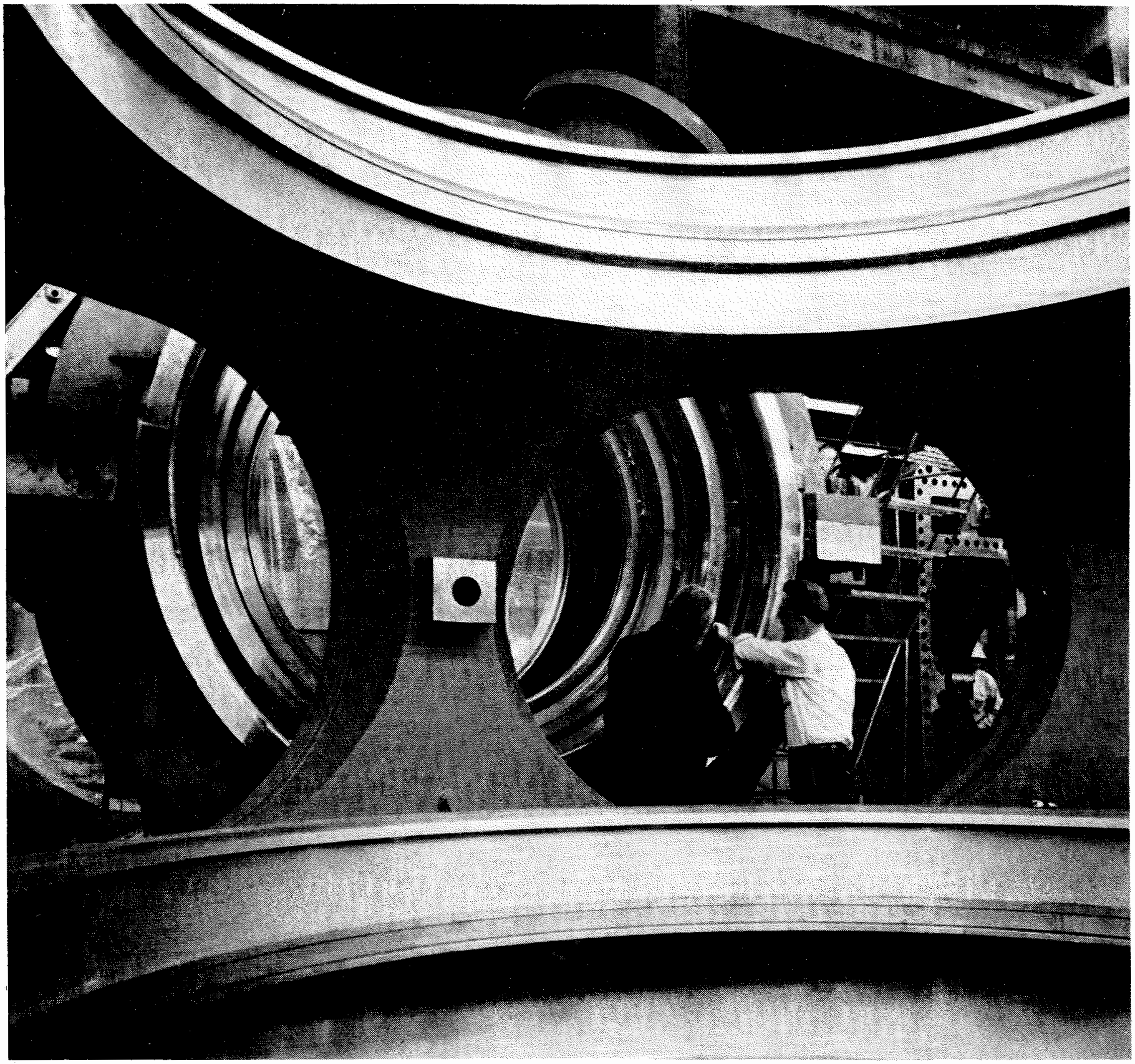
Engineering and Science

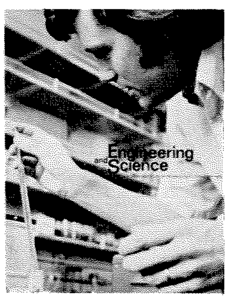
CALIFORNIA INSTITUTE OF TECHNOLOGY / FEBRUARY 1973



Engineering and Science

FEBRUARY 1973/VOLUME XXXVI/NUMBER 4

In this issue



On the Cover

William A. Wood, professor of biology, uses a pipette to draw off liquid containing *E. coli* and its parasite, the T4 virus. T4 has been the subject of intense study at Caltech for about 25 years, first as an ideal experimental material for exploring the nature of the gene, and now as a complex supramolecular structure built up under the control of a viral genetic program. "Virus Assembly Line" (page 20) summarizes the work of Wood and his colleagues and suggests that it may have implications for understanding similar processes in more complex forms of life.

Division Digest

When all the division chairmen are speakers on a single program, it's an important occasion. When each one summarizes the work of his division, you wind up with a profile of the academic life of the Institute. That's about what happened at the Alumni Leadership Conference held on campus last fall to launch the 1972-73 Alumni Fund. "What's Going On Here" (page 3) is an adaptation of the chairmen's reports at that conference.

Doughty Campaigner

Caltech's crusading Arie J. Haagen-Smit, professor of bio-organic chemistry emeritus, may be retired, but he's far from through speaking his mind on environmental—and human—problems. "The Sins of Waste" (page 16) is adapted from his recent lecture at Beckman Auditorium.

STAFF: *Editor and Business Manager*—Edward Hutchings Jr.
Managing Editor—Jacquelyn Hershey
Associate Editors—Bernard Cole, Janet Lansburgh
Art Director—Kathleen Marcum
Photographer—Don Ivers

PICTURE CREDITS: 4, 12, 14—Floyd Clark/24-25—Charles Newton/26—James McClanahan/Cover, all others—Don Ivers.

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

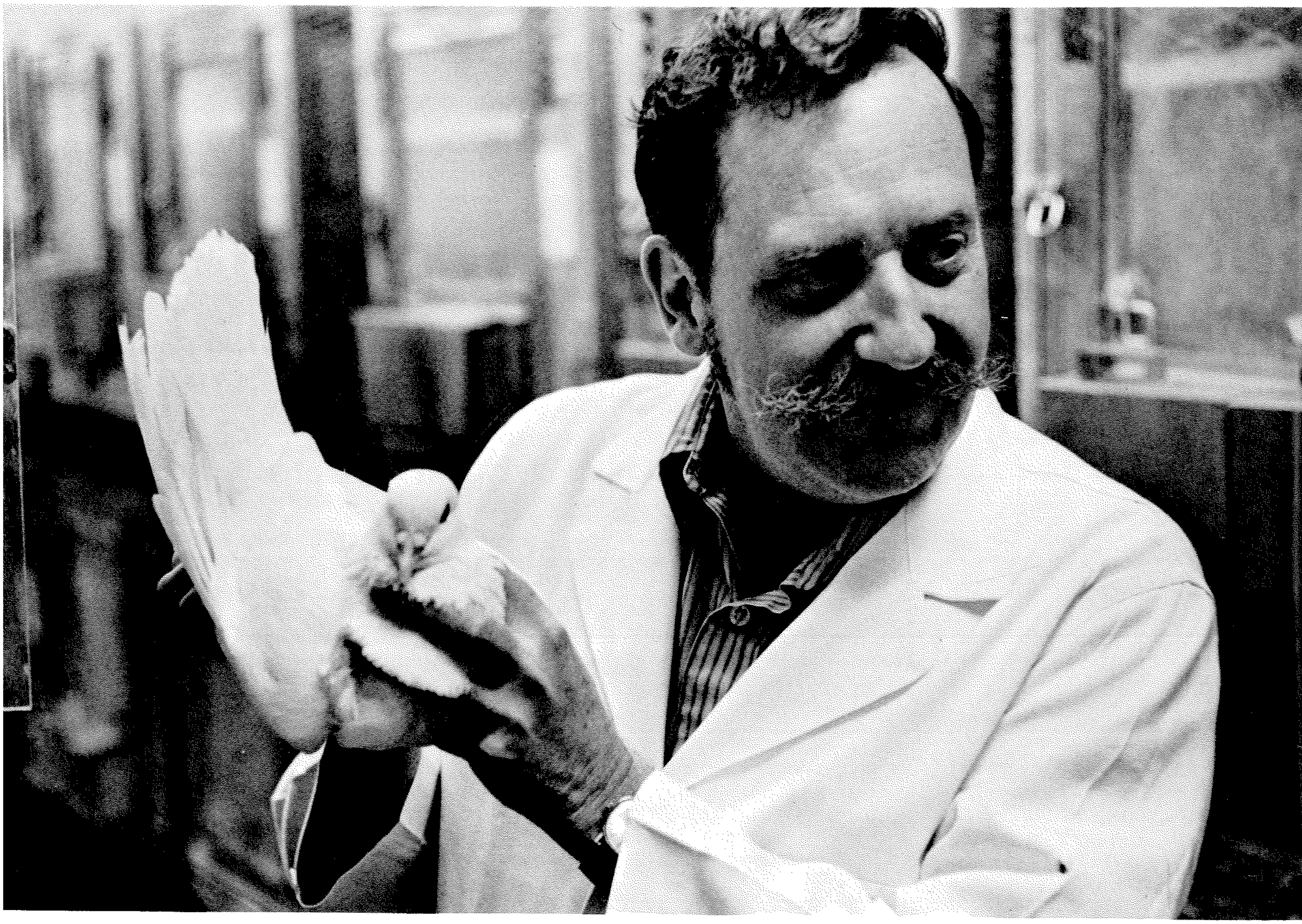
PUBLISHED BY THE CALIFORNIA INSTITUTE OF TECHNOLOGY AND THE ALUMNI ASSOCIATION

WHAT'S GOING ON HERE

The division chairmen report on recent research and developments in Caltech's six academic divisions

DIVISION OF BIOLOGY

Ray D. Owen*



*Ray D. Owen, professor of biology, substitutes for the current chairman of the division of biology, Robert L. Sinsheimer, who is on leave at the University of Zurich. Owen was chairman of the division from 1961 to 1968.

Among alumni, biology must be remembered as a relatively unpopular option, at least for undergraduates. It used to have about as few as geology, didn't it? Four biology majors was once a good year for the division. But things have changed. For third-term registration this past year there were 15 seniors in biology, 28 juniors, and 36 sophomores—a total of 79 undergraduate majors in biology. There were 46 chemistry majors and 13 chemical engineers—59 in all, as compared with 79 in biology. Eighty-nine physics majors were listed—10 more than in biology—but among the sophomores there were 31 in physics and 36 in biology. There were 32 sophomores in the engineering division—not counting the applied physicists—as compared to 36 in biology.

So student preferences have changed pretty fast, and you can see by the sophomore-junior-senior distribution just how fast they have been changing. Eleven of the 27 sophomore girls and 13 of the 32 graduate women are biologists. That is part of the reason the option is attractive, I think.

There are, of course, other reasons for the switch. It isn't only a Caltech phenomenon; in respectable circles everywhere much more attention is paid to biology these days. One reason is the growing conviction that biology is where the action is. And it's true; we are experiencing the fruits now of several decades of phenomenal progress in the understanding of life. Caltech has been an important part of that. Biology as a whole is big and at Caltech biology is little, but we have been very fortunate in the choices we have made of particular fields to emphasize. What was picked was genetics, biochemistry and biophysics (molecular biology), and neurobiology. These words represent much of the excitement of the last three decades in biology, and Caltech was lucky enough to be right at the heart of it. Even more important—to our chemists, physicists, and engineers, as well as to our biologists—we are in a most remarkably fortunate position as we approach the coming decades; we are where the action will be. Among the questions that excite people today in science are: How does the brain work? How does it develop so that it functions like the remarkable organ that it is? Are you going to change genes—or develop clones of people? If so, how? A large fraction of disease problems have their seat in the genes; will we develop gene therapy to correct the genes? Or in other problems of health and disease, like cancer: What goes wrong in a cancer? How can you correct it? These kinds of questions are the kinds of things we are, or can be, productively concerned with here at Caltech.

There are many examples of "relevance" that help to explain why young people are going into biology these days. Think, for example, of population problems, of world food supply, the fertility of the people, the quality of the environment. These problems are related to the possibility of constructive social action—partly through biology, partly through engineering, and partly through social and behavioral science. So not all biology is in the biology division. Divisional and disciplinary boundaries don't exist on this campus. It's easy to get into effective interaction with engineers, chemists, geologists, physicists, and mathematicians with a minimum of administrative interference here. Caltech is really a unique place for that kind of freedom, and that is part of the reason we have been so successful.

