternity for chemists, Alpha Chi Sigma, has given its 1973 award for chemical engineering research to C. J. Pings, professor of chemical engineering and chemical physics. The award, which consists of a certificate and $1,000, recognizes outstanding recent accomplishments in fundamental or applied research in the field. Pings was cited for contributions to the measurements of the properties of liquids, the development of new approaches to the prediction of those properties, and for the use of modern instrumentation techniques for more precise measurements of diffusivities.

Pings is a Caltech alumnus (BS '51, MS '52, PhD '55) and has been a faculty member since 1959. He is also now vice provost and dean of graduate studies.

Regular readers of *Engineering and Science* magazine may have noticed that we tend to shun the use of capital letters—a style known in our trade as "down." Imagine how startled we were to find ourselves typing the following copiously capitalized item:

Michael E. Levine, Henry R. Luce Professor of Law and Social Change in the Technological Society, has been appointed to Los Angeles Mayor Tom Bradley's Council on Controlling the Cost of Living.

In so worthy a cause, we're really happy to have things looking "up."

A Caltech professor and an alumnus were recent recipients of awards from the National Aeronautics and Space Administration.

Donald S. Burnett, associate professor of nuclear geochemistry, has been awarded the NASA Exceptional Scientific Achievement Medal "for his outstanding contribution to the achievement of lunar science in the design and implementation of the lunar neutron probe experiment which successfully measured the neutron flux in the lunar surface during the Apollo 17 mission." The experiment made it possible to determine the rates at which neutrons have reacted with lunar material and how depth causes these rates to vary (*E&S,* February). Burnett received his BS at the University of Chicago in 1959 and his PhD at UC Berkeley in 1963. He then came to Caltech to do postdoctoral research in physics. In 1965 he joined the Division of Geological and Planetary Sciences, and in 1968 was awarded a two-year Alfred P. Sloan Foundation Fellowship for research in geochemistry.

Alumnus Frank E. Goddard Jr. (PhD '57), assistant director for research and development at Caltech's Jet Propulsion Laboratory received the NASA Exceptional Service Medal for "outstanding performance in advancing the technology of automated spacecraft design."

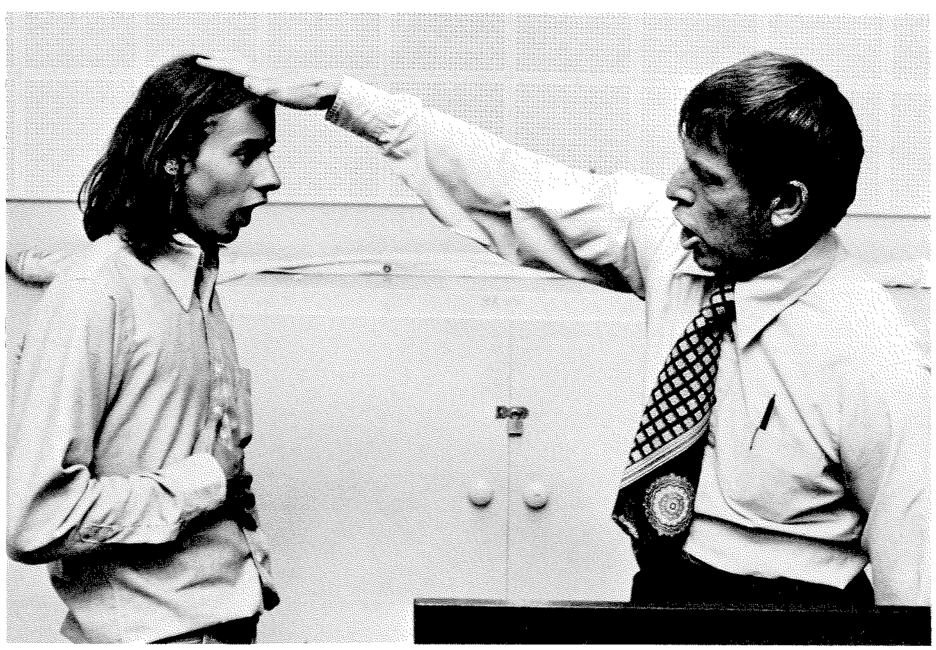
IT MAY LOOK EASY–

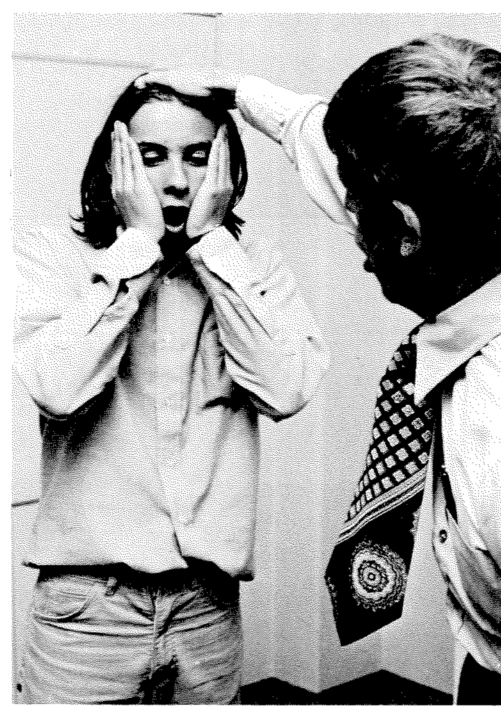
—but that's just part of the training. Olaf Frodsham, Caltech's director of choral music, is a man who believes that *anyone* can learn to sing—and he's been proving it every year for the last 20 by transforming a random group of novices into a first-rate singing ensemble, in record time. His technique may be unorthodox—as demonstrated on the following pages—but it's undeniably effective.

The three freshmen in the front row, Marc Sengstacke, Bob Vogel, and Jim Brubaker, have already become competent, trained singers.

