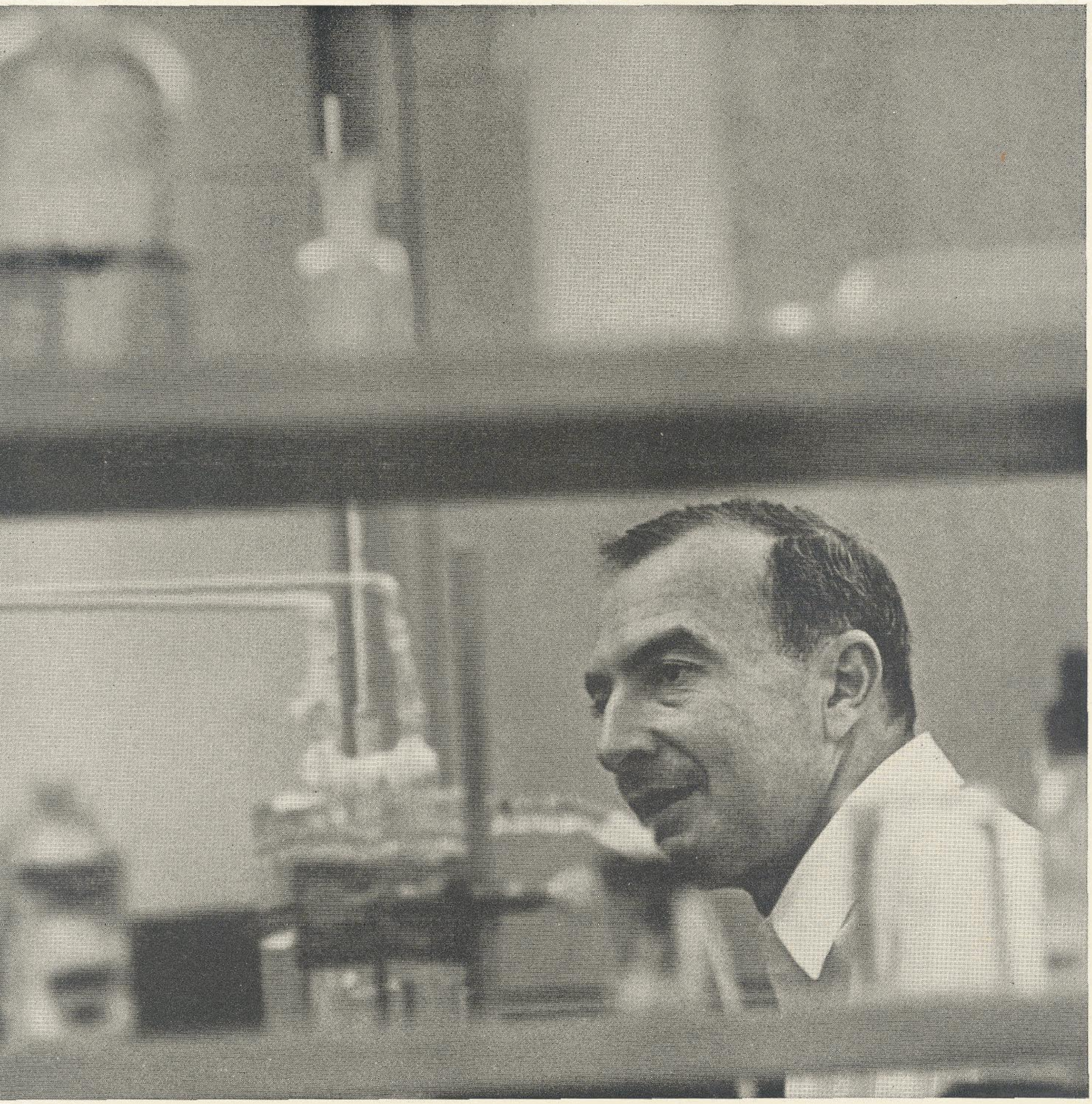
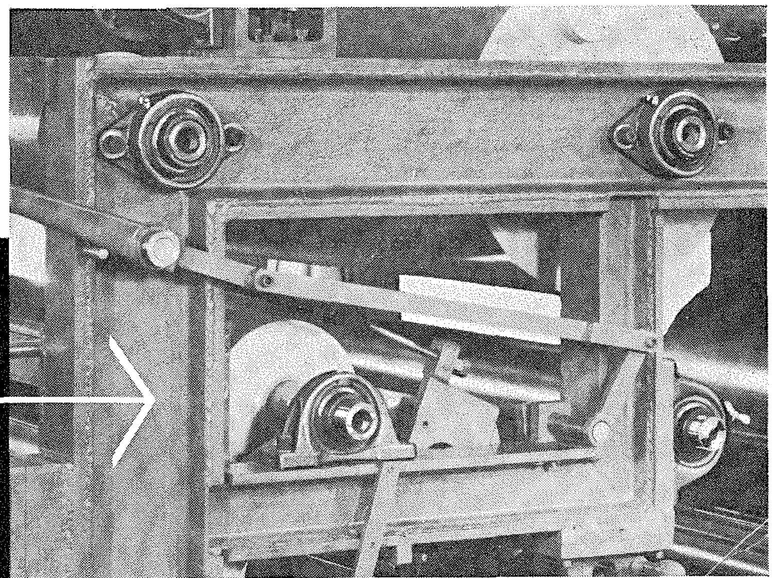
MAY 1967

ENGINEERING AND SCIENCE



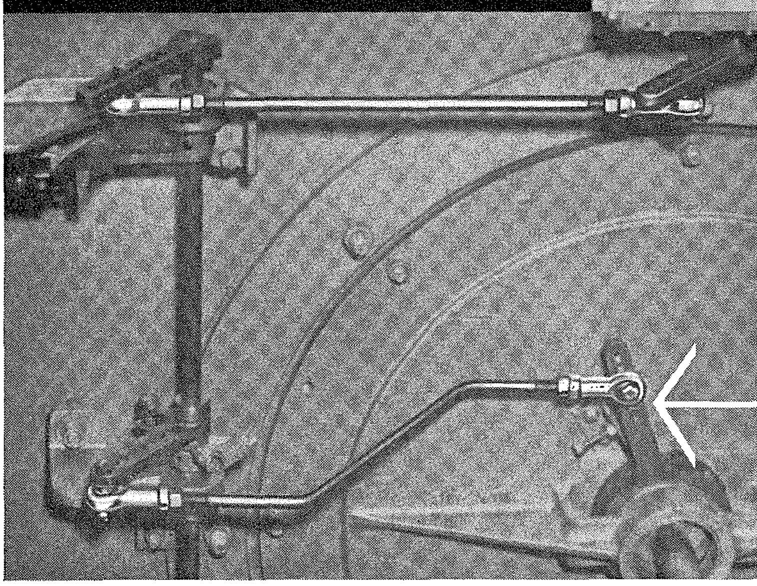
PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

For rotation...



SEALMASTER®
Ball Bearing Units

For motion transfer or linkage...



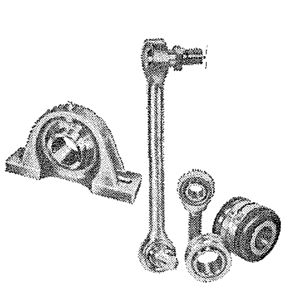
SPHERCO®
Bearings & Rod Ends

Sealmaster Ball Bearing Units are quality built to take high and normal operating temperatures. They're designed with outstanding engineering features and manufactured from vacuum degassed steel and other selected high grade materials to stand punishment day after day. Available in a complete line of pillow blocks, flange, take-up, and cartridge units.

Spherco Bearings and Rod Ends are available in a wide range of styles, sizes, and materials. Built-in quality insures long bearing life.

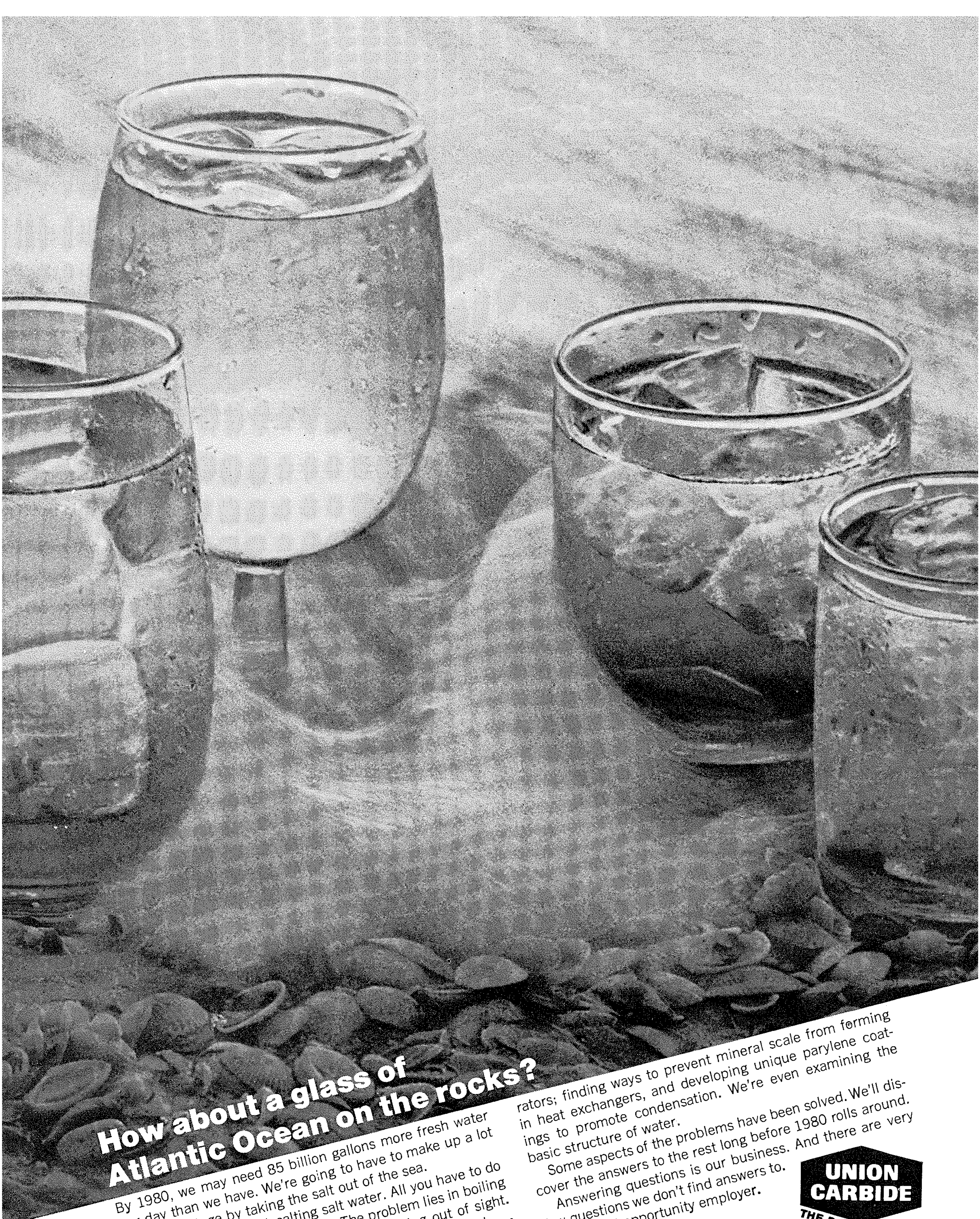
GET INFORMATION

For information on the complete line of Sealmaster and Spherco Bearings, write for Catalog 164 on your letterhead.



SEALMASTER®
BALL BEARING UNITS

SEALMASTER BEARINGS
A DIVISION OF
STEPHENS-ADAMSON MFG. CO.
49 Ridgeway Ave. • Aurora, Ill. 60507



ENGINEERING AND SCIENCE

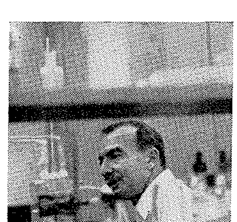
MAY 1967 / VOLUME XXX / NUMBER 8

PICTURE CREDITS: Cover, 17—Leigh Wiener / 9, 24, 25, 27, 29—James McClanahan / 11—Gerald Soffen / 20—Midge Quenell.