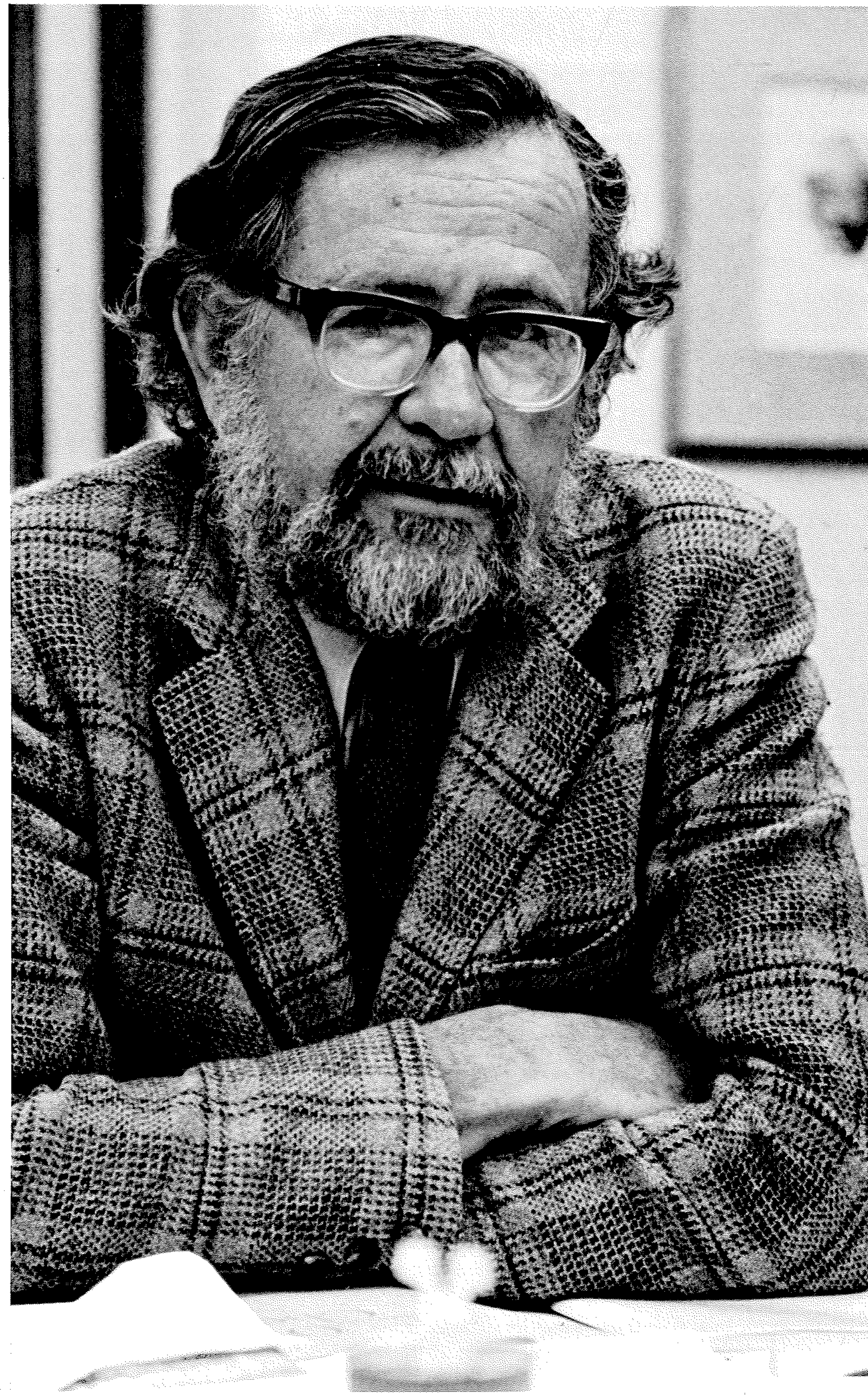
What do we need money for? We haven't had much trouble in getting research grants for the well-developed programs we have in progress. The big problem is finding unrestricted gifts that can be part of general funds and can be used for things that don't fit into the immediate confines of the governmental grant and contract programs in support of research. The biology division, like the other divisions, depends very strongly on general funds. We need money for student support at both the undergraduate and graduate levels. All kinds of costs are going up and—unless we increase our base of funds—as the cost per person supported increases, the number that can be helped is sure to decrease. The problem is particularly critical at the graduate level these days, as a result of the almost total disappearance of federal fellowships that carry tuition support and, now, the threat to manpower training programs—particularly in the health-related sciences. Our students contribute at least as much as they take from Caltech by the research they do, and the part they play in our teaching. They are an integral part of the Institute and, considering their quality, we get their services pretty cheap.

Faculty salaries are in a somewhat similar situation. It is conventional for every faculty member who can do it, and we expect almost everybody can, to get a substantial fraction of his salary out of his research grant. That's fine but as funds begin to tighten elsewhere, the feeling of independence of this kind of salary support begins to disappear. We then run a danger of getting into a spot

continued on page 28

DIVISION OF CHEMISTRY AND CHEMICAL ENGINEERING

John D. Roberts
acting chairman



Twice in the last ten years, Caltech's Division of Chemistry and Chemical Engineering has been ranked as number two in an allegedly impartial national survey; behind Harvard and ahead of Berkeley, Columbia, and Stanford—whom I regard as our principal competitors. Harvard has some aging problems, and you might say that we have some youth problems. In chemistry we have only two professors now who are over 60, four in their 50's, and most of the rest of the present staff is under 40. Hardly a predominantly gray-haired group—for a long time to come. We've long been known for innovative teaching. And we're still at it, although the knowledge explosion makes it increasingly difficult to know what are the best things to teach in the decreasingly available time.

I think it's clear that chemistry still is very much alive, because many of the things that are being done in the field right now are things that we would really like to have time to tell students about in our elementary courses. I suspect this is less the case for physics and mathematics, but very much the case for astronomy and biology, as well as chemistry.

In teaching, we find it really very difficult to get agreement as to the proper balance to strike between theory and practice, between facts and principles, among students, among staff, among alumni, and among the people who hire our students. Thirty years ago quantitative theories of chemical structure really were not worth very much discussion at the elementary level. Now, to a great extent because of the success of Caltech research, theories of structure are so well developed that in our elementary courses we can spend practically full time on theory. Yet, chemistry is really not that theoretical. Almost all of us still find out more from experiments than from calculations. But the problem is to decide what kind of approach we should take for our bright young undergraduates who are often very theoretically inclined. I can assure you of one thing—that our best people are heavily involved in undergraduate teaching. And when George Hammond, who was our immediate past division chairman, decided that he was going to revolutionize the teaching of chemistry for undergrads, probably the worst problem that he encountered was that the rest of the members of his staff had their own strong ideas about how this should best be accomplished.

In research, I think we're in very good shape, although we can see some difficulties ahead. A very important one has to do with space. Because of earthquake damage in 1971, the Gates Laboratory has been condemned for use by chemistry. So we've had to pack the former occupants into our other buildings, and we've constructed a small temporary building adjacent to the Noyes Laboratory for use as an undergraduate laboratory. Since the plumbing and hoods in this new building are alleged to have only about a five-year life span, we need to get going on plans for a new laboratory to house our undergraduate facilities as well as expanded research effort.

Twenty or so years ago our research was oriented toward determining molecular structures and theorizing about them. This was correctly perceived by Linus Pauling to be the most productive research area at that time. We're still in the structural chemistry research effort, but we have greatly expanded in other directions in the area of what one might call molecular dynamics—that is, the way in which molecules react. And we have research which ranges from the study of reactions between ions and neutral molecules in the gas phase, to the mode of action of digestive enzymes and the action of antibodies in living systems.

The biological end of our research spectrum is now receiving particular emphasis. We have professors who are working on the way in which light striking the retina of the eye is converted to nerve impulses, on the details of how cellular membranes function, on the nature of the hereditary mechanisms of tumor viruses, on the way hemoglobin molecules change shape when they absorb oxygen, and on the mode of action of metalloproteins in photosynthesis. These activities may not sound like chemistry at all, but I can assure you that the approaches that are being taken to them are fundamentally chemical approaches. And they are in especially fruitful areas for the application of chemical principles—with, of course, many profound and important implications for the health and welfare of humanity.

Chemical engineering at Caltech has also changed drastically in the past few years. Twenty years ago the emphasis in research was on the thermodynamic properties of petroleum hydrocarbons—a very important subject to the petroleum industry at that time. But now we've expanded our work to include the engineering aspects of artificial kidneys, combustion mechanisms, solid-state catalysis, structures of liquids, polymer properties, reactions in plasmas, and reactions that go on in air pollution. And again, as in our chemistry effort, we have on the average a very young, vigorous faculty.

Of one thing you can be sure—we are not doing the same old things we've always done. We're moving—we're moving very fast.

DIVISION OF ENGINEERING AND APPLIED SCIENCE

Ours is called the Division of Engineering *and* Applied Science, and we take the responsibility for both components very seriously. It was in 1959 that the Ford Foundation gave Caltech a multimillion-dollar grant for the development of graduate work in engineering. It was, I think, partly based on the success aeronautics had had at the graduate level over the years. Other areas of engineering wanted to strengthen their graduate programs, and the Ford grant enabled Caltech to develop one of the finest graduate schools in engineering in the country.

Concurrent with this was the decision to put an increasing emphasis on applied science. In the sixties we saw the emergence of a strong group in applied mathematics here at Caltech. It grew out of the excellent theoretical work we had done earlier in fluid mechanics and related areas. This effort enjoyed a growing national reputation. Applied mathematics at Caltech has ties with both the Division of Engineering and Applied Science and the Division of Physics, Mathematics and Astronomy.

More recently we have seen the reemergence of a program in applied physics, which had existed here during the years before World War II. It somehow was discontinued, and in more recent years students who came here wanting to do various kinds of applied physics had to undertake work under the title of theoretical physics or particle physics, or electrical engineering, or geophysics. So we established a formal program in applied physics, and I think it is now showing great progress. It, too, cuts across divisional boundaries. It has ties with electrical engineering, materials science, fluid physics, physics, chemistry, chemical physics, and geophysics.

It is my own view that the pendulum perhaps swung too far in giving greater emphasis to applied science and to graduate work. I believe that now is the time for us to strengthen the engineering component of our work and to give greater attention to our undergraduate program. We have already made a few moves in that direction. In 1969 we launched a substantial program in environmental engineering. The vigor of this activity is exemplified by the recent major undertaking of a half-million-dollar contract with Bechtel Corporation, Pacific Gas and Electric, and Southern California Edison to study thermal diffusion, wave defense, and off-shore conditions for two large nuclear power plants—one at Mendocino and the other at San Onofre. The program's vigor is also exemplified by, for instance, the work of Wheeler North in restoring the giant kelp beds off the southern California coast. And it is exemplified by the work that Sheldon Friedlander, Rudolf Husar, and James Huntzicker are undertaking in a major study with the Air Resources Board for characterizing and studying the aerosols in the southern California atmosphere. The program in environmental engineering is a growing one. Graduate enrollment is rising, and so is undergraduate interest.

Along with this academic program on the environment, we have undertaken a challenging new experiment—the Environmental Quality Laboratory, which is not in the direct academic line. It is an action-oriented laboratory set up to play an influential role in environmental affairs at the local, state, and national levels. Those who believe we should do something of social relevance will, I think, applaud the activities of EQL Director Lester Lees—his work with the legislature, with various industries, and on the national scene on various aspects of the environment. Those of a more conservative bent will view with some alarm this Caltech move into the political arena, where—if we are not careful—we may get our fingers burnt. There has been a great deal of debate here at Caltech about this matter. We are trying to find our way in this new area where science and engineering can play an influential role in bringing to the public a fair and unbiased analysis of environmental alternatives, and still not overstep the bounds of advocacy and political involvement.

We have increased our work in earthquake engineering. At the time of the February 9, 1971, earthquake, we had established a strong-motion network here in southern California against the day when a great earthquake would occur. From it we hoped to obtain for the first time strong-motion data as to what happens around an epicenter in the urban areas that are affected by it. The San Fernando earthquake gave us more data on strong motion than had been accumulated in all the rest of history up to that time. Fortunately, it occurred at a time, a strength, and a place where there was no major loss of life or property. But it did awaken all of us to the possible damage that a great earthquake might cause in the Los Angeles area. Caltech now has a major program of analyzing these data and relating them to needed changes in building codes and structural design. More recently Caltech has become a national information center for earthquake engineering.

Francis Clauser, chairman

As a result of our activity in studying the disastrous effects of earthquakes, we have reexamined our strengths in other areas of research on natural disasters. About two years ago we determined that there was need for a major review of the problem of wind loads on buildings. Our faculty called a national conference on this subject, and since then Caltech has played a leading role in research in this area. We took further stock and found that we had a group that had become well known for its work on fires—forest fires, fires in buildings, and fire storms. The same was true for landslides, for tsunamis, and for floods. All of the people working in these areas had a common interest—not so much for the technical aspects of their work as for the effect that the disasters they were studying had on society. They were drawn together because the results of their work led to such things as new building codes, new structural design requirements, new insurance laws, and revised needs for communications during a disaster, as well as the need for hospitals, police stations, and fire stations to continue to operate effectively during and after a major disaster. This common bond of interest has caused us to establish a center for the study of natural disasters.

The new Jorgensen Laboratory for computing and information science, given to us by Mr. and Mrs. Earle Jorgensen, will permit us to expand substantially our work in computing. As a first step we have rather clearly separated out the academic and research work in information and computer science from the responsibilities of providing service in computer programs on the campus. The Booth Computer Center will be the focus for the service, and the Jorgensen Laboratory will be the focus for the expanded academic program in computing and information science.

In another area, we brought John Pierce—one of our distinguished alumni, who was for many years at Bell Labs—back to the campus. He and Hardy Martel and others are now laying plans to establish a program in communications. The potentialities are great. We have close ties with JPL, of course, which I think is the leading practitioner of space communication in the world; with Hughes Aircraft Company, which has an outstanding reputation for its communications satellites; and with Bell Labs, the world's leading laboratory for communication research.

continued on page 28

DIVISION OF GEOLOGICAL AND PLANETARY SCIENCES

A prominent current development that involves the Division of Geological and Planetary Sciences is the construction of the new Seeley G. Mudd Building of Geophysics and Planetary Science. The building will house our group of planetary scientists and also the Seismological Laboratory, which will move to the campus from its present location in the San Rafael hills. This will bring the division's geophysicists into close contact with our geologists, geochemists, and planetary scientists, and we expect many beneficial results. The move to the new building is expected in 1974.

Research in the division has expanded into many new areas in the past few years, ranging from the earth's deep interior out to the moon, Mars, and beyond, with much of significance in between, right here on the earth's surface.