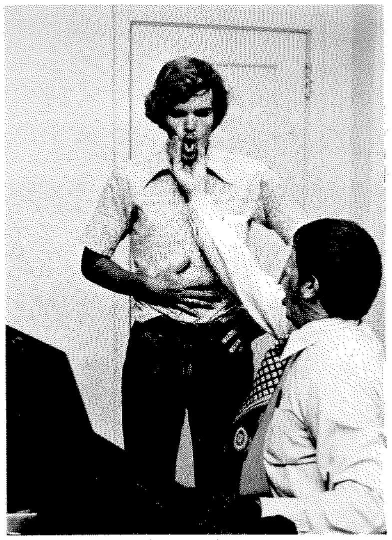
–but first you have to SUFFER

Most of the students who turn up for Glee Club tryouts have never even sung in the shower, so Frodsham starts with a few basics—like helping Marc Sengstacke sound his "awe," a vowel that requires an open mouth and relaxed jaw for proper vocalizing.

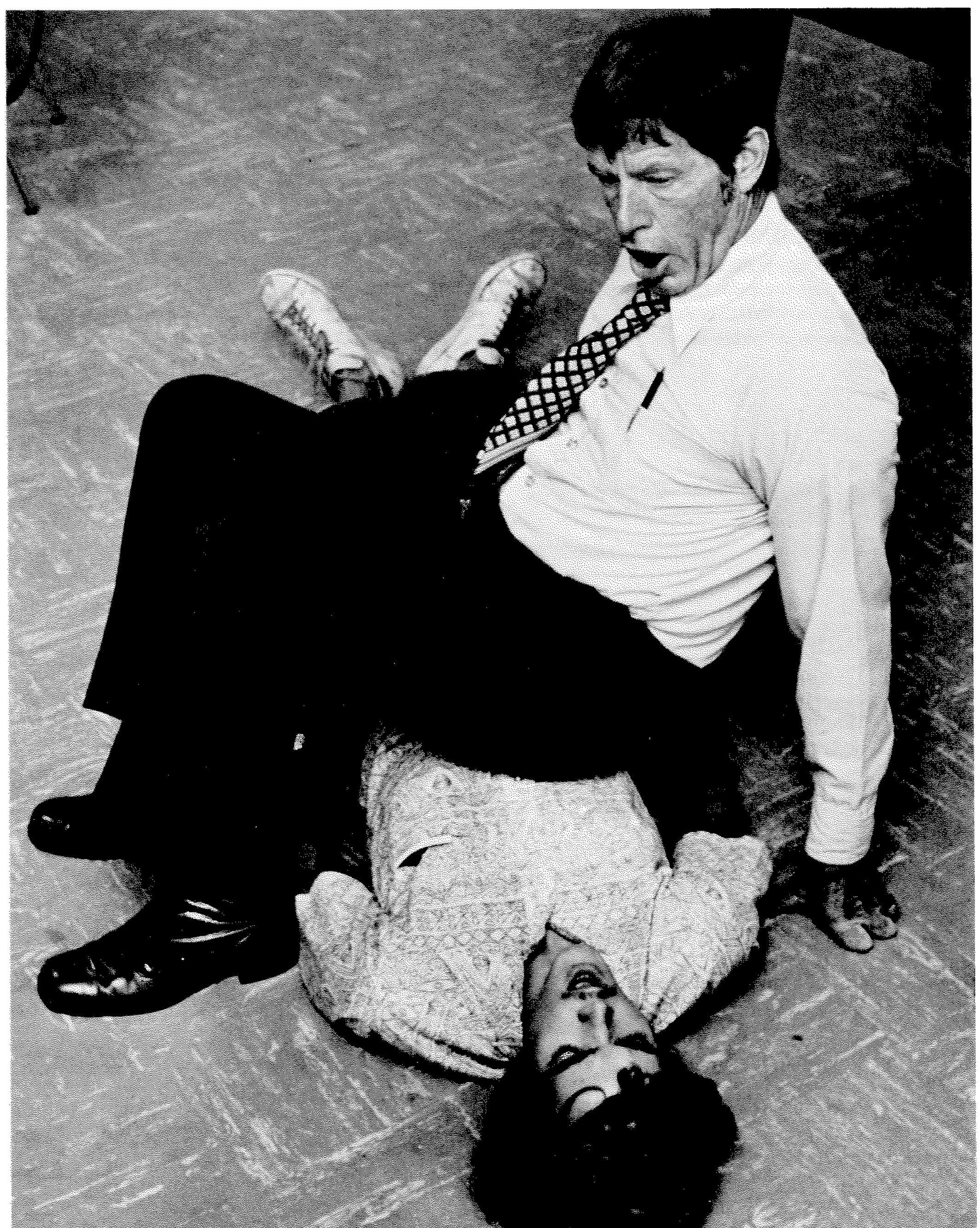




Bob Vogel is intent on producing a full round tone, and Frodsham is making sure he doesn't turn into a "necktie tenor"—a singer who tips his head back another notch every time he hits a higher note.



Two essentials for a singer—proper breath-control in spite of obstacles, and strong abdominal muscles. Jim Brubaker develops them both in one violent lesson.



Project Oldstone–Greenland 1973

After the cold and dreary winter of 1972-73, every member of the Caltech community should have looked forward to the warm, if smoggy, summer. Along with millions of Angelenos, all Tech people should have flocked to the beaches or the desert to soak up the sun's rays. So why would seven members of the Division of Geological and Planetary Sciences head for the fog-shrouded shores of Greenland? To pick up samples of the oldest rocks on earth, of course.

In an immensely successful expedition (one of the largest ever to work out of Caltech) we collected 20 tons of rock samples, which now constitute North America's most complete suite of samples from the west coast of Greenland. Among the prizes are many samples of Amîtsoq gneiss, the world's oldest known rock formation, tentatively dating from 3.7 billion years ago. During our travels along 200 miles of the coast from Fiskenaesset to Sukkertoppen, we also collected samples of pegmatite dikes (coarse-grained intrusive rocks), gneisses younger than the Amîtsoq gneiss, anorthosites, granites, and supracrustal rocks (metamorphosed sediments).