STAFF

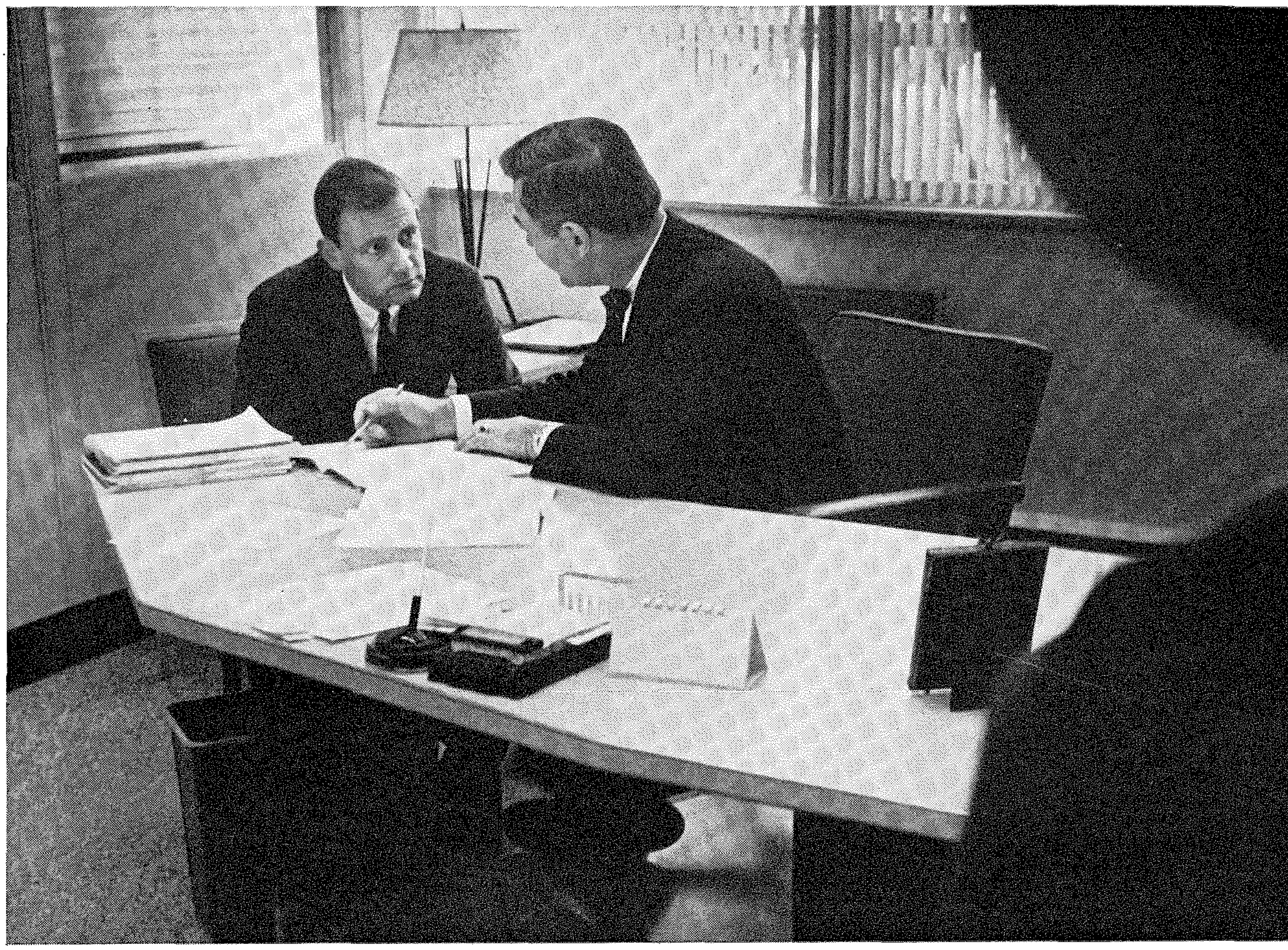
Publisher . . . . Richard C. Armstrong '28
Editor and Business Manager . . Edward Hutchings, Jr.
Associate Editor . . . . Bruce R. Abell '62
Assistant to the Editor . . . . . . Phyllis Brewster
Photographer . . . . James McClanahan

Published monthly, October through June, at the California Institute of Technology, 1201 East California Blvd., Pasadena, Calif. Annual subscription $4.50 domestic, $5.50 foreign, single copies 50 cents. Second class postage paid at Pasadena, Calif., under the Act of August 24, 1912.



COVER

The work of Sheldon K. Friedlander, Caltech professor of chemical engineering and environmental health engineering, involves the use of engineering methods in the fields of health and medicine. The problems confronted and the advances made in the relatively new field of bio-engineering are discussed by Dr. Friedlander in his article, "Plastic Hearts, Membrane Lungs, and Artificial Kidneys—The Engineering of Vital Organs" on pages 13-17.



General Motors is people making better products for people.

Don Trites's dummies lead a rough life. For your sake.

To Don Trites, these dummies are very special people.

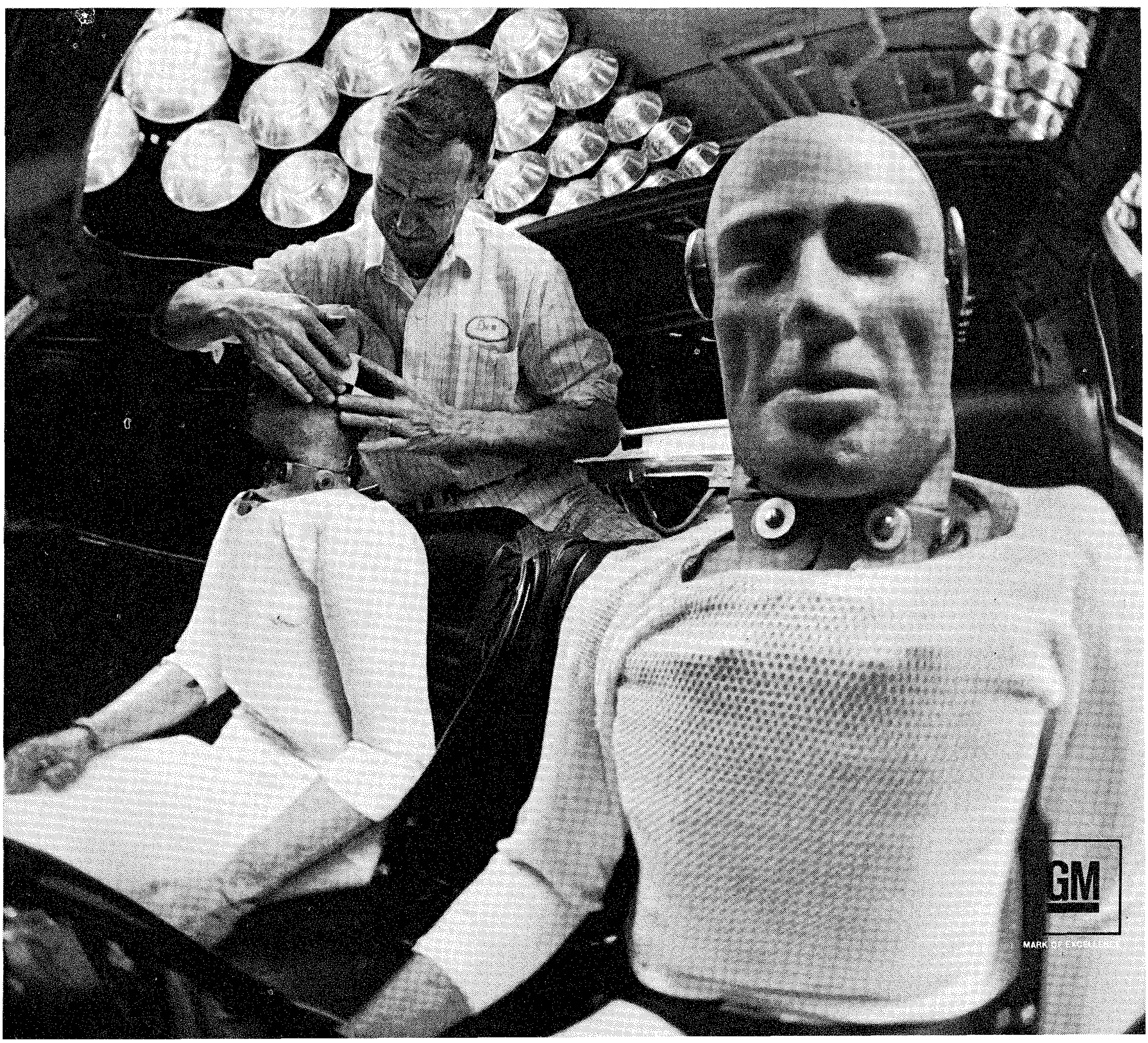
True. Their expressions never change, but they do have feelings. Mechanical feelings that can be measured by Don in moving simulated impact tests. These tests have helped GM safety engineers find and develop automotive designs that are safer for real people.

The tests go on day after day, year after year, ever increasing in sophistication and value.

Safety is an important part of every General Motors car. Maybe that's why Don thinks his dummies are something special.

They're silent heroes.

Don Trites, experimental technician, General Motors Proving Ground, Milford, Michigan.




STATE

ENGINEERING
AND SCIENCE
May 1967, Vol. XXX, No. 8

THE SEARCH FOR EXTRATERRESTRIAL LIFE

by William H. Pickering

It may be elusive, or subtle; it may be beyond the range of our early instruments; but if it is there, we will find it.

The Mariner-Mars project 1969 now under development is raising the curtain on the search for extraterrestrial life. The primary objective of the project is to make exploratory investigations of Mars which will set the basis for future experiments, particularly those relevant to the search for extraterrestrial life. Two spacecraft similar to Mariner, IV, which photographed Mars two years ago, will be flown. These spacecraft include no instruments designed to examine interplanetary space; the entire payload is planet-oriented. During the approach to Mars, a series of pictures of the whole planet will be taken. Then, at close range, a group of instruments will trace a path across the surface of Mars, collecting infrared and ultraviolet spectra, a temperature profile, and high- and medium-resolution pictures. The television format will contain 16 times as many elements as the Mariner IV picture format. And finally, the same radio occultation and celestial mechanics experiments as were performed on Mariner IV will again be conducted.

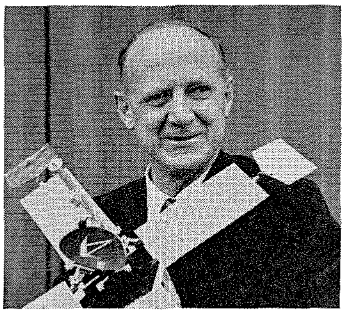
The search for extraterrestrial microbial life began, appropriately, with Louis Pasteur about a century ago. He used rigorous and new sterile techniques to drill out samples from the inside of the Orgueil meteorite and culture them in hopes of detecting biological activity. This meteorite, which fell in 1864, was the original carbonaceous chondrite, a stony meteorite containing a number of organic constituents. Pasteur found no extraterrestrial life forms in the meteorite. But he set an excellent example for modern researchers in careful techniques and the practice of avoiding contamination.

The likelihood of finding a highly advanced, intelligent life native to other planets of our solar system is not considered reasonable by responsible scientists. The search for extraterrestrial life, then, raises two questions: first, is there evidence of *any* life on our neighboring planets? Second, is there intelligence elsewhere in the universe, outside our solar system?

Because of the tremendous distances involved, the search for extraterrestrial intelligence is, at present, a communications matter. It is under study, in a limited sense, through such efforts as Project Ozma, which was established to listen with a sensitive radio telescope for any sort of intelligent radio signals from interstellar distances.

The search for life on a neighboring planet is of such universal interest that it is considered a major scientific goal of the space program.

One of the prime motivations in the search for life on the planets is related to the origin of life itself. Present-day biologists feel strongly that the life



As director of Caltech's Jet Propulsion Laboratory, William H. Pickering is involved in the development and supervision of space and satellite programs for the government. "The Search for Extraterrestrial Life" has been adapted from a speech given by Dr. Pickering on April 12 at the 38th Annual Scientific Meeting of the Aerospace Medical Association in Washington, D.C.

we know on earth began from a single primordial series of events. The life forms which fill our planet, from Arctic to Sahara to Amazon to city street, all flowed from a single source. Evidence for this is found in the genetic coding mechanism, which is common to all life forms so far studied, however different the genetic information coded. The fact that the same 21 amino acids serve as major building blocks in the construction of proteins for all terrestrial organisms is a second point. Third, is the fact that these amino acids are all left-handed stereo-isomers, and the sugars we earthly creatures use are right-handed. Apparently, we are all chemically trademarked, "Made on Earth."

We do not know whether terrestrial-type biology is universal. Another genetic mechanism or another set of amino acids might serve as well. We could, for example, postulate a life based on right-handed aminos and left-handed sugars.

If life forms of a different trademark were discovered on Mars, the implications to biology and medicine, and to all science and philosophy, would be staggering. These new life forms would be immediately recognizable as truly and originally extraterrestrial. The single primordial series of events on earth would clearly have been paralleled elsewhere. Comparison of the two forms would reveal a great deal about the fundamental nature, form, and function of life. And the fact that two such sequences could be completed in our small solar system would indicate a high probability for life generation and that the universe must be widely populated.

