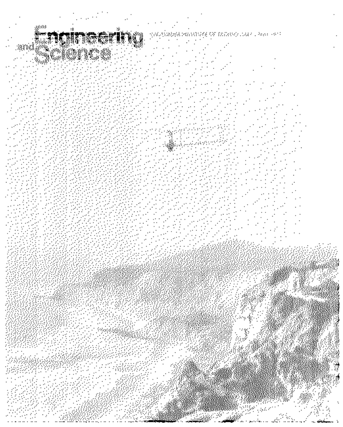
Engineering and Science

CALIFORNIA INSTITUTE OF TECHNOLOGY / MAY 1973

In this issue



Hang It All

On the cover—Caltech freshman Taras Kiceniuk Jr. soars above the beach at Torrey Pines north of San Diego in a swept-wing version of the Wright brothers' biplane. Unusual as this sport may be for college students, it's nothing new to Taras; nor is it just a sport. He has been a hang-glider since he was a freshman in high school, and he has designed, built, and marketed—as well as flown—several such craft. "High-Flying Freshman" (page 9) shows something of what goes into putting in a day in the air.

Caltech isn't exactly new to Taras either—even though he is in his first year here. His father is an alumnus (MS'50); has been a group leader, research engineer, and lecturer in engineering design at the Institute; and is now mountain superintendent at Palomar Observatory.

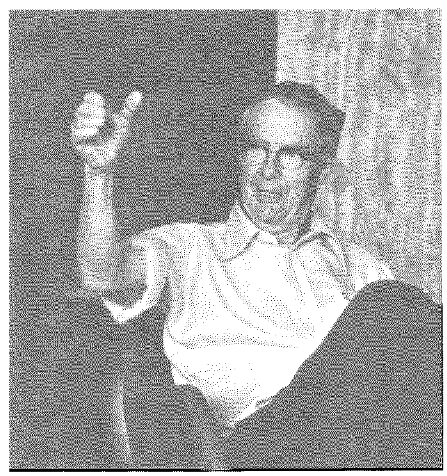
In Sickness and in Health

William J. Dreyer, professor of biology, reported to Caltech's board of trustees last winter about new developments in biomedical research and technology, what they can mean to physicians and their patients, and how the Institute and the Jet Propulsion Laboratory might combine their special talents and abilities to strengthen the practice of medicine. "A Changing Concept of Health Care" (page 2) is adapted from that talk.

Dreyer was a natural to speak on this subject. Since he was an undergraduate, his experiences and research have intermingled to reinforce his interest in understanding the nature of both sickness and health. He is a 1952 graduate of Reed College, and did his graduate work in biochemistry at the medical school of the University of Washington. For seven years after receiving his PhD in 1956 he did medical research for the National Institutes of Health on viruses, molecular genetics, and a special type of cancer cells which were used to develop a theoretical understanding of immunology. In 1963 he came to Caltech where, in addition to his basic research, he has developed several automated instrument systems for biochemical research. He has also consulted with numerous research and development groups on medical instrumentation systems and the application of immunology to medical problems.

Riddle Me This

Almost everybody likes a good mystery, and more than 1,500 people showed up at Beckman Auditorium on April 9 to prove it. Nobel laureate Luis Alvarez, professor of physics at UC Berkeley, was here to describe how he is amalgamating his interest in the pyramids and his knowledge of cosmic radiation to discover if there is a hidden chamber in the second pyramid at Giza. This was the third annual Charles C. Lauritsen Memorial Lecture, and "Where Were the Pharaohs Buried?" (page 18) is a summary of the status of the research to date. During the rest of the week Alvarez spent on campus, he met with faculty and students in several seminars and open discussions (below).



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Engineering and Science

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A Changing Concept of Health Care

During the past two decades there has been an incredible revolution in our understanding of the scientific basis of life, particularly in molecular biology and genetics. This has been paralleled by a revolution in technology, particularly in the space and military fields. The combination of these two seems to us to open the door for vastly improved possibilities of health care.

The revolution in our understanding of life processes has occurred so quietly and so rapidly that many individuals, even in the field of medicine, are unaware of the extent of our new knowledge. Nevertheless, during the next two decades this knowledge which is coming out of the research laboratories will inevitably bring about changes in health care of such a magnitude that they will modify all of our lives and indeed our social institutions —our philosophies, laws, and politics—as well as the practice of medicine.

It is significant that Caltech students, some of the brightest young people in America, see this future perhaps more clearly than their elders and are turning in steadily increasing numbers toward subjects related to scientific medicine.

The changes in medical practice that are certain to occur over the next two decades will result from the cooperative efforts of geneticists, molecular biologists, chemists, physicists, engineers, and physicians. They will be put into practice most rapidly by those physicians whose training is heavily biased toward scientific medicine. Undoubtedly, we will see the application of many of the resources developed in our space and military research programs turned toward such health-care problems, since it is exactly this type of high technology that will bridge the gap between research and application in scientific medicine.

Many of us believe that there is an exciting opportunity for Caltech and the Jet Propulsion Laboratory, together with local medical institutions, to play a major role—indeed a leading role—in bringing about these developments.

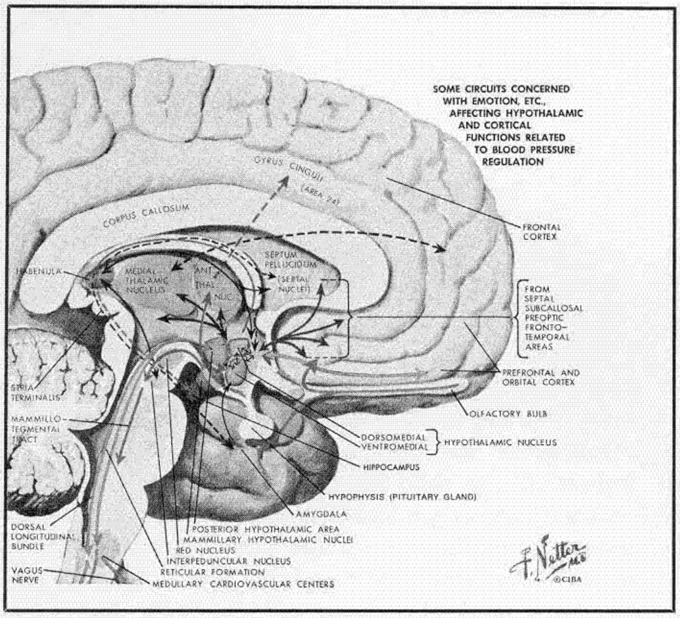
Caltech and JPL are in a unique position. On the one hand we have a long-established and internationally recognized leadership in genetics and molecular biology, and on the other hand internationally recognized expertise in the most advanced level of modern engineering. Thus between us we have almost all of the key ingredients required to lead the way: geneticists, molecular biologists, chemists, physicists, engineers, and space-age technologists. Furthermore, we have the most gifted student body in the world, with, as I have already pointed out, an ever-increasing number of them turning their attention to the very problems we are discussing. Moreover, as a result of agreements between NASA and Caltech, we have the promise of facilities at Caltech's Jet Propulsion Laboratory together with some of the world's most advanced instrumentation—much of which is directly relevant to our needs.

I say we have almost all of the requirements. In my view, we lack a small but vitally important "critical mass" of medical experts, specifically trained and experienced in the new scientific medicine. But, for now, I simply want to give you a feeling of how these views have come about —and the best way I know of to do this is to get very personal, and share with you some of my own experiences over the past two decades—the time in which these revolutionary advances in biological knowledge have occurred, and also the time in which I have been involved both academically and personally in biology and medicine.

In the early 1950's I was an undergraduate at Reed College. Reed, like Caltech, has an excellent student body and encourages undergraduate research programs. I was inspired to undertake one such project, but found it impossible. Both the reason for my interest and the reason for my frustration are, I believe, significant.

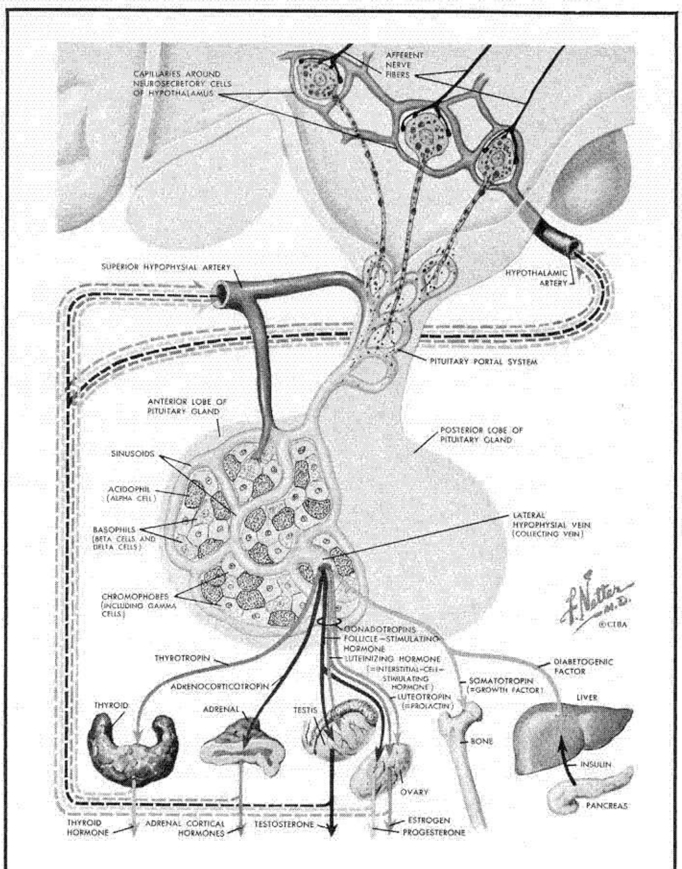
Some time earlier, when my grandmother was in her late 40's, she had developed a goiter, and a thyroid operation was necessary. This problem is rare nowadays since we have learned the importance of iodine and include it in our salt. Unfortunately, the surgeon also removed her parathyroid glands. The results over the next ten years were shocking. She rapidly developed many of the symptoms of advanced aging—poor vision and hearing, hardening of the arteries, premature senility, and finally death from coronary artery disease while she was still in her 50's. In less than ten years she had progressed through a 40-year cycle of aging.

My curiosity was quite naturally aroused, and I was motivated to learn more about the parathyroid hormone and its role in control of vital life processes. But my



The brain (above) is not only the center of our conscious thought processes, it is also the control center for our emotions and sexuality, for the programming of our growth and aging processes, and for all of our biochemical activities. The hypophysis, or pituitary gland, is a very small but vitally important lobe just below the hypothalamic region.

The pituitary gland and hypothalamus are shown in a schematic enlargement below. When the proper signals are received by the hypothalamus, small groups of specialized neurons release factors into an extraordinary circulatory system which disperses the control molecules throughout the anterior pituitary. Each of the different types of "releasing factors" reacts with a particular class of cells. In response, the pituitary excretes the appropriate one of the numerous pituitary hormones, thus regulating the various organ systems illustrated across the bottom of the drawing.



by William J. Dreyer

The new knowledge coming out of basic research laboratories will result in changes in health care of such magnitude that they will modify all of our lives and indeed our social institutions—our philosophies, laws, and politics—as well as the practice of medicine

studies into the matter showed me rather quickly that my search was futile. That is, it was impossible to approach such a problem as this scientifically at that time. There was no real knowledge of the role of the parathyroid glands. Although the concept of hormones existed, there was no knowledge of the chemical structure of the particular hormone associated with the parathyroid and certainly no knowledge about its connection with the process of aging. One could not obtain the hormone itself. There was no simple or effective assay nor any solid scientific theory of its mode of action—or of the activity of any hormone, for that matter. Now we have a large part of this knowledge. Today we know the exact chemical structure of the parathyroid hormone and many others. We know how to synthesize them, or at least their active portions. We know how to assay for them in a simple way, using antibodies. Furthermore, we have a preliminary understanding of their role in the central control systems which program all of our critical life processes.

This system operates through the brain. The brain is the control center of our thoughts, our feelings, and our attitudes. It controls our muscular activity and our biochemical activity. When the proper signals are received in a particular part of the lower portions of the brain, small groups of cells (which you might think of as micro-syringes) introduce active factors into a complicated and very special circulatory system through which they are dispatched to the pituitary gland. In response to a particular factor, the pituitary excretes the appropriate one

William Dreyer

of the numerous pituitary hormones. These hormones play a major role in the function, growth, and aging of the body. For example, growth hormone—which determines our size—is excreted by the pituitary under the control action of one portion of the central nervous system. Of course, there is a feedback mechanism from the body back to the brain which provides information to this control system as to when to turn on or turn off the controlling chemicals. The details of all this control circuitry are certainly not completely understood yet. But compared to our knowledge of 20 years ago, the information now at our command represents, as I keep emphasizing, a revolution.

Many people have regular chemical tests of their urine and blood—usually as part of an annual physical checkup. And such tests generally include one for sugar in the urine—an indicator of hormone function. But have you ever had assays performed on any of your vital hormones? Very few people have ever had such a checkup.

Let me reiterate the present situation. We now understand the role of hormones in the central controls of bodily functions. Specialized research laboratories can assay for many of these hormones. We know that we could manufacture them artificially and inject them into the individuals who need them. And yet, in standard medical practice, such diagnosis and therapy are rare. Why? The answer is this: At present, both the assay procedures and the syntheses are complex and expensive laboratory procedures. They need not be so. With the application of the technology that has been developed in space and military research and development over the last two decades, automatic assay and synthesis equipment could be designed and marketed so as to make hormone therapy as accessible and as inexpensive as antibiotics.

Furthermore, if such automatic assay and synthesis equipment were readily available, it would immediately result in still more research into the role of hormones in a variety of major health problems such as premature aging, heart disease, and the control of our mental and emotional well-being.

So much for hormones. Let me go on with the second personal experience which came about just as I was starting graduate studies in biochemistry at the University of Washington Medical School. I was married by then to my wife, Mary, and our first daughter, Brynn, was on the way. A physical examination revealed that I was the victim of cancer. I had a chance of about one in ten of living one year. I was subjected to the only therapies available, radical surgery and radiation treatment. The inevitable secondary effect of the radiation therapy kept me sick for three months. But, as you see, I was one of the lucky 10 percent who beat the odds.

But that was more than a decade ago, and what has happened in the meantime? Now we are able to identify cancer cells from a specimen of body tissue or fluid, and, in a manner of speaking "paint them red" for identification, using specialized techniques involving antibodies. Furthermore, we know that the immune system of the body is set up to attack cancer cells. Our immune system recognizes them as foreign. Some researchers believe that 9 out of 10 cancer cells (which occur throughout our body) are destroyed by our own immune systems. Some put the figure as high as 99 out of 100. But every now and then a cancer cell manages to coat itself with a layer of protein (thought to be a malfunctioning type of antibody) which protects it. It disguises itself so that the rest of the immune system fails to recognize it as a foreign body, and a tumor develops.

This new knowledge of the role of immunochemistry in the development of cancer opens up a new diagnostic procedure; we can detect cancer cells. We can also assay body fluids for those particular antibodies and antibody cells that are produced to fight cancer cells. If these are present, then we know that the individual in question has cancer cells in his body. If these antibodies disappear over an appropriate time period after surgery, we will have increased confidence that all of the cancer has been removed.