Project Oldstone was conceived in June 1972, when graduate student Alex Gancarz wrote the Greenland Geological Survey (GGU) requesting permission to join a GGU field party in order to collect rock samples for isotope age-dating as part of his PhD thesis. They replied that he would have to form his own expedition—with the approval of the Danish government—and thus 11 months of frustrating letter-writing and telephoning began.

By June 11, 1973, the project had been funded by the National Science Foundation; equipment had been purchased, packed, and shipped to Greenland; the members of the expedition had learned to drill and blast rock; and Alex and fellow graduate student Bob Dymek were ready to venture into the unknown. Their itinerary included 8,000 miles of air travel for the 3,400-mile trip because the only scheduled flights to Greenland originate in Copenhagen; hence, their first view of the famed icecap came midway through the 11-hour flight from Los Angeles to Denmark.

After two days of meetings in Copenhagen, they flew to Greenland on June 15 and experienced a reverse cultural shock: Instead of finding primitive settlements, they encountered modern cities quite like those in Denmark, apart from the snowstorms. Godthaab, Greenland's capital and Oldstone's base of operations, is a town of 8,000, featuring high-rise apartment buildings, and with television, supermarkets, a modern hotel, good restaurants, paved streets, and even a discotheque!

While Alex and Bob unpacked the expedition's equipment, did some sampling, and watched the snow fall in Greenland, the other five members of the expedition did some last-minute shopping and packing in California. On June 25, professors Jerry Wasserburg and Arden Albee, their sons Charles Wasserburg and James Albee, and I boarded our flight to Copenhagen. There, we too had two days of meetings and sightseeing, and then flew to Greenland, arriving in Godthaab on June 30. After a day of stowing gear aboard our chartered ship, the *Jens Jarl*, Alex hoisted the expedition's orange flag, and we sailed out of Godthaab on the first of eight cruises in the land of the midnight sun.

Squeezing nine people aboard a 33-foot boat was no easy matter; feeding them was nearly impossible. The ship's owner and resident Viking, Rudi Burghardt of Godthaab, decided to sleep ashore every night rather than wedge himself into one of the narrow bunks. Jorgen Ostergaard of Qorqut, the captain and old salt of the ship, slept in the wheelhouse, leaving the two main cabins to the Americans. The senior citizens of the group (Jerry, Arden, Alex, and Bob Dymek) slept in the main cabin and were forced to get up every morning so that breakfast could be prepared in the cramped quarters. By breakfast time all nine of us had to be very ductile in order to fit around the ship's 4- x 2-foot table. The forward "cabin," which had barely enough floor space for one person to stand, served as sleeping quarters for the kids (Charlie, Jamie, and me).

After a week at sea, we had established a routine for collecting samples. In each interesting location two or three people went ashore, chose a sampling site, and

Charles Wasserburg mans the expedition's indispensable tool—a gasoline-powered drill that bored about 500 holes in behalf of Project Oldstone.

radioed to *Jens Jarl* requesting the necessary tools; then those on ship went ashore with the tools and set to work. One instrument that always went with us was the gasoline-powered, air-cooled drill. In seven weeks we used it to drill approximately 500 holes, each of which was used for either plug-and-feather-wedge splitting or blasting. Of course, the more mundane sledge hammers and chisels also did their part in procuring fresh, football-sized samples of the old stones, but without the drill the expedition's output probably would have been cut by 80 percent.

Project Oldstone owes a great deal to Dr. Vic McGregor of the GGU. He spent much of his field season showing the Americans his favorite outcrops, but he also played a major role in the expedition's only near-disaster, which all involved refer to as "the drowning." On the morning of July 6. Vic took Jerry, Alex, and Bob Dymek in his tiny two-man dinghy to show them a favorite outcrop. They were about 30 yards offshore when the overloaded boat swamped, throwing its occupants into the icy water of Ameralik

Fjord. Vic, Alex, and Bob managed to swim ashore while Jerry stayed with the overturned boat until Jorgen Ostergaard, in the *Jens Jarl* dinghy, arrived at the scene two or three minutes later. Soon after this the Albees and I arrived with McGregor's boat, the *Pingo,* retrieved the floating gear, and bailed out the swamped dinghy. Luckily the only losses were two pairs of eyeglasses and two ruined cameras, but the potential seriousness of such accidents made everybody careful not to overload a dinghy again.

Much of the time in Greenland was spent gathering samples, but several unusual incidents, of course, will survive in our memories long after the monotony of drilling and hammering is forgotten. For instance, one day when *Jens Jarl* was refueling in Napassoq, Jorgen returned with a half-caribou he had purchased, so for a few days everyone ate fresh—and, eventually, not-so-fresh—caribou stew rather than dehydrated beef stew. A few days later, on Friday, the 13th of July, Jerry, Arden, Alex, and Bob Dymek went ashore for a "15-minute" sampling stop before dinner—and dinner was postponed for four hours while various sampling methods backfired.

The shortest swim on record occurred one sunny morning off Narssaq when James decided to go swimming. Diving in, he found that 29°-water is colder than it looks, and he popped out like a champagne cork after one second of immersion. And one evening Jerry went ashore to look at the rocks and came back with a five-pound sea catfish he had caught with his bare hands!

The highlight of the expedition was the voyage south to Fiskennaesset, where Project Oldstone visited the GGU permanent camp at Midgaard. In addition to such luxuries as outhouses and a shower, the GGU used the ultimate in rock-sampling equipment: two three-seater helicopters. In the two days we borrowed their helicopters for our work, we collected two tons of samples from remote areas—the only old stones not acquired near the high-tide line. And nobody from the expedition will ever forget the rides aboard the whirlybirds—hair-raising because their Swiss pilots loved to fly through narrow gorges, skim over cliffs, and chase ducks at 90 miles per hour.