In trying to figure out what is going on deep in the interior of the earth, we ask such questions as what is the chemical composition of the material down there, what mineral phases occur, and what are the physical properties of these phases under the conditions of high pressure and temperature that prevail? The answers to these questions bear on the functioning of the earth as a great heat engine, whose activity causes faults to move, continents to drift, and mountains to be upraised. Because the interior can't be sampled, we have a problem of indirect interpretation, and it is difficult to get reliable answers. The primary evidence comes from seismology. Our geophysicists have been using modern data on the propagation of seismic waves through the earth, and on the elastic oscillations of the earth as a whole, to deduce in beautiful detail the layered distribution of density and elastic wave velocity in the earth's interior. Interpretation of this information now draws heavily on solid-state physics and chemistry. A combination of high-pressure experimental work and solid-state theory by Don Anderson, Tom Ahrens, and their colleagues is beginning to yield definite conclusions showing how—by a succession of phase transformations—the minerals known at the surface transform structurally to dense, unfamiliar forms as we go deeper and deeper into the earth. We are thus on the brink of a real understanding of what the earth's interior is all about.

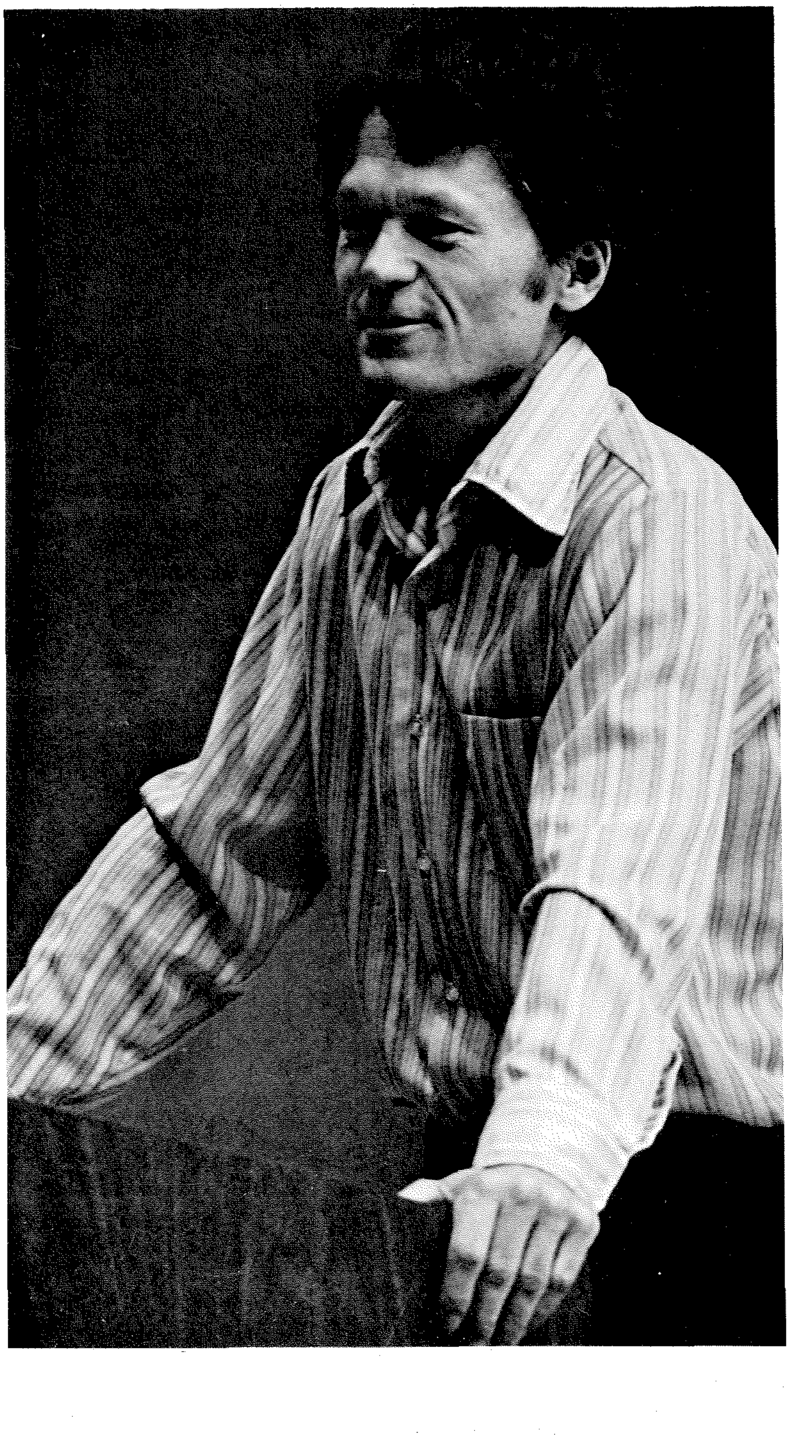
The study of materials at the extreme pressures of millions of atmospheres that occur deep in the earth is a very difficult experimental problem, which we are now tackling thanks to Tom Ahrens' application of the methods of shock-wave physics. His new shock-wave apparatus, which will be installed in the Lindhurst Laboratory in the new building, will be able to generate shock pressures up to more than one million atmospheres. Methods of measuring the internal energy, volume, elasticity, temperature, and spectra of rocks and minerals at high pressure in the shocked state are being developed. Caltech is leading the world in the application of these methods to the geophysical problems of the earth's interior.

Dynamical processes in the earth's interior are probably responsible for what happens geologically at the surface, and we hope ultimately to understand in detail the connections between the two. A surface event of much importance locally was the San Fernando earthquake of February 1971, and we are still much involved in the geophysical and geological study of this event. Investigations are continuing of the mechanism of the earthquake, the fault movements involved, the origin of the rupture at depth and the details of its propagation to the surface, and the effects of the fault movements in producing regional patterns of strain, uplift, and subsidence. These studies aim to give us an understanding of the earthquake good enough to relate it to our best-known earthquake hazard, the San Andreas fault, and to allow an evaluation of the potentialities for similar events in the future. This is the kind of question that Clarence Allen is particularly concerned with.

Another example of a vigorous research area dealing with important phenomena of the earth's crust is the geochemistry of water. By isotopic analysis of oxygen and hydrogen in the rock-forming minerals, Hugh Taylor is able to detect chemical effects of the water that was associated with the intrusion of masses of molten rock into the crust and that to some extent escaped and reacted with the surrounding host rocks. Understanding the role of water in these igneous processes bears on questions such as the significance of primary magmatic ("juvenile") water, and the origin of ore-forming hydrothermal fluids. The isotopic geochemical study of water includes water at the earth's surface and water in the form of ice and snow, a field pioneered by Sam Epstein. His studies of samples from a core hole through the Antarctic ice sheet show the history of the isotopic composition of water deposited in the ice sheet, and give a record of world climate clear back through the ice age. The end of the ice age about 10,000 years ago is particularly striking in this record. This kind of investigation sheds light on current trends in worldwide climate and helps in the effort to understand their causes.

Important advances in studying the origin of rocks are being made by the technique of electron microprobe chemical analysis, which allows micron-sized regions of individual mineral grains to be analyzed chemically in

Barclay Kamb, chairman



great detail. Arden Albee's development of this technique has greatly increased its capabilities through use of new instrumentation and an on-line computer, so that you can now get a complete chemical analysis in about ten minutes. Such a powerful and efficient technique has many potential applications in the earth sciences and in science and technology at large. It is fair to say that Caltech now has the world's leading facility of this kind.

The electron microprobe is playing an important role in the study of the Apollo lunar samples, which is a very lively current research activity in the division. These samples are too small and too valuable for conventional chemical analysis, but can be analyzed in detail, non-destructively, with the microprobe. Such analyses are a basis for inferring the origin and history of lunar rocks.

Determining the ages of rocks by mass spectrometric measurements of radioactive elements and their decay products is one of the division's well-known fortes, which has been developed to a peak of perfection for the study of the lunar samples. The radiometric ages found for the lunar lavas are 3.1 to 3.8 billion years, older than any rocks known on earth (with rare exceptions), but distinctly younger than the age of 4.5 billion years inferred for the original formation of the moon. This points to a 1- to 1.5-billion-year period of ancient activity and development within the moon prior to its lapse into the state of in-activity that we see today. What is known of the basic chronology of events in the moon's formation and development is due almost entirely to work done at Caltech by Professors Burnett, Silver, Shoemaker, Wasserburg, and their colleagues. New measurements and ideas are being added almost daily in this vigorous research area. Piecing together the history and evolution of the moon, comparing it with the geological history of the earth, and trying to explain the behavior of these two planetary bodies on a common basis of understanding is the central current challenge in the scientific rewards of the Apollo program.

Spectacular results of hypervelocity impacts on the lunar surface are now recognized over a tremendous range of dimensions, from the microscopic, beautifully sculptured "zap craters" punched into exposed surfaces of lunar rocks by tiny particles traveling at great speeds, up to huge impact craters and entire mare basins, such as Mare Imbrium, blasted out by immense projectiles of asteroid size. The "gardening" of the lunar surface by all this impact activity is responsible for the widespread mantle of breccias and "soils," which contain the most

continued on page 28

DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES

I suppose my career at Caltech is very much like the Division of Humanities and Social Sciences. I've had every odd job, and the division might well be called the Division of Everything Else at Caltech That Isn't Covered by Other Divisions. On our faculty we have 9 historians, 11 people in English literature, 9 economists, 3 political scientists, 3 philosophers, 3 psychologists, 1 anthropologist, 1 geographer, 1 professor of science and government, 1 information scientist, 6 people in languages; and working part-time, 1 sociologist, 1 senior research fellow in population studies, 2 art historians, 1 lecturer in science communication, and 1 linguist.

In its original conception the division was primarily concerned with adding an element of humanities studies to the education of engineers and, to a lesser degree, scientists—although the balance has now changed. That is still the division's primary function, but things have changed both in staffing and scope of work. Originally, the staffing of the division largely consisted of graduates of eastern colleges, at whose feet budding engineers could

Robert A. Huttenback, chairman

sit and gain some veneer of culture. (I don't mean to denigrate this, because I think our most influential and best teachers came from that tradition. I doubt if we ever had a more influential teacher at Caltech than Harvey Eagleson. It's a sad thing that such people don't even exist anymore.) But in our recruiting now we want not only excellent undergraduate teachers, but people with a great interest in research—the kind of interest that has made Caltech great in all the other divisions. In this we have been, to a large degree, very successful. In the humanities the young people we have recruited are people who have followed successful research careers. This is something we wish to continue to do.

Social science is relatively new at Caltech. I think the first branch of social science which was indulged in here was economics, and the prime function of economics originally was to teach engineers (many of whom went into business) some rudiments of business economics, or corporation work, or stocks and bonds. (Speaking of influential teachers, I must also mention Horace Gilbert, who recently retired from teaching economics here, and who had a major influence on many generations of Caltech students.) This is something we still think is very important, but we have added a whole panoply of social scientists who not only teach undergrads but also follow research careers in many important fields.

Last year, after careful scrutiny, a graduate program toward the PhD was approved in social science. This is the first graduate program in a nonscientific or non-engineering field to be approved at Caltech. This program is an interdisciplinary one. It doesn't attempt to give a degree in political science or economics or sociology, but it attempts to distill those important elements which the social sciences have in common and give a degree—which can be very valuable—in social science. In keeping with Caltech tradition it's essentially a very narrow program. It doesn't attempt to cover the whole waterfront. We intend to devote most of our interests to the area of social change. The program will be largely theoretical, but will have practical aspects and will be to a large extent quantitative. All students admitted to the program will be expected to have a high degree of sophistication in mathematics, and the outstanding faculty of social scientists we have recently recruited are all highly competent in mathematics.

This year, for the first time, we are starting both an undergraduate program in social science and a graduate program—and we now have our first graduate student. We are hoping for a program that will involve something like 5 graduate students a year, to a total—when it's in full swing—of about 20.