On the other hand, if such Martian life bore the same trademark as our own, this also would have interesting implications. It would first have to be clearly established that the life forms were not introduced to Mars by our own contaminated spacecraft equipment. For that reason, the policy of NASA is that all spacecraft and instruments which are expected to enter the atmosphere or land on the surface of another planet will be sterilized.

If these earth-type organisms are proven to be indigenous to Mars, it would then be necessary to reexamine the possibility that life began independently but identically on both earth and Mars or, as an alternative, the idea that the seeds of life were transported from world to world.

Another possibility is that we will find no life at all. But, considering the amazing variety and durability of life forms on earth, this is improbable. It may be elusive, or subtle. It may be beyond the range of our early instruments. But if it is there, we will find it.

In searching for extraterrestrial life, we are constrained to work at the limits of our knowledge of life. We define life generally in terms of the abilities of an organism to reproduce itself and to mutate. However, neither of these definitions provides a clear-cut criterion for the detection of life. Mutation can be studied only after life itself has been detected. Reproduction may be technologically difficult to prove. Experiments could be based on a number of attributes such as mobility or respiration, but biologists feel that a group of experiments will be necessary to determine unequivocally the presence of life on Mars.

Three classes of planetary missions are possible: flybys, orbiters, and soft-landers. From a flyby it is possible to obtain some surveillance while the spacecraft passes over the planet, lasting perhaps half an hour and coming as close as one or two thousand miles. This can be done in the visual, infrared, and ultraviolet portions of the spectrum. The spacecraft telemetry signal can be used, as in the case of Mariner IV, to gain information regarding the nature of the atmosphere.

The orbiter affords an opportunity for obtaining many high-resolution photographs of the planet and permits mapping of the surface topography and the investigation of seasonal changes. It can also aid in the selection of landing sites and in guiding landed spacecraft.

The soft-landed spacecraft will make the first direct contact with the surface. This spacecraft can examine the surface for the presence of biological specimens, the geological processes at work, and the local physical character of the environment.

A surface-roving vehicle, brought to the surface aboard a soft-lander, is capable of expanding area coverage and may become the most important instrument for the biological exploration of the planet.

The return of samples to earth for analysis is the most ambitious, sophisticated, and difficult variation of the planetary landing capsule. If manned landings are the climax of this series of missions, this task might well be left to the men. Some biologists feel that sample return may be the only way in which the question of life can be fully answered.

Human explorers could bring to the search the breadth of human senses, the speed of human reaction and judgment, and the deftness of human hands. In any robot operations at interplanetary distances, the communications time is many minutes each way. But men could also bring a variety of terrestrial life forms, so that extreme quarantine measures and guarantees will be necessary. And men cannot be written off as expendable, as can unmanned spacecraft.

There are a number of instrumental approaches to the search for extraterrestrial life. The first method is purely physical observation and measurement and is dominated by photographic and television systems.

The television mode used in the Ranger and Surveyor projects was similar to commercial television—the image was scanned off an electrostatic plate in several hundred lines. In Lunar Orbiter, the image was developed first on film and then electronically scanned in narrow strips. For Mariner IV, working at a distance of more than a hundred million miles, another format was used. The picture was divided into forty thousand elements. The brightness of each was converted into a number with zero representing white and 63 black. These numbers were then stored on a tape recorder and transmitted slowly but accurately back to earth, where they were reconstituted as pictures. These data were processed by a computer to remove noise and distortion, rectify the picture, increase the contrast, and perform other corrections.

Future spacecraft will carry television systems on such instruments as the telescope and the microscope and may transmit images obtained outside the visible spectrum. In addition, surveillance television will be used to observe any digging or sample-handling by the spacecraft.

The second instrumentation approach is the chemical. Here the search is for compounds associated with life—biochemical constituents, products, and organic precursors. Periodic analyses might show changes in concentration or kind of organics caused by life processes.

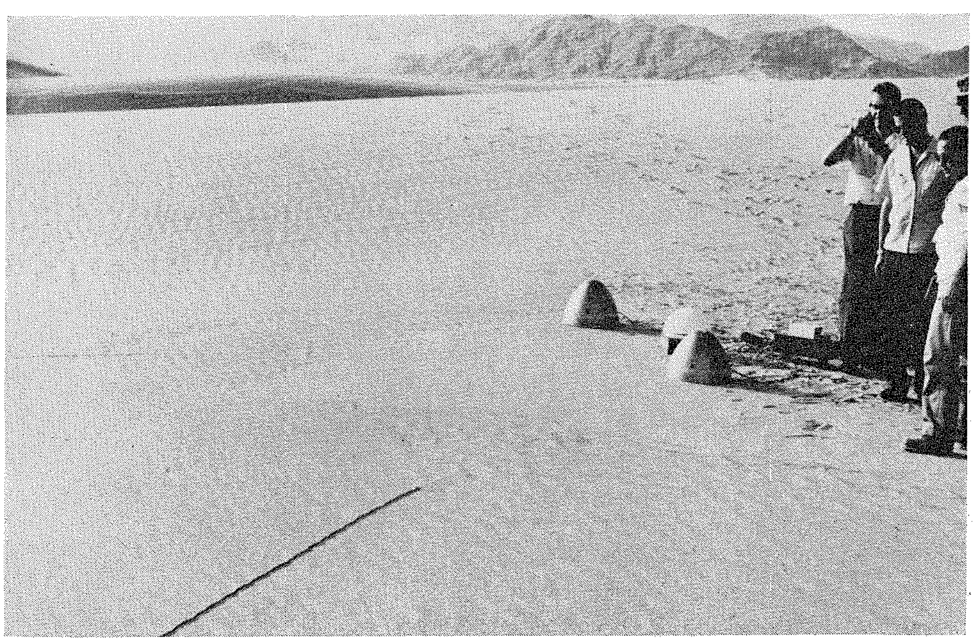
An interesting member of this group of instruments is the gas chromatograph, of which a compact space-flight version is being developed. In this instrument a sample is heated to vaporize its organic constituents. These vapors are then forced through an absorption column with an inert gas medium. Each compound has its own distinct rate of passing through the column so that the various compounds in the sample are separated at the output and identified.

Probably the most interesting instrument approach to life detection is the biological. The activity of the living organism itself is the object of the search, not its chemical or physical effect on the environment. The advantage of this method is that a positive result is unmistakable. Its disadvantage is that the life form in the sample may be so selective in its metabolism that a positive indication cannot be observed.

The Gulliver experiment is an excellent example of the biological approach. In this device, a sticky string is propelled out on the planetary surface by a projectile and is reeled in like fishing line—covered, it is hoped, with local microbes. The string is cultured in a nutrient fluid with isotopically labeled molecules. Gases given off by the culture are tested for radioactivity. Any radioactivity found would indicate the presence of a metabolic product. As the organisms multiply, the signals would be increased. An exponential rate of increase would be interpreted as growth.

The biological experiment may also be combined or sequenced with other experiments. For instance, after an interval, the sample could be filtered and the microorganisms examined under the microscope. Or the remaining nutrient fluid could be analyzed to discover which constituents have been taken up. The sample could also be tested for polar-

The Gulliver instrument, designed to detect bacterial life, is tested on the sands of Death Valley. A sticky tape is propelled onto the land surface to "catch" local microbes. The tape is reeled in and examined for the presence of bacterial life. Gulliver will be an important device in the search for extraterrestrial life.



ized-light rotation to discover whether, for example, right-handed sugars are selectively removed.

There are, however, some limitations on this program of ways to search for extraterrestrial life in the solar system. They derive—except for the sterilization requirement already discussed—from inexorable laws of physics. They primarily concern energy, which affects both the schedule for conducting missions and the size of the spacecraft.

The schedule limitation is that, because of the relative positions of the earth, the sun, and the target planet, it is possible to launch an interplanetary flight only during a brief period approximately every two years. The interval between these launch periods is 18 months for flights to Venus and 25 months for flights to Mars. The length of the launch period depends on how small a spacecraft is to be launched with how powerful a rocket vehicle and on the particular launch geometry.

The size problem is simply that, under the best conditions, it takes a very, very large rocket to launch a very small spacecraft to a planet. The energy cost of flying to Mars is very high, and the rocket engineering cost of this energy is very high. For example, the quarter-ton Mariner IV with 41 pounds of scientific instruments was launched by the 138-ton Atlas/Agena rocket. The half-ton Mariner-Mars 1969 with 112 pounds of scientific instruments will use the 150-ton Atlas/Centaur. The Saturn V, which weighs more than 3,000 tons, could launch 20 to 25 tons of spacecraft to Mars. A ton of scientific instruments landed on the surface might reasonably result from such a launch.

The search for extraterrestrial life can be defined only by what it is looking for—not by what it finds. It is a characteristic of scientific work that, however closely you pursue the object of the search, other discoveries force themselves upon you. This search may find many objects. Some of the technology may draw on and stimulate medical technology and be able to hand back to medicine some new study tools. Another part will draw on communications, a technology already flourishing in conjunction with the space program. The many fields of knowledge and of application which may benefit from this search can only be guessed at.

Today we are starting the search for extraterrestrial life. Science is ready and eagerly awaiting the evidence. Technology is ready and preparing to obtain that evidence. The Mariner series of missions, designed to prepare the way for the search, is progressing well. The Voyager series, designed to land on the planet and take the first steps in the search itself, has begun. We stand on the threshold of new worlds. And we are not standing still.

PLASTIC HEARTS, MEMBRANE LUNGS, AND ARTIFICIAL KIDNEYS — THE ENGINEERING OF VITAL ORGANS

by Sheldon K. Friedlander

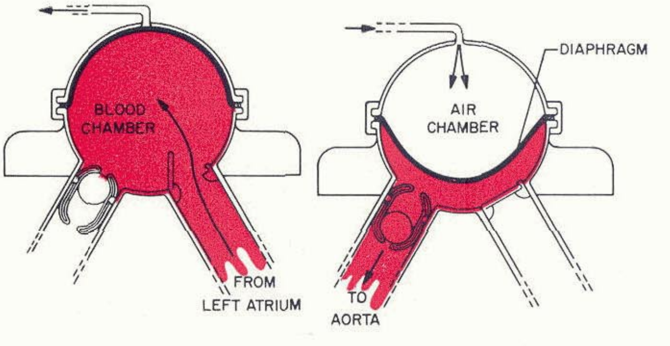
Why are engineers taking more and more interest in problems of health and medicine? In part, perhaps, it is a question of a guilty conscience. After all, engineers have seen the destructive power of their inventiveness in the effects of air and water pollution, weapons for the military, and biological and chemical warfare. Can they have as much impact, of a positive sort, in such fields as health and medicine?

While I am convinced that this is part of the story, it is necessary to ask the more general question: What makes any field of technology develop at the particular time that it does? One important factor is the state of the backup technology. For example, the rapid growth of the aircraft industry rested in part on the base of a commercially successful method for winning aluminum from its ores. A second requirement is the willingness and ability of a society to provide financial support for the development. Either mass markets, as in the case of the automobile, or military-political stimulus, as in the space program, may provide that support.

The backup technology in the form of new polymeric materials and electronic instrumentation now exists for significant advances in certain fields of medical technology. Development costs are unlikely to be supported by mass markets, and there is little doubt that the government will have to underwrite these expenses, which can be huge. While some government funds *have* been allocated to this field, they have been small in comparison with outlays for space spectaculars, military hardware, and Asian wars.

Still, progress has been made. Until recently, it has been possible to make replacements of human parts only of the most primitive types such as wooden legs and false teeth. Within the past 20 years or so, artificial hearts, kidneys, and lungs have been developed to the point where they can be used in some cases to prolong life indefinitely, in other cases to at least permit repairs during surgery. These are among the simplest of organs in their function, and it was natural to begin with them in our bioengineering efforts.

The diagram below shows an artificial heart of the type recently used by Michael DeBakey, MD, and his surgical group at Methodist Hospital in Houston. The plastic heart, about the size of a grapefruit, is activated by an air pressure mechanism which moves the diaphragm back and forth,



A schematic diagram of an artificial heart, designed to carry part of the pumping load for a period of days after a patient has undergone heart surgery. The diagram on the left shows the heart as blood is drawn in, and the one on the right as it is pumped into the aorta.