These helicopter rides marked the last activities of the Albees and the Wasserburgs in Greenland. On August 6 they left Godthaab for another 8,000 miles of flying to return to Los Angeles. Meanwhile Alex, Bob Dymek, and I did some final sampling, lowered the now-famous Oldstone flag, and packed the expedition equipment for shipment back to the United States. After saying "farvel" to all our Greenland friends, we left Godthaab on August 25, ten weeks after our arrival. We spent a day in Copenhagen, and then flew back to the USA. When the rock samples arrive—all 20 tons of them—they will provide the age-daters in Tech's Lunatic Asylum and elsewhere in the world with material for years of research into questions concerning the formation of the earth's oldest rocks.

—Bob Kieckhefer, '74

It's a great place to spend the summer—if you're a geologist. Dwarfed by icebergs and threatened by fog, the *Jens Jarl* cruises up Godthaabsfjord on Greenland's west coast.

Notes on a Trip to the Soviet Union . . . *continued from page 15*

large place with about 250 PhD scientists and 700 people. It must be the largest photosynthesis institute in the world.

We return from Pushino at risk of our lives again, and then to the circus—which lasts three hours. In Moscow the circus is really good. It's in a new building which looks like a permanent tent, but designed by a really imaginative architect. After the circus, and all starving, we go to dinner in the hotel.

WEDNESDAY, SEPTEMBER 19

In the a.m. our entire party goes to Moscow University. There we are met by the rector, R. V. Hoholov. The rector describes the structure of the University, which is basically an independent institution with a consultative council composed of members of the Academy, etc. It has a population of about 40,000 students and involves itself in all branches of science, social sciences, and the humanities.

Professor Kost, chairman of the Department of Chemistry, describes the organization of a typical department. It is organized into inorganic, organic, and physical chemistry divisions. There are 32 full professors, but many other staff members who are re-selected every three to five years. They have about 280 entering freshmen each year in chemistry, and 60 to 80 new graduate students in chemistry each year.

Back to the hotel, lunch, and a little bit of shopping. We go shopping in the dollar store or Berioka. It's not just a dollar store —any kind of hard currency will do, but one can't buy anything in it for rubles. There are such stores in every major hotel, in the airport, and everywhere in the Soviet Union where foreigners might appear. The idea is to sell all the good things that Russia has to produce for hard currency. The Russians are not permitted in them except as guests of foreigners. All of the good things we bought in the Soviet Union are in these dollar stores, but there is not much to be bought.

I buy Ingelore a mink hat because I have suddenly come into the possession of about 500 dollars in rubles—royalties which the Russians have saved up from publication of two of my books in Russian. Jack Roberts and John Pierce each get considerable amounts of royalty. We can't find any way to spend all of the royalties in rubles, but Colene has a suggestion. We give all our rubles to Jim Glanville, who acts as banker, uses the rubles to pay the trustees' expenses in Russia, and will pay us back in dollars when we all get home. Good idea!

In the late afternoon Ingelore and I go to the Institute of Molecular Biology. Director W. Engelhardt remembers me from previous meetings. All of his laboratory directors are present; I give a seminar, many questions, all very stimulating.

I returned there on Monday, September 24, and we spent a lot of time talking about how we could have better exchange between Soviet and American scientists, both interpersonal and by communication.

I asked my friend Gyorgy Georgiev, a corresponding member of the Academy, to tell me about how he came to the U.S. last year. He said it took him almost two years of hard work. He thought up a good experiment that he wished to do and corresponded with Renato Dulbecco, who said it was a good experiment and could be done only in Dulbecco's lab at the Salk Institute. Georgiev then asked the Soviet Academy for permission to go to work in Dulbecco's laboratory. It took 1.35 years before he received permission to make this visit. His application was then turned down by the United States on the basis that San Diego is an area closed to Soviet citizens. Harrison Brown learned of this impasse and took up the matter. It still took six months on the U.S. side for Georgiev to gain permission to go to San Diego. All in all, it took him a full two years. His recommendation is to find some way to speed up the whole process. I hope that by our talks with Keldysh and others we have done something along this line.

Now as to scientific exchange. Sending preprints is not so easy from the Soviet Union. In the first place all manuscripts have to be screened by a censor before they are permitted to be sent abroad, either to international journals or anywhere else. Anyway, Georgiev says such permission is not so hard to get. The main problem is that he can't send preprints to everybody because the Xerox machine they have—which is an honest-to-God U.S. Xerox machine—does not work very well. It breaks down and cannot be fixed because Xerox service men do not come.

Ingelore Bonner

We made an arrangement. He will send me one carbon copy of any article destined to be published in an international journal. He will also send me a list of people he wants preprints sent to. I will Xerox preprints and send them out. Sounds like a good arrangement and I hope we can make it work. I also promised to send him reprints on various things.

Then at midnight to the Red Arrow Express which goes from Moscow to Leningrad in eight hours, overnight. It must be one of the plushest trains left in the world. We have a large, very comfortable compartment and sleep away the miles.

THURSDAY, SEPTEMBER 20

We arrive in Leningrad promptly at 8:15 a.m. and are whisked off to the Leningrad Hotel, an absolutely beautiful new hotel overlooking one of the many canals—almost rivers—that divide the seven islands on which Leningrad is built. The Leningrad Hotel is a very cosmopolitan place, full of tourists from all over the world, and from our room we look directly across the canal at the cruiser *Aurora* which is kept as a national shrine, and from which the signal shot was fired to start the storming of the Winter Palace in the October Revolution.

After a quick breakfast, off to the Institute for the Study of High Molecular Weight Compounds. This is an Institute of the Academy of Sciences. First a formal meeting with the director and the deputy director. The general areas of work in this Institute are the synthesis of carbon carbon, and heterocyclic and metal carbon polymers. They also study polymerization of all kinds, and the properties of each kind of polymer which they make.

In the evening, a tour of the city—first to Peter and Paul Fortress, the first building built by Peter the Great when he established Leningrad. Then to Saint Isaac's Cathedral, which Larry Williams has always wanted to see and now sees, and a tour of the cruiser *Aurora*. Dinner in the hotel.