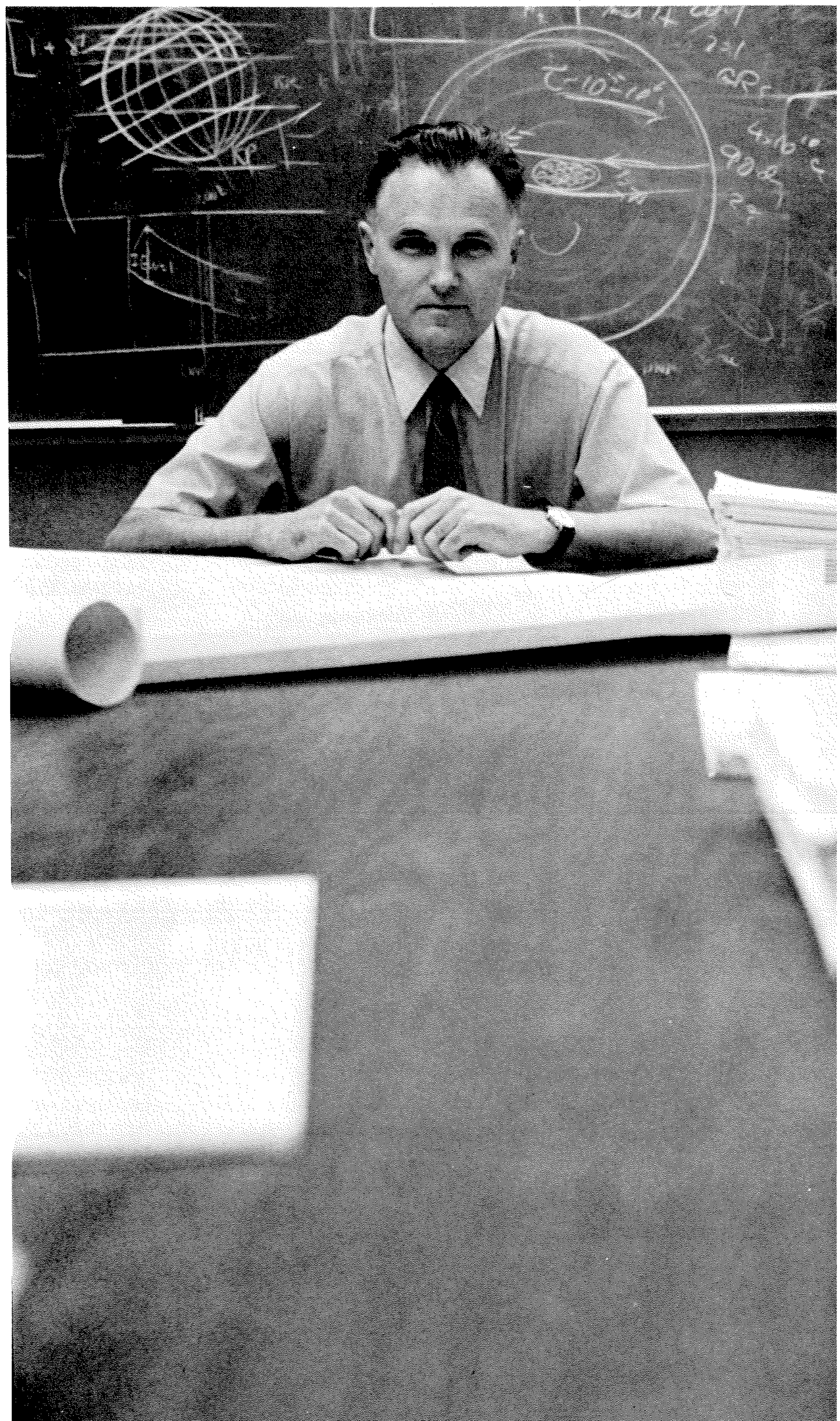
The research the social scientists do is considerable and diffuse. We have people interested in urban housing, health delivery systems, legislative behavior, and even the economics of professional sports. There's been a major attempt to cooperate with other divisions. Social scientists have been very active in the Environmental Quality Laboratory. And there's been a great deal of cooperation in the area of environmental engineering science. We have long hoped for increased cooperation with biology; and with the new behavioral biology building going up there's a real possibility of doing something in the area of child learning. (Jerome Bruner, who came under our auspices last year to give a series of lectures here, has been the catalyst in this direction.)

The prime function of the humanities in the division continues to be teaching Caltech students who major in science and engineering. We now also have four undergraduate major programs in economics, history, English, and social science. These draw—particularly economics—a fair number of people, but of course students do not come here initially to major in one of these fields. Research in the social sciences looks much more like research in the sciences, in that teams of people quite frequently work together on a project. This is not true in the case of the humanities, where the research is individual, making for serious implications for funding. Individuals can often obtain support for a year, but are very unlikely to get it over many years. So the humanities section lives very heavily off the general budget.

Another function has accrued to our division which I think is an Institute-wide responsibility. This is a cultural responsibility.

We have an art gallery, which has had some very significant exhibitions in the last several years. We've done some experiments with repertory theater. We've had a couple of poets in residence. We've funded a film-making program. We've had an artist in residence. All of these things have a significance, we feel, for the entire Caltech community. In the area of music, where I think there's probably more intrinsic interest by the Caltech community than in any other area of the arts, we fund a chamber music series and various other things. We were very fortunate last year to receive from the Mellon Foundation an endowed visiting professorship that should allow us to invite authors, musicians, and artists to the campus for periods up to a year. I think this will be a great enrichment of the whole life of the Institute. So we feel that we have a triple responsibility—to the graduates, the undergraduates, and the Institute community.

DIVISION OF PHYSICS,



Robert B. Leighton
chairman

MATHEMATICS AND ASTRONOMY

The names Ph 1 and Ph 2 have a special meaning to Caltech alumni. If they were to come back and sit in a class of Ph 1, even if they had been away for some decades, they would find that almost all the equations were familiar. Some of the problems might be a little difficult to solve, but that would not be a real change from the time when they were students here! It isn't so much that nothing has changed; it's that Newton's laws are still true and valuable, and it would be a shame to raise a generation of scientists to whom they were alien.

With respect to the number of majors in the Division of Physics, Mathematics and Astronomy, about half the undergraduates at Caltech major in one of the subjects under this division. And if we stop to think about it, 89 physicists—if that's the right number—is a lot of physicists. It may be surprising to learn that we have 20 mathematics majors per class these days. It used to be that mathematicians were here in 3's and 4's. They are still by some margin among the brightest of our students.

With regard to research, I'll have to tell you right away that I'm not going to say anything about research in mathematics—partly because I'm not competent at it and partly because they tell me that we should now regard mathematics as a fine art and put it in the Humanities Division.

A returning alumnus would find much of the research in physics and astronomy to be along the same lines as when he was a student here. The principal endeavors are still aimed toward study of the fundamental properties and organization of matter and of the cosmos. Some of us will remember that, in the 1930's and 1940's, Robert Millikan and Carl Anderson were analyzing cosmic rays to find out where those huge energies came from. Were they the birth pangs of the atoms? Charlie Lauritsen had reversed the polarity in the big high-voltage generator in Kellogg to accelerate protons instead of electrons—and so put Caltech in the nuclear physics business.

Ira Bowen, Fritz Zwicky, and the Mt. Wilson astronomers were busy delving into the cosmos. In that era, not long after the spiral nebulae were established as being external to our own stellar system, the expansion of the universe was discovered. It has been a key and prime line of research ever since.

Today, some activities have diminished, some have greatly expanded, and some are relatively new. Atomic spectroscopy is no longer the central thing that it was in the days when Ira Bowen was analyzing the spectra of complicated elements. But Ward Whaling is doing marvelous new things in Bowen's old laboratory. The fundamental properties of matter—what we used to call elementary particle physics—is still a central line of endeavor both experimentally and theoretically. However, experimental work has of necessity moved outside this campus—to Stanford's linear accelerator, to Berkeley's Bevatron, to Brookhaven, and now to the National Accelerator Laboratory (NAL) where there is a new machine operating at 300 billion volts that will power a number of experiments for our so-called users' groups.

Would you believe that the first of these experiments will involve a beam of neutrinos? The neutrino is about as close to intangibility as we can get in this world—the human soul, perhaps, being the next stage. A beam of neutrinos, it is calculated with reliability, could penetrate through *light years* of solid iron with a good probability of emerging at the other end without having hit anything! And yet they're going to have a *beam* of neutrinos (God bless them!)—enough neutrinos that, even with that small probability, some of them are going to hit something in a big stack of iron plates and spark chambers and do something to elucidate whether neutrinos are formed in the peculiar way that people now think, or, more understandably, through an "intermediate boson." (That's not a joke; that's one of the terms you hear in the esoteric world on the top floor of the Lauritsen laboratory here.)

Other Caltech people are studying what are called quasi-two-body reactions at NAL. When I was a student here, Millikan had just written his book with the red cover called *Electrons (Plus and Minus), Protons, Neutrons, Mesotrons, and Cosmic Rays*. If you were to write that book today, you would have to put in multitudes of hadrons, meson families, the leptons, and all that kind of thing. It would be a difficult thing to do. There are, in fact, more of these so-called elementary particles than there are chemical elements. Unlike the chemical elements, there is apparently no limit to finding new particle families.

One of the main theoretical endeavors at Caltech, as a matter of fact, is based on this business of families of particles. Richard Feynman, Murray Gell-Mann, and their colleagues who deal with these things have come down to a new idea of elementarity—you've heard of quarks? You probably could have been thrown out of Caltech back in the 1930's if you had seriously mentioned a particle that had one-third of an electron charge. Millikan would not have stood for it. And yet it seems possible that quarks are the fundamental things that compose matter. They come in three flavors—up, down, and strange; and in three different types—red, white, and blue. (This is the latest word from a conference recently held in Chicago.)

We have no idea right now whether quarks might have any practical application or not; nobody can say. Most likely not. And yet, is it inappropriate at a place like Caltech that significant effort should go into studying things like this? I think it adds to our appreciation of the grandeur of the universe to understand these funny little quarks—with their third-of-an-electron charge!

continued on page 29

THE SINS OF WASTE

by Arie J. Haagen-Smit

In December 1950, I wrote an article for *Engineering and Science* which ended this way:

> Smog elimination has entered a new phase. Careful studies have to be made of the amounts and nature of the organic material released into the air. Only in this unemotional way can we hope to bring relief to this area.

The "unemotional way" turned out to be not exactly a tea party. Apparently, the professor had never before looked beyond the walls of his laboratory. My microworld consisted of distilling liquids and crystallizing substances, and whenever a distraction threatened a discovery, I hightailed it back to the safety of my laboratory.

This time the getaway was not so easy. Too many interests were at stake, and strong medicine was needed. In 1950 all pollution was believed to be sulfur and smoke. The cleanup of refineries, steel factories and foundries, dumps, and incinerators was in full swing. So my discoveries that organic material released into the air—mostly hydrocarbons—was oxidized through the combined actions of oxides of nitrogen and sunlight to become photochemical smog did not go over very well.

The losses of gasoline into the air in the early fifties were astounding. The estimates varied between 120,000 and 240,000 gallons per day—at an average cost of $10 million to $20 million a year. This was the incentive for some soul searching by the petroleum industry, and the result was a general cleanup. By 1956, most of the hydrocarbon sources at the refineries were controlled, and the stage was set for the control of smog components from automobiles and power plants.

In recent years, pollution experts, news media, and public-spirited groups all over the world have stressed our dependence on a healthy environment. The resources for that environment are the same as the four principles of

Lecture Circuit

"The Sins of Waste" has been adapted from a Watson Lecture given by Arie J. Haagen-Smit, professor of bio-organic chemistry emeritus, in Beckman Auditorium on December 4. The new Earnest C. Watson Caltech Lecture Series is a successor to Caltech's famous old Friday evening demonstration lectures—and Haagen-Smit has given one of those about once every four years since he came here 35 years ago. In his December 4 talk, he paid this tribute to the founder of those lectures.

It has always been an adventure to follow the tradition set by Earnest Watson's Friday evening lectures. Those who knew him remember that you could not get away with just any kind of a lecture. It had to be groomed to perfection.

Experiments were a *must.* There was the resounding boom in the High Voltage Laboratory when Dr. Sorensen made his own lightning while we watched from the gallery. And there was Dr. Watson himself, whose lecture on liquid air always drew a full house. Anyone who ever saw his skill in capturing his audience remembers the case of the deep freeze: the goldfish and the rubber ball. When the fish and the ball were both frozen stiff at —180°, he threw the ball against the wall of Bridge, and it shattered like glass. He put the fish in water and, lo and behold, after a few minutes, it was swimming (I suppose, happily) around. We kept waiting for it, but he never mixed up the two experiments.

It was in 1950 that my Friday evening lecture served as a forum to tell Los Angeles what smog was all about. Following the custom of the old-style lecture, the table was crowded from one end to the other. On the blackboard I had written the master reactions leading to the typical smog symptoms: nitrogen dioxide, photochemically dissociated into nitrogen oxide and atomic oxygen. The atomic oxygen was ready to attach itself to organic compounds, gasoline and the like, and eye-irritating, plant-damaging substances were formed. All these reactions were accompanied by the formation of aerosols—that is, a haze—and, strangely enough, ozone. The ozone formation was the great stumbling block in convincing key people that something had to be done about the primary reactants: hydrocarbon (meaning gasoline), automobile exhaust and solvents, and the products of the union of nitrogen and oxygen—the oxides of nitrogen.

After exactly one hour (Dr. Watson's orders), the lecture was over, and the people had seen a demonstration of the formation of ozone from an organic compound and light (diacetyl and air).

alchemy: air, water, soil, and fire. All four are important, of course, but I would like to add another one. It is "time." For the individual, this is clearly a nonrenewable resource, and the old saying is still true: "Time goes fast; use it well."

Following time, energy is probably next in importance. If we have energy, we can reclaim water, refine our mineral resources, and have food for all.

Let us look at a key operation in our daily lives: the production of energy in a central power plant. The story of that energy began millions of years ago with the sun converting the randomly spread carbon dioxide into packages of starch, bundles of cellulose, and the like. The next step was a loss of water, coupled with hydrogenation and dehydrogenation which resulted in the formation of gas, oil, and coal. These products are converted into mechanical and, subsequently, into electrical energy in a power plant. All these conversions are governed by two fundamental laws of thermodynamics.

The first one is known as the law of conservation of energy. It says that work produced can never be greater than the heat applied. The second law goes further and says that it must always be less. A popular version of the two laws of thermodynamics is sometimes expressed as follows: (1) You can't win. (2) You must lose.

The second law denies the possibility of converting *all* the energy in the fuel into useful work. It predicts that in all energy conversions there will be waste. Some of the energy is used up in friction, heating up the environment, in noise, and in light. The dissipation of energy to a nonusable form is measured by entropy, which increases when reactions such as the burning of fuel take place. It is more or less a measuring stick for downgrading our energy.

The statistical version of the second law says that order will tend to become randomness or disorder. This random dissipation of materials is, of course, what we do to our natural resources. We mine the pockets of pure or highly concentrated mineral resources and spread them over the earth or into the atmosphere. For example, the lead from the rich deposits in our mines goes as ethyl and methyl lead into gasoline and ends up finely dispersed all over the globe and in the ocean waters. When we want to recover the resources—lead, copper, nickel, and many other minerals—we must deal with extremely lean mixtures which take lots of labor (that is, energy and money) to recover. But we have made progress in utilizing fuel more efficiently. There has been a steady increase in the yield of useful energy from fuel in power plants, for example. In 1900, seven pounds of coal were necessary to produce 1 kilowatt; today, only four-tenths of a pound produce the same electrical energy.