Here again, as in the case of hormones, such assays are complicated and expensive laboratory procedures, but here again they need not be. With the help of modern technology, such procedures can be made as automatic and as inexpensive as those now used for routine clinical laboratory testing of glucose or any of the other substances picked up in your annual physical checkup. Scientists at Caltech and at JPL are already at work on a joint program aimed at developing just such a system. Rational therapies are also being designed by the cooperating scientists and engineers.

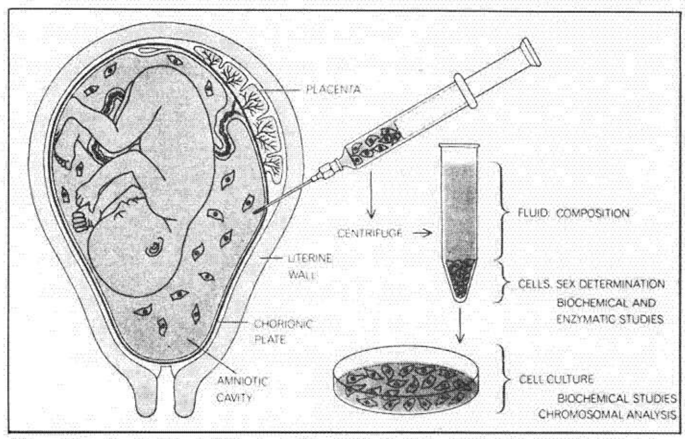
The third personal example has to do with my best friend in graduate school, Murray Thelin. Murray happened to be a victim of a genetic disease, hemophilia. This is the disease, well known in royal families, which causes severe bleeding problems from even minor injuries. He was a gifted young man and, not surprisingly, took up the study of blood-clotting control mechanisms. Unfortunately again, the needed factor was not available; its structure was not known, and its role in the control process was completely obscure. Nothing much could be done, and the odds against Murray were very great indeed —he died of a brain hemorrhage. Today we can isolate the factor; we understand much of the elaborate control circuit in which it plays a role, and there are several possible approaches to the control of this genetic disease in the future.

It is now known that to a considerable extent both hormone problems and cancer development represent aspects of this much broader problem—the problem of genetics. Every cell in our body, and all the organs constructed from these cells are, fundamentally, under the control of the genetic information stored in the nucleus of those cells. When something goes wrong with that genetic information, then abnormality and disease usually result. It is now believed that all types of cancer cells are genetically altered—sometimes by viruses, or by certain chemicals, or even by cosmic radiation. In some types of cancer the error in genetic information is known to be congenital.

Well over a thousand other congenital genetic diseases have now been identified, including sickle cell anemia, cystic fibrosis, and mongolism. Undoubtedly, some of you have within your own families, or families very near to you, examples of such tragic problems, and know well the heartache that results. For in fact there is, as yet at least, little that can be done when a genetic malfunction is present.

But modern genetic knowledge combined with modern technology opens up a path to prevention, if not cure. It is now possible to sample the cells released by a fetus in its very first months after conception and to determine whether certain genetic defects are present. It is possible to do this early enough so that the option of a therapeutic abortion may be offered to the parents if the results show the inevitability of a deformed child.

In order to carry out this procedure it is necessary first to obtain a sample of the amniotic fluid—that is, the fluid that surrounds the growing fetus—by puncturing



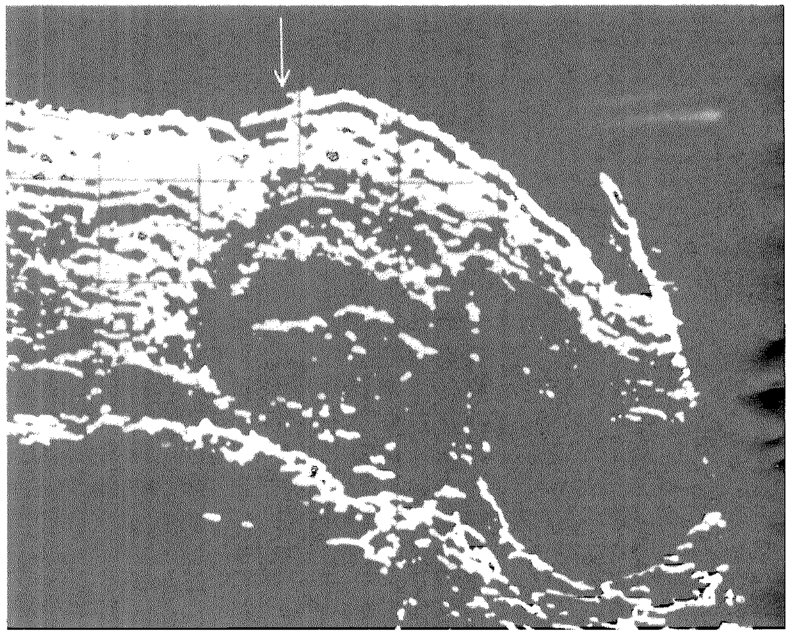
New biochemical and genetic knowledge has made it possible to detect serious hereditary diseases early in pregnancy. Medical research scientists accomplish this by removing a sample of fluid surrounding the fetus—a process known as amniocentesis. The loose cells contained in the fluid can be cultured and their chromosomes analyzed. Hundreds of biochemicals can also be monitored for evidence of a serious genetic malfunction.

through the wall of the uterus. Of course, this must be done in such a manner that the fetus itself is not injured. Even at this step, modern technology comes into play. Ultrasound techniques permit a physician to view the position of the fetus within the uterus in a method that avoids the potential harmful effects of x-rays while at the same time visualizing soft tissue structure normally invisible to x-rays. Ultrasound techniques, which have reached an advanced state of development in military applications, are in their infancy in this medical application; an expert is required to interpret an ultrasound image and be sure that the needle he inserts would indeed be safely located. It is of interest to point out that engineers at JPL are working on an improved ultrasound system that will produce x-ray type images that a doctor can immediately recognize. It is possible that this work will lead to an improved viewing system for examing the fetus and for the placement of the needle.

Space photography systems are very appropriate for yet another related project which is under way at JPL. New optical systems are being used to permit a physician to view and photograph a fetus. This is possible using optics inside of a long needle less than 2 mm in diameter. In this way the fluid-sampling process could be monitored visually while, at the same time, the fetus could be photographed and examined for serious birth defects.

There is also another approach (though in all fairness I must point out that this is in the stage of exploration and thus highly speculative) that may permit fetal cells to be sorted out of the blood of the mother without having to puncture the uterus at all. This possibility arises because a tiny fraction of cells from the fetus work their way through the placenta and into the bloodstream of the mother, where they can be detected.

What can be done with fetal cells and amniotic fluid after they are obtained? One procedure already in practice is called karyotyping. This is an examination of the chromosomes of the cell, the carriers of the genetic code. Once a few cells have been obtained from the amniotic fluid, they can be cultured and their chromosomes examined. It is possible to make a map of these chromosomes, actually arrange them in a definite order, and compare them with those that are typical for a normal human being. Normally, there are 23 pairs of chromosomes in any human cell. Their length and their appearance under the microscope permit them to be numbered and arranged in a chart called a karyotype. It is important



This sonogram was made by ultrasonic scanning of the abdomen of a pregnant woman. With this technique the fetus can be viewed within the uterus without the harmful effects of x-rays, and it aids physicians in locating the placenta before performing amniocentesis. Engineers at JPL are working on a new ultrasound system that could produce greatly improved images of the growing fetus.

to note that in Down's Syndrome (mongolism) there is an extra chromosome number 21. So if amniocentesis is performed on an expectant mother, and a karyotype is made and an extra number 21 chromosome is found, then it is absolutely certain that the child would be born a mongoloid.

As you can imagine, obtaining the amniotic fluid, culturing the cells, taking microphotographs of chromosome displays, and finally arranging these chromosomes into an understandable chart is a laborious process—and consequently expensive. One can hardly "cost account" the human aspects of this disease, the emotional trauma which inevitably occurs in a family upon the birth of a mongoloid child and the other problems, but let me say a word about the economics. It has been estimated that the cost for the support of the mongoloid children born this year in the United States will be one billion dollars! (This estimate assumes a cost of $250,000 for the lifetime institutional care of each severely retarded child.) Furthermore, statistical data are adequate to show that if every expectant mother of the age of 40 or older (a high-risk group) could be examined by the process of

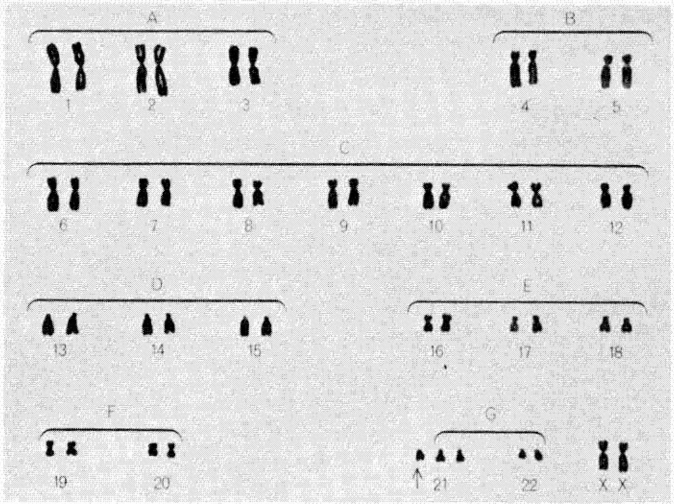
Today amniocentesis and karyotyping are expensive and laborious processes, but with new technology they need not be

amniocentesis and karyotyping (with subsequent termination of pregnancy if indicated), the annual birth rate of mongoloids would be cut in half.

As for the emotional cost, do you know any families who have produced a mongoloid child? To speak personally once more, I have a close relative whose wife spent six months in intensive psychotherapy after the birth of a mongoloid child, because of the intense guilt she felt over this genetic accident.

Today, amniocentesis and karyotyping are expensive and laborious processes. But here again, they need not be. The Jet Propulsion Laboratory has already developed a prototype device for automatic karyotyping in which the computer automatically searches over a microscopic slide after an operator has scored several convenient arrays of chromosomes. The computer then automatically arranges them into a chart suitable for a doctor's interpretation. The cell-culturing step could also be automated, and the procedure of obtaining the fluid might be made more safe and certain with the help of the new ultrasound techniques. All of this, the result of modern aerospace technology applied to medicine, means that in a few years karyotyping can be a routine examination procedure available at reasonable cost whenever the physician feels it is indicated.

Indeed, it may be indicated in a variety of situations.



Chromosomal analysis of cells obtained by amniocentesis can be used to detect hundreds of severe genetic defects. This karyotype shows that the fetus is a female (two X chromosomes) and that she will be seriously mentally retarded (mongoloid) as a result of the extra No. 21 chromosome.

Mongolism is only one genetic problem that can be detected by amniocentesis. Let me emphasize these points. First, more than 1,600 genetic diseases have already been identified, many of which we know can be detected by amniocentesis. Many of them are quite rare, but all together they represent enormous human suffering and enormous cost to society.

Second, we already know how to determine the presence of such congenital defects via amniocentesis in ample time to permit a healthy termination of pregnancy. We are steadily learning how to make still more tests, how to do the present testing in a safer manner, and perhaps even how to sort fetal cells from samples of the mother's blood without ever having to puncture the uterus at all.

Third, these procedures and these tests are still in a laboratory stage, and can be carried out only with the help of expensive equipment and highly trained experts. However, modern technology is already at hand which can automate, simplify, and greatly reduce the expense of all these procedures.

Caltech and JPL have for more than a year been holding committee meetings on the question of how to push forward our efforts in this area—how to combine the scientific leadership of Caltech with the engineering expertise of JPL in the service of health care and research.

A Changing Concept of Health Care . . . *continued*

Very early in the committee meetings I suggested the possibility of some sort of workshop meeting which would bring outside medical experts together with a few people from Caltech and JPL to discuss these problems. By a procedure which I am sure you are all familiar with, it was suggested that I take on the task and, specifically, locate some funding sources to defray the inevitable costs of such a meeting.

This was accomplished with the help of Dr. Milton Wexler and his California Chapter of the Committee to Combat Huntington's Disease, a foundation whose aim is to find either a prevention or a cure for a very tragic neurogenetic disease—Huntington's Chorea. The representatives from Caltech at this workshop included the chairmen of the divisions of biology and engineering—Robert Sinsheimer and Francis Clauser—as well as William Corcoran from chemical engineering and John Baldeschwieler, the newly appointed chairman of the chemistry division. Leroy Hood, a campus immunologist and cancer specialist, was present as were Norman Horowitz and Richard Russell, both outstanding scientists in the field of genetics. William Pickering, the director of the Jet Propulsion Laboratory, was present along with some of the other JPL people who have the largest amount of responsibility for JPL's program in medical technology—Frank Goddard, Al Hibbs, and Robert Mackin. We had about a dozen experts from government, medical schools, and outstanding biology and biochemistry departments of other universities.

We found that there was great interest in this subject, as indicated by the fact that of all the outside experts we invited to attend this workshop not one refused the invitation and almost all were able to attend.

I have no intention of reviewing the three days of discussion or of speaking for all present, but the consensus of the group was strong on some points. For instance, we agreed that over the next two decades we will witness a revolution almost impossible to imagine in the practice of medical science, as new biological and chemical knowledge and new skills in high technology and engineering are brought to bear on health care. Furthermore, as we ourselves believed—and our visitors agreed—Caltech and JPL together have almost all the key components to lead the way in this revolution. The component that is missing is medical leadership—a critical mass of outstanding experts in scientific medicine who could communicate with our molecular biologists, geneticists, and engineers; who could help teach our students who are already excited about these new fields of interest; and who could work with us to make sure that the application of our scientific and engineering knowledge is pointed in the correct direction.

Caltech and JPL together have almost all the key components to lead the way in the coming revolution in health care

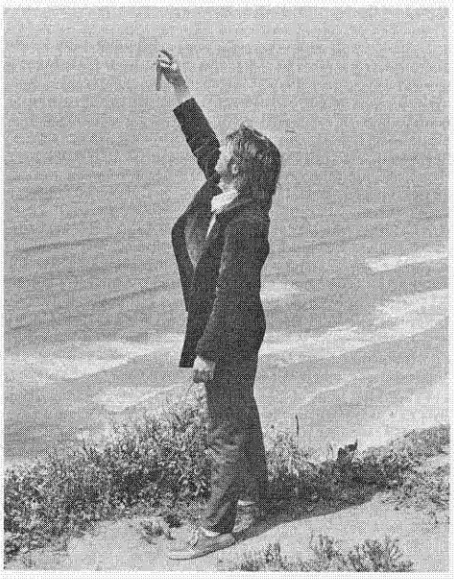
As to how many such individuals are needed, numbers ranging from one to twenty were suggested, together with a variety of implementation plans. Nothing attracts a great scientist more than other great scientists; that is to say, outstanding men and women seek an environment in which there are others equally able and who work in closely related fields. I believe it is for this reason that the consensus at the workshop seemed to suggest—as a minimum starting position—that we should attempt to find three outstanding specialists in molecular and genetic disease, place them on our staff at the earliest possible time, and provide them with the facilities and technical support which they would require.