FRIDAY, SEPTEMBER 21

Up early and with John Pierce and Arnold Beckman to the I. P. Pavlov Institute of the Academy of Sciences. This is about 30 kilometers outside Leningrad on a large estate. The original Pavlov laboratory building is still standing, although it is no longer used for active research. Scattered through the woods of the estate are his doghouses, each the size of a modest family home, and these too are no longer used. We were met by L. Chistovich, the director, who is a lady, and the only slim middle-aged lady that I saw during our entire visit to the Soviet Union. She was accompanied by her husband, Dr. Kozshevnikov. The portion of the Institute in which they work directly is a division on speech perception and speech production. Dr. Chistovich works on perception, the psychophysiology of speech. They try to combine knowledge of speech perception from neurophysiology with all electronic knowledge, and are moving toward the study of how speech signals are processed in the central nervous system. In speech perception humans depend mainly on amplitude peaks in voice sound. These are cut off by something like lateral inhibition in seeing. They have made an electromechanical model of the basilar membrane. It has 100 narrow band pass filters. It acts very much like a basilar membrane. Each unit consists of a nonlinear rectifier, an amplitude adapter which includes the cutoff, and finally the narrow band pass filter which reduces the input sound frequency to a single neuron signal.

John Pierce is very excited. Dr. Chistovich says it would have been easier to model the whole thing on a computer but they don't have a computer with capability to do so. I asked John Pierce later what sort of computer it would take. He said, "Maybe a PDP-10 or possibly a PDP-11 at the most. Fifty thousand dollars' worth of computer would have saved them all that trouble."

In the p.m. a tour of the Hermitage Museum—which, as it stands, is a combination of the old Winter Palace, the Old Hermitage, the new Hermitage, and the new, new Hermitage. This complex of four buildings is now one huge museum with about 35 kilometers of walking. Trustee Bill Keck tells me that he once spent two days walking the halls of the Hermitage and didn't finish a fraction of what is to be seen. He says it's the most wonderful museum in the world. Anyway, we get a three-hour tour by the Deputy Director for Research. We start first on the gold ornaments. The oldest are from about 600 B.C. on, all the way up through the collections of the Czars. It's a really high-class collection and fills room after room. Then, by popular vote, we go to the French Impressionist art collection. These were collected by two Leningrad private collectors from about 1895 to 1912. The collection was nationalized after the October Revolution. There are rooms full of Matisse, Picasso, Gauguin, and others. There are more of Matisse and Picasso than I have ever seen anywhere. There are lots and lots of good Gauguins also. There is a great collection of Renoir and of other less famous French Impressionist painters. The Picassos are good—they're from his least nutty period. All these paintings were saved during the siege of Leningrad which lasted 900 days; although the Nazis never actually entered the city, they did a great deal of destruction by bombing. The Museum was pretty badly beat up, but has since been restored to its original condition. All of the art work in the Museum was evacuated by the director, who commandeered the last train out of Leningrad and sent the whole collection to a safe place in the Far East. This is true of the Summer Palace and of the Peterhof Palace also. Each room in the museum and in the palaces that we saw contains a photograph of how it looked in 1944 when it was recaptured from the Nazis. They all looked awful. One can understand why the Russians hate the Germans so much and why they're so worried about the possibility of being overrun again by someone.

The Red Arrow Express from Moscow to Lenigrad must be one of the plushest trains left in the world

In the evening to *Swan Lake*—a very different production from that in Moscow. Good, but softer and less interesting.

SATURDAY, SEPTEMBER 22

Up bright and early and to Pushkin and Paul's estate (Pavlovsk). This used to be the Summer Palace of the Czars. Pushkin grew up here and loved the place very much. It was named after him on the 100th anniversary of his birth. The palaces are all very grand. They were occupied by the Nazis and destroyed but have been rebuilt. In the late p.m. a little shopping. We buy a gift for Bill Keck at the dollar store and present it to him. He is, I think, touched. Then to two antique stores—no good antiques—nothing.

In the evening Ingelore and I try to get dinner on our own in the hotel instead of going to the circus. The maitre d' is snooty and there is a long, long wait to get a table. Finally at 9:30 p.m. we do get a table, modest dinner and wine, 3.1 rubles each, not expensive. After dinner Ingelore gets sick from all the tension and commotion!

SUNDAY, SEPTEMBER 23

In the a.m. by hydrofoil to Peterhof, or, in Russian, Petrodvorets. This was the summer home of Peter the Great, and although it was made more complex by the later czars it's basically a simple place. His own retreat is on the shore of the Gulf of Finland, a small oak-paneled house right on the waterside, very plain but nice. Oak paneling, Dutch blue tiles (he was really big on Holland, where he went to learn how to build ships) lots of art, mostly of ships. There are also 1,000 fountains of every description. Water is brought by conduit from some kilometers away, all downhill. The palace and the fountains were laid out about 1700 and they still work. Peter the Great also started the main huge palace which was rebuilt continuously until 1917. It's extremely grand.

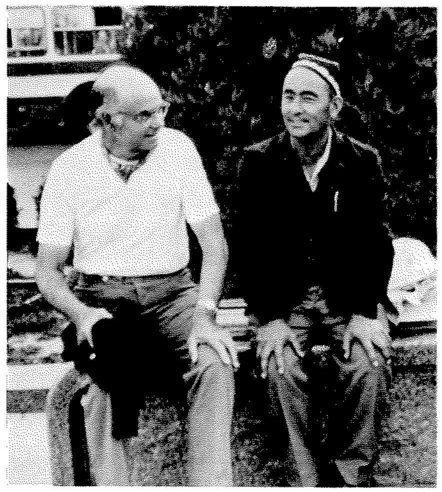
In the p.m. our group takes a tour of the Russian State Museum. Ingelore and I rest and then we all go to dinner in the evening at the Sadko Restaurant, very nice and different, and then to the Red Arrow Express at midnight and thus back to Moscow.