But the relentless demand for power, which doubles every ten years, keeps neutralizing the gains. The energy crunch is now openly discussed, and more and more technical experts are pointing to the limitations of our fuel supplies. Faced with finite resources of fuel—gas, oil, and coal—we must now look toward a greatly increased use of nuclear power through breeder reaction and, eventually, nuclear fusion processes. The use of large-scale solar energy is no longer limited to science fiction stories. A 250-square-mile area filled with solar batteries would generate all the power now used by Los Angeles. Farming the deep heat inside our planet is under serious consideration, and deep wells are being drilled now.

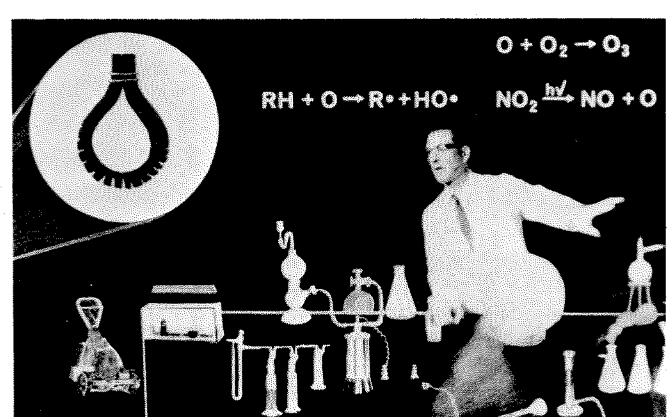
Even in the use of fossil fuels, exciting new techniques are being developed. The magnetohydrodynamics process (in which a stream of ionized atoms generates electricity by passing through a magnetic field) is able to increase the efficiency of a boiler plant from about 40 to 60 percent of its fuel input. Nothing is taken for granted; losses formerly considered inevitable are now being carefully scrutinized. The transportation of electricity at near absolute zero where resistance—and, therefore, energy

---

They had seen in a time-lapse film how ozone cracks rubber strips under stress. They had seen the oxidizing effects of ozone when it passed through different solutions of reagents. (One bottle turned *red*, another *white*, and a third one *blue*. Just try to figure out how to do that.) Dropping a few drops of gasoline into a bottle filled with ozone never failed to cause some excitement in the first rows. The stuff *smelled and hurt the eyes*, just like smog. But the oh's and ah's came when a solution of *luminal* (4-aminophtalhydrazide) reacted with ozone in a Rube Goldberg apparatus, giving an eerie, blue light—almost like firecrackers in a bottle.

The origin of the oxides of nitrogen in high-temperature combustion was shown with the help of a bunsen burner and with a power lawnmower that appeared and started at just the critical time. The last stunt was an explosion of gasoline and ozone, a cold burning or oxidation of the gasoline in the hollow of my hand. I thought it was about as good as Dr. Watson's fish or Dr. Sorensen's thunder and lightning.

It was, of course, several days of work, but it was also a challenge, and in that early period, it was essential to get your point across. One can talk chemistry to legislators and supervisors for quite some time, but there is no better argument than fumigation with home-made smog—the stronger the better.



Complete with a photo of himself at the time, A. J. Haagen-Smit offers his own pop-art portrayal of what went into the 1950 lecture in which he first demonstrated the formation of smog.

heat loss—is at a minimum is being worked on with considerable success, opening up the possibility of locating power centers at a distance from the users.

We can save even more in the way we make use of our fuel. Why, for example, do we make electricity from burning fuel and then convert it back into heat? Use of waste heat for heating and cooling, agriculture, and aquatic cultures is feasible and should be promoted wherever possible. The "Save-A-Watt" propaganda deserves more than mild criticism and derision. The battle for economy in the use of energy consists of making a multitude of small gains all down the line, in industry as well as in homes.

The Automobile

One-third of all the fuel we burn is used to propel our automobiles. The energy we waste with these little power plants is way beyond reason. Not only do they use an inordinate amount of energy in moving people around, but they contaminate the air on a scale no other emissions source has managed to do. No wonder that after most stationary sources in Los Angeles had been controlled, the automobile emerged as a major source of trouble.

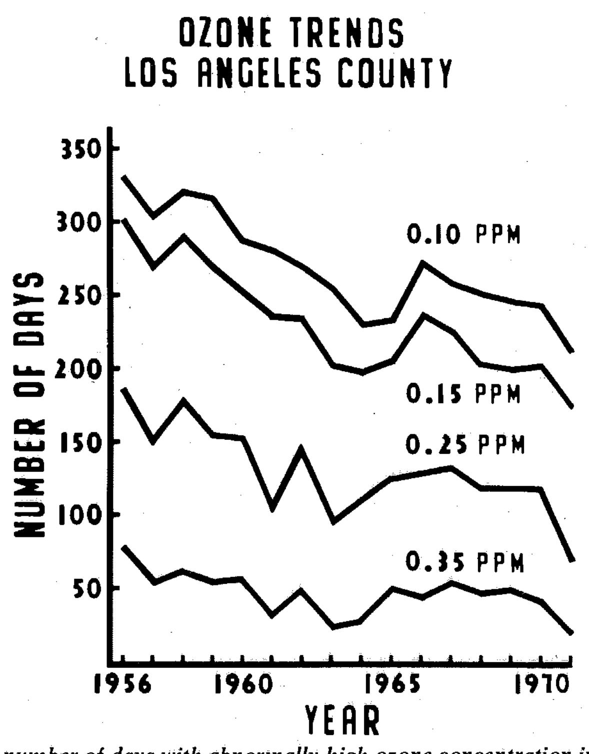
The discovery of the reactions leading to the type of smog we see in Los Angeles has prompted an intensive effort to control the emissions of hydrocarbons, oxides of nitrogen, and carbon monoxide. In the past, hardly any attention had been paid to the fate of the unburned fuel, but now it was shown that there were several escape routes for the substantial amounts of hydrocarbons that are exhausted—through the tailpipe, 65 percent; through the crankcase, 20 percent; while the remaining 15 percent came from evaporation of fuel in the carburetor and from the fuel tank. The reduction of hydrocarbons and carbon monoxide emissions started in California around 1960 with control of crankcase exhaust emission, and has continued since with control of the exhaust, tank, and carburetor emissions.

Automobile laboratories now routinely test new cars coming off the assembly line by simulating city driving on a dynamometer that has fast-turning rollers instead of a roadbed. The official federal emission test includes starting, accelerating, cruising, decelerating, and idling. The results are expressed in grams per mile. An average car, before controls were instituted, emitted through its tailpipe 17 grams of hydrocarbons, 120 grams of carbon monoxide, and 4 grams of oxides of nitrogen per mile. Our latest results from the 1972 crop of cars showed marked progress, with emission of only 3 grams of hydrocarbon, 30 grams of carbon monoxide, and 3.4 grams of oxides of nitrogen per mile.

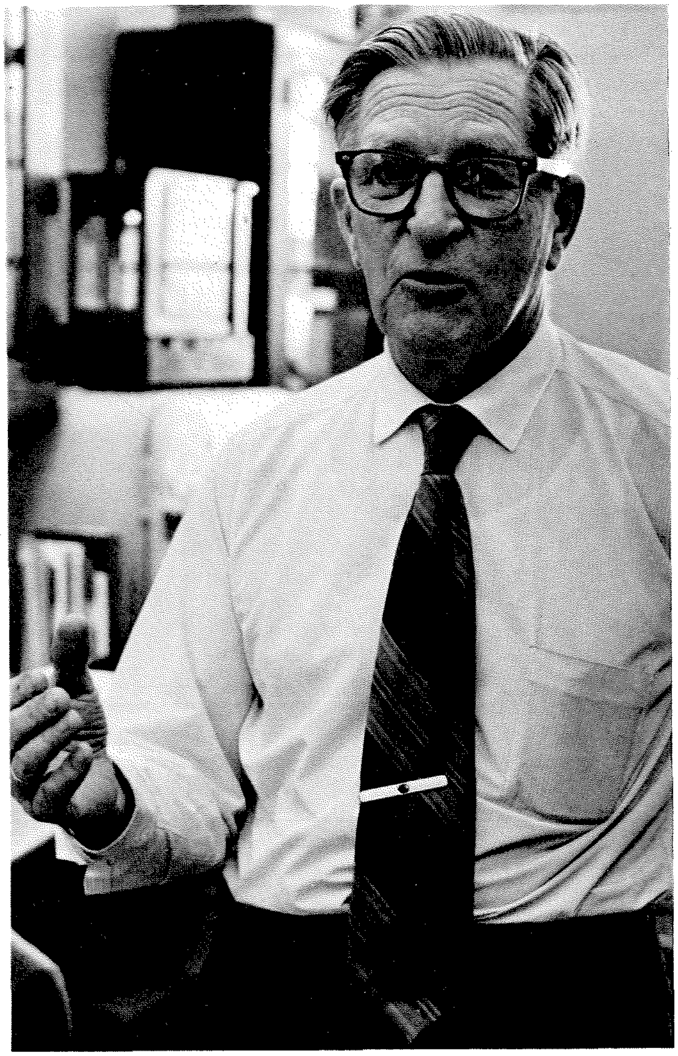
Taking into consideration control at all emission points, the new 1973 cars have an emission reduction of 90 percent for hydrocarbons, 75 percent for carbon monoxide, and 35 percent for oxides of nitrogen.

The effect of these steps is now being recorded on the Los Angeles air-monitoring systems. The concentrations of both hydrocarbons and carbon monoxide in the ambient air show a downward trend for the second year in a row. The same is true for the number of days of eye irritation and for the amount of oxidants in the air. At the same time, random sampling of cars has shown an average 50 percent reduction in pollutant emissions. This average is compiled from 1972 cars with crankcase, exhaust, and evaporative controls, and from older cars which are not yet controlled. It is gratifying to see that our laboratory testing results confirm, and run parallel with, the analytical findings of the monitoring systems.

Refinement of controls will continue until, in 1976,



The number of days with abnormally high ozone concentration in the air of Los Angeles County has shown a general downward trend since 1956. Each jagged line shows the number of days in the year on which the oxidant reached the indicated values—expressed in parts per million (ppm). In 1971, for example, ozone in the atmosphere surpassed the California Health Standard of 0.10 ppm on 210 days; it surpassed 0.15 ppm on 175 days; 0.25 ppm on 70 days; and 0.35 ppm on 20 days.



One-third
of all the fuel we burn
is used to propel our automobiles.
The energy we waste
with these little power plants
is way beyond reason.

97 percent control of hydrocarbons and carbon monoxide has been achieved; emission of oxides of nitrogen will be reduced to one-tenth that of the uncontrolled vehicles. These last few percentage points (between 1972 and 1976 standards for controls) represent major technological problems, which are as yet unresolved.

While some laboratory cars are probably coming close to the 1976 standards, the penalties for excessive control within too short a time span are beginning to appear. Complaints about poor drivability are mounting, and a fuel penalty of 10 to 20 percent will cause a decided increase in the cost of running an automobile.

The need for a drastic reduction in automobile emissions, while preserving the advantages of our present cars, has stimulated the search for ways to modify the existing automobile power plant. The most successful contender is the rotary engine, which is already being produced on a mass scale and which by the mid-seventies will take an important place in the propulsion of light vehicles. Cars equipped with two-stage combustion in the stratified charge engine and its Honda-type modification will undoubtedly command a large portion of the automobile market. Less important contenders are diesels, turbines, Stirling engines, and electrically driven cars.

There is no doubt that the activity set in motion to deal with emission control will bring us many exciting innovations in the coming years. There is, however, much misinformation. It is common to hear about the terrible waste of energy in the internal combustion engine. And anything bad that is said about the so-called "infernal" combustion engine is received with applause by the old-timers who remember the Stanley Steamer.

But both the internal and external combustion engines are subject to the same energy laws. The efficiency of the power plant is dependent on high pressure and temperature. As soon as we lower these, down goes the efficiency. The limitations on the practicability of high-pressure and cooling equipment in a vehicle result in a drastic lowering of its efficiency. Thus, the efficiency of the steam car becomes comparable to that of the internal combustion engine—that is, it only uses about 10 to 15 percent of the fuel energy.

The Wankel rotary engine is not more efficient than the gas combustion engine. The peculiar form of the combustion chamber with high surface-to-volume ratio also makes for less complete combustion. Inherently, rotary engines are dirty, and they are equipped with

continued on page 30

Research Notes

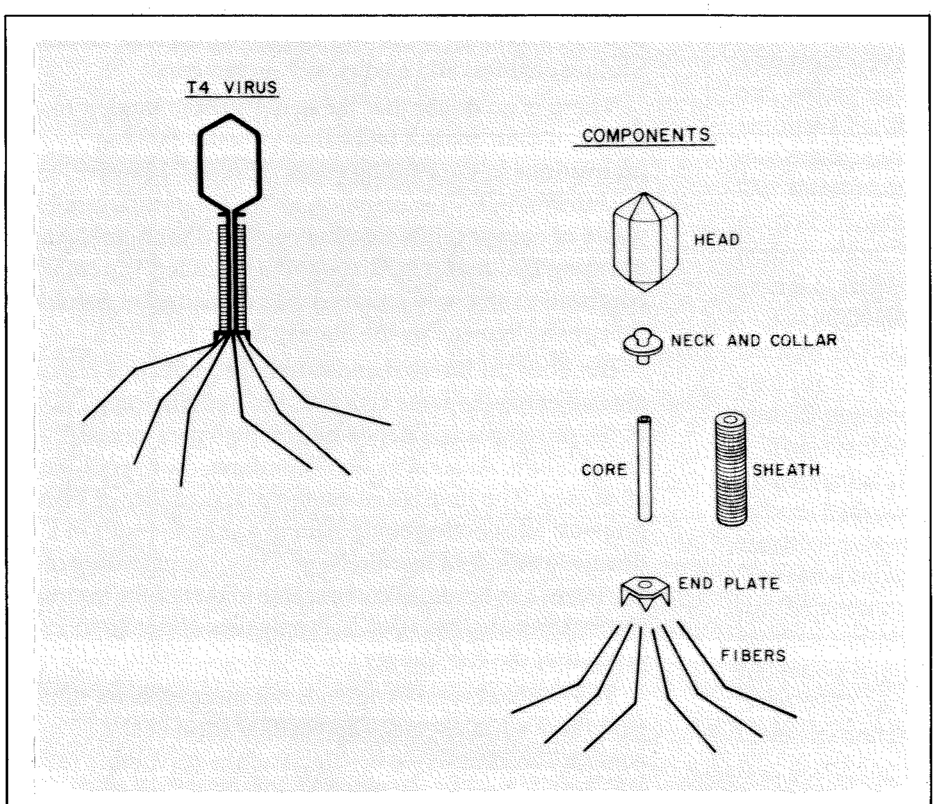
Virus Assembly Line

A group of investigators under William B. Wood, professor of biology, is gaining new understanding of the role of certain protein molecules in the formation of a virus known as T4. Wood hopes that the study of molecular architecture at the level of viruses will shed light on the structuring of more complex forms of life.