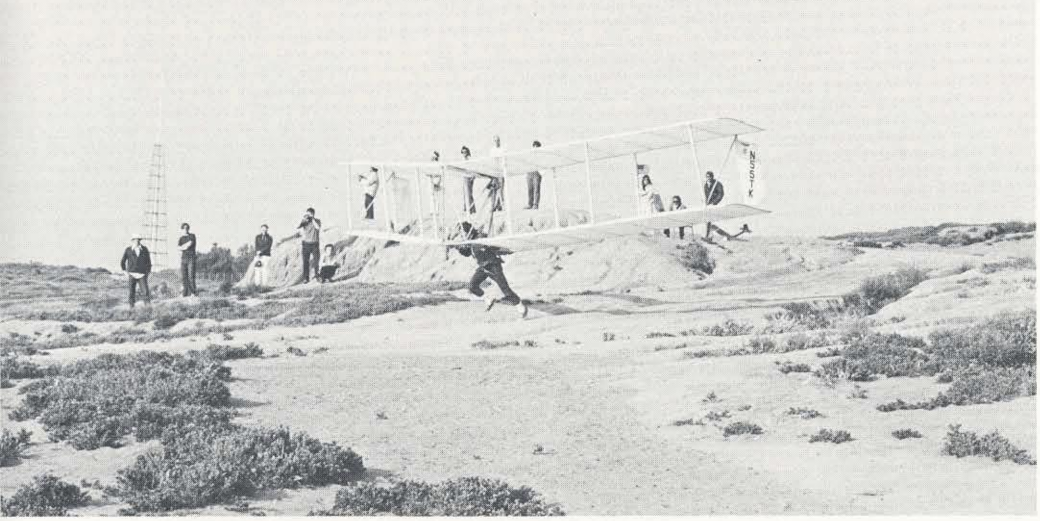
How this might be accomplished we do not yet know. But that it can be accomplished seems amply demonstrated by the enthusiasm of our guests at the workshop—individuals of the same caliber as those whom we would seek. That it needs to be accomplished, by us, here and now, I hope I have convinced you. □

High-Flying Freshman

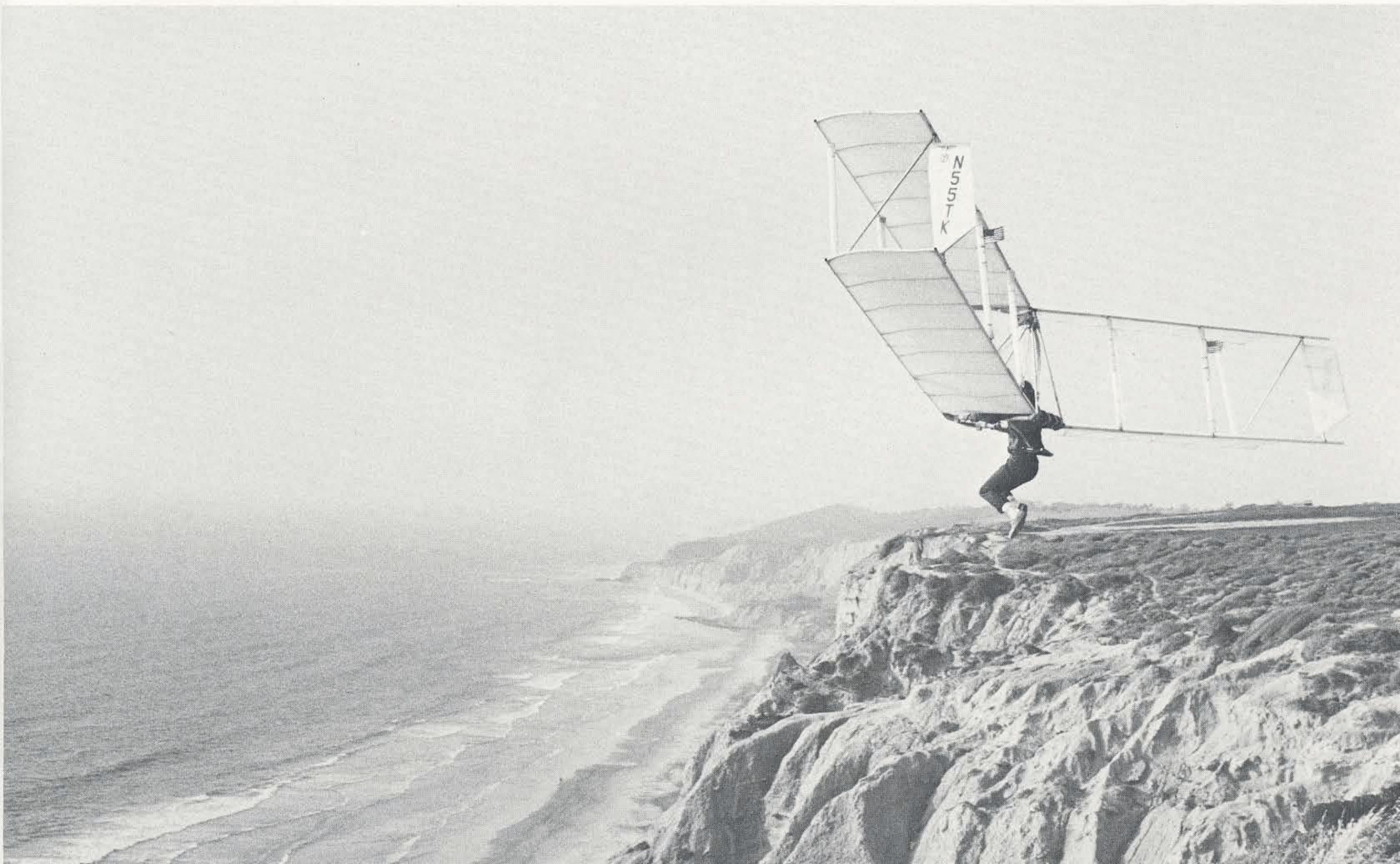
Once a month Caltech freshman Taras Kiceniuk Jr. spends a day at his favorite occupation—hang-gliding—with, of course, a little help from some other glider buffs to carry his craft to a good jumping-off spot. Taras usually goes to Torrey Pines, which has 400-foot-high cliffs and updrafts from the beach strong enough to carry him high above the land. He soars for an hour or two, dangling by his armpits beneath his flimsy-looking biplane, Icarus. The craft is one of several he has designed, built, and marketed since he took up this daredevil sport as a high school freshman.

Each flight takes meticulous preparation. First, the 55-pound, 29-foot-wide glider has to be assembled (in this case, with the aid of a novice in the sport—Eugene Shoemaker, Caltech professor of geology). The craft is made of heavy-duty aluminum tubing, 500-pound-strength wire, and double-ply plastic covered by aircraft doping. It takes about an hour and a half to put together. A second—and critical—step is to test the wind velocity and direction. Ready to go at last, Taras lifts the glider's control bars up under his arms, adjusts his seating, and waits for a good gust of wind.

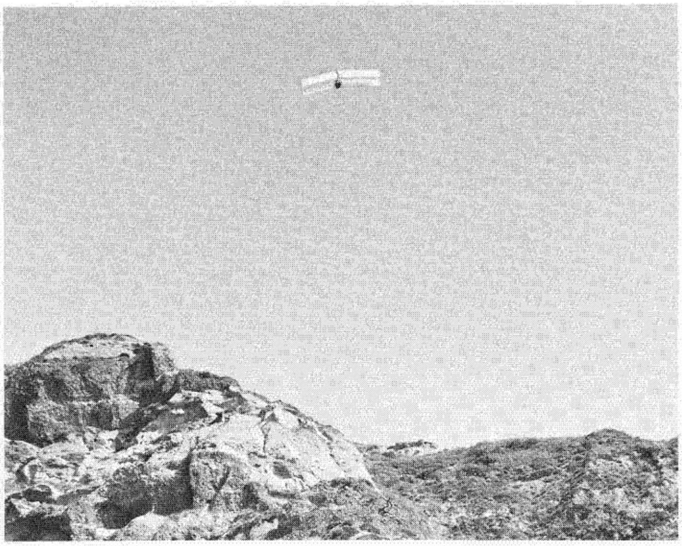




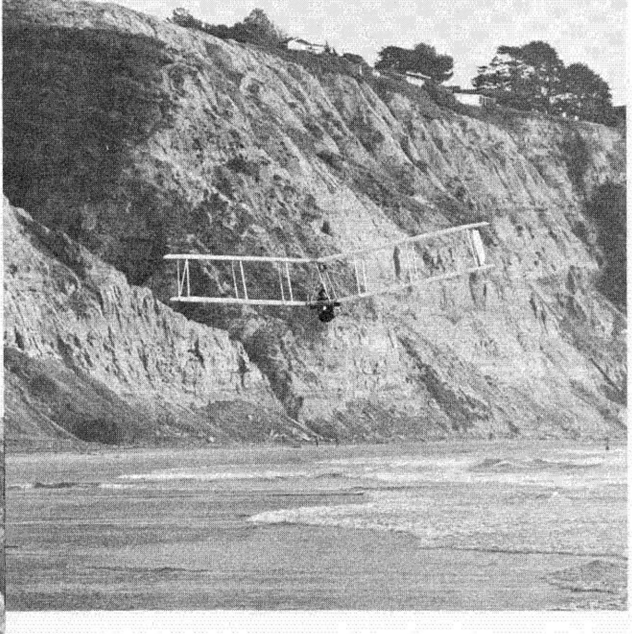
A good hang-glider pilot must, first of all, be a good sprinter. He also must be confident (i.e., crazy) enough to race at full speed to the edge of a cliff and jump off, relying on the homemade wings of the glider to support him. For a successful takeoff, Taras and *Icarus* must be traveling at about 15 miles an hour.

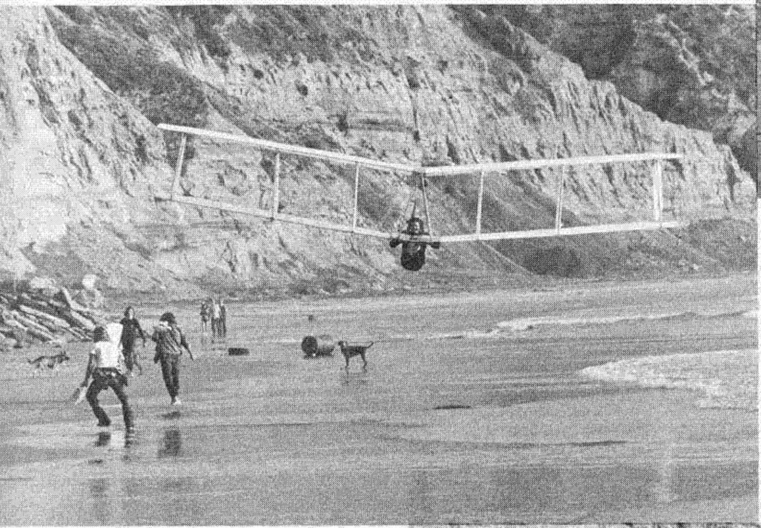


High-Flying Freshman . . . *continued*

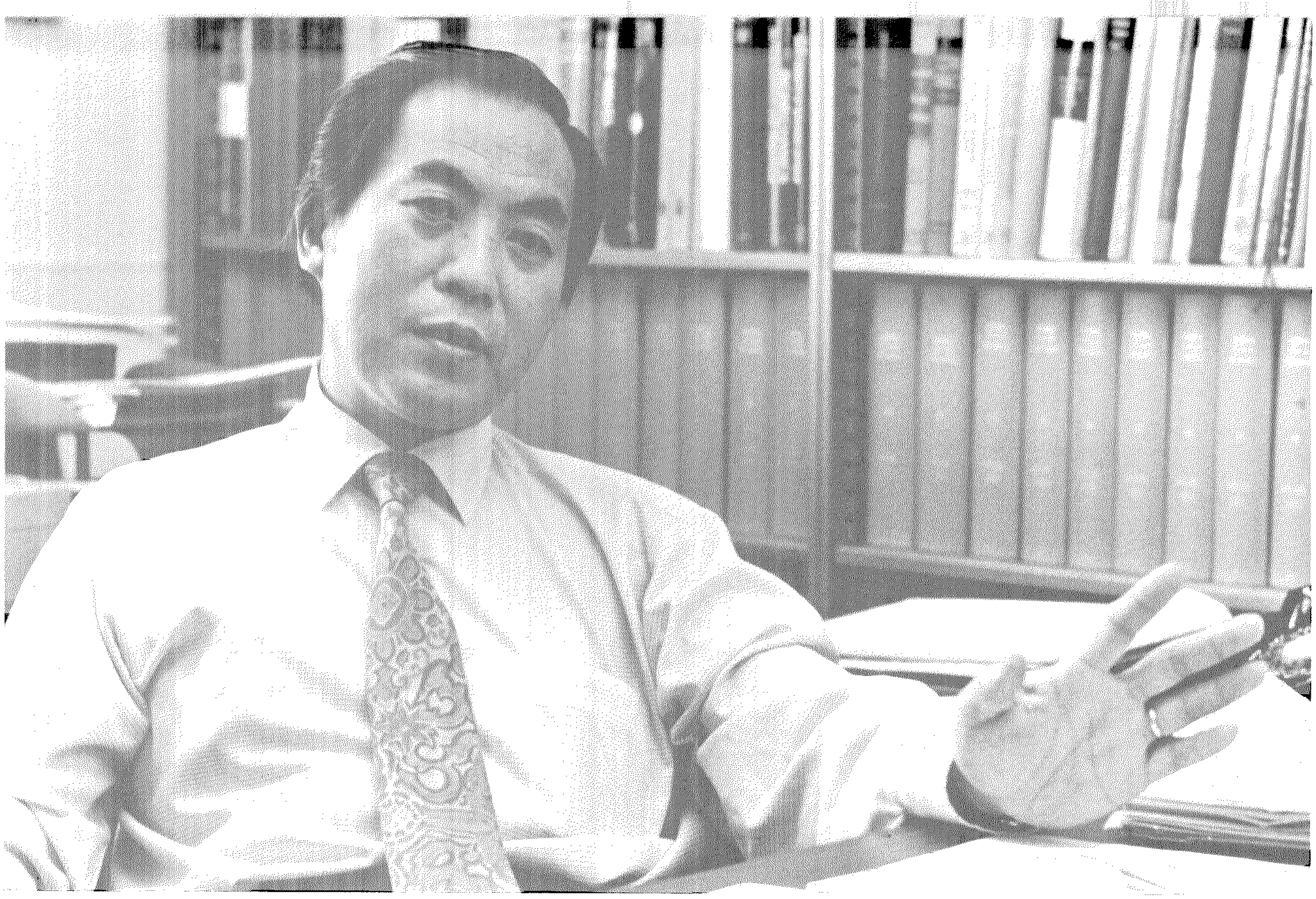


By the time Taras finishes gliding leisurely back and forth along a two-mile stretch of beach at Torrey Pines, he will have flown about 50 miles, or 300 times farther than the Wright brothers did 70 years ago in an engine-powered biplane of similar design. Other people have gone higher in hang-gliders, because they have jumped from higher spots, but Taras has set a world record for total altitude gain—jumping from a 500-foot cliff and soaring to 1,800 feet.





At the end of the flight, Taras brings *Icarus* in for a gentle landing. He braces his feet on the aluminum tubing and swings backward and forward in the seat sling to control the glider. A final backward motion brings the front of the glider up enough to slow his speed for a comfortable landing. Then, dropping his feet, he calmly walks to a stop.



Ted Wu

Man in the Swim

The aqueous environments of planet Earth have kept Theodore Yao-Tsu Wu, professor of engineering science, fascinated for 25 years. Not only the visible ones, which range from oceans down to ponds, but the flows within living creatures as well, and now even the propulsion of microorganisms.