MONDAY, SEPTEMBER 24

I spend the day at the Institute of Molecular Biology as noted. In the p.m. we have dinner and leave for the airport at 9:45. We get an 11:20 flight to Tashkent. It's not a nice four-motor jet as advertised, but a four-motor prop-jet of the Electra generation. It's an Ilyushin 18, and they have been in service for almost 20 years—noisy, cramped, and very uncomfortable. We get to Tashkent at 4:30 a.m., by which time it has magically turned into 7:30 a.m. in Tashkent. The flight is full, very crowded, but we all sleep. Great! Get off at the airport—VIP treatment—and with our new guide, interpreter Vladimir Plachenko, to the Hotel Tashkent.

TUESDAY, SEPTEMBER 25

Tashkent was shaken by an earthquake in 1966 and many buildings fell down. To hear people in Tashkent talk about "The Earthquake" one would think it was the biggest thing that ever happened. It turned out it was only of magnitude 5.5 and buildings fell down because they are made of adobe bricks, sun dried. Luckily the earthquake happened at night in the summer and most people were sleeping outdoors. Nobody was killed, but there was vast destruction. Now new reinforced concrete superboxes are being built everywhere, and also several very beautiful new buildings of nice design, like the new library and the new circus.


Lawrence Williams, touring trustee, and a local resident find a handy place to rest.

First we go to the museum of the Republic of Uzbekistan. Really good history of Uzbekistan from 6000 B.C. to 1924. The museum contains a history of successive incursions into Uzbekistan, the Greeks, Alexander the Great, etc., about 300 B.C., then the Arabs in the sixth, seventh, eighth centuries A.D., bringing Islam with them; then Ghengis Khan at the end of the thirteenth century; then the Turks, then Timur, or Tamerlane, at the end of the fourteenth century. It remained a Turkish society (even though it was captured by Catherine the Great) until 1924, when the Republic of Uzbekistan was established by the Soviet Union as a member republic, and vigorous modernization took place. Today one person in seven in Uzbekistan is a Russian, from the north, and the rest are Uzbeks, Tahjiks, Kazaks, Iranians, Afghans, etc. It's the melting pot of Europe and Asia, a really interesting society.

Our party, which now is composed of Dr. and Mrs. Beckman, Jerry and Naomi Wasserburg, Larry Williams, and us, goes on to the Seismological Institute. This is an Institute of the Uzbek Academy of Sciences, and the officials are all Uzbeks. Their earthquake of 1966 was small, but it created great interest in seismology. The new institute building was built directly over the epicenter of the 1966 earthquake. They have 1,100 empty places in the institute, but they have quite a large staff already. They have studied wave propagation in different kinds of soil. Silt is the worst for buildings. I think that's been found out at Caltech also. The water content of the soil makes some difference in the extent of damage to surface structures. They have mapped all the faults, and studied the plate movements—India is still going north. They have displacement gauges, and they adjust high buildings during construction on every other floor by vibrating them and determining their resonance frequencies. They have a large set of field seismometers out. They get about 2,000 earthquakes per year of magnitudes 3 to 4. It seems an excellent place and Jerry Wasserburg assures me that it is.

WEDNESDAY, SEPTEMBER 26

We stay in the Hotel Tashkent over Tuesday night and early Wednesday take the plane to Bukhara—an ancient city with an ancient and honorable tradition. It was destroyed by Alexander the Great about 300 B.C. It was destroyed again by Ghengis Khan after having been rebuilt, and was destroyed again by Timur in the late fourteenth century. The ancient, domed market stalls still exist; ancient gravesites from the sixth and seventh centuries are still to be found standing outside the city. It's a cold and miserable day, but we take pics and sightsee, and Jerry Wasserburg buys a karakul cap. The Hotel Bukhara is just as awful and primitive and unplumbed as it was 12 years ago so we don't stay there—we take an evening plane to Samarkand and spend the evening of Wednesday in the Hotel Samarkand. This is a nice new hotel, but already beginning to fall apart.

THURSDAY, SEPTEMBER 27

In the a.m. we visit the Institute of Archaeology of the Uzbek Academy of Sciences and are met by the director. He has a nice office, but the thing that immediately strikes us is a very gorgeous carved stone Buddha about two and a half feet tall. It is the most beautiful one I have ever seen, and the director tells us that it is the oldest. It's from the first century B.C. and was discovered in an archaeological dig of a Tibetan stupa in the Pamirs near the bor-

Back in Moscow our room had been warmed up to 19° C

der of the Soviet Union and the Sinkiang Province of China. They have photographs showing the carved Buddha lying on his face inside the partially ruined stupa, and a photograph of the discoverers turning the Buddha right side up in amazement at the perfect preservation of the stone carving after 2,000 years. I ask for permission to photograph it, but this is immediately denied. It is a new find; it has had nothing published about it, etc., etc. During the day we hear a message from the dig in the Pamirs that eight more Buddhas have been discovered there.

We take a trip through the museum of the Archaeological Institute. They have remains from all ages, Old Stone Age, New Stone Age, beginnings of agriculture 8,000 years before the present right up to 1924. It's really impressive. Every mound in the region of Samarkand must be suspected of being an ancient city or temple of some kind. We then make a trip to visit the observatory of Ulan Bek. He was Timur's grandson and became king of Tamerlane's kingdom after Tamerlane's decease. His real interest was astronomy and he built this observatory; also a huge madrasah, a mosque for teaching muezzins, but in this mosque he taught people astronomy. The conservative clergy became very opposed to his practices and declared that he must take a trip to Mecca to cleanse himself. He started on the pilgrimage but a few miles outside of Samarkand was waylaid and beheaded. The observatory was destroyed. It was not rediscovered until close studies by a Soviet archaeologist determined its location, I think in the 1930's. It has not been restored; one can see about one-quarter of the original sextant, which is the main instrument. Since Ulan Bek was in communication with other astronomers all over Europe and since he wrote profusely and his writings have been preserved, we know the exact structure of the original observatory and it would be really interesting to rebuild it to its original condition. This is being considered by the Uzbek Academy of Sciences. Ulan Bek cataloged exact positions of over 1,000 stars, the biggest effort in this direction up to that time.