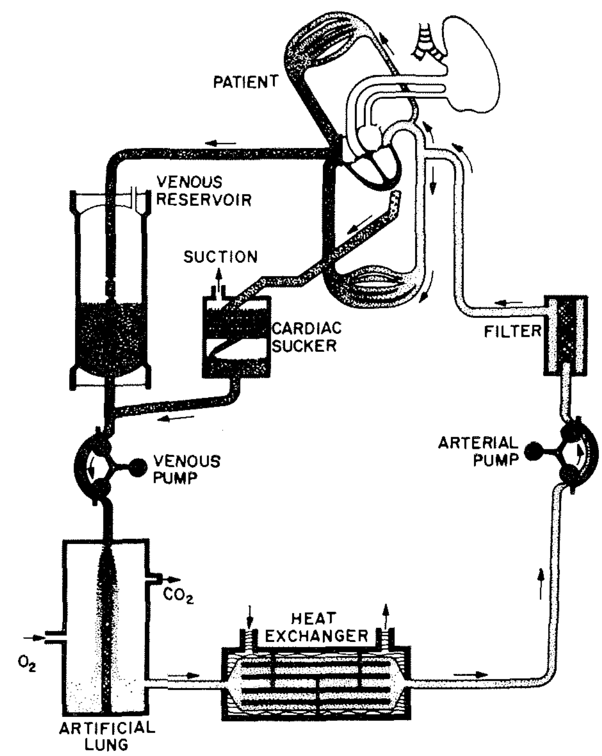
thereby producing the pumping action. Currently such devices are used for a period of days to give the patient's heart a partial holiday during and after surgery.

In a commercial artificial kidney, blood flows along one side of a membrane, and a salt solution on the other. When kidney function is impaired, this device can be used to remove potassium ions as well as urea, creatinine, uric acid, and a variety of other toxic products of metabolism normally removed by the healthy kidney. The separation in this way of smaller molecules from larger ones is known as dialysis.

The artificial kidney was first used successfully with human patients in 1945. Current treatment with these large devices is expensive and time consuming, and the number of trained personnel qualified to operate them is small. First-year costs of treatment have been estimated to be about $20,000 per patient. Each year 90,000 people die of chronic kidney failure, and of this number at least some fraction could be saved by treatment with the artificial kidney. Only a limited number of patients can be treated with the facilities available, and the problem of selecting those who will live has been discussed at length in the popular press and on TV.

Shown below is an external circulatory system of the type used during heart surgery. It demonstrates rather clearly the characteristics of systems which engineers are accustomed to dealing with. Here we have pipes, hold-up tanks, pumps, gas absorption and desorption apparatus, a heat exchanger, and a filter. The component of this system which has been of most interest to our group at Caltech is the absorption part, the artificial lung. Just as in the case of the natural lung, its function is to absorb oxygen and give off carbon dioxide. In the one shown here, blood flows over a screen, and the oxygen and the blood are in direct contact. A major problem in the use of such systems is the deterioration of the blood which occurs after a few hours of passing through the machine. This limits the surgeon's operating time and prohibits the use of the device during the post-operative recovery period. To reduce blood damage, plastic membranes have been introduced between the blood and the gas, and this appears to help matters.

ARTIFICIAL DEVICE	CURRENT STATUS OF DEVELOPMENT	DEVELOPMENT GOAL
LUNG	USED FOR A PERIOD OF HOURS DURING HEART SURGERY	USE OVER A PERIOD OF DAYS DURING RECOVERY
HEART	USED FOR A PERIOD OF DAYS AFTER HEART SURGERY (WITH INDIFFERENT SUCCESS)	PERMANENT IMPLANTATION
KIDNEY	INTERMITTENT USE IN FIXED LOCATIONS OVER A PERIOD OF YEARS	CONTINUAL USE OF A PORTABLE DEVICE



External circulatory system of a type used in heart surgery (from Heart-Lung Bypass *by Galletti and Brecher, Grune and Stratton, New York, 1962).*

The chart above summarizes the current development of these devices and the goals we have set for future developments. In the case of the heart and kidney, we hope to develop permanent, portable devices, implanted if possible. In the case of the lung, we have set a more modest goal, perhaps, because our current achievements are more modest.

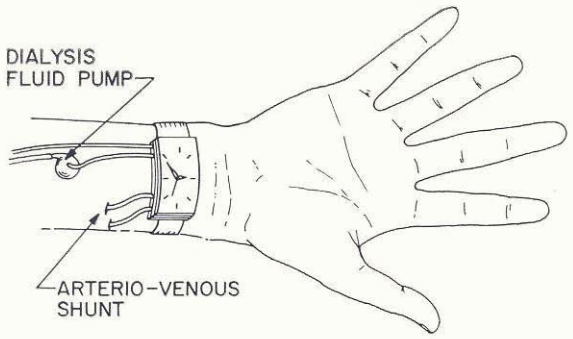
An idea of what we are aiming for is shown, (right) in the artificial kidney of the future.

There are two major requirements associated with the design of these devices. First, in the case of the exchange devices (lungs and kidney), there is the need for an adequate rate of transfer of the molecular species of interest into or out of the blood. Second is the need to use materials of construction which do not damage the blood as the result of undesirable surface reactions. Some success has been achieved in both cases, but we still have a long way to go before we reach the transfer rates and non-toxic surfaces needed for prolonged used of compact devices.

The problems of exchange rates and non-toxicity are related because devices with large surface areas, hence greater exchange rates, are likely to produce more denaturation of the blood. Moreover, the denaturation products may collect at the surface and plug the membranes of the device. These two problems are interesting from an engineering point of view. Engineers, who can do almost anything with air and water, turpentine and alcohol, are now trying to coax blood into acting like these other well-behaved fluids.

A cross section of a membrane oxygenator, an artificial lung, is shown at the right. Here we see the diffusion path which must be taken by a molecule of oxygen or carbon dioxide (or urea or creatinine). An oxygen molecule passes from the gas phase, wiggles its way through the membrane, and wanders around in the plasma until it chances upon a red blood cell. It enters the cell through a membrane before it finally reacts chemically with the hemoglobin in the cell. Carbon dioxide passes in the other direction. The blood is flowing on its side of the membrane, and the other fluid, oxygen flows on its own side. A similar picture could be drawn for the artificial kidney, except that the substances which must be removed from the blood include urea and creatinine, and saline solution instead of a gas flows along the opposite side of the membrane from the blood. Clearly a prime requirement is a membrane which will let the molecular species in question pass at a sufficiently rapid rate.

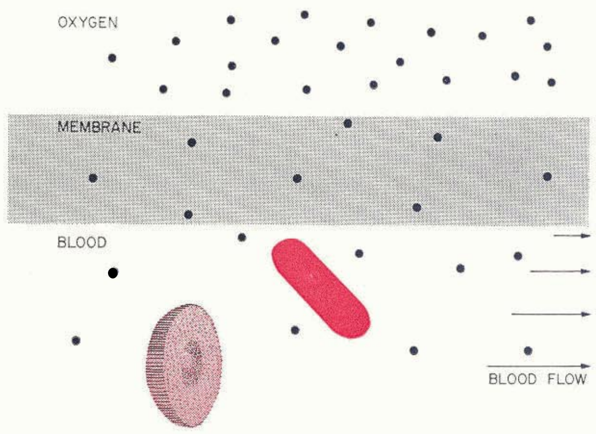
In some types of membranes there actually appear to be little holes or pores which are bigger than the molecules which want to pass through.



Artificial kidney of the future, as envisioned by Dr. L. W. Bluemle, Jr., of the University of Pennsylvania. The device would work continuously as part of the arterio-venous shunt using dialyzing fluid from a reservoir located on the patient's body.

The kinetic theory of matter tells us that molecules in fluids execute an endless dancing motion which allows them to penetrate these pores. More often, however, it appears that a rigid, sieve-like structure does not exist. Instead the diffusion of a molecule through the membrane can be likened to the passage of a marble through a ball of worms with the little wrigglers displaying the molecular motion of the polymeric segments composing the membrane. Here and there holes open up in the polymeric material only to close again as the chain-like molecules wriggle about.

For membrane lung design, silicone rubber has been found to be remarkably permeable to oxygen and carbon dioxide molecules. Using membranes



Schematic diagram of the oxygen-membrane-blood interfaces in the artificial lung. The film of slowly moving blood at the membrane surface inhibits oxygen absorption. Shown also are two red cells (viewed from different angles) with the one nearer the membrane more highly oxygenated.

one thousandth of an inch thick, Ed Spaeth, a Caltech graduate student in engineering, found that the major resistance to the passage of oxygen is a relatively thick, slowly moving film of blood which accumulates on the blood side of the membrane and inhibits exchange. When the blood film resistance controls, improving membrane performance adds little to the speed with which transfer occurs. It is a case of a very large and a very small resistance in series; reducing the magnitude of the smaller resistance results in little change in the current. Spaeth determined film thicknesses as a function of blood velocity and oxygen pressure. Films were thinnest at high velocities and at oxygen pressures which correspond to those found in the tissues of the body where the oxygen is released to the cells of the body. These experimental results and the theory which goes along with them represent a significant step forward toward the rational design of membrane oxygenators. Now for the first time we can predict film thicknesses, hence exchange rates, as a function of velocity for different geometric configurations of the oxygenator. This means that we can calculate surface area and total volume and determine optimal values for both.

The exchange situation for the artificial kidney is in some ways more complicated than for the lung. There are more molecular species to deal with, and greater specificity in the performance of the membrane is necessary. Urea must be moved and, if possible, creatinine and uric acid as well. But the permeability must not be so great that larger protein molecules such as serum albumin can escape from the blood to the other side of the membrane. Such membranes are usually made of common cellophane. Their permeability can be controlled to a certain extent by dipping them in acids or other chemicals, and they do an adequate job of separation. To reduce kidneys to something approaching wristwatch size, still more effective membranes with unusual geometric configurations are needed. But development of improved membranes is a slow process, in part because the market for such materials is not sufficient to stimulate extensive research efforts. How to stimulate development? One suggestion has been to find a plastics manufacturer with a chronic kidney disease.

The improvement which results when patients suffering from chronic kidney disease are treated with the artificial kidney is not lost when urea is included in the dialysis bath, thereby blocking urea removal. This indicates that the undesirable effects are produced in the body not by the urea but by small quantities of other substances, as yet unidentified, which accumulate as a result of the reduction of kidney function until toxic concentrations are reached. The molecules of these agents must be small enough to be removed at the same time as urea by the dialysis membrane. Clearly this adds an element of uncertainty to membrane design. We can only *hope* that if known materials, such as urea, are passed by the membrane, the unidentified toxic agents will also get through!

Serious damage to the blood may occur as it passes through one of the devices. When blood is brought into contact with a foreign surface, coagulation takes place over a period of time which varies greatly with the nature of the surface. Even the least clot-promoting of polymers, silicone rubber, causes clots to form within 20 minutes in laboratory tests. The clotting time depends on a number of variables including the "wettability" of the surface and the surface electrical charge. Glass which is highly wettable induces clotting much more readily than a nonwettable material like paraffin. Clearly there must be more to the phenomenon than this, however, since the blood vessel walls themselves are highly wettable. The importance of electrical charges is indicated by experiments which have shown that clots form around a positive electrode placed in a blood vessel and are inhibited at the negative electrode. It is argued that the normal vascular wall is negatively charged and that damage to a vessel which produces clot formation also causes it to be positively charged.

Not only is clotting promoted as the blood passes through one of these devices, but the formed elements—red cells, white cells, and platelets—tend to break down. There are two schools of thought on the causes of hemolysis or red cell destruction. According to one, mechanical shear in the flow system rips the cells apart, although these may have previously been weakened by physico-chemical effects. According to the other, destruction results from the red cells hitting the walls of the flow system. The exact mechanism is not clear. Perhaps the delicate cell membrane adheres momentarily to the wall and is torn when the cell is pulled loose by the motion of the fluid.

Damage to the blood passing through an artificial external circulatory system during an operation has serious consequences. The clotting which is produced in the external circuit is countered internally by certain enzymes released by the body to dissolve the clots. The result is, on the one hand, a tendency toward premature clotting in the extracorporeal circuit and, on the other, the possibility of severe bleeding internally. Avoiding these dangers requires administration of correct dosages of the anticoagulant heparin and its neutralizing agent protamine at the proper times during the course of extracorporeal circulation procedure.

To further complicate matters, some of the constituents of the blood tend to deposit on foreign surfaces. For example, a fibrin coat forms on the inside walls of artificial hearts made of an impervious plastic in a matter of seconds after blood is introduced. The fibrin is produced by conversion of the protein fibrinogen, which is soluble in the plasma, into an insoluble form. The film builds up but is only loosely attached to non-porous plastic surfaces. Eventually it tears loose and disintegrates, appearing as an accumulation at both valves or embolized in the arterial system.