In the course of his studies Wu has become an international authority on the design, stability, and propulsion of ships. He is equally recognized for his knowledge of tidal waves, and of how swimming creatures—from microorganisms up to whales—propel themselves. His theoretical work on microorganism propulsion, which is being done in cooperation with a physiologist and several engineering scientists, is expected to answer many heretofore unexplained mysteries about this vital area of life.

Wu's research interests have always been strongly theoretical—which is not surprising, considering his nationality. "China," he says, "has produced few experimental scientists, for the simple reason that, until recently, there was not enough scientific equipment in the country to work with."

Ted Wu was born in Changchow, a city 100 miles northwest of Shanghai, in 1924, when the country was in constant ferment. Internally, the Nationalists and the Communists were squaring off. Externally, Japan was a growing threat (and soon precipitated the Sino-Japanese War).

Ted's life and schooling were marked with all the turbulence and disarray of leaves in a whirlwind. Even so, he received an excellent education because his father, a banker-economist, recognized his son's ability and insisted that he get the finest education possible—even if it meant sending him hundreds of miles from home to find it.

He rarely stayed in any school for very long, because the place would inevitably be in the path of Japanese aggression, and would have to pack up and relocate, or disband. He was fortunate enough in high school to spend both his sophomore and junior years in one school in Shanghai, though the school changed locations two times because of bombings, or because the buildings were requisitioned for military use by the Japanese army.

Ted had always been interested in science. Even back in the third grade he had looked up all the astronomy articles he could find. Now, with some of his classmates, he started a science newspaper for students of high school age or younger. With the whole educational situation at sixes and sevens, textbooks were becoming scarce, and many young people were unable to find reading material in basic subjects.

Ted's high school by now had been moved to a neutral

Someone once asked Wu if it hadn't been difficult, making the big jump from China to Iowa.

"Yes," he said seriously, "it took me two weeks to feel at home."

extraterritorial section of Shanghai controlled by Great Britain and France—and not even a small science paper with the slightest hint of Chinese patriotism was allowed to be printed there. But the students found a printer who thought it would be a privilege to help bring more knowledge of science to Chinese boys and girls—even if he had to print in a basement, behind locked doors. The paper had a thriving, if sub rosa, circulation. Copies were read and passed on, often to young relatives and friends in other parts of China.

The paper went out of business when Ted and his classmates had to flee Shanghai. For their senior year they found a high school out in the provinces, in an area dominated by Chinese guerillas. The students found lodging where they could. Some lived with the guerillas and, as Ted understates it, "even saw a little action" with them, between classes.

Ted graduated from high school in 1942, and he and his friends decided to try to enter Chiao-Tung University, one of the the nation's finest. Originally located in Shanghai, the school had been moved almost 3,000 miles west to the wartime capital of Chunking. There was no public transportation and no direct way to go. Where there was a road, it wound tortuously along the high rugged gorges of the Yangtze River. But to the group of 20 boys and girls who set out, the trip was the lark of their lives.

Sometimes they hitched rides on boats, but mostly they traveled on foot, often through what Wu describes as "delicate areas" where they had to hide by day and travel by night. Otherwise, they were up by dawn and walking until dark.

The trip took four months. When the group arrived in Chunking in November, their number had dwindled to eight; the others had decided to stay at various points along the way.

The term was well under way, but the Ministry of Education was so impressed by the group's demonstrated desire to attend the university that it offered them special entrance examinations.

Even with a late start, Ted finished the university course in three and a half years, and was elected student body president in his junior year.

By 1945 Japan was too busy reeling from defeat by the allied powers to do anything more about China. Life there began to smooth out, and the university quietly moved back to its old home. Ted spent his final semester in Shanghai, united with his family, who had long since been forced to move from Changchow to the larger city.

After his graduation, Ted stayed on an additional year as a teaching assistant. By now his interests had definitely turned toward aeronautics. This was a frustrating field for a young Chinese, because the air force had been all but wiped out by the Japanese as far back as 1937, and the outlook for any kind of an aeronautics industry in China was still in a murky future.

Ted thought he needed some practical engineering experience before he started on his postgraduate studies, but his parents and professors insisted he finish his education. Actually, the prospects of continuing his education in a more orderly manner were looking up—although not particularly in China. World War II was over, but the Nationalists and Communists, no longer having to coalesce against the Japanese, were at each other's throats again. The educational system in China was still in chaos. But it was becoming easier once more for Chinese students to attend universities in the United States.

One of Wu's friends was already enrolled for graduate work at Iowa State University. He wrote Ted recommending Iowa on two counts: It was one of the few universities admitting students quarterly, so Ted wouldn't have to wait out the year; and the Middle West was so friendly that it was an ideal spot for a Chinese to get acquainted with a new country and culture.

So Wu left his family and friends for his longest educational pursuit yet. Someone once asked Wu if it hadn't been difficult, making the big jump from China to Iowa.

"Yes," he said seriously, "it took me two weeks to feel at home."

He made all kinds of friends, both on campus and off, from the landlady to students from other countries, and he was continually and delightedly surprised at the openness of the Americans in contrast to the more reserved Chinese.

Ted Wu keeps things both buoyed up and toned down. By nature a non-confronter, he turns negatives into positives.

It was almost incredible to be going to school in a peacetime atmosphere. He soaked up the material in his courses like a dry sponge. But the greatest excitement of the year was the new doors that opened in his two favorite subjects, physics and mathematics.

Even as a college student in China, Ted had his sights set on Caltech. Now, news of what the Institute was doing in aeronautics was one of the hottest items on the national academic grapevine. Thedore von Karman had infused the Caltech aeronautics department with a hard-to-match vitality. And when Ted was accepted at Caltech in 1949 to study under Paco Lagerstrom (now professor of applied mathematics), aeronautics was bursting with the knowledge of impending developments. Work was just starting on super- and hypersonic flow studies, investigations into missiles, supersonic flight, and space flight.

Wu was struck by the Institute's smallness after sprawling Iowa State. And he had never been anywhere where people worked so hard or seemed so centered on what they were doing.

As much as he became immersed in his graduate work in hydrodynamics, there was one important diversion. Chin-Hua Shih, a chemistry student he had met during his last year at Chiao-Tung University, was now in graduate school at UCLA. In June of 1950 they were married. After she got her PhD degree, Chin-Hua joined the chemistry division at Caltech, and is now a research fellow.

Milton Plesset, professor of engineering science at Caltech, was on the committee for Ted's doctoral examination, and he still smiles when he remembers how "Ted was completely self-possessed because he knew his subject so thoroughly.

"We've been friends and associates for 21 years now," he says, "and it's been a pleasure—but no surprise—to see where Ted's come in that time."

Plesset considers Wu number one in the world in the field of surface hydrodynamics—the interface between the media of water and air.

"In ship theory, sea waves, cavity flow, and all other kinds of surface hydrodynamics, I can't think of anyone anywhere with his mastery of the subject, or who has made such creative contributions," Plesset says.

For a number of years Wu's research involved propulsion of slender bodies. He first became interested in this because of his work in that part of hydrodynamics dealing with ship theory, where the study of slender bodies is a classic area. If ship bodies are to be designed to give maximum performance in the water, where better to look than at fish and their propulsion?

This logically took Wu into probing how fish swim. His fresh insightful theory work, tested against working models of fish observed in Caltech's hydraulics laboratory, agreed in large part with the experimental data obtained, suggested further paths of investigation, and brought forth some of the first understanding of physical principles underlying the movement of aquatic animals.

Wu's colleagues in this research effort were Milton Plesset; Chris Brennen, a senior research fellow in engineering science; research fellows Allen Chwang, John Blake, and Howard Winet, who is also a physiologist; and a group of graduate students.

His current research on the propulsion of small organisms is a different field for Wu, and one which, until recently, has been very limited. Now it is gaining in interest—and to an important degree because of Ted's theoretical work.

For the most part, microorganisms have been of concern only to biologists. In recent years a few theoretical men in fluid mechanics, like Wu, have felt they could contribute to analyzing and understanding the reasons for the varied and amazingly rapid propulsion systems of microorganisms.

Winet, Chwang (a former graduate student of Wu's), and Brennen are working with Wu in this new study. Brennen originally came from Oxford to work with Wu on cavity flow, but he soon became caught up in microorganism propulsion. The group has also added John Blake, a fellow of Trinity College, Cambridge, who formerly worked with Sir James Lighthill, a leader and pioneer in the field. Another participant this year is J. A. Sparenberg, a visiting associate at Caltech on leave from the Mathematics Institute of the Groningen University of the Netherlands.

Ted and his group, and colleagues in other countries—as well as an increasing number of biologists—feel that such studies will throw light on many physiological flows where further research is needed. They could, for instance, bring to light more information about why sperm swim as they do, the flow of ovum, and the interaction between sperm and ovum during fertilization. They could help us

THE MEN WHO WORK WITH WU: *Christopher Brennen, senior research fellow in engineering science; Allen Chwang and John Blake, research fellows in engineering science; Milton Plesset, professor of engineering science; and Howard Winet, physiologist and research fellow in engineering science.*

understand blood and lymph flows, and mass transport in the lung and kidneys. They might help explain the motility of bacteria, and give us more information on how to inhibit some bacteria without inhibiting others. The interaction with the biological stimulae that create the movement in microorganisms is not known, but eventually it may be, because of better understanding of their propulsion.

Wu also believes that developments in this research may cast more light on the evolutionary thesis and "whether more than a billion years of continuous competition between various species of animals must necessarily have eliminated the less effective species in favor of those having the ability to utilize their optimal movements."

Because of the physics, engineering, and biology inherent in this new approach, Wu's associates have had their ups and downs in learning to work together. For one thing, the different "languages" of engineering, physics, and biology have been barriers to understanding.

"The language of biology is particularly diffuse in comparison to the others," Winet says. "In everybody's own specialty, one word can convey so much meaning, or lack of it. When we started working together on the microorganism studies, the difference between a genus and a species could be a *cause célèbre*! And a simple physical principle could be a source of misunderstanding. There were many stumbling blocks to our interdisciplinary approach, but I'm sure everybody in our group thinks it's been worth it."

As a matter of fact, Chwang has been taking some biology so that he can meet Winet more than halfway.

Meanwhile, Wu keeps things both buoyed up and toned down. By nature a non-confronter, he turns negatives into positives, and also, his co-workers say, has a unique way of translating ideas into terms which they all understand. In fact, they admit, it has been Wu's stability, kindness, and respect for others that has made them a successful working group.

His colleagues, his students, and anybody else who has ever needed anything from Ted are quick to volunteer that his helpful nature extends far beyond his research group. What seems to be a deep sense of the importance of the succeeding generations brings out in him a special sense of duty to the young, whether they are his own daughter and son—Melba, 13, and Fonda, 11—or students.

Francis Clauser, the chairman of the division of engineering and applied science, says, "I know Ted plays a greater role in the outside life of a lot of the students here than we know about. I just get glimpses once in a while. I know he's brought students to this country, arranged scholarships—things I doubt he'd tell you about."

Plesset agrees, saying that sometimes Wu gives so much he is sometimes imposed upon. "Anyway," Plesset says, "I know we're all richer for having him with us."

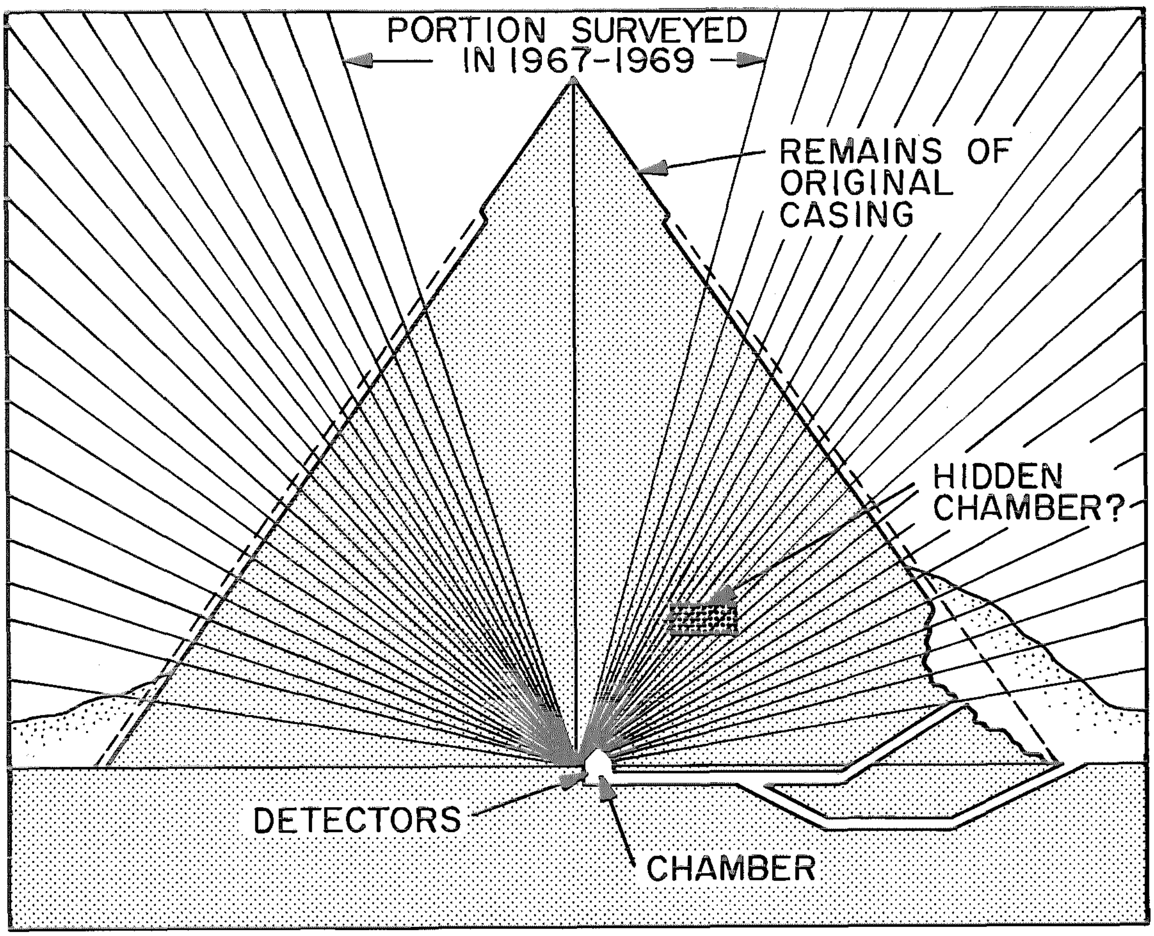
—Janet Lansburgh

Where Were the Pharaohs Buried?

Luis Alvarez is using the cosmic radiation from space to analyze the internal structure of Khefren's pyramid.

Probing for the secrets of the pyramids has a long and somewhat checkered history. For more than 4,500 years, the rewards of the search tended to vary with the motivation of the seekers. Grave robbers plundered the pharaohs' tombs for the wealth they contained, and archeologists plumbed them for nuggets of knowledge about the nature of life in ancient Egypt. But both the seeking and the finding were fairly haphazard until, in the last few years, science—in the form of high-energy physics—entered the game. Now the odds for success seem considerably increased.