Then we make a very colorful trip to many of the points of interest of Samarkand, a beautiful city—perhaps one of the most interesting in the world—and full of history. In the evening, back to an Ilyushin 18, back to Moscow, and back to the Hotel Rossia. They've warmed it up to 19° by this time. That's neat!

FRIDAY, SEPTEMBER 28

During our visit to the university we met a Dr. Valiry Soyfer, who is an official in the Academy of Agricultural Sciences. Valiry Soyfer was a classmate both of Yuriy Sivolap at Moscow State University and of Garick Panosyan and knows them both well. He said that he would arrange for them to come to Moscow to visit us on this day, and sure enough, Yuriy Sivolap appears, but not Garick. Both of them have gotten a lot of mileage out of their trip to the U.S. (They were postdocs in our lab.) Garrick is just about to become a Professor in Yerevan State University as well as Deputy Director of the Armenian Academy of Sciences. Yuriy looks fine. He is Director of the Institute of Molecular Biology of the All-Union Academy of Agricultural Sciences, and has his laboratory in Odessa. We spend all day with him and inquire discreetly while walking outdoors what happened to him when he returned to the Soviet Union. Nothing happened to him, he said. He had a bad cold when he left and it turned into pneumonia and he was hospitalized for a while, but when he recovered he wrote to us. He has nothing but good to say of his trip to the United States and his visit to Pasadena. I must remember to send him preprints, etc. We spend the day talking, buying each other gifts, etc. In the evening we have a formal supper in the restaurant of the west wing of the Hotel Rossia. The supper falls a little flat because Harold Brown is in bed with intestinal flu and Academician Keldysh is in the hospital with pneumonia. Anyway, we have a fine supper, and thus to bed.

SATURDAY, SEPTEMBER 29

Off to the airport with all ceremony. We get on the bus to go to the plane, but they don't let us on the plane. Instead, they return us to the airport. We wait an hour and a half and again get on the plane. It's an Ilyushin 62, a four-engine jet which looks just like an English VC10. It takes off, flies three hours toward Frankfurt, circles Frankfurt two hours because of the air controller's slowdown, and finally lands. There we find out we have missed our connection to the U.S. and must stay the night in Frankfurt. We go to the Frankfurt Airport Hotel, very luxurious, very nice. Ingelore dials our house direct—you just call 0-100-213-797-7194. Bell rings twice and there's Joel Gottesfeld on the phone. We explain our delay. We have a nice supper with the Beckmans who are wise enough to have arranged in advance to stay overnight. Larry Williams is glad to stay overnight too. The next day we go to the Frankfurt airport, catch our Lufthansa flight—which is a 707, and fly nonstop Frankfurt to Los Angeles, arriving about 7:30 p.m., a really nice flight and a good end to an exhausting but interesting trip.

Statement of ownership, management and circulation (Act of August 12, 1970: Section 3685. Title 39. United States Code). 1. Title of publication: Engineering and Science 2. Date of filing: September 24, 1973 3. Frequency of issue: 7 times a year. 4. Location of known office of publication: 1201 E. California Blvd, Pasadena, Calif. 91109. 5. Location of the headquarters of general business offices of the publishers: 1201 E. California Blvd., Pasadena, Calif. 91109. 6. Names and addresses of publisher, editor, and managing editor: Publisher: California Institute of Technology Alumni Association. Editor: Edward Hutchings, Jr., Managing Editor: Jacquelyn Bonner, 1201 E. California Blvd., Pasadena, Calif. 91109. 7. Owner: California Institute of Technology Alumni Association, 1201 E. California Blvd., Pasadena, Calif. 91109. 8. Known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages or other securities: none 10. The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during the preceding 12 months. 11. Extent and nature of circulation: A. Total no. copies printed: average during preceding 12 months, 9550; actual number of latest issue, 9000. B. Paid circulation: 1. Sales through dealers and carriers, street vendors and counter sales: average during last 12 months, 20; actual number of latest issue, 20. 2. mail subscriptions: average during last 12 months, 5931; actual number of latest issue, 5235. C. Total paid circulation: average during preceding 12 months, 5951; actual number of latest issue, 5255. D. Free distribution by mail, carrier or other means: 1. samples, complimentary, and other free copies: average during preceding 12 months, 3345; actual number of latest issue, 2845. 2. copies distributed to news agents, but not sold: none. E. Total distribution: average during preceding 12 months, 9296; actual number of latest issue, 8100. F. Office use, left-over, unaccounted, spoiled after printing: average during preceding 12 months, 254; actual number latest issue, 900. G. Total: average during preceding 12 months, 9550; actual number of latest issue, 9000. I certify that the statements made by me are correct and complete. Edward Hutchings Jr.

Conversation Pieces

Technically intriguing items from TRW, guaranteed to add luster to your conversation and amaze your friends.

How Many Days in a Year? A year is the time it takes for a planet to make one complete revolution around the Sun. Our own planet earth, for example, completes its orbit every 365.24199 days, a time which doesn't divide nicely into 52 seven-day weeks. Responding to this knotty situation, Julius Caesar devised a calendar in which he picked up an extra quarter day by having 365 days in the first three years and 366 in the fourth (leap year). While an improvement on the existing system, the Julian calendar was just over eleven minutes longer than the true solar year, so that every 128 years it gained a full day on the Sun.