When blood flows through an artificial kidney, a layer of white cells deposits on the surface of the membrane. This effect is even more serious when the blood has been damaged. We have taken blood which had been circulated through a heart-lung machine during an operation—there is always a certain amount of blood needed to prime these devices and an equivalent amount remains at the end—and passed this "used" blood over a membrane to measure its diffusional resistance. Over a period of about two hours, the membrane resistance increased to about six times its original value, and inspection of the membrane showed that a deposit of material from the blood had accumulated on the surface. No deposit or increase in resistance was observed in experiments with fresh blood.

How can we change the nature of the surface to prevent blood damage? One method used with artificial hearts takes advantage of the protein deposition phenomenon which I mentioned before. When an *impervious* plastic is utilized as an artificial substitute, the fibrin coat which deposits on its inner surface is anchored only at its ends, at the tissue connections. As a result the coat disintegrates rather easily and embolizes. Learning from this lesson, DeBakey's group places a nylon or dacron felt liner inside the plastic heart; when blood is introduced, a coating of fibrin develops on the felt which is so tightly bound that disintegration and embolization do not take place. The fibrin layer protects the blood from further contact with the foreign surface. When such liners are used, the level of plasma hemoglobin falls to preoperative levels indicating that red cell destruction is at a minimum. However, the possibility of applying this "grow your own skin" technique does not seem too promising for the large surface areas of extracorporeal circulatory devices.

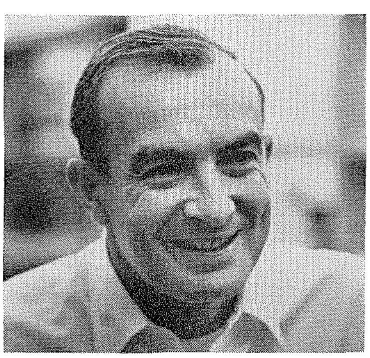
Another method which has been developed for inhibiting clotting is the alteration of the chemical nature of the surface over which the blood flows. One clever technique involves the bonding of heparin to the surfaces of polymeric materials. (Heparin is found in blood vessel walls as well as in the liver and lung tissue.) This is done by first incorporating in the surface layer a quaternary ammonium salt which has a special ability to bind heparin. The method is new and is currently being evaluated by implanting heparinized plastic rings in the veins of dogs. Polypropylene rings showed no evidence of clotting after a two-week period, but when polystyrene rings were used, about half had clots after the implantation period. Cellophane can also be treated with heparin, and membranes prepared in this manner retain their ability to dialyze.

Why surface-bound heparin inhibits coagulation is not known. Tests have shown no evidence of heparin *in* the blood which clots normally when coagulants are added so that it appears to be a true surface effect. While these developments sound promising, a serious problem remains: The hemolytic or red-cell-destroying character of almost all polymer surfaces increases several times when treated with heparin. Clearly the search must continue for a material with the compatibility of the internal surface of the healthy circulatory system.

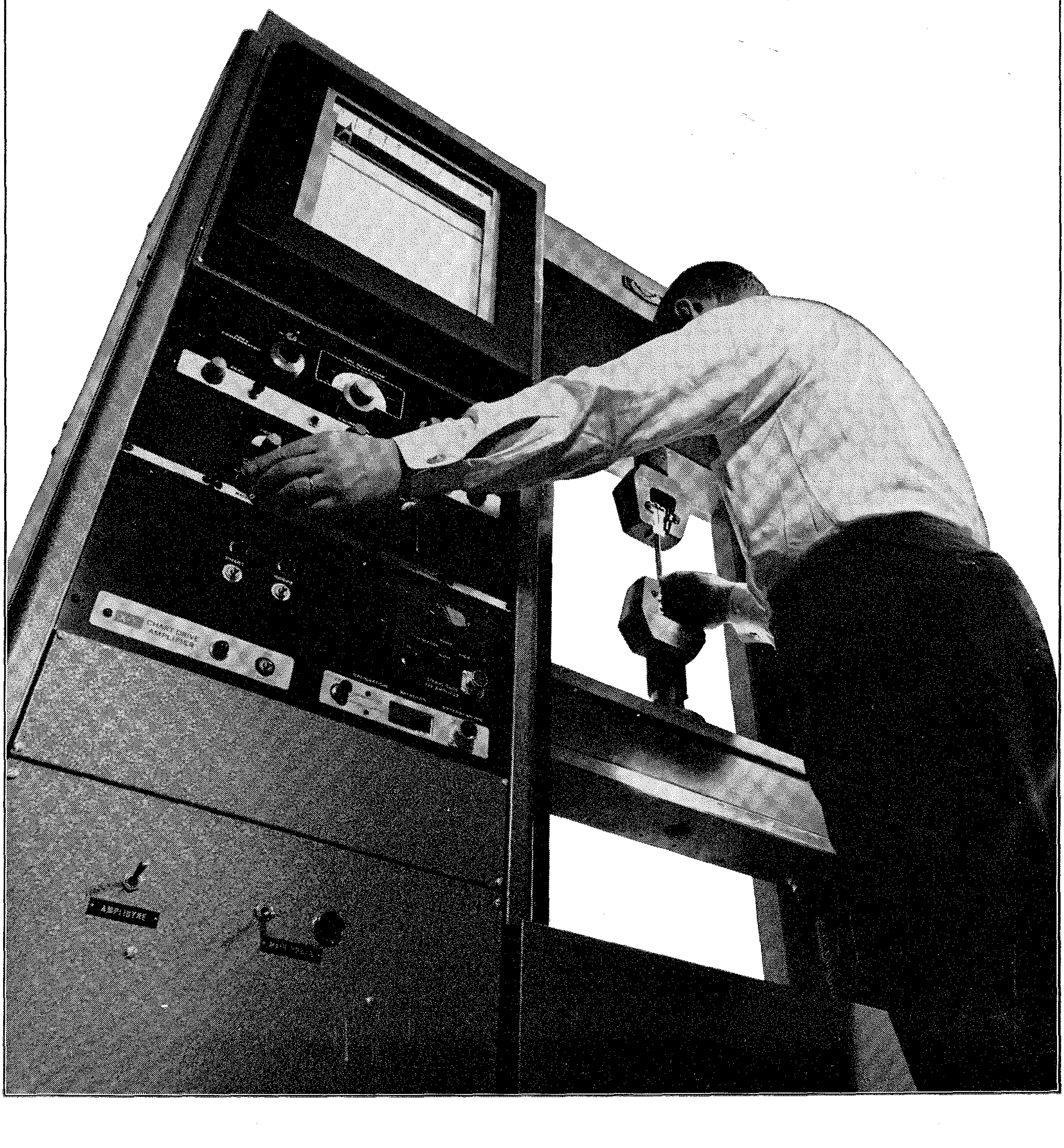
The use of artificial devices, perfected to the point where they can sustain life over long periods of time, will increase the dilemma faced by modern medical practitioners who can maintain life, of a sort, long after a creature has ceased to function effectively as a human being. One can conceive of situations in which, by accident or as a result of disease, one organ ceases to function while the others continue to perform in a satisfactory manner. In such a case, the substitution of an artificial organ would be an obvious solution. On the other hand, old age, while it may result in the complete breakdown of only one organ, may be accompanied by the general deterioration of others as well as the nervous system. Should the substitution of the new organ for the old be made?

The question might become academic (in the worst sense of the word) if bioengineers of the future are able to grow entire new creatures from single cells of that creature. Then instead of replacing worn-out parts, there will exist the possibility of trading in an old model for a new one *of the same type*.

While I will not speculate any further on these questions, I will not disclaim interest or responsibility on the grounds that I am merely a technician and that the decisions must be made by politicians and theologians. The responsibility of scientists to participate in decisions concerning the applications of their brain children is important.



"Plastic Hearts, Membrane Lungs, and Artificial Kidneys—The Engineering of Vital Organs" has been adapted from a lecture given by Sheldon K. Friedlander at Caltech's 30th Annual Alumni Seminar on April 22. Dr. Friedlander is professor of chemical and environmental health engineering at the Institute. The major areas of his research are concerned with the application of engineering methods to problems of health and medicine. Research studies done recently under his supervision include work on the characteristics of high-speed beams of small particles, the mathematical theory of the particle size distribution of coagulating dispersions, and the diffusion of gases in flowing blood. Dr. Friedlander became involved with current developments in artificial organs, while working on the flowing blood project.



WHAT'S SO CRAZY ABOUT CALIFORNIA POLITICS?

by Robert L. Woodbury

Throughout much of the nation, California politics is viewed as a political carnival. A variety of political cults, extremist groups, erratic voting behavior, candidates from an unreal world, and a year-round, bumper-sticker war fascinates, baffles, and amuses much of the country. Sometimes it even embarrasses Californians.

This image is spread and sustained by the national press. Note the titles of recent articles on California politics: "Notes from the Land of Political Pop," "Political Fun and Games in California," "Tom Sawyer Enters Politics," and "The Land of Loony Schemes and Political Extremes." An old joke about California politics can still be heard in respectable places in the East: "Tilt a continent and all the oddballs will roll with the tilt."

The laughter of the rest of the nation, however, is a nervous one—and for good reason. Candidates who can win statewide elections in the nation's largest state instantly become potential presidential and vice-presidential candidates. The New York lesson is lost on few. In all but two presidential election years since 1872 at least one of the two major parties placed a New Yorker on the national ticket. Further, there is considerable apprehension east of the Rockies that patterns emerging in California may be a curtain raiser for their own politics.

It could hardly be disputed that California's political history has been dotted with color and variety that has repeatedly attracted the attention of the national press. The depression of the 1930's produced a variety of cure-all plans and demagogues, as well as radical reform programs that excited uncommon support. The Technocrats and the Utopian Society blossomed, as did political counterparts of religious cults of the Aimee Semple McPherson variety. The Townsend Plan calling for a $200-a-month allotment to every person over 60 on the condition that the money was spent within three months flourished in California, as did the "Ham and Eggs" scheme that appeared on the 1938 state ballot.

Less popular political movements—ranging from the John Birch Society to the 1961 Organization to Remove (Arthur) Schlesinger from Public Life—have appeared on the fringes of California politics throughout the 20th century.

But the overriding conclusion about the political experience of California in this century is not the erratic character of its politics but how closely it has paralleled the national experience. The dominant response of California to business power and corruption early in the century; the convulsions of war, prosperity, and depression in the intervening years; and the emerging problems of a rapidly growing mass urban society after World War II are more coincident with the national experience as a whole than that of almost any other state. California's most successful political leaders for over half a century have clearly occupied the broad mainstream of our national political life.

The progressive period provides a good example. Throughout the nation after 1900, the progressive sought greater public supervision of business activities, popular electoral reform, and greater legislative attention to those who were casualties of a maturing nationalized economy. Although the movement came late to California, it rapidly duplicated the national experience. Theodore Roosevelt called the 1911 California legislative session "the most comprehensive program of constructive legislation ever passed at a single session of an American Legislature."

Nor did California stray from the main route after the progressive period. The era of Harding, Coolidge, and Hoover was slightly more progressive, both in California and elsewhere, than historians have previously concluded; but the state nevertheless duplicated the dominant national pattern of a "return to normalcy," popular suspicion of stepped-up governmental activity, and the consistent election of Republican leadership.

During the depression decade of the 1930's, California did not elect a New Deal governor until 1938, but it did follow a pattern of increased Democratic success and moderate reform. The shift of the focus of governmental activity to Washington was an experience common to statehouses across the country.

Since World War II California has virtually defined the mainstream political response to the problems of a rapidly growing, increasingly urbanized, affluent society. One need go no further than Earl Warren for the story of moderate progressive adjustment to the demands of a complex urban society.

To argue that for 60 years California has followed, and more recently duplicated, the national political experience as a whole does not mean that California politics hasn't responded to any distinctive factors.

Several elements peculiar to California politics are quite familiar: the repeated antagonism between north and south; the important role of the Mexican-American, Oriental-American, and increasingly the Negro-American communities in the life of the state; and a vigorous urban-rural clash that is being replaced today by a much more crucial split between the suburbs and the core city. But even these distinctive elements are nationally relevant and increasingly describe the experience of many states.

Three other distinctive factors deserve special attention. First is the independent character of California voting behavior, which is partly a legacy of the progressives and partly due to a variety of sociological factors such as the role of migrants from other states. No other state so institutionalized popular participation and voter independence during the progressive period. One example, cross filing, has been eliminated, but the result has *not* been the evolution of strong party organizations nor have voters become less independent. It is also true that ticket splitting and weakened party ties increasingly describe voting behavior elsewhere.