T4 is a living hypodermic needle only one hundred-thousandth of an inch long. Like all viruses, it is a parasite. It keeps its family line going by squirting its DNA, the carrier of its genetic pattern, into one particular kind of cell—*Escherichia coli (E. coli)*, a common bacterium found in the intestine. This act destroys the cell's own genetic material, converting the bacterium into a factory that makes 100 or so T4 viruses—using T4's DNA blueprint—in about half an hour. The cell then bursts, freeing the new viruses, and dies.

T4 consists of about 40 different kinds of protein molecules that are assembled independently into three major components—head, tail, and tail fibers—that are then combined to complete the virus. Even the hair-like tail fibers are manufactured in two separate parts and then connected at a knee-like joint. Subsequently, the completed tail fiber is attached to the base of the tail. Wood and his group are currently concentrating on learning about the composition of the tail fibers and how they become attached to the virus's tail.

The tail fibers play a vital role in T4's reproductive life. When T4 bumps into an *E. coli*'s wall, the tail fibers of the T4 somehow grab the cell surface and hang on. The attachment is some sort of chemical bonding, but its exact nature is not yet known. When the six tail fibers are attached to the wall, the syringe-like body of the virus is in an upright position. The virus then contracts, squirting the DNA from the T4 head into the *E. coli* cell.



The components of the T4 virus seem to join together in assembly-line fashion, and the complete virus looks a little like a cross between a hypodermic needle and a spider.

Wood and his group have found that seven different types of protein take part in forming the T4's tail fibers. Four of them comprise the actual tail-fiber structure, and the three others serve as catalysts in the minute assembly line. "We know something about the three proteins that put the tail fibers together, but we don't understand how they catalyze assembly," says Wood. "This is what we would like to find out."

In addition to accessory catalytic proteins, assembly in higher creatures often depends on pre-existing structures, which guide the laying down of new material in some manner not yet understood. There are now indications that the T4 work of Wood and his associates may be able to shed some light on this feature of assembly too. In the assembly of T4, a pre-existing structure—the inner wall of the *E. coli* membrane—is used in some way to aid in constructing the heads of the viruses. Helen Revel, research associate in biology and a collaborator of Wood's, has found mutant strains of *E. coli* cells whose membrane has been changed so that T4 heads can't be made. All parts but the head are formed.

"Now we have a mutant T4 that will reproduce in the mutant cells," says Wood, "so we can ask which viral proteins interact with whatever it is that is changed in the bacterium. Experiments with these mutants will help us learn how the virus uses the host membrane to direct its own assembly."

Wood's research is supported by the U. S. Public Health Service.

William A. Fowler, Institute Professor of Physics, and Barbara Zimmerman, a member of the technical staff, go over a computer print-out that analyzes data from solar observations and experiments.

Much Ado about Nothing?

The sun may have the ability to turn its thermonuclear fires up and down as a thermostat does a house furnace, and it may have done so as many as ten times during the past several million years. In fact, the sun may now be going through one of these crucial up-down periods. It may have turned itself down within the last few hundred thousand years and just now be turning up, or it may now be in the act of dampening its solar fires momentarily.

This thermostat-like activity may be due to what William A. Fowler, Institute Professor of Physics, calls "transient mixing," one of two "desperate" explanations he offered in a recent issue of *Nature*, the British scientific journal, in an attempt to resolve a baffling solar mystery—the scarcity of solar neutrinos.

Most scientists believe that the sun's interior is burning at 15 million degrees above absolute zero. But at this temperature (with hydrogen fused and turned into helium by thermonuclear reactions at the core) the sun should also be emitting about 3 percent of its energy in the form of neutrinos—subatomic particles, having energy but no charge or mass, that are by-products of nuclear reactions. However, it is increasingly evident that, at most, the sun is only spewing out about one-tenth the number of neutrinos predicted by theoretical astrophysicists.

"Quite obviously something is wrong, either with some of the most basic laws of nuclear physics, or with our theories about the sun," says Fowler. "I prefer the latter explanation." Working in Kellogg Radiation Laboratory with a group that includes professors of physics Charles Barnes, Ralph Kavanaugh, Thomas Tombrello, and Ward Whaling; research fellows Arthur Huffman and Mirmira Dwarakanath; and a member of the technical staff, Barbara Zimmerman, Fowler has been attempting to find out what is wrong with our solar theories.

The first explanation he suggests—transient mixing—challenges the standard models of the sun. Current theory contends that the sun's interior is stable to convection; that is, there is no mixing of elements due to massive motions of material caused by the transfer of heat energy. Fowler speculates that perhaps the sun sometimes becomes convectively unstable and that materials at a temperature of 15 million degrees in the center of the sun are suddenly mixed with lighter, cooler materials from the sun's surface. Such mixing would cool the interior slightly and thus reduce the flow of neutrinos. Since neutrinos generated at the sun's center reach the earth in only eight minutes, any dampening of the solar fires would be evident immediately in a decrease in the number of neutrinos. There is no lessening of the sun's brightness because of this interruption, since light generated in the sun's core takes about 30 million years to work its way up to the solar surface.

Fowler's second desperate explanation—one that he is not particularly enthusiastic about—is that possibly one of the critical reactions in the core of the sun has a resonance in it; that is, it goes a lot faster than predicted. If this is so, it would, in effect, "short-circuit" the production of neutrinos, and would also make the theorists' models agree with the experimental results. Dwarakanath has searched for the necessary resonance, but has detected none so far in his experimental observations. "It doesn't appear that this particular explanation is viable, but it did seem necessary to test the possibility experimentally," says Fowler. "If true, it would have constituted a loophole in the logic of solar nuclear physics, but what a letdown it would have been. Not understanding something in the nuclear reactions would have been an answer all right, but not a very exciting one. It wouldn't have led to anything new."

But the transient-mixing explanation does, as Robert Rood, a former research fellow under Fowler who is now assistant professor of astronomy at the University of Virginia, found out. He took Fowler's suggestion seriously enough to develop an elaborate theoretical model, the results of which were published in *Nature* in December. Rood's calculations indicate that the sun—and thus similar stars—could undergo transient mixing as many as ten times before the flow of neutrinos would be reduced to the few that have been observed.

Where the sun is in this mixing process—whether it is due to heat up or cool down—determines whether the earth is headed for another ice age, or for a long-term tropical heat wave. "If, for instance, the sun has been cooling off over the last 30 million to 100 million years, has its lowering temperature affected the earth?" asks Fowler. "If it has, one immediately thinks of glaciation in the very recent geological past. But we aren't sure there's any relation between the two phenomena. When you're speculating about theories of solar activity, you can't be very positive about effects on earth. 'Much ado about nothing' may turn out to be the appropriate way to describe the search for solar neutrinos, but the 'ado' has been exciting and the 'nothing' now poses serious problems in physics and astronomy."

Probing for Neutrons on the Moon

A volcanic area of the Owens Valley—similar to Littrow Crater on the moon—makes an ideal site for terrestrial tests of the lunar neutron probe. Don Burnett and assistant Jim Weiss begin a trial run by measuring distances.

One of the many instruments taken to the moon during the Apollo 17 mission in December was a 6½-foot-long tube that measured the rates at which neutrons reacted with lunar materials. Astronauts Eugene Cernan and Harrison Schmitt placed the tube—called the lunar neutron probe—in the hole they had drilled to obtain a deep core sample of the lunar surface, left it there for 40 hours, and then returned it to the lunar module for the long trip back to the earth and—eventually—Caltech.

The probe was designed by Donald Burnett, associate professor of nuclear geochemistry; Dorothy Woolum, research fellow in geology and physics; and Curtis Bauman, research engineer. It was constructed in Caltech's central shop for the National Aeronautics and Space Administration.

The neutrons tracked by the probe are secondary particles produced by the impact of cosmic rays on the moon. These rays strike the lunar surface and penetrate a few yards into it. When they collide with the atoms in the lunar rocks, complicated reactions occur in which the atoms of the lunar material are partially fragmented. The resulting secondary particles include neutrons.

The upper few yards of the lunar surface have been bombarded with these neutrons for billions of years—an assault that has produced small, but accurately measurable, changes in the isotopic composition of some elements found in lunar samples. Many measurements—primarily those made by G. Price Russ, graduate student in chemistry, and Gerald Wasserburg, professor of geology and geophysics—show the extent of this long-term neutron bombardment.

The number of neutrons that have reacted with a given sample of lunar material depends on how long (and where) the sample has been in the upper few yards of the lunar surface. Consequently, the measurable effects of the neutron bombardment help us to understand the processes that move and mix material on the moon's surface. But for accurate interpretation of lunar-sample data, it is necessary to know the rates at which neutrons react with lunar material, and how depth causes these rates to vary. The neutron probe should provide this information. "We already have theoretical estimates of how neutron-capture rates vary with depth," says Burnett. "With these we can build up fairly detailed models of what we think is going on. But if, instead of theoretical estimates, we have experimental data on the rate at which neutrons react down to a depth of six feet, we should be able to work out the history of the lunar samples with considerably more accuracy."

Burnett and his co-workers are now analyzing the results of the probe experiment and hope that it will provide this direct experimental information. They designed the probe in the form of a hollow tube, into which a rod is inserted. The apparatus contains two neutron detectors. The inner side of the tube has a strip of uranium 235 down one side and a strip of plastic down the other. The outside of the rod has a strip of boron 10 on one side and pieces of mica in a strip on the opposite side. When the astronauts placed the probe in the hole, they rotated the rod so that the uranium and mica strips faced each other to form one detector; the boron and plastic also faced each other to act as the second. When neutrons reacted with the boron, alpha particles were given off. They struck the plastic, leaving little tracks. When the neutrons reacted with the uranium, nuclear fission took place, causing the individual uranium atoms to break, or fission. When the subatomic fragments of this fissioning entered the mica, they also produced tracks.

Because of their uncertainty about the extremes of temperature the moon probe might have to undergo, Burnett and his co-workers designed it to collect information over a very wide temperature range. Temperatures on the moon vary from about 210 degrees Fahrenheit to about 240 degrees below zero. The boron-plastic recording method is more sensitive than the uranium-mica one, but loses its ability to detect alpha particles above 160 degrees. However, if the temperature had climbed above this point, the less sensitive, but hardier, uranium-mica recorder would have still registered neutron hits.

Although the probe's detectors appear to have done their job, Burnett and his co-workers are now trying to determine how much correction will have to be made for the effect of the radioactive isotope generator used to power the other instruments in the ALSEP (Apollo Lunar Scientific Experiment Package). When isotopes break down to produce heat and electricity in the generator, they produce neutrons as a by-product. To test this before the Apollo 17 mission, Burnett took the probe to California's Owens Valley, and in an area resembling the lunar landscape he analyzed the effect of an intense neutron source similar to the one in the ALSEP generator. He plans to run another series of similar tests within the next few months so that he can double check his results.

"One thing we *didn't* have to worry about was what would happen if the astronauts couldn't dig a hole for the probe and had to hammer it in," says Burnett. "We made sure it was sturdy enough by testing it thoroughly before the mission. Our standard procedure was to take it out to the flower bed in front of Mudd every now and then and pound the thing into the ground."

Quasars—A Stage in the Evolution of Galaxies?

"Things are seldom what they seem" could be the theme for much of modern astronomy. For example, the results of a study by Jerome Kristian, staff member of the Hale Observatories, provide new support for the idea that quasars, rather than being a distinct class of astronomical objects, may reside in the centers of giant galaxies.

This view, which has been argued for since the early 1960's by Allan Sandage of the Hale Observatories staff, is based on several lines of evidence. Among the strongest of these are studies of two special types of galaxies—Seyferts and N galaxies. These have very bright, small nuclei, or central cores, which look like "mini-quasars." Although they are fainter than quasars, they have spectra and colors similar to quasars, and they change brightness in times as short as weeks. Such rapid change is one of the most striking properties of quasars, implying sizes as small as a few light weeks in diameter. This is a million times smaller than the sizes of giant galaxies, although some quasars are hundreds of times brighter than the brightest galaxies. The source of the quasars' great energy is still a puzzle.

More recent evidence that links quasars and galaxies includes studies by John Bahcall, former associate professor of theoretical physics at Caltech and now of the Princeton Institute of Advanced Studies; James Gunn, professor of astronomy and a staff member of the Hale Observatories; and their colleagues. These studies place some quasars in large clusters of galaxies.