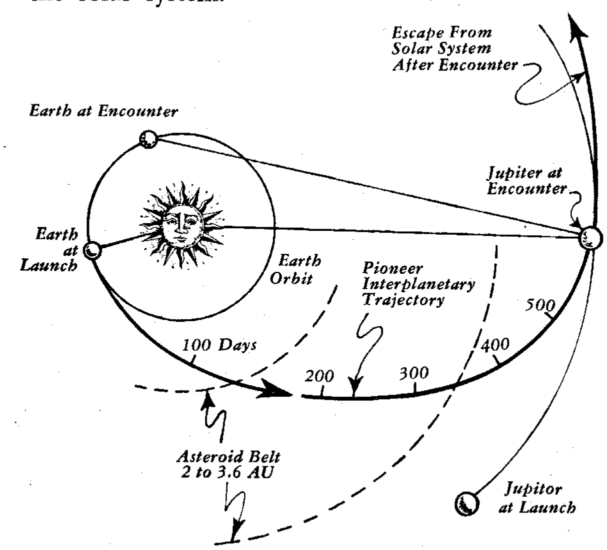
Pope Gregory narrowed the discrepancy by ruling that years ending in 00 were not to be leap years unless they were divisible by 400. This saved three days every 400 years and put the Gregorian calendar (which we presently use) within 25 seconds of the true solar year.

The year on the planet Jupiter is informatively different. Its great distance from the Sun (half a billion miles compared with the earth's 93,000,000) means that it takes Jupiter 11.86 earth years to complete one of its vast orbits. Unlike the earth (which rotates on its axis once every 24 hours), giant Jupiter rotates once every 9 hours and 51 minutes. Thus its day is less than half as long as ours. The combination of short days and long years on Jupiter means that there are more than 10,500 days in the Jovian year. Like everything else about Jupiter, its calendar is big and bulky. In fact, its immense size has caused one astronomer to remark that the solar system is made up of "the Sun, Jupiter, and some debris."

On December 3 of this year, a historic event involving the earth and Jupiter will take place. The Pioneer 10 spacecraft, built by TRW for the NASA-Ames Research Center, will fly past Jupiter. For 21 months, Pioneer has been streaking toward its target at speeds ranging from 30,000 to 80,000 miles per hour. Jupiter is so far from earth that a signal sent to Pioneer at encounter will take 45 minutes to get there, even though it travels at the speed of light (186,000 miles per second).

Pioneer's onboard experiments, which have already provided space information enroute to Jupiter, are designed to yield useful data as far away as 20 astronomical units–about 2 billion miles.

Early next year when the Pioneer data has been examined and analyzed, we'll have some first-hand information for you on this giant of the solar system.



Pioneer trajectory to Jupiter. This path uses the spacecraft's available energy most efficiently.

For further information, write on your company letterhead to:

TRW®
SYSTEMS GROUP

Attention: Marketing Communications, E2/3043
One Space Park • Redondo Beach, California 90278

Development and Design. Is this the kind of engineering for you?

Trying to figure out the exact kind of engineering work you should go into can be pretty tough.

One minute you're studying a general area like mechanical or electrical engineering. The next you're faced with a maze of job functions you don't fully understand. And that often are called different names by different companies.

General Electric employs quite a few engineers. So we thought a series of ads explaining the work they do might come in handy. After all, it's better to understand the various job functions before a job interview than waste your interview time trying to learn about them.

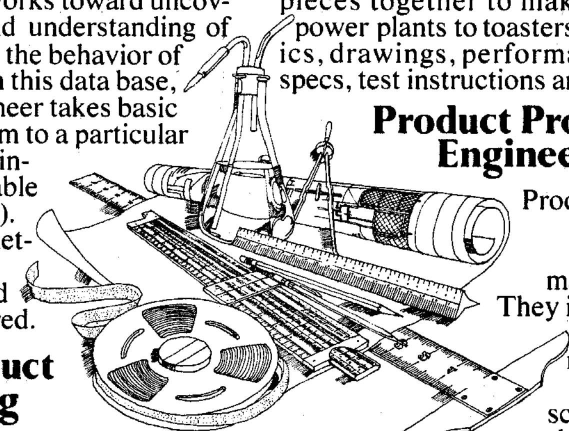
Basically, engineering at GE (and many other companies) can be divided into three areas. Developing and designing products and systems. Manufacturing products. Selling and servicing products.

This ad outlines the types of work found in the Development and Design area at GE. Other ads in this series will cover the two remaining areas.

We also have a handy guide that explains all three areas. For a free copy, just write: General Electric, Dept. AK-1, 570 Lexington Avenue, New York, New York 10022.

Basic/Applied Research Engineering

Motivated by a curiosity about nature, the basic research engineer works toward uncovering new knowledge and understanding of physical phenomena (like the behavior of magnetic materials). From this data base, the applied research engineer takes basic principles and applies them to a particular need or problem (such as increasing the energy available from a permanent magnet). Output is aimed at a marketable item. Both work in laboratories and advanced degrees are usually required.



Advance Product Engineering

Advance engineers bridge the gap between science and application. Their job is to understand the latest advances in materials, processes, etc., in a product area, then use this knowledge to think up ideas for new or improved products or to solve technical problems. They must also prove the technical feasibility of their ideas through laboratory testing and models. Requires a highly creative, analytical mind. A pioneering spirit. And a high level of technical expertise. Output is often a functional model.

Product Design Engineering

Design engineers at GE pick up where the advance engineer leaves off. They take the product idea and transform it into a product design that meets given specs and can be manufactured. Usually, they are responsible for taking their designs through initial production to prove they can be manufactured within cost. Requires a generalist who can work with many experts, then put all the pieces together to make a product. From power plants to toasters. Output is schematics, drawings, performance and materials specs, test instructions and results, etc.

Product Production Engineering

Production engineers interface between the design engineer and manufacturing people. They interpret the product design intent to manufacturing. They maintain production scheduling by trouble-shooting during manufacturing and determining deviations from specs. When necessary, they help design adaptations of the product design to improve quality or lower cost without changing the essential product features. Requires intimate familiarity with production facilities.

Engineering Management

For people interested in both engineering work and management. Engineering managers plan and coordinate the work of other engineers. They might oversee product development, design, production, testing or other functions in marketing and manufacturing. Requires a strong technical base gained through successful engineering work. Sensitivity to business factors such as cost and efficiency. Plus the ability to work with people.

GENERAL ELECTRIC

An Equal Opportunity Employer