A second factor of considerable importance in California political history is rapid population growth, fed by continued high migration. This growth has created elements of instability and bur-

New groups, with new concerns and interests, are coming to the center of American politics . . .

geoning social problems that have not quite been duplicated elsewhere. The rate of population growth in California has been almost constant for a century. If this rate continues, however, California's population will equal that of the United States by the year 2070.

A third important factor is the implication of the cliché that California is more like a nation than a specialized sub-political unit. A highly diversified society and the sixth most productive economy in the world cause California politics to be involved in a far more complex myriad of conflicting interest groups and problems than exist in a state where groups such as the dairy farmers or the automobile workers can exert effective leverage. Even this characteristic, however, suggests why California politics has so closely approximated the national experi ence, and the reality of diversified economies is increasingly apparent in many states.

These distinctive factors—rapid growth, a highly diversified society, independent political behavior, the impact of urbanization—have affected the path of California politics for decades. But these factors appear less distinctive when compared with the nation as a whole and, as other states increasingly respond to similar pressures, these factors may buttress our understanding of California's place in the mainstream of American politics.

It is true that the prominent role of the zany, extreme, and unorthodox in the story of California politics in the 20th century cannot be ignored. It can, however, be placed in some perspective. First, California has had no monopoly on extremists or nuts. In fact, a man like Upton Sinclair, the EPIC candidate for governor in 1934, would rate rather low on any zaniness scale with the likes of Jimmy Walker, Huey Long, and Ma Ferguson.

Second, the national press often features a story of the offbeat when it comes from California and underplays a more extreme demonstration elsewhere. For decades Americans have somehow seen California as "the nation becoming." This not only made any article on California more important but created a climate where people almost had to have an excuse for not migrating themselves.

In the light of California political experience in the 20th century, we have little reason to expect that the state has suddenly moved off into some eddy of United States politics in the 1960's.

In a society like ours politics is the major public arena where the tensions, hopes, aspirations, and interests of people are expressed. As societies change, constituencies and their interests change, and the substance of politics will change also.

Important changes *are* taking place in American society today, and we may expect a new politics. "The United States," Peter Drucker wrote two years ago, "almost certainly is entering into a period of political turbulence unlike anything we have known for at least a generation. In the decades just ahead, our domestic politics will be dominated by unfamiliar issues—not only new, but different in kind from the things we have been arguing about since 1932." Drucker has suggested a model that is particularly applicable to California.

First, the United States has become an urban nation. Within a few years, 75 percent of all Americans will live in less than 200 urban centers across the country; 40 percent will live in or on the fringe of three giant urban belts—one stretching from Boston to Norfolk, one from Milwaukee to Cleveland, and one extending almost without interruption from San Francisco to San Diego. The case of California is particularly dramatic. According to the Census Bureau, almost 90 percent of Californians today live in urban areas.

Second, the United States is more and more a "Youth State." The median age in the U.S. today is 26 and still declining. In 1960, the median age was 33. It has dropped one year annually over the last seven years. Those of us who are baffled by the youth generation have reason to be worried: the 15-24 age group is now 30 percent of our population. In the 1968 presidential election, 14 million young people who were too young to register in 1964 will be able to vote. The group with the power to lay down the law will not be 40- and 50-year-old businessmen, lawyers, laborers, and housewives, but young adults pushing baby carriages or still attending school.

Third, we are not only a Youth State, but a "Knowledge State." By 1970, one-third of our nation's population will be in school full time. We currently spend well over 30 billion dollars on education, and this figure will probably double in the next five years. Not only will a large majority of Americans be students or parents of students, but the coalition of their concerns will be joined by another huge power group—those directly involved in the education business as teachers or administrators. Even today they make up the largest single occupation group in the United States. Few of us need to be reminded that California is already the Knowledge State par excellence. We will soon have close to a million students enrolled in institutions of higher education. At the lower educational level we already have a million more students than New York State, although the state populations are equal.

What does all this have to do with a so-called new politics? It simply means that new groups, with new concerns and interests, are coming to the center of American politics and that some of the power groups which defined the issues over recent decades will decline in importance.

Peter Drucker has suggested that this new power group will consist of "a professional, technical, and managerial middle class—very young, affluent, used to great job security, and highly educated . . ." They will live in the megalopolis and work for large and amorphous public or private bureaucracies. Assured of salaries of $15,000 and more, they will also be politically untied, secure, eager to use leisure, concerned with the quality of life in the urban-suburban complex, and intimately concerned with the educational system. They will not be captured politically by resurrecting the issues and the ideological warfare of the 1930's or even the 1950's.

Constituents of this future power group, such as the students at Caltech, have grown up in an era of uninterrupted prosperity. Already we see their challenge to traditional concepts of work, leisure, occupation, material measures of status and worth, and other values laid down in an older America. The form of the challenge may range from psychedelic withdrawal to service in the Peace Corps. More likely, it will be reflected in a persistent uneasiness about their commitment to managerial, professional, and technical careers and family life in the latest Leisure Village. To say that this generation will eventually turn out like its predecessors may be comforting, but if it turns out *not* to be true, it may have some astounding political implications.

In California this new power group has already begun to emerge, and some of their political concerns are apparent. To people living in the great megalopolis, the key issues are increasingly smog, water pollution, regional government, crime, and urban renewal. To a youth society intensely concerned about education, issues of campus size, the ghetto school, technological innovations in teaching, and student power are more and more becoming dominant political concerns.

But there is also a more complex ingredient in this so-called new politics. By older definitions the affluent young professionals of this new power group should have it made. But they are an uneasy and anxious lot. The individual is caught up in a mass society where people are numbered; where his face is not known; where his position in an amorphous bureacracy is unclear; where a string of credit cards is his introduction, but everyone has the same cards; where he lives in a tract home—a world where the traditional definitions of place, position, status, occupation, class—of identity—do not exist. He *should* have it made, but no one recognizes him on the street and tells him that he's important, that he's a community leader, that his advice is crucial, that he has really achieved.

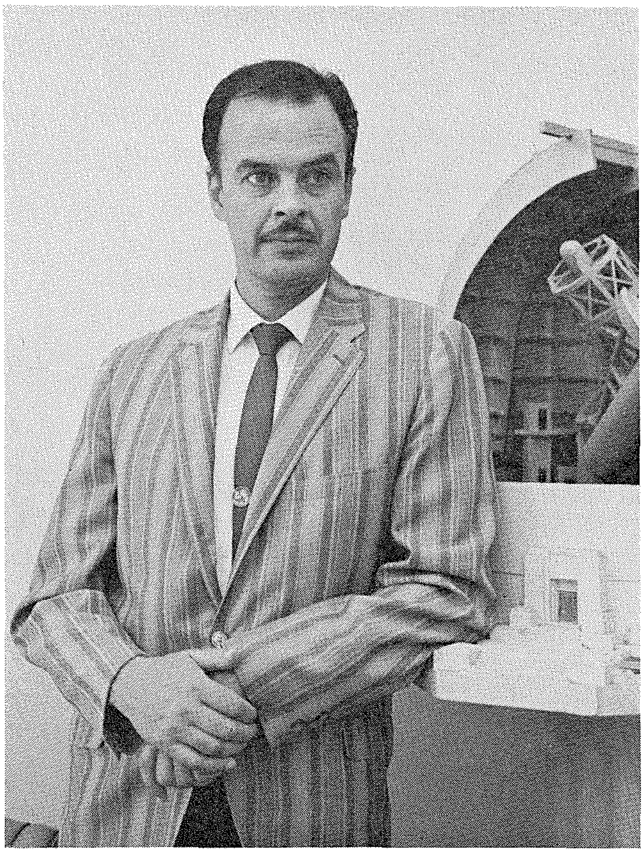
Perhaps something is wrong. Who or what is to blame? Is it Negroes who are pushing too fast? Is it ungrateful students at Berkeley? What about crime in the streets, or Communists, or soft judges, or people on welfare, or the decline in morals?

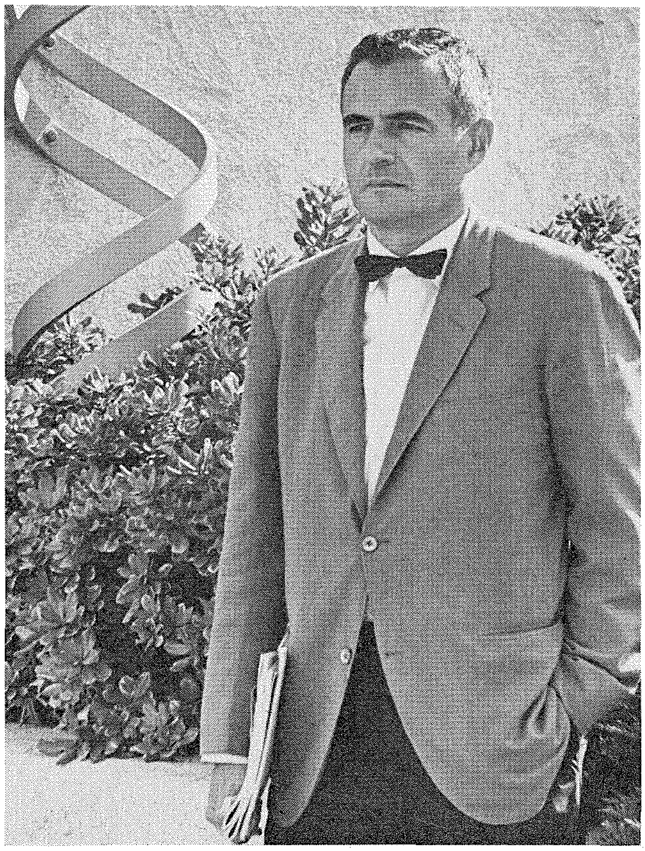
These concerns and anxieties are no less real than were those of job insecurity for a laborer, or hog prices for a farmer, or income for a retired couple during the 1930's; but they introduce a far greater complexity to our understanding of politics. Politics *was* easier in a time of economic scarcity and insecurity when political parties could offer more well-defined programs directed primarily at economic interests. But what happens to politics when economic interests are joined or obscured by anxieties involving status or by concerns not directly linked to income or job security? What political program is appropriate in these circumstances?

The people in this new power group *are* ambivalent. On the one hand, they respect the political leader who, like themselves, is a managerial type: competent, skillful, and technically knowledgeable. On the other hand, they have real anxieties not rooted in economic interests that are no less important socially or politically. Social scientists have begun to use the term "status politics" to describe the political expressions of resentments and uncertainties that are no less real but considerably more difficult to transcribe into a specific political program. In any case, the role of status politics cannot be ignored in any outline of the new politics.

If my portrait of the new issues, new power groups, and new battlegrounds of American politics —and the social changes underlying them—sounds familiar, it should. The shift is already well under way in California. These issues did not form the mainstream of California politics two decades ago, and they are only now influencing the politics of the rest of the nation. California is now, for better or for worse, suggesting the direction of domestic American politics in the coming decades.

"What's So Crazy About California Politics?" has been adapted from a talk given by Robert L. Woodbury, Caltech assistant professor of history, at the 30th Annual Alumni Seminar on April 22.


Guido Münch


Robert L. Sinsheimer

THE MONTH AT CALTECH

THE NATIONAL ACADEMIES

Two Caltech faculty members have been elected to the National Academy of Sciences and two to the National Academy of Engineering: Guido Münch, professor of astronomy and staff member of the Mount Wilson and Palomar Observatories, and Robert L. Sinsheimer, professor of biophysics—to the Academy of Sciences; Arnold O. Beckman, chairman of the board of trustees, and Frederick C. Lindvall, chairman of the division of engineering and applied science —to the Academy of Engineering. Their election brings Caltech's total membership in the Academy of Sciences to 32 and in the Academy of Engineering to 7.

Dr. Münch has made important contributions to research on the atmospheres of stars and planets. He has done work on the structure of galaxies, on interstellar matter and gaseous nebulae, and on the mechanism of helium production in stars. A native of Mexico, he received his BS and MA degrees from the Universidad Nacional Autonoma de Mexico, his PhD from the University of Chicago, and his U.S. citizenship in 1947. He has been at Caltech since 1951.

Dr. Sinsheimer is noted for his work in genetics. He discovered the first organism known to have single-stranded DNA and the ring-shaped structure of the virus ϕX174. He has also made significant contributions in the field of chemical analysis of genetic material by the determination of nucleotide sequence. Dr. Sinsheimer has three degrees from MIT. He came to Caltech in 1953.

Dr. Beckman, who is founder and chief executive officer of Beckman Instruments, Inc., has been a member of Caltech's board of trustees since 1953. He received his PhD from the Institute in 1928, served as research assistant from 1926 to 1929, and as assistant professor from 1929 to 1940. Dr. Beckman was cited by the Academy for his invention and development of precision instruments.