Nobel laureate Luis Alvarez, professor of physics at UC Berkeley, came to Caltech last month to give the third annual Charles C. Lauritsen Memorial Lecture at Beckman Auditorium—and explained what is happening. In



A pyramid is no small structure; Khefren's, for example, is taller than a 40-story building, covers more than 11 acres, and contains more than 2,000,000 stones weighing an average of more than 2 tons each. Even cosmic radiation has a hard time penetrating it. But the strikes that are being recorded on detectors in the one known chamber should reveal whether or not it has any hidden hollows.

"Where Were the Pharaohs Buried?—Probing the Pyramids with Cosmic Rays," he described how he and a group of Egyptian scientists are "x-raying" the second of the three great pyramids at Giza, Egypt, in the hope of finding its builder's tomb. Cosmic rays are a special interest of Alvarez, and they can be used to outline the internal structure of the pyramid in much the same way as x-rays outline the bony structure of a human being.

Pyramids are essentially huge stone mounds erected to hide the bodies and burial trappings of the ancient pharaohs. This one—458 feet high and 708 feet on a side—was built by Khefren, whose face is memorialized in the nearby Sphinx. The first pyramid in the group, built by Khefren's father, Cheops, and the third, built by his son Menkure, contain intricate mazes of blind passageways and hidden chambers—all designed to baffle grave robbers. It was a worthy but unsuccessful ploy, because these labyrinths never did more than delay the sneak-thieves in their breaking and entering.

Khefren's pyramid has only one easily accessible chamber—as far as anyone knows. It was discovered in 1818 by an Italian archeologist named Giovanni Belzoni, but he found that someone had been there before him. The lid to the empty sarcophagus was lying on the floor. Why didn't Khefren try harder to hide his burial place? Or did he? Is this chamber a decoy, and is his true sarcophagus hidden somewhere else in the pyramid? Is the apparent simplicity really duplicity? The anomaly mystifies scientists and challenges them to check it out.

Checking it out is what Alvarez has been doing at intervals since 1967. With a pair of six-foot-square spark chambers that act as detectors, and some sophisticated electronic equipment that includes a digital computer, he is using the cosmic radiation from space to analyze the internal structure of Khefren's pyramid.

The technique for the search is based on the fact that cosmic rays, which continuously bombard the earth, collide with atoms in the earth's atmosphere and create a variety of sub-atomic particles. These particles strike the earth at known energies and rates. One of them, the muon, is being used to solve the riddle of the second pyramid.

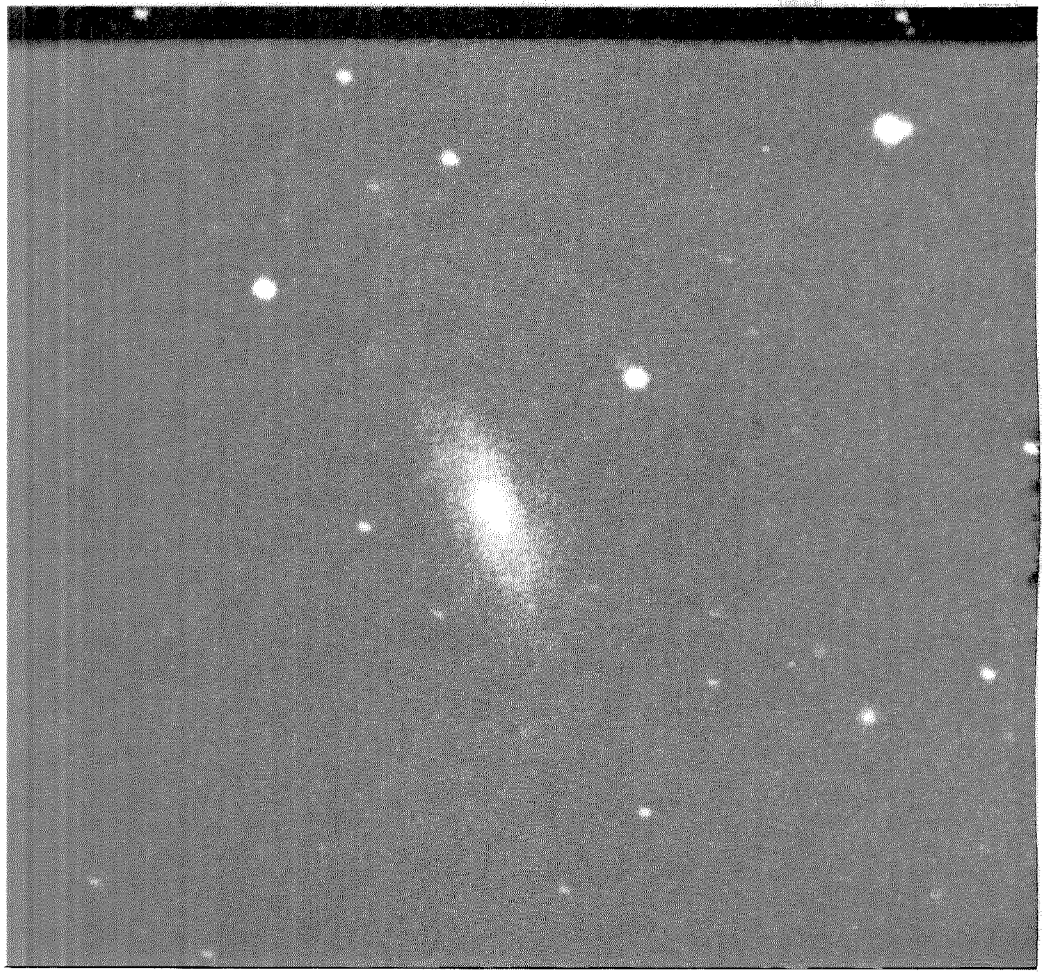
The two spark-chamber detectors are mounted one above the other in the only known room in the pyramid, and they record the number of muons that penetrate through it and the direction from which they come. It is known how many muons would strike the detectors every day if they were out in the open. But the pyramid's five million cubic yards of stone are in the way, and that amount of rock blocks a calculable number of muons from reaching the detectors. If, somewhere in the seemingly solid structure, there is a hole, more muons would come through simply because there would be no rock in that space to impede them. The detectors should show a greater number of strikes in the direction of such a hole; for example, a 15-foot hole in a 300-foot pyramid would give a 10 percent increase in intensity of muon strikes.

In surveys made in 1967 and 1969, the detectors were rigidly fixed and could scan only a cone-shaped portion directly above them around the vertical axis of the pyramid. But even that limited area proved the feasibility of the technique because the portion surveyed includes the small remaining section of the pyramid's original limestone casing, and the detectors accurately recorded the additional thickness. (They also identified precisely how far off center the detection chamber is.) Now the detectors have been remounted so that they can be "pointed" in any direction and the whole pyramid can be surveyed. To date they have been pointed consecutively at the western and southern faces and the northeast corner of the pyramid, and they are currently trained on its southwest corner.

The strikes recorded by the detectors are stored on magnetic tape and returned to Berkeley for computer analysis. The latest tape, with more than 400,000 muon strikes on it, is now being processed. And a computerized image of the strikes shows an area about halfway up one side of the pyramid that appears to be a little darker than the surrounding areas.

Does this indicate a hidden chamber? Perhaps. But the strikes have to be sorted out by a kind of analysis of statistical fluctuations before anyone can really tell. As in flipping a coin, in 100 flips the coin is likely to come up heads 50 times and tails 50 times—or at least not vary more than 60-40. But if something about it weights the probability of one side or the other turning up more often, it will have to be flipped many times more than 100 to prove that the effect is real and not random. In the same way the data from the muon detectors at Giza must be "flipped" many thousands of times until the statistical fluctuations are quite small compared to the effect being sought. If that happens, the scientists will be fairly sure of the existence of a hidden chamber. Of course, the smaller the chamber, the longer it will take to find it—but no matter how small, if it is there, eventually it will show up.

If the cosmic-ray search does reveal a hidden room, Alvarez will have made the greatest archeological find since King Tut's tomb was discovered in 1922. But if Khefren's pyramid turns out to be as straightforward as it seems, that too will be an answer, and high-energy physics will have provided archeology with a reliable tool for the age-old game of treasure hunting.



100 Supernovae— The Reward of a 40-Year Search

by Fritz Zwicky

At maximum luminosity, supernovae are thousands of times as bright as common novae—and billions of times as bright as the Sun

In the fall of 1928, thanks to the persistent efforts of George Ellery Hale, then director of the Mount Wilson Observatory, the Rockefeller Foundation awarded the California Institute of Technology a grant of $6,000,000 for the construction of a new astrophysical observatory, to include a 200-inch telescope.

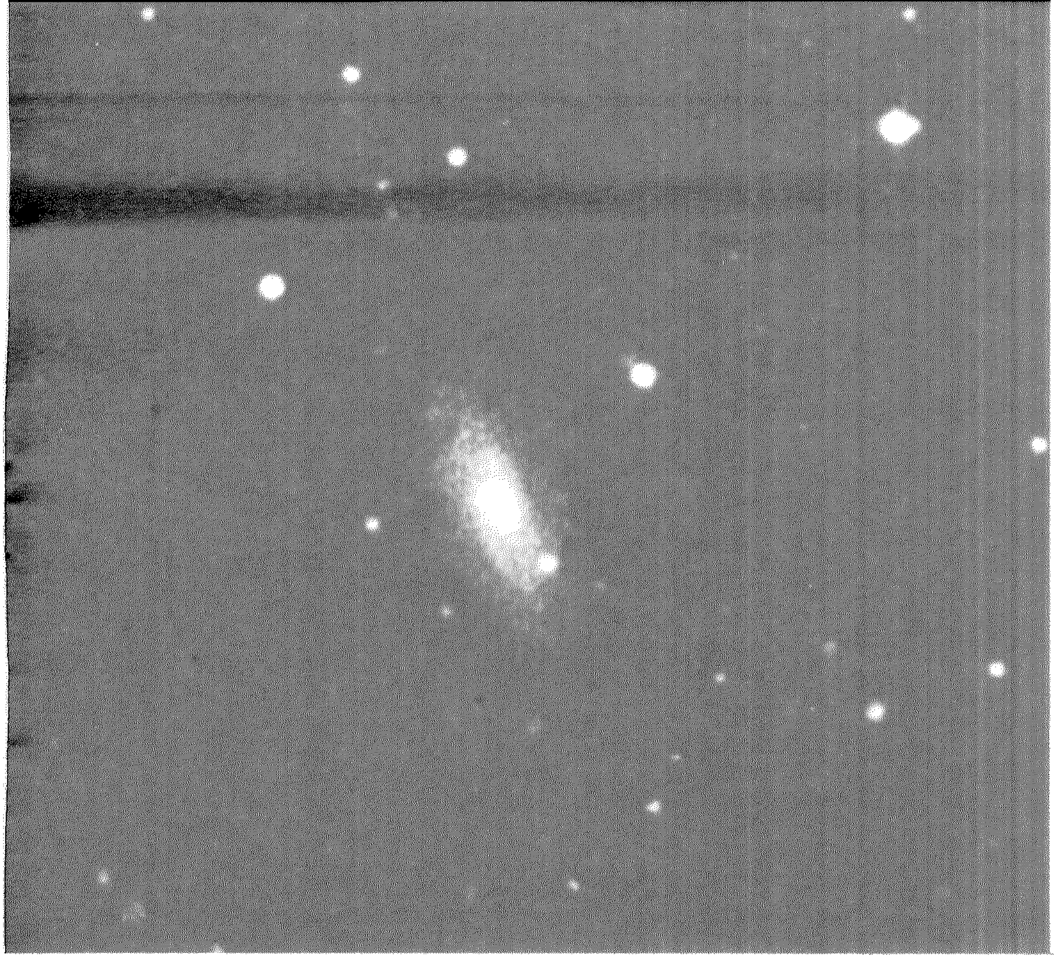
At that time, four members of the physics division of the Institute—Drs. J. J. Johnson, Sinclair Smith, John Strong, and myself—had already been dabbling in some problems of theoretical, instrumental, and observational astronomy. The inviting prospect of a new observatory inspired us to gradually switch our allegiance from physics to astronomy. Dr. Hale's advice, "Do not make any mean plans," encouraged us on our way.

For my part, I felt that developments in astronomy, in spite of the work of thousands of years, had only just been started and that in particular a relentless search for new cosmic bodies and phenomena should prove most rewarding. It seemed to me that the study of cosmic implosions and explosions and their inevitable results of compaction and dispersion of matter had not been given enough attention.

Focusing our attention on one of the best known phenomena in this realm, Dr. Walter Baade and I engaged in a study of novae—stellar implosions and explosions which, within a few hours or days, result in outbursts that increase the luminosity of the stars involved by factors up to the order of one million. A careful perusal, however, revealed that, in addition to what we proposed to call common novae—such as the well known Nova Persei of 1901, Nova Aquilae of 1918, and others—some outbursts had been observed and reported on in the past which indicated the occurrence of a much brighter class of novae. These, in 1933, Baade and I proposed to call supernovae.

There were two types of observations that pointed to the existence of supernovae—which at maximum luminosity were thousands of times as bright as common novae, or billions of times as bright as the Sun.

In the first place, since the discovery in 1885 of a temporary star near the nucleus of the great extragalactic nebula in Andromeda, about a dozen stars had flared up in the line of sight of distant galaxies, nearly equaling the apparent luminosity of these galaxies. Since no similar one-time events had been observed in the enormously greater regions of the sky which are not covered by galaxies, Baade and I concluded that these flare-ups must



A spiral galaxy in the constellation of Leo—photographed in February 1950 (left) and again four years later (right)—shows one significant difference. In the second picture a brilliantly clear supernova has appeared on the southwest edge of the cloud-like galaxy. The outburst probably occurred about 200 million years ago, and the light from it has been speeding toward the earth ever since.

have been caused by exploding stars which were members of the respective galaxies themselves, and therefore supernovae.

Secondly, the so-called Tycho star of 1572 became as bright as Venus. It was easy to calculate that if it had been an ordinary nova, it would have had to be within a few dozen light years of the Earth. Its remnants then would have been easy to locate with large telescopes, since Tycho had given a very good position of the nova. But no remnant of any kind could be found to the limit of the 100-inch telescope on Mount Wilson. From this we could conclude that Tycho's star must have been so distant that its brightness at maximum equaled that of billions of suns.

In 1934 Baade and I published our conclusions in the *Proceedings of the National Academy of Sciences.* To prove that we were right I bought a Wollensack 3¼-inch lens camera and between 1934 and 1936 started photographing the rich Virgo cluster of galaxies. Luck was not with me, for no supernovae appeared on my plates, although I expected two or three—having calculated from the meager historical data available that supernovae, in the galaxies within reach of my camera, make their appearance about every thousand years.