Kristian's new results were based on a search for underlying galaxies on photographs of quasars taken with the 200-inch Hale telescope at Mt. Palomar. At the Sixth Texas Symposium on Relativistic Astrophysics in December he reported evidence for galaxies surrounding at least six quasars and possibly four more. He offered as an explanation for the fact that galaxies are not seen around all quasars—even though they may be present—that the quasars' brilliance may simply swamp the fainter image of the galaxies.

Although quasars are much smaller than galaxies, observing them is complicated by what happens when their light passes through the earth's atmosphere. This distorts what would otherwise be a very small image and smears it into an image which is progressively larger for brighter quasars. The image size of a larger, extended galaxy, however, depends mainly on how far away it is, as measured by its redshift. If a distant galaxy has a very bright quasar in its nucleus, the quasar image can be larger than the galaxy image, and the galaxy may not be seen at all. From measurements of the image sizes of galaxies and stars, Kristian was able to predict for each of 26 quasars studied whether a galaxy should be seen or not. "The results were as predicted," he says. "Where you expect to see a galaxy you do, and—at least as important—where you expect not to see one, you don't. This association of quasars and galaxies makes quasars look a little less exotic and galaxies more so. We still don't know what is happening in quasars, but it looks as though they may be a stage in galaxy evolution."

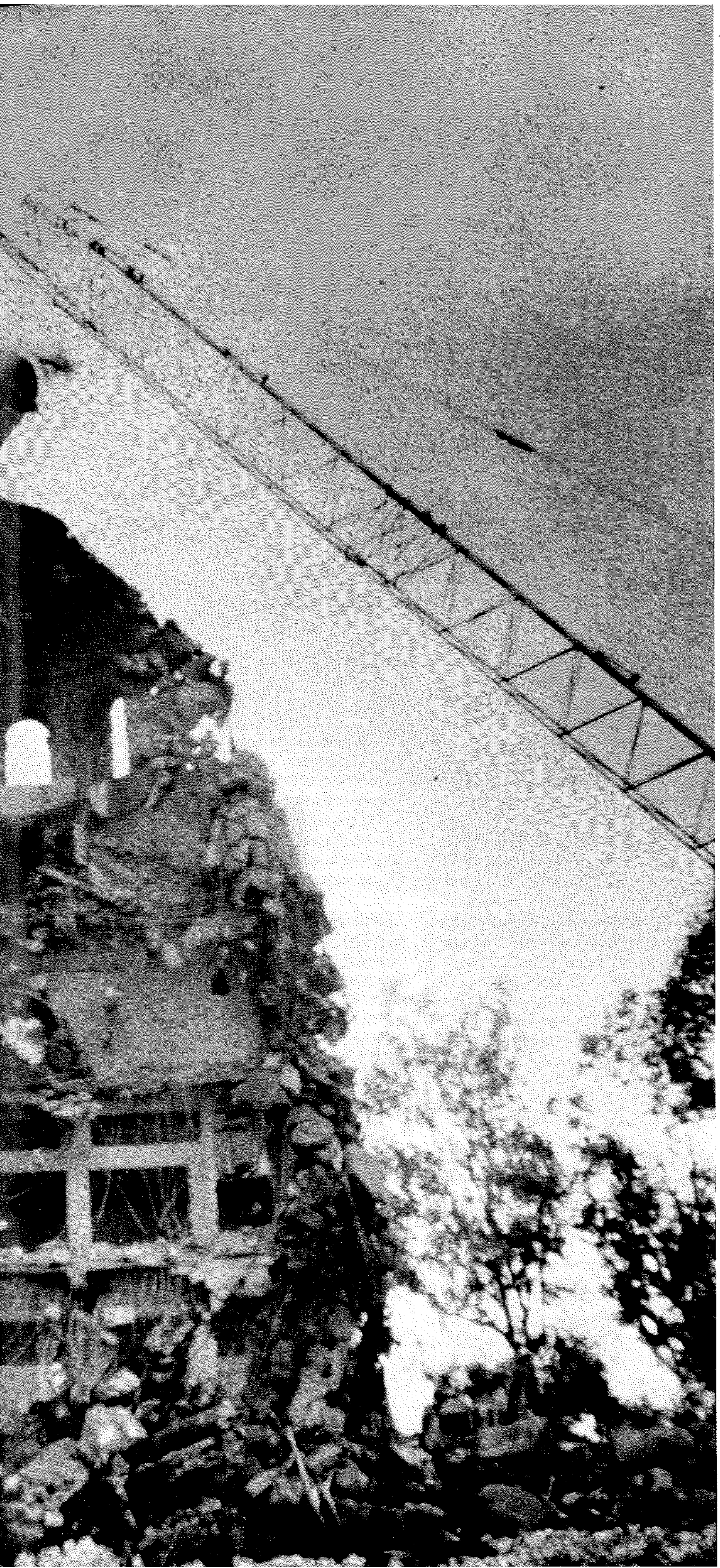
If this is true, it raises many interesting questions. What fraction of galaxies go through a quasar stage? How long-lived is a quasar? What is its effect on the history of a galaxy? Is it an incidental thing that only happens under special conditions, or is it related in some fundamental way to galaxy evolution in general? Does the apparent absence of quasars with redshifts larger than 2.8 point to the time at which galaxies were born?

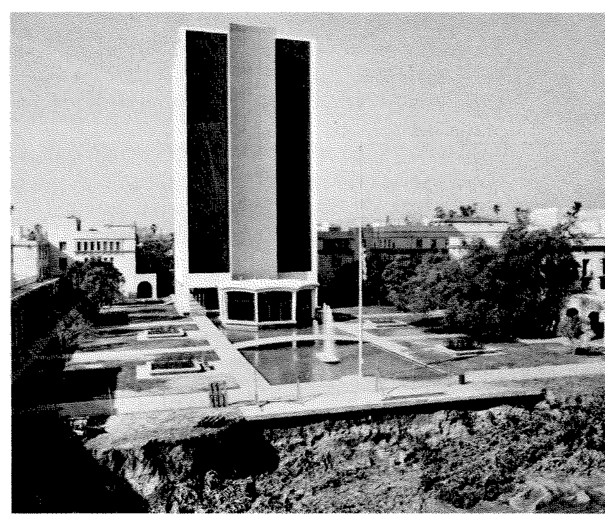
Kristian, Sandage, and James Westphal, associate professor of planetary science, are planning further studies of quasars over the next year using a newly developed silicon diode vidicon photometer (*E&S*, June 1972) to give the 200-inch telescope more sensitivity at great distances.

THE END

It took about six weeks for the headache ball to obliterate Throop Hall, which put up enough resistance to elicit a lot of respect—and some wry comments ("It would have taken a helluvan earthquake to knock that thing down!") from the sidewalk superintendents.

For everyone who wasn't there to watch the drama—and for the record—here is the grand finale.





The Month at Caltech

Population Conference

For Caltech's third annual population conference, 14 members of the faculty and the Environmental Quality Laboratory staff, 13 members of the American Universities Field Staff, and 14 other participants crammed into the Millikan Library board room for two days last month to discuss "Population Pressures—Perception and Policy."

The visitors included Paul Erlich, Stanford biologist and a prime mover in the Zero Population Growth organization; and his colleague Carl Djerassi, professor of chemistry at Stanford and an expert on new types of birth control. Japan sent Toshio Kuroda, who heads the population policy division of its ministry of health; and a leading Latin-American demographer, Julio Morales-Vergara, came from Santiago, Chile. Harrison Brown, Caltech's population program director, was the conference chairman.

The results of the meeting will be published and distributed by the U. S. Agency for International Development.

New President

Caltech alumnus Joseph E. Mayer is the new president of The American Physical Society. Mayer, who is currently professor of chemical physics at the University of California at San Diego, received his BS in chemistry at the Institute in 1924.

Where Have All the UFO's Gone?

John Northrop, co-founder of the Northrop and Lockheed Aircraft companies, came to the campus on January 23 to talk about Unidentified Flying Objects—a subject he has pursued for more than 20 years.

What his audience heard was that Northrop believes there *are* UFO's and that further study might be worthy of an institution like Caltech. He thinks there have been enough sightings by qualified observers to make a case for the UFO's, and he's convinced that there might be more testimony worth listening to if more people were not afraid of ridicule. And he blames human nature in general, and the scientific community in particular, for an unwillingness to investigate anything new that is not explainable.

Since UFO's sighted by trained observers would seem to have a source of power far beyond present comprehension, Northrop would like us to find out what that source is.

When one member of Northrop's audience asked why the beings who man the UFO's never seem to communicate with us, another audience member retorted: "If they're that smart, why would they want to?" And that ended the seminar.

You Can Go Home Again

Harrison (Jack) Schmitt, '57, had some unofficial time to himself last month during a NASA-sponsored tour by the Apollo 17 astronauts, and he elected to spend some of it with members of Caltech's geology division.

On Saturday evening, January 13, in the Athenaeum, undergraduates and graduate students of the division got in on some heady shop talk about what it was like to be the first geologist on the moon. Schmitt showed slides and described the various Extra Vehicular Activity stations and their geological features. (Getting into the lunar rover, Schmitt said, was "a process of leaping backward, hoping to come down on the right part of the vehicle." And the lunar dust was "the most abrasive environment I've seen, next to Tech.")

Sunday night was a little more formal—but not much. About 70 geology faculty members, graduate students, and technicians who had worked on Apollo 17 experiments honored the division's most newsworthy alumnus with a dinner in the Athenaeum.

It was reminiscence night, and Jack was presented with a whole series of mementos from his undergraduate years. In 1957 he won a prize for the best rock specimen in an annual contest conceived and conducted by Ian Campbell, now professor of geology emeritus. At the dinner Jack got his rock back with a few embellishments, mounted against midnight blue velvet on oiled oak, bearing an engraved brass plaque. It was borne into the dining room on a silver tray by ex-division chairmen Eugene Shoemaker and Robert Sharp. And Ian Campbell made the presentation.

Schmitt's discovery of orange soil on the moon was appropriately noted as Professor Don Burnett presented him with an orange Caltech T-shirt, numbered "17."

Barclay Kamb, the division chairman, gave Jack some reminders of a summer geology field camp conducted by Kamb in the Sacramento Mountains of New Mexico. The mementos included Jack's survey and mapping report on the six-week project, and a picture of him in what may have been his most abrasive Caltech environment—standing under a broiling sun in a field of cholla cactus.

Books

Ernest G. Anderson
1891-1973

Ernest G. Anderson, professor of genetics emeritus, died on January 30 in Columbia, Missouri. He was 81.

A native of Concord, Nebraska, Anderson received his BSc from the University of Nebraska in 1915 and his PhD from Cornell in 1920. He came to Caltech in 1928 as associate professor of genetics, became full professor in 1946, and retired in 1961.

Anderson was known for his research in the field of cytogenetics, particularly in corn. Using plantings of descendants of seeds exposed to radiation in the Bikini and Eniwetok atom bomb tests, and normal corn exposed to measured doses of X rays, he made fundamental studies of heredity and transmitted traits —and of the effects of radiation on food crops.

SHAKESPEARE'S ROMANCES
A Study of Some Ways of the Imagination
by Hallett Smith
The Huntington Library $8.50

Reviewed by J. Kent Clark
Professor of English

Hallett Smith brings to his study of Shakespeare's last plays three priceless assets besides critical finesse and careful scholarship. These are an ear for the music and weight of words, a feeling for dramatic values and the demands of stage presentation, and an almost unique sanity. Employing these gifts and a crisp, incisive style of writing, he illuminates Shakespeare's romances—*Pericles, Winter's Tale, Cymbeline,* and *The Tempest*— in a way that not only adds to our abstract knowledge of sources, dramatic strategies, and essential themes but actually sharpens our appreciation of the plays themselves. In the process he brings us close to Shakespeare's creative methods, showing how the poet's mind selected and stored words, phrases, and images and how these appear transmuted into dramatic poetry and sometimes expanded into whole scenes. On a larger scale, he shows how Shakespeare, responding to contemporary tastes in romance, transformed the wild, violent, and implausible tales of the Greek-cum-medieval tradition into something rich and strange—and magical.

Since Shakespeare's romances do not fit into any traditional or easily definable genre, since they defy most canons of literary "realism," and since they often explore (or obliterate) the boundaries between dream and reality, they are a fertile source of insanity among critics. With a little coercion, a little selective misreading, and a little evasion or ignorance of their sources, they can be made to yield an alarming number of "interpretations," according to the intellectual fads of the time or the particular mania of the critic. In combating these aberrations, particularly the recent tendency to transform the plays into elegant restatements of primitive cultural myths or into crypto-theological tracts, Dr. Smith employs several essential strategies. He places the dramas in the literary and historical context of their times, traces and describes the sources from which Shakespeare drew his materials, compares and contrasts important elements in the romances with similar materials in the comedies and tragedies, and analyzes Shakespeare's use of imaginative "landscaping," theatrical spectacle, and verbal stage setting. For this task he is able to draw upon the rich fund of scholarship that has accumulated since Shakespeare's time, especially in the last 50 years, and upon the critical insights of many great literary men. The result is much more than a clearing away of scholarly underbrush and critical aberration; it is a remarkable synthesis of scholarly and critical materials into a coherent, illuminating, and sane perspective. To Dr. Smith, I should add, even absurd theories have their value. Like the inhabitants of Arden, who found sweet uses in adversity, he can draw meat from nuts.

If all this sounds recondite and formidable, I hasten to testify that it is not. Non-scholarly readers of Shakespeare may find the tour through the grotesque plots of Renaissance tales a bit exhausting and they will certainly wish they had read the later plays more thoroughly and more recently, but they will find themselves gracefully entertained along the way and they will find their imperfections pieced out with the author's thoughts. They will also notice that Hallett Smith has improved their perceptions of *King Lear, Midsummer Night's Dream, As You Like It, Macbeth,* and the "problem comedies" in the process of explaining the romances. If, like him, they have an ear for music and a feeling for style, they will find his chapters on landscape and language a delightful contribution to their understanding of poetry. In short, although *Shakespeare's Romances* will be required reading for all future scholars and critics of Shakespeare's last plays, it will also serve as a permanent source of wisdom and pleasure for readers who do not fancy themselves experts.