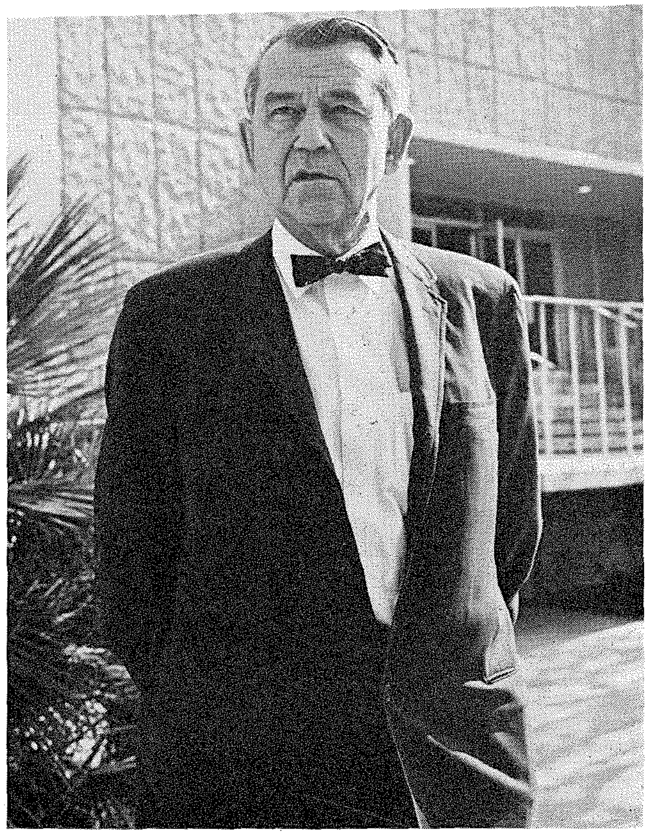
Dr. Lindvall, who also received his PhD from Caltech in 1928, joined the faculty here in 1930. He was honored by the Academy for his contribution to the research and development of equipment for transportation and underwater ordnance.

HONORS AND AWARDS

Rodman W. Paul, Caltech professor of history, and Kip S. Thorne, research fellow in physics, have been named winners of Guggenheim fellowships for 1967. The fellowships are awarded annually for scholarly and scientific research and for outstanding creative ability in the fine arts.

Dr. Paul plans to complete a book on the history of the Far West and Great Plains from the Civil War to World War I and to do research in the Western Americana collections at Yale and Harvard li-

Arnold O. Beckman



Frederick C. Lindvall

braries and the Huntington Library in San Marino.

Dr. Thorne will spend the summer at the Institut d'Astrophysique in Paris doing research in relative astrophysics. He will return to Caltech in the fall to teach and continue his research.

Two Caltech professors are recipients of Alfred P. Sloan Foundation fellowships for 1967-68. John N. Bahcall, assistant professor of astrophysics, and William A. Goddard III, Arthur Amos Noyes research instructor in chemistry, are among 92 physical scientists to receive the two-year fellowships. The Sloan Foundation program for basic research in the physical sciences was established in 1955 to give young men on university faculties the "opportunity to make full use of their research potential."

Three Caltech scientists were awarded honorary degrees by the University of Chicago at its 75th Anniversary Convocation May 5. Max Delbrück, professor of biology; Murray Gell-Mann, professor of theoretical physics; and Allan R. Sandage, staff member of the Mount Wilson and Palomar Observatories, were among 25 recipients from seven countries who were honored for scholarly achievement.

Dan H. Campbell, Caltech professor of chemistry, has been awarded the Distinguished Service Award of the American Academy of Allergy. Dr. Campbell, a member of the Academy for 20 years, was cited for his contributions as a teacher, an organizer, and as an inspiration to other members of the Academy.

BEST RADIO SERIES

The Caltech-sponsored radio series "About Science" is one of two winners of the 1967 Major Armstrong Award for the best radio programming on commercial or noncommercial FM stations. The program, which has been on the air since March 9, 1966, is designed to provide current scientific information in a manner easily understood by the general public. It is broadcast by 103 stations throughout the country each week.

CALTECH AT CAMBRIDGE

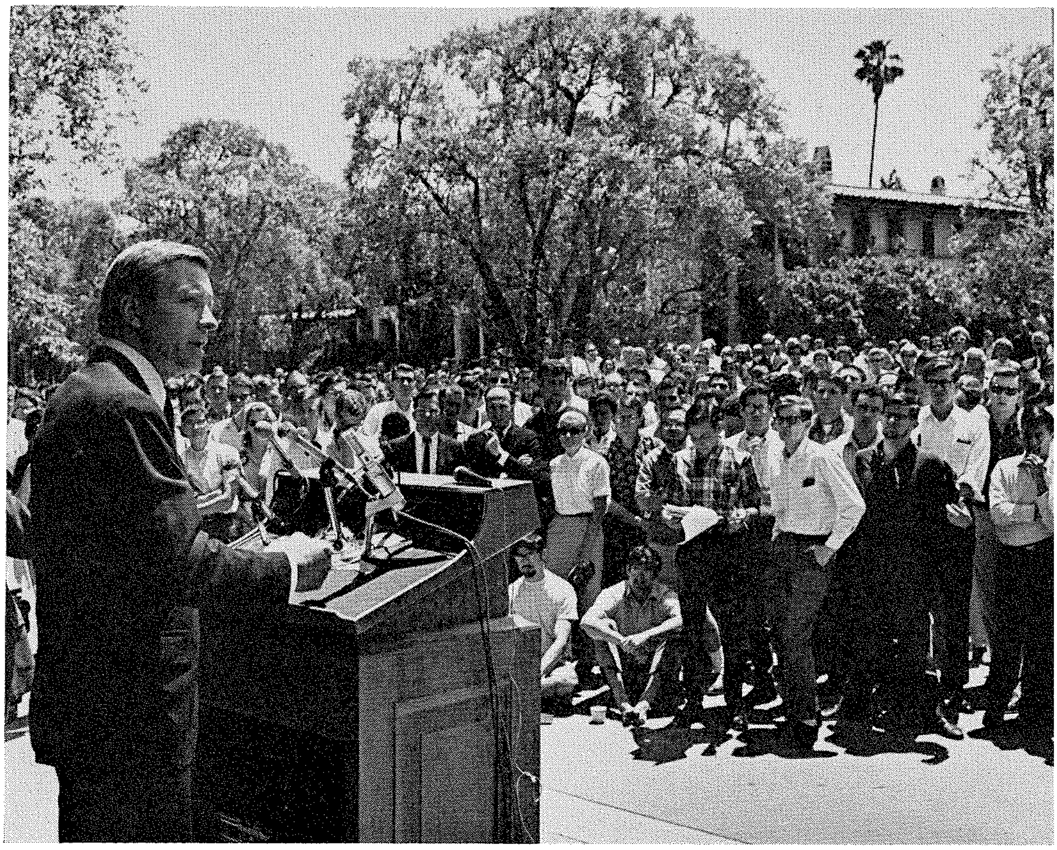
William A. Fowler, Caltech professor of physics, arrives this month at the Institute of Theoretical Astronomy at Cambridge, England, where he will spend the summer working with Fred Hoyle, director of the Institute, Cambridge professor, and visiting associate in physics at Caltech. They will be joined by Caltech colleagues Donald D. Clayton, visiting associate in physics, and Robert V. Wagoner, research fellow in physics. The visiting researchers are among the first to study at the new Institute, and will be involved in astrophysics research dealing with the origin of the elements.

ON CAMPUS

MAY 1

SENATOR CHARLES H. PERCY

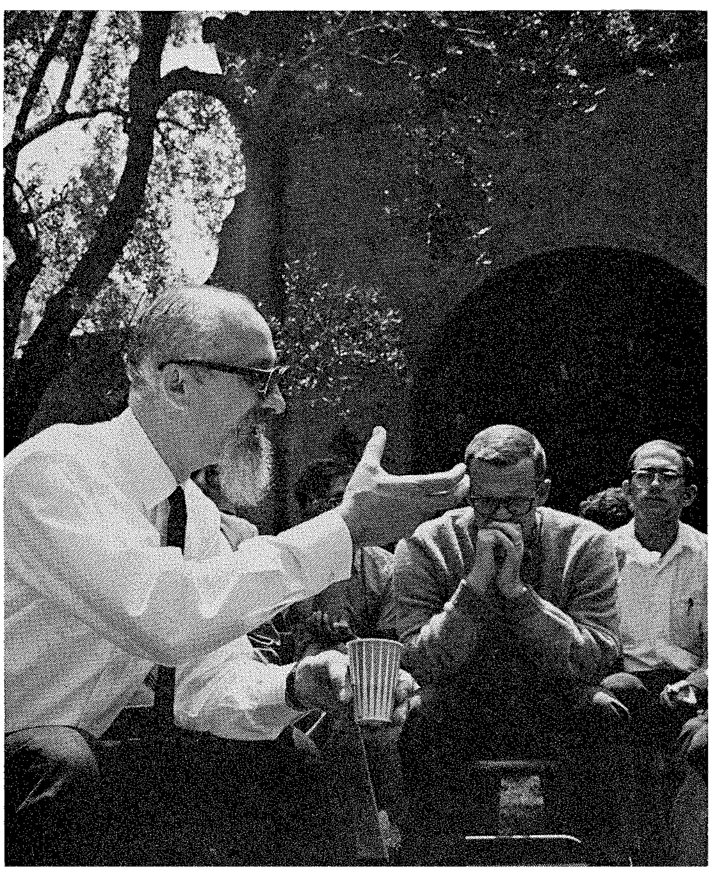
"Prosperity itself is what brings many of our problems to us. Education alone—universal education such as we have—creates dissatisfaction. Before, people didn't know what they didn't have. But with increasing education they became more discontent. And this discontent is not something to be bemoaned. Only through discontent do we find a basis for moving ahead and making progress."



MAY 1-4

PROFESSOR ABRAHAM KAPLAN

"My capsuled definition of philosophy is: to examine the prevailing trends of thought in every area and to stand aside and say, 'However . . .' "



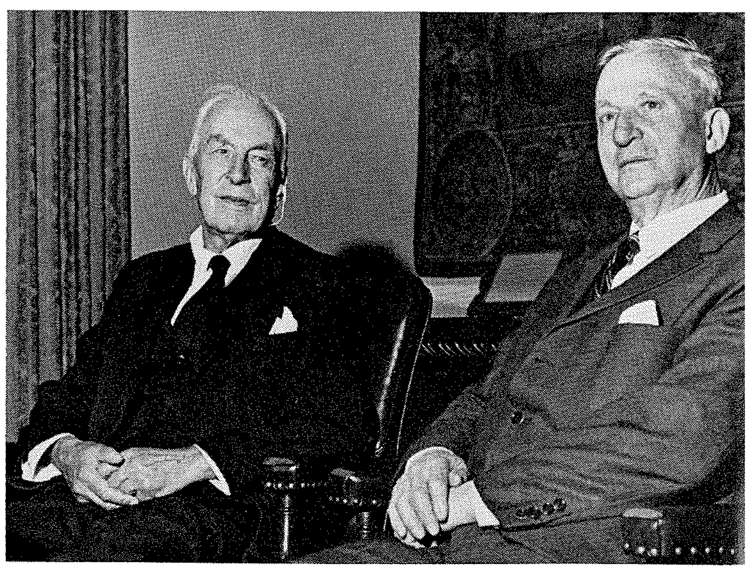
APRIL 29

ARNOLD TOYNBEE

"Only if the United States and the U.S.S.R. form a partnership can the United Nations be forced to put the world in order."