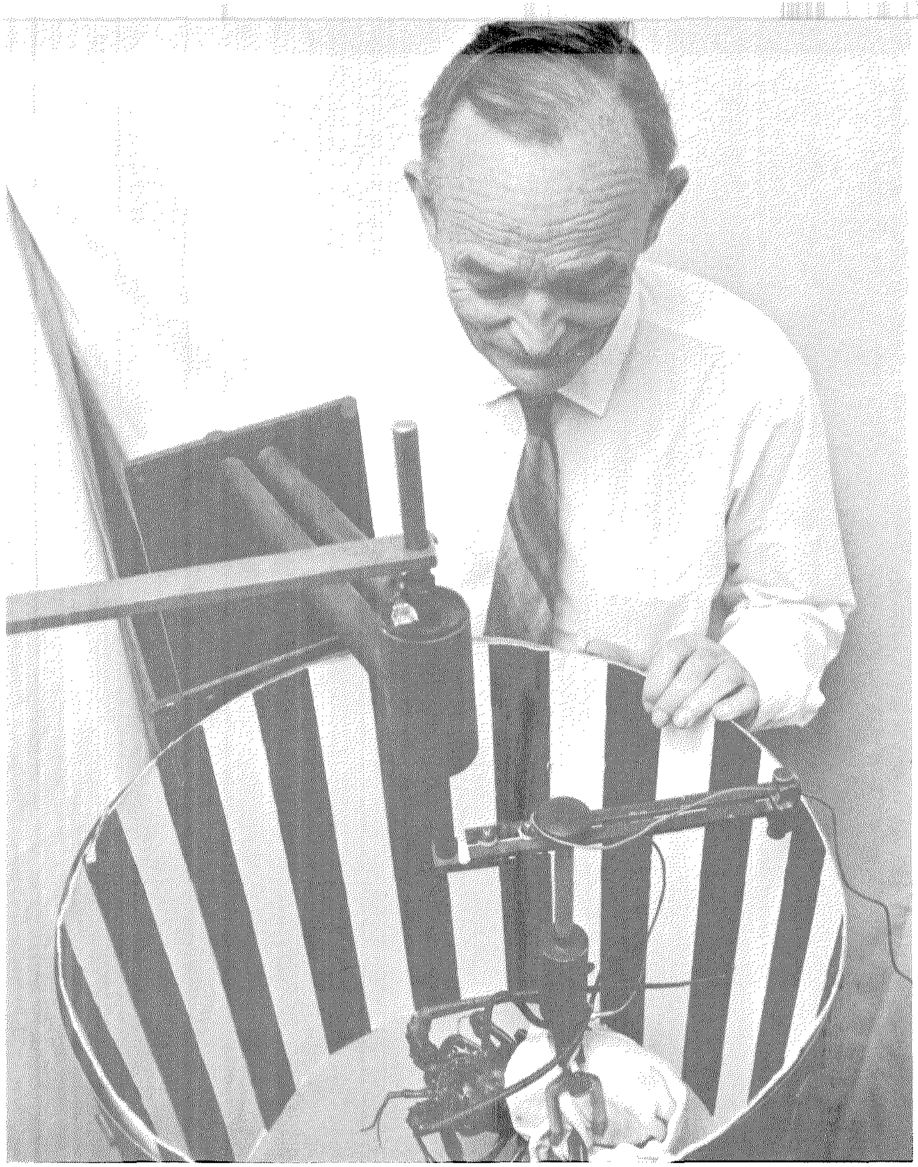
During my fruitless search from the roof of Robinson Hall at Caltech, I heard that Bernhard Schmidt in Hamburg had invented a very powerful type of wide-angle telescope, which is now famous and bears his name. I visited him in Bergedorf in 1935 and upon my return managed to persuade our Chief, R. A. Millikan, that with a fair-size Schmidt telescope it would be a cinch to find supernovae. He agreed, stating laughingly that my project had scientific sex appeal, and he helped me persuade Dr. Hale to allocate $25,000 of the Rockefeller grant to build an 18-inch Schmidt telescope. With the expert help of Drs. J. A. Anderson, Sinclair Smith, Russell Porter, and superb mechanics like Albert R. Brower we built the 18-inch Schmidt within a year. I put it in operation on the night of September 5, 1936, spending thereafter 21 nights on Palomar in a row to show what a determined physicist could do. Beating the "tar" out of the sky, I found my first supernova in March 1937 and the brightest one of this century on August 26, 1937. A third excellent one followed on September 9, 1937. After that, J. J. Johnson and I kept rolling steadily, discovering about four supernovae every year.

By this time we had established the Schmidt telescope as one of the most powerful innovations in astronomy, and we had discovered the previously unknown dwarf galaxies, luminous intergalactic matter, many clusters of galaxies, and other cosmic objects. These successes induced Dr. Hale to ask the Rockefeller Foundation for an additional $450,000 for the construction of the 48-inch Schmidt telescope, which I put in operation on the night of January 31, 1949. Thereafter it was used exclusively for the project of a total-sky survey, and it became available for other projects—including the search for supernovae—only in 1958. This search, with the 18-inch Schmidt, had also been interrupted because of World War II.

While working on our six-volume catalogue of galaxies (which was completed, after 30 years, in 1968), some of my collaborators, particularly P. Wild and H. S. Gates, looked for and found a few supernovae in the 1950's. A new large-scale search with the 48-inch Schmidt was initiated in 1959 when Milton L. Humason joined my group after having retired from the staff of the Mount Wilson Observatory. Things really started to move on an international scale after the International Astronomical Union established a Committee for Research on Supernovae at its general assembly in Berkeley in 1961. I have served as the chairman of this committee since its inception.

Thanks to the joint efforts of about 15 observatories all over the world, the number of bona fide supernovae discovered since 1936 has now risen to about 350, of which 260 have been discovered by the group of a dozen collaborators working with me at Caltech. I myself found my hundredth supernova about a month ago—a milestone (the parsec stone?) which, I think, will entitle me to write a book on the subject. □

Research Notes



Any resemblance the striped cylinder has to a tide pool is intentional; the crab at the bottom is supposed to feel at home for studies C. A. G. Wiersma is making on how memory works.

Clever Crustaceans

Crabs, crayfish, and lobsters may not have the mnemonic abilities attributed to elephants, but they can remember some things accurately for as long as eight minutes.

What's more, a crab's memory enables it to detect changes in the position of its body relative to the visual background with far greater precision than a man can. In fact, it can remember its surroundings so well that it will recognize a shift of only one-sixtieth of an inch in the position of background objects—even though it didn't see the shift being made.

As with humans, one crustacean's memory may be better than another's, and—as is also true with humans—memory seems to become more hazy with advancing age. In a bright member of the clan, however, accurate memory forms within a half-second, builds for 20 seconds, and lasts for about 8 minutes.

These are some of the interesting facts being turned up by Cornelis A. G. Wiersma, professor of biology, and psychologist Richard L. Hirsh, a research fellow in biology, in their current studies at Caltech on how memory works.

Crustaceans make excellent research subjects for these studies because their memories are conveniently accessible to "wire tapping." Their eyes are located on external stalks, which carry the optic nerve circuitry, so Wiersma has developed a technique for monitoring the minute electrical impulses from their memory mechanism. A minute metal electrode is inserted into one eye stalk in such a way that it touches one of two specific motor nerve fibers. (Finding these precise fibers among the available bundle of them is a fine art.) The fibers connect the memory mechanism to the muscles that move the eye. One fiber moves the eye to the left; the other moves it to the right. When the eye moves in the negative sense for the fiber investigated, the normal discharge rate (about 10 per second) of the fiber is lowered. The difference between the frequency of the impulses from the memory mechanism between a positive and negative change in background measures the memory. The electrical signals of these impulses, about one-thousandth of a volt in strength, are recorded on tape, displayed on an oscilloscope screen, and fed into a loudspeaker. Thus, they can be both seen and heard as often as wanted.

To find out how memory controls eye movements, Wiersma and Hirsh house their subjects in a miniature version of their ocean homes—a cylinder lined with two-inch-wide black and white stripes. The pattern of the cylinder is similar to that of an ocean tide pool. The crab is placed in a fixed position near the bottom of the container, and a light is switched on for one minute so that it can get its bearings. The light is then switched off, and the striped cylinder walls are turned, say, one inch. When the light is switched on again, the crab moves its eyes to take in the shift, indicating that it remembers the former position of the striped walls. It not only knows that the cylinder has been turned, but it also knows how much.

This reaction probably means that in its native habitat the crab's position in relation to his background is very important to him.

After they learn as much as they can about the qualities of the memory, Wiersma and Hirsh may go looking for the site of the memory storage—which may be somewhere in the crustacean's brain, or in the motor cell itself. If that search is successful, then they can look for what happens in the individual neuron to create memory.

The research is supported by the National Science Foundation and the U.S. Public Health Service.

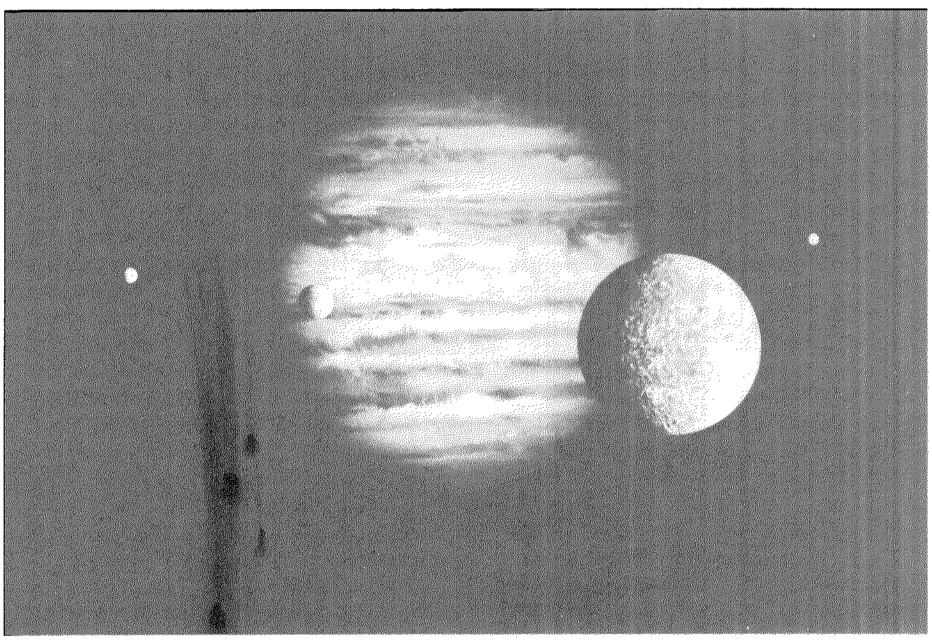
Pioneer 11—An Ace in the Hole

With Pioneer 10 about three-quarters of the way along on its 21-month journey to the planet Jupiter, a twin spacecraft—Pioneer 11—streaked away from Earth on April 5 on a similar voyage. The first probe will reach its destination sometime in December of this year. Pioneer 11 will reach Jupiter early in 1975.

While the missions of the two spacecraft are similar, Pioneer 10's performance as it flies by Jupiter at a distance of about 87,000 miles will determine the objectives for Pioneer 11. If the first probe, for instance, should encounter lethal radiation that destroys its sensitive electronic equipment, the second spacecraft will repeat the mission at a greater distance from Jupiter. But if the first vehicle succeeds—and the threat from Jupiter's powerful radiation belt does not materialize—the follow-up craft will be switched to one of several alternative missions. It could, for example, be steered into a different trajectory to look at a second swath of Jupiter's multicolored, cloud-covered surface. Another alternative would be to bring Pioneer 11 to within 27,000 miles of the planet. Still another possibility would permit the use of Jupiter's gravity to whip the spacecraft on to probe Saturn. If either or both of the Pioneers survive all the hazards of their primary missions, they will loop out of the solar system toward other stars in our galaxy—the first man-made objects to do so. Because they could conceivably be our first contact with an extraterrestrial life, each spacecraft carries a message plaque devised by Carl Sagan (director of Cornell University's Laboratory for Planetary Studies) while he was at Caltech as a visiting associate in planetary science (*E&S*, March-April 1972).

Like Pioneer 10, Pioneer 11 weighs over 550 pounds and is almost an exact duplicate except for the addition of a special magnetometer to measure strong fields in the vicinity of Jupiter. The 14 experiments aboard Pioneer 11 (and the 13 experiments on Pioneer 10) are designed to collect detailed information about Jupiter's internal structure, atmosphere, heat balance, radiation belts, and magnetic fields. In addition, scientists hope to learn more about some of Jupiter's 12 moons, the solar atmosphere, the interstellar gas, cosmic rays, and asteroids and meteoroids in the solar system. Several of the experiments aboard both spacecraft were designed by scientists at Caltech and the Jet Propulsion Laboratory (*E&S*, May 1972).

Perhaps the most intriguing of all the questions scientists hope to answer with the two Pioneer probes is why—and how—Jupiter radiates more energy than it receives from the sun. The answer to this question is central to determining whether life could exist in Jupiter's atmosphere, which is believed to consist of the same ingredients that produced life on Earth about 4 billion years ago. If, beneath its frigid cloud layer, Jupiter has regions that reach earthly "room" temperatures, the conditions are present for the growth of living organisms.



Looking like a striped beach ball, the planet Jupiter looms in space behind 4 of its 12 moons. Jupiter is the target for Pioneer 11's recently launched fly-by mission.

Superconducting Alloys

A new class of alloys that could have a significant effect on the way superconductivity is used to generate and transmit electrical power has been developed by Chang C. Tsuei, research associate in applied physics.

Superconductivity is a property of certain metals and alloys whereby they lose all their electrical resistance at very low temperatures, so that currents induced in them seem to flow indefinitely. At the same time the metals in this state become almost perfectly diamagnetic; that is, they exclude the lines of force of a magnetic field. A bar magnet dropped over a superconducting dish, for example, will hover above it, repelled by its own magnetic image. Entire new technologies are developing around superconductivity—from powerful new magnets for nuclear fusion reactors to new techniques for the transmission of very large amounts of electrical power. But much of this development has been blocked because the most promising superconducting materials are hard and brittle, making it difficult to mold them into wires, strips, and tubes for transmitting electricity. And the metals that can be shaped—most particularly copper, which is an excellent conductor at normal temperatures—are, unfortunately, not superconducting.

Tsuei has been able to eliminate most of these shortcomings by developing a hybrid alloy that combines copper with 5 percent niobium, a superconducting metal, and 1.5 percent tin. The metals are melted by conventional metallurgical methods into an ingot, rolled into wires, and heated at a moderate temperature for a few days. The niobium atoms form particles that are uniformly distributed in the copper-tin mixture and are elongated into long filaments after rolling. Reheated, the tin atoms diffuse out of the copper, move toward the niobium filaments, and form the superconducting niobium-tin compound. By this simple process, Tsuei, in effect, manufactures fine niobium-tin wires inside the copper. The result is a "copper" wire that has essentially the same properties as that of pure copper except that it is superconducting.

The new alloys are the result of ten years of basic research by Tsuei on the electrical and magnetic properties of metal alloys. The U.S. Atomic Energy Commission, which supports his research, has applied for a patent on the entire class of alloys. This new class of materials has been named SUPERCALT alloys (after the code name for Caltech's AEC project, CALT, for the study of the structure and properties of alloys). Tsuei is co-principal investigator with Pol Duwez, professor of materials science.

Replication Site in DNA

Paul H. Johnson, a Caltech research fellow in biology, has discovered—and isolated—the site in a viral DNA molecule where replication starts. This achievement should make possible a better understanding of the mechanism of DNA multiplication—which is essential for understanding either normal or abnormal growth, such as occurs in cancer. It should help reveal how living things function at the most fundamental level.

In collaboration with Robert Sinsheimer, professor of biophysics and chairman of the division of biology, Johnson has been studying a virus known as Phi X 174. Its genetics are already well known through Sinsheimer's work. Phi X 174 is a small, comparatively simple virus whose ring-shaped DNA has only eight genes. The genes carry the blueprint for replication.

Johnson "cut" the virus's small DNA molecule into more than 20 specific fragments. The cleaving was accomplished by two enzymes, which are protein molecules that in this case degrade the DNA. The exact sites where the breaks occur cannot be controlled, although they take place at the same locations each time.

Using specific fragments of the DNA molecule, Johnson succeeded in reconstructing a viral physical-genetic map showing the location of Phi X's eight genes on the individual fragments and the starting place and order in which they are replicated.

It is important now to determine whether the initiation site for replication is between two genes or is actually inside and near the end of a single gene. If the latter is true, it means that a single gene can function in two ways. For instance, it can be involved in the intiation of replication, and it can also code for the manufacture of a protein.

When the replication sequence is turned on—perhaps by an enzyme that recognizes the chemical pattern at the replication site—the first step is for the single-stranded DNA ring to manufacture a complementary strand, a mirror image of itself. The resulting double-stranded DNA ring is then ready to serve as a template for the synthesis of RNA and ultimately for the manufacture of proteins that are needed to reproduce the DNA and build the mature virus.

Johnson hopes to determine the chemical pattern of the DNA—that is, the order in which its 5,500 bases are joined together. DNA contains four bases—adenine, cytosine, quanine, and thymine—and their sequence determines the genetic information in all organisms.

The research, which has been under way about two years, is supported by the American Cancer Society and the U.S. Public Health Service.

Flying Mountain

A two-mile-wide mountain of rock, believed to be the skeletal remains of a comet, is whirling past the earth some 25 million miles out in space. It was discovered by Charles Kowal, research assistant in astrophysics, using the 48-inch Schmidt telescope at Palomar Observatory. Called an Apollo-type asteroid, it is the fourteenth such object to be found in the solar system.

Kowal's find appeared as a streak of light on a photographic plate that he was scanning for supernovae in the course of his job. However, Apollo-type asteroids and lost comets fascinate him, and he has been looking for them in his spare time.

Typical asteroids orbit the sun in a well-defined area between the planets Mars and Jupiter. But these unusual asteroids (named after Apollo, the first of the group, which was originally sighted in 1932 and has only been seen again very recently) are believed by many scientists to be the remains of comets that have lost their streaming tails of dust and gas. These skeletal comets sweep near the sun and then whip far out beyond Mars in great elliptical orbits—each one on its own time schedule for return.

Apollo-type asteroids are among the most elusive objects in the solar system. The speed at which they pass the earth is so great that it has been hard to keep track of them long enough to determine a reliable orbit and predict where they will reappear. Many of them have been sighted only once. But interest in them is increasing, and with the use of the Schmidt telescope and advanced computational techniques, Kowal's newly discovered asteroid is not likely to get lost.

A second sighting of this asteroid was made by Eleanor F. Helin of the division of geological and planetary sciences, and a third was made in Switzerland by Paul Wild. These additional sightings were necessary to establish this asteroid's orbit. Preliminary estimates indicate that it should pass the earth every two years, and if it can be seen on two subsequent revolutions, Kowal will have the privilege of naming it. His choice for that is "Loretta," after his daughter.

Mrs. Helin is co-investigator with Eugene Shoemaker, professor of geology, in a search program for new Apollo-type asteroids—a project that will take about five nights a month for an indefinite period. One reason for setting up the project is that learning about the origin, evolution, and structure of such objects helps scientists understand more about the history and evolution of the solar system. Another somewhat more pragmatic reason is that it has been estimated that every few million years one of the Apollo asteroids collides with the earth. Even though the chances are slight, it would be useful to find out when another such collision might be expected. □

Retiring This Year

C. Hewitt Dix

C. Hewitt Dix becomes professor of geophysics emeritus this year after being on the faculty since 1948. But his association with the Institute goes back a lot further than that. In some ways it even goes back further than his four years as a student at Caltech, because he grew up in Pasadena and was in and out of the Robert A. Millikan household for years as a close boyhood friend of Glen Millikan.

Dix's student days at Caltech, from 1923 to 1927, are memorable for him not only for the education he acquired but for the men he met. Arthur Amos Noyes was his particular friend and benefactor, and he helped Dix get through school in a very practical way—by hiring him as a carpenter to work on the building of his home in Corona del Mar. Noyes was helpful in less tangible ways too; Dix says he learned more about the art of management from observing Noyes than he ever got from all the books he read on the subject. Noyes was also a shrewd judge of the potentialities of people, and Dix remembers him predicting that Linus Pauling would be a great scientist, and Arnold Beckman a remarkable industrial chemist.

After he got his Caltech BS in physics, Dix went to Rice Institute in Houston, Texas, where he took an AM in 1928 and a PhD in 1931, both in mathematics. He stayed on at Rice until 1934 as an instructor in mathematics; then, because of financial pressures, he took a job with the Humble Oil and Refining Company as a research geophysicist.

This leap into a new profession was challenging, but fortunately his training in physics was not as far removed from geology as it would be today. Besides, Dix had had some work in geology in the first courses John Buwalda taught at Caltech, and this background, coupled with a genuine interest in geophysical phenomena and a creative approach to problems, launched his 13-year career in the petroleum industry.

From 1939 to 1941, Dix was a geophysicist with Socony-Vacuum Oil Company, and in 1941 he returned to Pasadena as chief seismologist for the United Geophysical Company. He remained with this company until 1947, becoming both a vice president and a member of the board of directors.

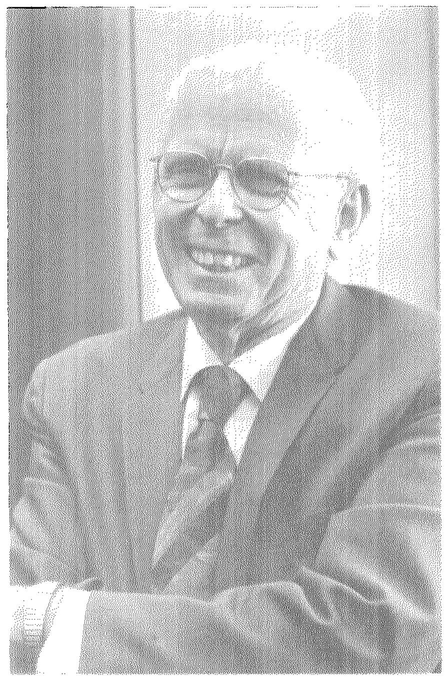
During his years in industry, Dix spent a good deal of time in some of the far corners of the world—particularly, Brazil, Venezuela and Colombia—making some very successful oil exploration studies. He also worked for the U.S. Navy during World War II, planning and setting up the first oil exploration work on the north coast of Alaska. (His book, *Seismic Prospecting for Oil*, was published in 1952.)

Gradually, travel became less and less appealing to Dix, and he couldn't help being eager to realize his long-felt determination to return to academic life. He was happy, then, in 1948 to accept the position of associate professor of geophysics at Caltech—though he hedged his bets by keeping a half-time consulting schedule for several years. In 1954 he became full professor of geophysics.

Dix's research at Caltech has been concerned chiefly with investigations of the theoretical aspects of the propagation of seismic waves. This has been done in various research projects—all of them, according to his colleague Robert Sharp, "displaying an amazing ability to think of new ways of doing things in the field of applied geophysics." He did several series of experiments with the aid of a miniature bus which had been converted into a mobile laboratory by the addition of extensive instrumentation. With it Dix and his students investigated discontinuities in the earth's crust down to a depth of 22 miles.

With a portable rig, they would drill a series of holes about 30 feet deep, place about 100 pounds of dynamite in each, and detonate two to eight shots simultaneously. About a dozen pairs of geophones were set out to monitor each shot. They were sensitive enough to pick up ground motions as small as one-millionth of an inch—so sensitive, in fact, that they were buried a few inches deep to reduce surface noises such as wind. The geophones were linked by wires to recorders in the bus. The recorders picked up from the geophones the reflected shot waves, which traveled at about 18,000 feet per second through the ground, reflecting off discontinuities at different depths.

The bus is now long gone, but from it Dix monitored artificially produced seismic waves all over the southwest, and this work helped him come up with a theory to explain the processes of mountain-building and the mechanism by which ocean basins maintain their integrity.



Another important aspect of Dix's work at the Institute—and one that is much harder to measure—is his careful, sensitive direction of graduate students. All over the world there are distinguished geophysicists who owe their distinction to the concern and influence of Hewitt Dix, who took the time to work with them on their problems. (He always made sure that the problems remained *theirs*, incidentally; he believes strongly in encouraging the creative ideas of young people, but he also believes in utilizing their interests to help them help themselves.)

While he considers retirement a "mixed grill," Dix is looking forward to working on things that for many years he has had to leave undone, including some theoretical problems in mathematics he had to drop when he left Rice. "Ever since," he says, "I've hung onto the field by clinging with my fingernails to the edge of the cliff. I believe the really good work comes from young people so I don't expect big results, but maybe I can get some kind of handhold now." □

The Month at Caltech

Hour of Glory

When is a president not a president? One answer is—when he's ASCIT President Mark Johnson occupying Caltech President Harold Brown's chair. Johnson began the most cordial student sit-in in history last month when he discovered that Brown and most of the rest of Caltech's top brass were at MIT for the annual administrative note-comparing. Not being a man to ignore the knocking of opportunity, Johnson immediately wired Brown:

> WITH YOU, DR. CHRISTY, DR. MARTEL, AND DR. HUTTENBACK IN BOSTON, I HAVE SEIZED CONTROL. DETAILS FOLLOW.

But Brown, too, seemed to hear opportunity at the door. He immediately wired back:

> DELIGHTED TO HEAR GREAT NEWS. WILL HENCEFORTH PASS ALL DIFFICULT PROBLEMS OF CONFLICTING WISHES TO YOU. UNFORTUNATELY, RESOURCES AND PEOPLE TO RESOLVE WILL CONTINUE TO BE UNAVAILABLE AS THEY HAVE BEEN TO ME. EXPECT ALL TO BE SOLVED BY TIME OF RETURN WEDNESDAY. GLAD CHILIASTIC MOVEMENTS NOT ALL PAST. GOOD LUCK.

Brown returned to find the "Office of the President" signs replaced by "Provisional Student Government"; he also found an invitation from Johnson for him to preside at the next ASCIT board of directors meeting, which he graciously accepted.

It isn't raining rain, you know

Whatever poets and weathermen say about the month of April, what rains on the faculty at Caltech at this time of year is awards. April 1973 was no exception.

National Academy of Sciences

Four Caltech faculty men were elected to membership in the National Academy of Sciences at its 110th annual meeting in April. Election to the academy is in recognition of outstanding scientific achievement, and Caltech now has 48 members. Total membership is about 1,000.

The new quartet—all of whom are also Caltech alumni—are Gerry Neugebauer, professor of physics and a staff member of the Hale Observatories; Simon Ramo, research associate in electrical engineering and a member of the board of trustees; Robert P. Sharp, professor of geology; and Kip Thorne, professor of theoretical physics.

Gerry Neugebauer received his PhD in high-energy physics in 1960, spent two years in the U.S. Army working at the Jet Propulsion Laboratory, then came back to Caltech in 1962 as a member of the faculty. A recognized leader in the field of infrared astronomy, Neugebauer has been principal investigator in infrared radiometer experiments on several of the Mariner missions, has made an infrared survey of three-fourths of the sky, and recently made observations (with Eric Becklin, senior research fellow in physics, and Gareth Wynn-Williams, research fellow in physics and astrophysics) of a group of objects that seem to be embryo stars (*E&S*, March-April).

Simon Ramo, who is vice chairman of the board and chairman of the executive committee of TRW, Inc., has been a research associate at the Institute since 1946. His BS from the University of Utah in 1933 was in electrical engineering and physics, and his Caltech PhD in 1936 was also in electrical engineering. This led naturally to his fields of specialization—electronics, microwaves, and guided missiles. Ramo's systems approach to missile problems has resulted in important advances in the technology of that field, and he has been instrumental in applying the same study methods to research on urban and social problems. He was a founding member of the National Academy of Engineers.

Robert Sharp has been a member of the Caltech faculty since 1947 and was chairman of the division of geology from 1952 to 1967. He got his BS (1934) and MS (1935) degrees from Caltech. After receiving his PhD from Harvard in 1938, he taught at the University of Illinois and the University of Minnesota before he came to the Institute. He has had a greater influence on two areas of geological science than any other American—the direct observation and theory of glacier flow processes, and the analysis of desert processes—especially sand dunes. He made the first successful deep coring in ice to the bottom of an active glacier, with two major results: the use of oxygen isotope study of ice of different ages and depth, and the observation of glacier movement by successive measurements of core-hole deformation. His studies of the desert have dealt with both macro and micro forms, and he has recently applied his geomorphic knowledge to interpreting the data from Mars.

Kip Thorne graduated from Caltech in 1962, and then went to Princeton University where he received his PhD in 1965. He returned to Caltech for two years as a postdoctoral fellow, was appointed associate professor of theoretical physics in 1967, and became full professor in 1970. Thorne is recognized as the leading relativistic astrophysicist in the country. His field involves applications of relativity to the behavior of astronomical bodies, and he has also made major contributions to the physics of black holes. His comprehensive treatise on *Gravitation* is to appear this spring. In preprint form it has already been the basis of courses in relativistic astrophysics at Caltech and four other universities.

Another Caltech alumnus, Horace W. Babcock, '34, director of the Hale Observatories, was also honored by the NAS last month. A member since 1954, he was elected to the Council of the Academy for a three-year term beginning July 1.

Gerry Neugebauer

Simon Ramo

Robert Sharp

Kip Thorne

National Academy of Engineering

Two faculty members were elected to the National Academy of Engineering last month, bringing Caltech's membership to 14 in the academy's total roster of 429. The NAE was established in 1964 to share responsibility with the National Academy of Sciences in advising the federal government in matters of science and engineering, to sponsor programs aimed at meeting national needs, and to recognize distinguished engineers.

The Institute's two new members are Norman H. Brooks, professor of environmental science and civil engineering, and Donald E. Hudson, professor of mechanical engineering and applied mechanics. Both are Caltech alumni.

Norman Brooks

Donald Hudson

Brooks, PhD'54, who is also Caltech's academic officer for environmental engineering science, is active in research on hydraulics problems related to water quality management, fluid turbulence and diffusion, and density stratified flows. He has acted as a special consultant for more than 30 governmental agencies and consulting firms—mostly on design problems of outfalls for sewage and cooling water discharges.

Hudson, BS'38, MS'39, PhD'42, is a pioneer in the field of earthquake engineering with a long record of service to federal and state agencies. The instruments he has developed to record ground motions during earth shocks—now widely used—are vital in designing earthquake-resistant structures.

Kemp Medal

Gerald J. Wasserburg, professor of geology and geophysics, has received Columbia University's Kemp Medal "for distinguished public service by a geologist," for "making significant interpretations of the nature of the moon," and for his "major role in the direction of the lunar projects of the National Aeronautics and Space Administration which have given the scientific world a better understanding of that distant body."

Guggenheim Fellowship

Gordon Garmire, professor of physics, has both a Guggenheim fellowship and a Fulbright scholarship for the coming year. Garmire's research field is space physics and high-energy astrophysics. He will leave Pasadena in October to spend a month in Australia where he will be launching two rockets. After a brief stop in India, he will be at Cambridge University in England until June 1974, in France for the month of July, and then will return to Pasadena. Garmire has been at Caltech since 1966.

Sloan Fellowships

Four faculty members were awarded Sloan Foundation fellowships for 1973—Michael Aschbacher, assistant professor of mathematics; Jeffrey E. Mandula, assistant professor of theoretical physics; Robert W. Vaughan, assistant professor of chemical engineering; and Michael W. Werner, assistant professor of physics.