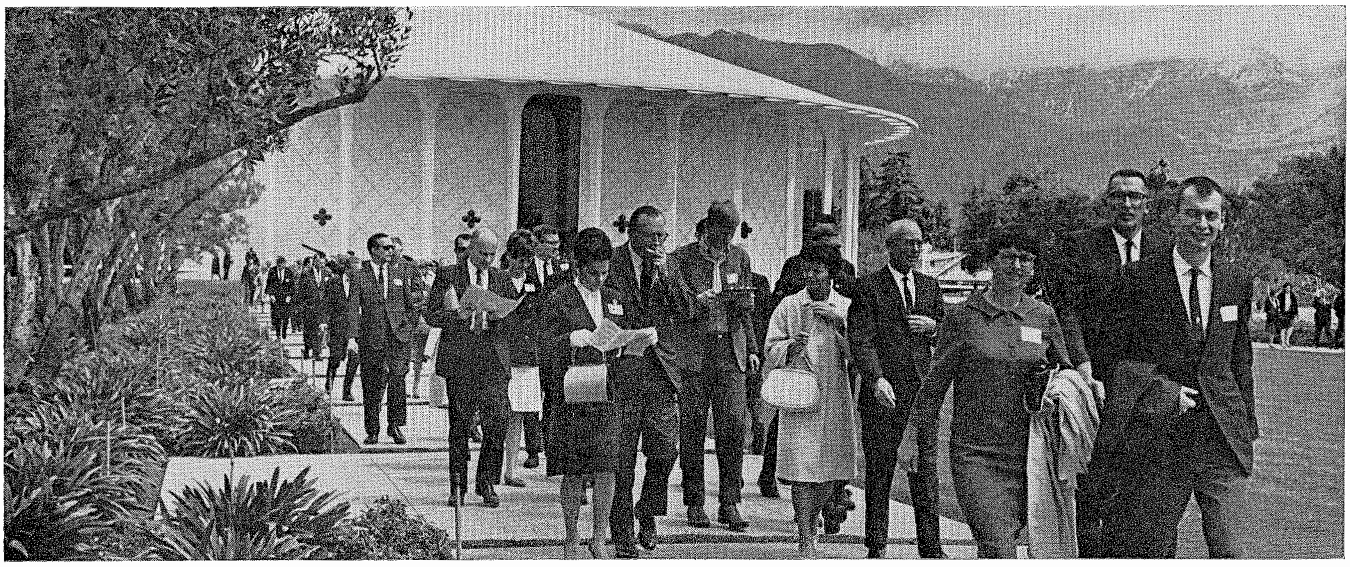
ALLAN NEVINS

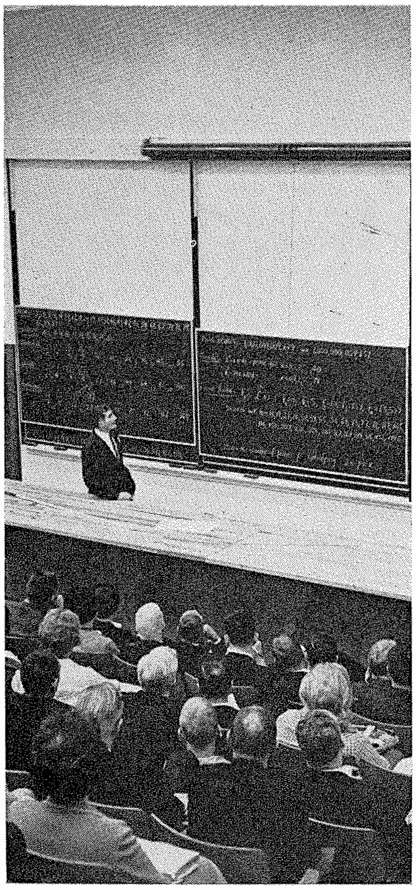
"Civilization is like a man on a bicycle, in precarious balance."

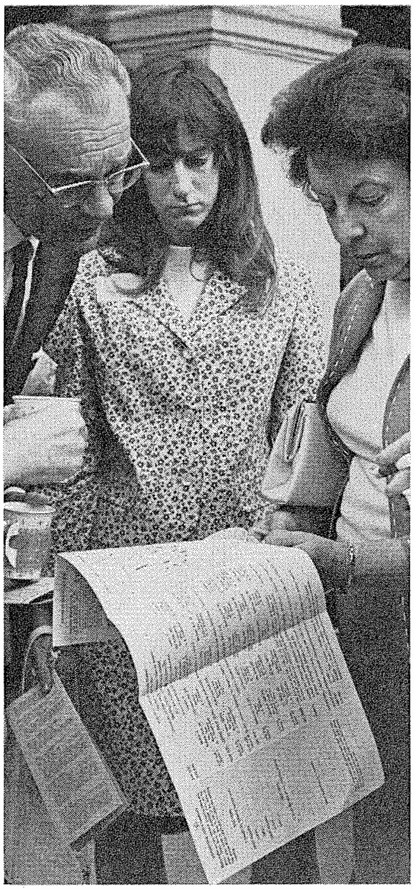


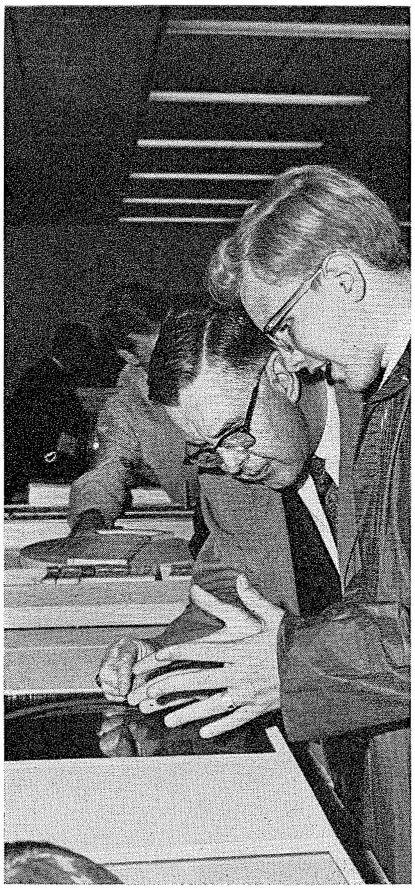
ALUMNI SEMINAR 1967

Caltech alumni and their guests, numbering 1,363, were on campus April 22 for the 30th Annual Alumni Seminar for a daylong program of lectures and exhibits. Peter R. Kyropoulos, MS '38, PhD '48, technical director for the General Motors Corporation styling staff, gave a special lecture in Beckman Auditorium on "Designing for People." Guest speaker at the evening banquet, was L. Eugene Root, MS '33, MS '34 Ae, president of the Lockheed Missiles and Space Company.









CALTECH IS DEDICATION

"We—the trustees, the faculty, the students,

and the community—

must accept our responsibility

for seeing to it that Caltech continues

to play its role of leadership, that it employs

its greatest resources to the fullest extent

for the benefit of mankind.

It must retain its vitality, its courage,

and its eagerness to explore

new frontiers of knowledge."

—ARNOLD O. BECKMAN

Chairman of the Board of Trustees

Support your 1966-67 Caltech Alumni Fund

PERSONALS

1924

MAURICE B. ROSS died on March 25 in San Diego. He was 65. Two years ago Ross retired as principal of Sherman Elementary School after holding the position for 23 years. He began teaching in the San Diego schools in 1925, and from 1936 to 1943 he served as assistant to the superintendent of the city schools. Ross is survived by his wife, Louise, and a daughter, Mary.

1927

HAAKON M. EVJEN, MS, PhD '29, died August 13, 1965, at Lake Mohave Ranchos near Kingman, Ariz. He had had multiple sclerosis for 25 years.

1932

ROBERT J. NOBLE died August 30, 1966, in Orange, Calif. Noble was chairman of the board of directors of the R. J. Noble Company at the time of his death.

1936

DAVID M. WHIPP, Pacific field director of the Environmental Science Services Administration's Coast and Geodetic Survey, has been appointed director of an International Tsunami Information Center in Honolulu, Hawaii. The center alerts Pacific Basin nations whenever a potentially dangerous tsunami (seismic sea wave usually caused by undersea earthquakes) has been generated. Whipp, who also serves as Hawaii's state tsunami advisor, has been with the Coast and Geodetic Survey for 28 years. He spent the 11 years prior to his assignment to Honolulu aboard hydrographic and ocean survey vessels.

1938

FRED E. LLEWELLYN has been elected president of Forest Lawn Memorial Parks in Los Angeles. Llewellyn, who has been with the company for 28 years, has been executive vice president for the past 20 years.

1941

HAROLD K. FINK, MS, has accepted a position as professor of psychology and philosophy at Drake College in Ft. Lauderdale, Fla. He will start the new assignment in September.

1949

KENT M. TERWILLIGER, professor of physics at the University of Michigan in Ann Arbor, has been elected to the board of trustees of the Argonne Universities Association. The association, which includes 26 midwestern universities, establishes the policies and programs for the Argonne National Laboratory of nuclear energy research near Chicago. Terwilliger has been on the University of Michigan faculty since 1952.

1953

GEORGE W. SUTTON, MS, PhD '55, chairman of the aerospace committee at the Avco Everett Research Laboratory in Everett, Mass., has been appointed editor-in-chief of the *AIAA Journal.* This monthly is a publication of the American Institute of Aeronautics and Astronautics.

1962

CHARLES H. RADOY, captain in the U.S. Air Force, has been awarded an MS degree in electrical engineering by the Air Force Institute of Technology at Wright-Patterson AFB in Ohio. Radoy is being assigned to L. G. Hanscom Field in Massachusetts, with the Air Force Systems Command, which manages USAF scientific and technical resources to develop missiles, aircraft, and aerospace systems.

1964

SPICER V. CONANT was married to Kim Untiedt in July and is now working in the AMFARE division of the American Machine and Foundry Co. in Stamford, Conn.

1966

HENRY G. SCHWARTZ JR., PhD, a senior engineer at Sverdrup & Parcel and Associates, Inc., in St. Louis, has been presented the 1966 Edward Bartow Award by the water, air and waste chemistry division of the American Chemical Society in recognition of the most outstanding paper presented during the past year.

All Alumni

of the

California Institute of Technology

are cordially invited

to attend the

Seventy-third Annual

Commencement Exercises

Friday afternoon, June ninth

Nineteen hundred and sixty seven

at four-thirty o'clock

on the Beckman Auditorium Mall

The Commencement Address

will be delivered by

President Lee A. DuBridge

ALUMNI ASSOCIATION OFFICERS AND DIRECTORS

PRESIDENT
Sidney K. Gally, '41

SECRETARY
Donald S. Clark, '29

VICE PRESIDENT
Frederic T. Selleck, '49

TREASURER
John R. Fee, '51

Theodore C. Combs, '27
Donald D. Davidson, '38
Manfred Eimer, '47
Craig T. Elliott, '58
Robert W. Lynam, '54
Paul D. Saltman, '49
Richard P. Schuster, Jr., '46
Martin H. Webster, '37

ALUMNI CHAPTER OFFICERS

NEW YORK CHAPTER

President — Bruno H. Pilorz, '44, 75 Echo Lane, Larchmont, N.Y.
Vice-President — Willis A. Bussard, '44, Appleby Drive, RFD 1, Box 78B, Bedford, N.Y. 10506
Secretary-Treasurer — Harry J. Moore, Jr., '48, Old Orchard Road, Armonk, N Y. 10504

BOSTON CHAPTER

President — Francis Morse, '40, 16 Reservoir Rd., Wayland, Mass
Vice-President — Theodore G. Johnson, '57, Blueberry Hill Rd., Sudbury, Mass.
Secretary-Treasurer — Thomas C. Stockebrand, '53, 55 Summer St., West Acton, Mass. 01780

WASHINGTON, D.C. CHAPTER

President — Willard H. Hanger, '43, 4720 Sedgwick St., N.W., Washington, D.C.
Vice-President — Bernard B. Watson '35, *Research Analysis Corporation, McLean ,Va. 22101*
Secretary-Treasurer — Josn T. Cookson '66, 1225 Noyes Drive, Silver Springs, Md. 20910

CHICAGO CHAPTER

President — Laurence H. Nobles, '49, Dept. of Geology, Northwestern Univ., Evanston, Ill.
Vice-President — Philip E. Smith, '39, Eastman Kodak Co., 1712 Prairie Ave., Chicago, Ill.

SAN FRANCISCO CHAPTER

President — G. Neal Huntley, '54, 3136 Padre St., Lafayette, Calif.
Vice-President — William N. Harris, '49, 5 Pembroke Pl., Menlo Park, Calif. 94025
Secretary-Treasurer — Harrison W. Sigworth, '44, 10 Casa Vieja, Orinda, Calif.

Meetings: Engineers' Club, 16th floor, Hong Kong Bank Bldg., San Francisco
Informal luncheons every Thursday at 11:45 A.M.
Contact Mr. Farrar, EX 9-5277, on Thursday morning for reservations.

SACRAMENTO CHAPTER

President — William D. Pyle, '49, 3920 Dunster Way, Sacramento, Calif. 95825
Vice-President — Paul J. Jurach, '46, 2824 Aurora Way, Sacramento, Calif. 95821
Secretary-Treasurer — Kenneth M. Fenwick, '28, 2954 26th Street, Sacramento, Calif. 95818

Meetings: University Club, 1319 "K" St.
Luncheon first Friday of each month at noon
Visiting alumni cordially invited—no reservation.

Class Reunions

June 6

Special program for members of the following classes: 1902, 1907, 1912, 1917, 1922, 1927, 1932, 1937, 1942, 1947, 1952, 1957, 1962.

Annual Alumni Meeting

June 7

This dinner meeting will include the presentation of 50-year certificates to the class of 1917 and a talk by Dr. DuBridge.