Sloan fellowships are designed to give young scientists the opportunity to do fundamental research at an early stage in their careers. The Sloan fellows are nominated by senior colleagues who are familiar with their capacity to perform outstanding and creative basic research, and the grant is for two years at an average of about $8,750 per year.

Passano Award

One of the country's important prizes for achievement in medicine, the $10,000 Passano Foundation Award, has been presented to Roger W. Sperry. Sperry, who is Hixon Professor of Psychobiology, has been at Caltech since 1954. He was honored for his studies of surgically separated brain hemispheres in humans and animals, research in which he has found that each hemisphere exhibits consciousness and differential skills—and that separate thoughts, perceptions, and emotions can occur simultaneously in both.

"These demonstrations," the citation reads, "make fundamental contributions to our understanding of the mind/brain relation and the neurological bases of human behavior."

Tolman Medal

James Bonner, professor of biology, received the Richard C. Tolman Medal at the April meeting of the American Chemical Society's southern California section. The medal has been awarded annually for the last 12 years, and Bonner is the third Caltech recipient, joining A. J. Haagen-Smit and Ernest Swift.

The citation noted Bonner's "many contributions to fundamental chemistry, biochemistry, and plant physiology, his work in regulation and control of growth and development, his outstanding texts in plant biochemistry, and his efforts as a stimulating teacher and example to his students."

Smith Medal

At a special dinner on April 23 in Washington, D.C., the National Academy of Sciences awarded gold medals and cash prizes to ten scientists. Clair Patterson, research associate in geochemistry, was one of them, receiving the J. Lawrence Smith Medal and $2,000. The awards were made to men "to whom honor has come not because of a dramatic breakthrough but because of career-long achievements laid one upon another that contribute significantly to man's understanding of himself, his world, and the universe."

Patterson, who has been at Caltech since 1952, was honored for his analysis of isotopes of lead in meteorites that established the age of the solar system at 4.6 billion years. (Recently he has applied isotopic methods to learning the history of ancient and medieval metallurgy and coinage—*E&S*, November 1971). He has developed methods of using lead isotopes to study the dating of rocks, determining the age of the earth and meteorites, and tracing the evolution of continents. He is also recognized for his discovery that the oceans, atmosphere, and lands of the earth are polluted with lead as a result of man's technological activities.

Putnam Competition Winners—Again

The William Lowell Putnam mathematics competition annually wrings six hours worth of anguished work out of the nation's best undergraduate mathematics students. The exam consists of 12 problems that test ingenuity and analytical power, and this year 1,681 students from 322 colleges competed. Caltech's team—consisting of juniors Arthur Rubin and Michael Yoder, and Bruce Reznick, a senior—won the competition for the second straight year.

These three, along with sophomore David Dummit and freshman James Shearer, were among 12 contestants who achieved scores of over 38 percent on the test. In fact, the scores of the three team members averaged 61 percent, compared with 32 percent for second-place Oberlin and 30 percent for third-place Harvard.

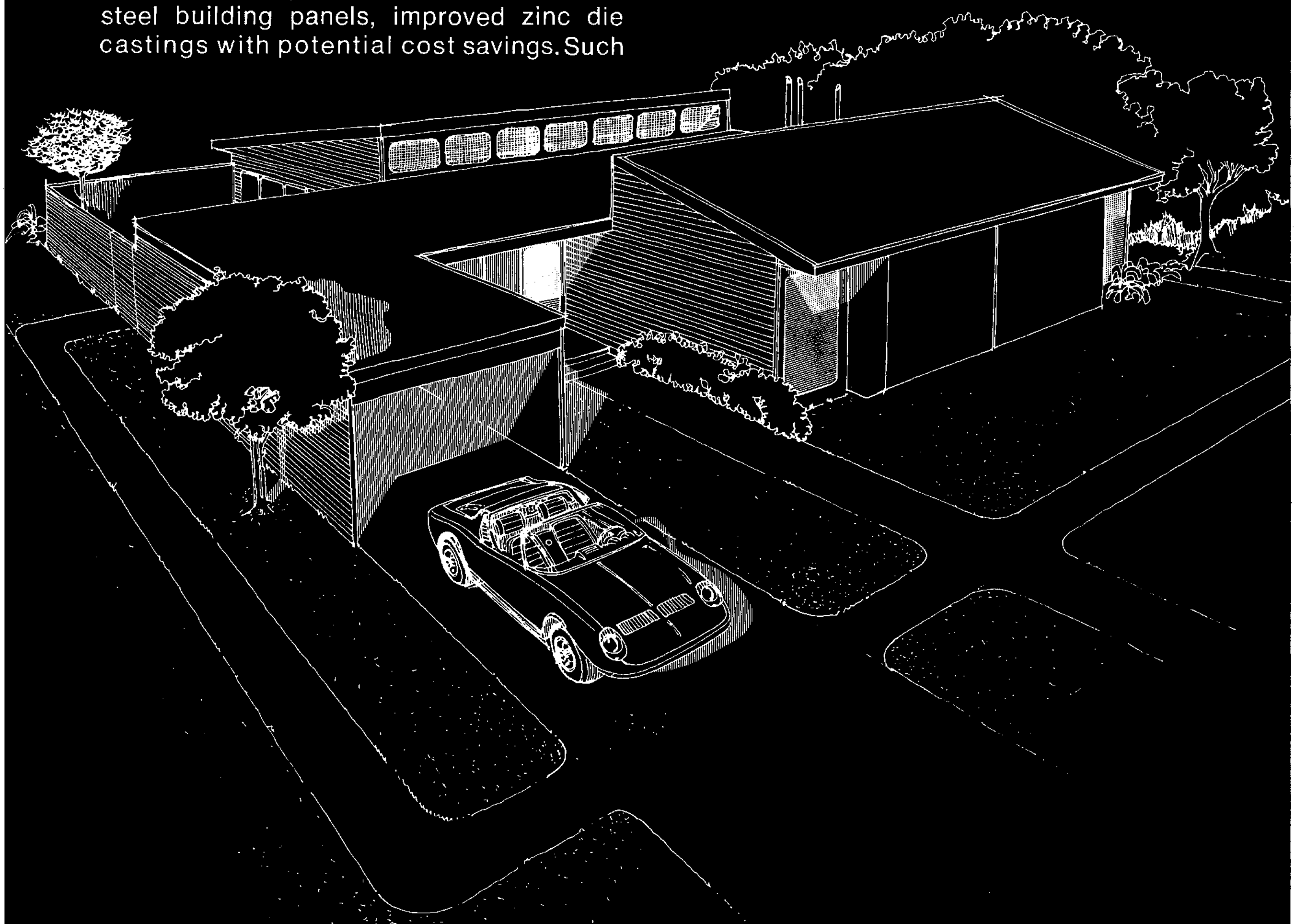
With only Reznick to replace—and a group of talented undergraduate mathematics students on hand—Gary Lorden, the Putnam team coach, predicts that Caltech will do well again next year too. Lorden should know; he is an associate professor of mathematics, an alumnus (class of 1962), and was a Putnam team member as an undergraduate. In the 33 years since the national competition began, Caltech has almost always been high in the standings and has taken first place five times. ■

Credits: Design: Rhode Island School of Design   Sponsor: International Lead Zinc Research Organization

This prototype lead/zinc house has answers for some of the problems of the future. Answers worked out jointly by university and industry personnel. This concept may help solve the lumber shortage that already exists in many parts of the world.

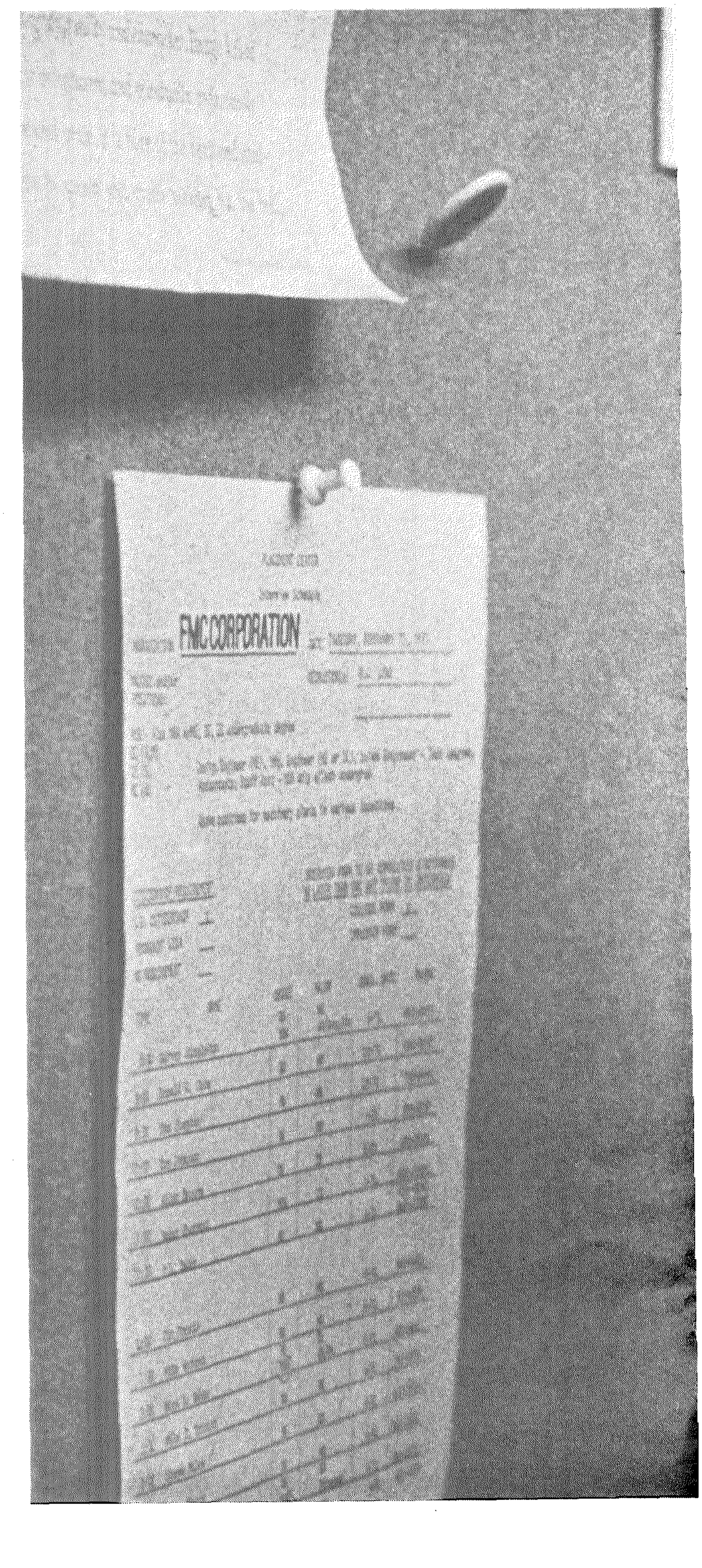
In addition to demonstrating traditional uses for lead and zinc in housing, the prototype will include new developments in lead products, wrought zinc roofing systems, new finishes and improvements for zinc-coated steel building panels, improved zinc die castings with potential cost savings. Such relatively new housing applications as sheet lead for sound attenuation will be included.

The metal house is intended for modular factory-built mass production anywhere in the world. It can be finished in many ways to satisfy individual tastes and requirements. For more information please write to Lead Industries Association, Inc., 292 Madison Avenue, New York, N.Y. 10017.



A house for the future in a lumber-short world.

Don't let our name confuse you.



Conversation Pieces

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

Is anyone out there? The question of whether life is unique to planet earth has long fascinated the mind of man. As early as the 4th Century B.C., the Epicurean philosopher Metrodoros said, "To consider the earth as the only populated world in infinite space is as absurd as to assert that in an entire field of grain sown with millet, only one grain will grow." In the sixteenth century the heretic Giordano Bruno announced that "innumerable suns exist" and "innumerable earths revolve about these suns ... Living beings inhabit these worlds."

Harvard astronomer Harlow Shapley approached the problem statistically. Of the 10^{23} stars in the universe, said Shapley, it is probable that 100 million have planets similar enough in composition and environment to earth to support life.

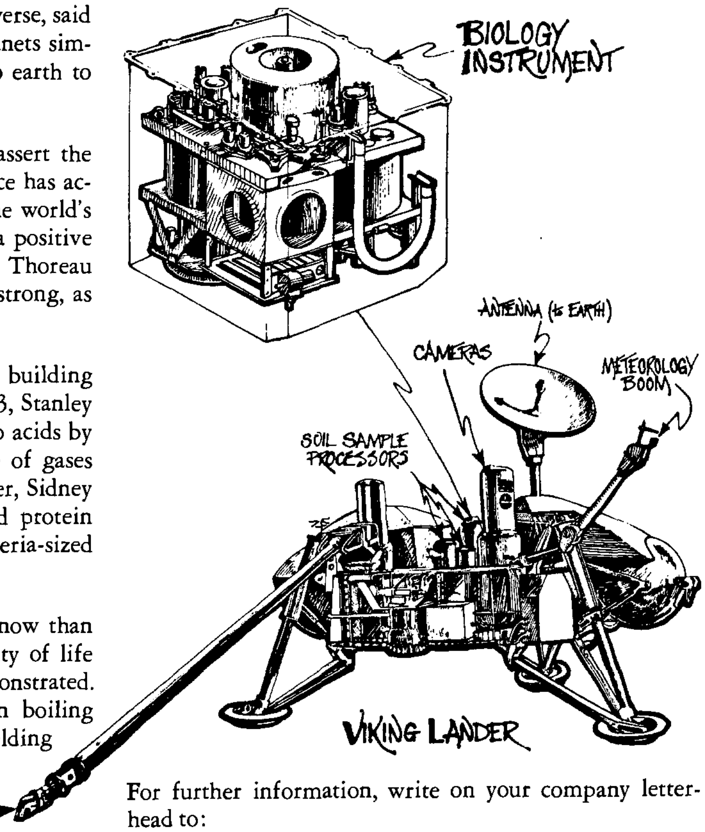
Although scientists cannot as yet positively assert the existence of extra-terrestrial life, enough evidence has accumulated in the last decade to make some of the world's leading scientists suspect that the question has a positive answer. The evidence is circumstantial, but, as Thoreau said, some circumstantial evidence can be very strong, as when you find a trout in the milk.

First of all, scientists have shown that the building blocks of life are rather easy to produce. In 1953, Stanley Miller of the University of Chicago made amino acids by passing electrical discharges through a mixture of gases that simulated our earth's early atmosphere. Later, Sidney Fox of Florida's University of Miami produced protein fragments which formed themselves into bacteria-sized spheres.

Not only does life seem easier to synthesize now than it did twenty-five years ago, but the survivability of life under presumably lethal conditions has been demonstrated. Organisms have been found living happily in boiling water, strong acids, and even in the water shielding the highly radioactive cores of nuclear reactors.

Recently, biologists have simulated the biologically rigorous conditions of the Martian environment in "Mars jars." Some of the organisms placed in the jars readily adapted themselves to the extremely cold carbon dioxide atmosphere.

As a subcontractor to Martin-Marietta, TRW Systems is at work on a NASA project which may shed some light on the question of extraterrestrial life. We are building the Viking Lander Biology Instrument, three tiny, fully automated laboratories, which will be landed on the Martian surface in 1976. On earth, these laboratories would occupy several rooms and a full crew of scientists. We are shrinking them into a single foot of space. We hope you're interested as we are in what Viking will find.



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