BIOLOGY

continued from page 5

where our faculty might become dependent on, and identified with, the agencies that support their research and salary rather than the institution that needs their full devotion—not only as researchers but as teachers and citizens as well. Even in research, we cannot run the risk of subordinating our free-ranging and independent creativity to direction from external agencies.

The new laboratory of behavioral biology will be finished a year from now, with new functional research units to be staffed and equipped. It is harder to get an operation going than to keep it operating when you have it going well. The expenses are substantial, especially if you are interested in getting good young people who need help from unrestricted funds to get started. But it is not just a matter of new buildings; the old buildings are a problem too. Come visit Kerckhoff someday, and I'll show you what I mean; or see our experimental animal facility, which faces a big change in requirements for the amount and quality of animal care. And our marine station is operating at absolutely top capacity with the new kinds of emphasis in biology and engineering. Teaching is charged to general funds, but the way costs have been growing, we can hardly afford to continue to teach the way we should, unless increasing general funds become available.

I wouldn't make a pitch as a biologist for Alumni Fund contributions to the Division of Biology. We need as an institution—of which biology is one lively part—the general funds that will make it possible for the Institute to move with the times, to maintain its unique distinction in teaching and research. These are times of severe stress for our Caltech.

ENGINEERING AND APPLIED SCIENCE

continued from page 9

We have for years had a great deal of work going on in biomedical engineering. Derek Fender has been studying the stimuli associated with human vision. Gilbert McCann and his associates have had a long program of investigating the neural systems of insects. Harold Wayland has had a program on the flow of blood in veins and arteries, and he has recently received a major grant from the Hartford Foundation for his work. Friedlander has been doing work on the flow of air in lung passages. All of this work has had ties with biology and chemistry. At present we are actively exploring the possibilities of uniting forces with some of the people at JPL to establish a major program in biomedical engineering.

All through our work here there is a strong interdivisional activity that would be very difficult at most universities, where high departmental walls make communication difficult. But at Caltech the ease with which we can cross interdivisional lines is a pleasure.

We are also moving to establish closer ties with industry. Each year we have five or six major conferences through our Industrial Associates program, which give people from industry a picture of the research activities that are going on here at Caltech. In addition, we've taken steps to invite people from industry to serve as visiting professors. Leo Stoolman from Hughes has spent a year here; others are Paul Dergarabedian and James Broadwell from TRW; Martin Goldsmith from Aerospace; Hirsh Cohen from IBM; David Malk from Beckman Instruments; Guy Pauker and Cliff Shaw from Rand; Mahlon Easterling and Ralph Miles from JPL. And we would like to invite more. Industry is a fertile source of new ideas, and it is to our mutual benefit to have closer ties.

GEOLOGICAL AND PLANETARY SCIENCES

continued from page 11

diverse assortment of powdered mineral grains, rock fragments in all stages of shock disintegration, and glass beads, shards, and coatings generated by shock melting. The nature of this "gardening" activity, and its history and consequences are being studied in detail by Professors Burnett, Shoemaker, Wasserburg, and their students and collaborators. Burnett's lunar neutron probe experiment on Apollo 17 represents a beautiful application of nuclear chemistry in revealing the time scale of the gardening process. The importance of impact shock effects on the moon (and also on earth, where recognized by discerning observations) is prompting experimental studies of these phenomena in Ahrens' shock-wave laboratory, which is thus serving a dual purpose as research tool for both geophysics and planetary science.

Still another facet of the division's activity is the lunar field geology program—the adaptation of terrestrial methods for field study to lunar conditions as anticipated in the Apollo missions. This was initiated and developed by Gene Shoemaker and then further advanced by Lee Silver in his field geology training expeditions for astronaut crews. The participation of Jack Schmitt (BS Ge '57) in Apollo 17 as the first scientist-astronaut to fly a lunar mission is a cause for particular pride and involvement on the part of the division. Perhaps Jack's selection for this mission goes back to his undergraduate field geology, and it strengthens our belief in the value of strong field experience.

Beyond the moon is Mars and Mariner 9, a beautiful accomplishment in which several of our staff participated, particularly Bruce Murray and Bob Sharp. Analysis of the great amount of photographic information obtained in this mission is still under way and will continue for some time. And research in the division by no means stops here, for our planetary scientists are at work on Venus and Jupiter, on the jovian satellites, and indeed right on out of the solar system to interstellar masers, pulsars, and who knows what next?

PHYSICS, MATHEMATICS AND ASTRONOMY

continued from page 15

The Caltech staff in astrophysics has grown greatly since the time that Fritz Zwicky and Joe Johnson, and maybe one other, were the only astronomers on our staff; but it still numbers less than ten people. Much of the astrophysics that Caltech has carried on has been in conjunction with the Carnegie Institution under the title Hale Observatories (which represents the Mt. Wilson and Palomar Observatories, Big Bear Solar Observatory, and eventually, probably CARSO—the southern station of the Carnegie Institution in Chile). Many of the things you read about—quasars, redshifts, deceleration parameters, cosmological constants, evolutionary effects, and things like that—come from Caltech and/or the Hale Observatories. Maarten Schmidt is on one side of a controversy that is now boiling about whether quasars are cosmological or relatively local. Nobody is sure. Some bits of evidence indicate one thing—other evidence indicates something else. It's nice that most of the people who worry about these questions, even though they're polarized, can remain friends about it. And it will eventually come out one way or another; people don't need to get personal about it. In the end, the universe will be like it is and not how we might wish it to be.

In the past 15 years Caltech has moved strongly into radio astronomy. We have a major (probably for universities, *the* major) radio observatory at Owens Valley. It has two dishes 90 feet in diameter and one 130 feet in diameter, and they are used to probe the structure of the many radio-wave-emitting sources out in the universe. Some of our people are participating in what is called VLBI experiments—very long base-line interferometry experiments. They find that some of the radio sources are changing in their angular size at such a rate that, if you interpret it as due to a velocity in the plane of the sky at the distance we think these sources are, we come out with speeds greater than the speed of light! Well, don't get worried; we don't believe it. But of course the science-fiction people jump right in and say: "We told you so."

Actually, much of the current research in the Kellogg Laboratory has to do with astrophysical questions, and much of the research that goes on elsewhere in the division is also directed toward astrophysics. The light-element nuclear physics that still goes on in Kellogg, with Van de Graf generators up to 10 or 12 million volts, is now directed toward understanding the processes by which stellar energy is generated. The cosmic production of the heavier elements is studied theoretically and to some extent experimentally at Kellogg. Our staff there has also taken the lead in the study of super-massive objects—elliptical galaxies, which often have radio sources in their centers. Our suspicion is that there's something at the center of those galaxies, down in the deep gravitational holes where matter can be held together in amounts greater than a star has. (A star just heats up in the middle, makes nuclear energy, and blows out the extra mass. But when you get inside a galaxy where matter is held in, maybe there can be objects quite unlike anything we can now imagine, with masses of tens or hundreds of millions of solar masses.) The laws of physics must be able to cope with these things; and if they can't, then we have to figure out what laws can cope with them.

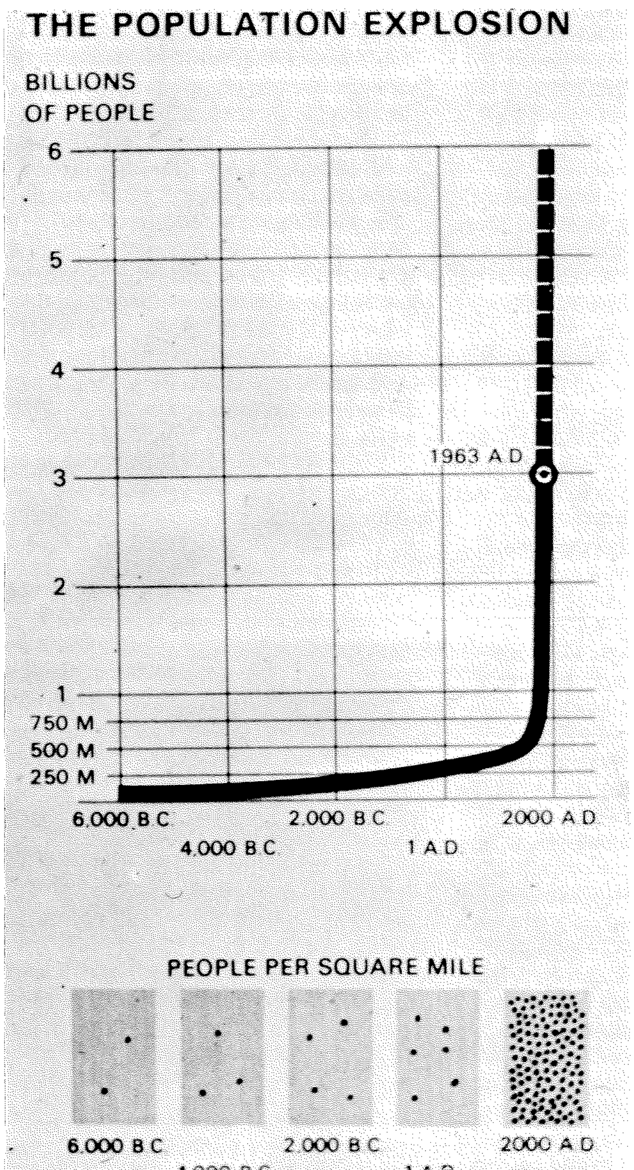
One of the big questions in Kellogg right now is: Where are the neutrinos? Neutrinos should be coming out from the sun. There's a detector down in a deep mine in South Dakota somewhere, with several thousands of gallons of chlorinated cleaning fluid to intercept neutrinos from the sun. There should be about six solar neutrino units (SNU's they call them) coming through the detector. But the measurements are down to less than half a SNU, and the number could be zero. There's no evidence of any neutrinos at all coming from the sun. That's a big problem.

We're still doing great things in cosmic rays, and Robert Millikan would be very proud of us. Remember, he was worried about where they came from and whether they were the birth pangs of atoms. We're still worried about where they come from. We still send up balloons just as he did, but now we also send equipment out in spacecraft and make *in situ* experiments. I think it's marvelous that Millikan's cosmic rays are still "in it" as far as our research is concerned.

As you can guess from the size of the things I've been talking about, much of this research is federally sponsored; much of it, of necessity, goes on away from the Institute; and much of it involves large budgets, time delays, and lack of flexibility. I should emphasize the importance of relatively modest, but readily available, funding. If we had as much as 1 to 2 percent of the divisional budget available yearly so that we could take advantage of an unanticipated opportunity—or start an activity which would lead to major funding from other sources, it would be a fantastic help. Only 1 to 2 percent! It isn't there. But we would like to see it.

afterburners to correct their poor combustion. The advantage of rotary engines lies in their lower emission of oxides of nitrogen, but they will need additional equipment to pass the 1975-76 federal standards of performance.

I would like to see all-electric transportation inside the cities, but this would only displace our problem of building more power plants. Moreover, the public is not yet in the mood to accept the limitations of present-day batteries. Turbines, now used for long distances, seem too cumbersome for the passenger car.



The "curve" of population growth for the world has become a line heading straight for trouble. In the U.S. at present the population increases at the rate of five persons per minute; the world's population grows even faster—five per second.

Fleets of vehicles and some private automobiles are being changed over to natural gas and LPG (liquid propane gas)—both low emitters. It is highly unlikely that the mandatory conversion—at a cost of $300 to $400—of all the ten million vehicles currently in use could be passed in the legislature (though conversion of fleet vehicles is well within the possibilities). And suggestions to use low-pollutant fuels, such as hydrogen or methyl alcohol, have not received much support. They involve reforming gasoline, which adds considerably to the price of the fuel and waste of reserves.

The venom sometimes directed at the internal combustion engine is actually rather silly. It is the *use*, not the instrument, that is the source of our troubles. Who determined that we should send half-a-million people to the center of Los Angeles every morning and see half-a-million (minus a few) come back every night? Who says that we must propel a 3,000- to 4,000-pound car to move a 160-pound person? Don't blame General Motors! We are the ones who make the decisions.

We make big noises about the difference of a few percentage points between the emissions of 1972 and 1973 cars. But two people in a car instead of one would bring about a 50-percent reduction in all emissions at no cost. (We would also benefit from not having to park and not wasting our minds in fighting traffic.)

Waste Makers

In recent years the sophism that the production of goods is the same as prosperity has opened a wonderland for a new industry that is based on waste. And a new profession, the "merchants of waste," has been born. With the phenomenal growth of industrial potential, new markets have to be found. Not that these markets necessarily represent actual needs. The sales departments create them by conditioning potential customers and luring them into buying things they really did not know they needed. All of this is not new, of course; only the squandering is worse—and on a larger scale.

Keynote speakers tell us that the individual should have the greatest variety of goods, services, and facilities. He should be able to choose the kind of habitat he prefers and enter many kinds of environment at will; he should have the maximum kind of personal control over his world. This is wonderful, of course, and a good election platform. Unfortunately, an average living space is now not more than 15 by 15 feet, and it gets smaller and smaller by the day. It is not only our increasing numbers that cause trouble. The higher standard of living, the social revolution, has demanded more and more energy. Today when a baby is born, the good fairy endows him or her with two gallons of fuel oil and one gallon of gasoline per day for the rest of his life. Every time a baby comes off the assembly line, three cars do the same in Detroit.

It is nice to have so much energy available. It is like having slaves. The amount of energy available to a single person, expressed in terms of human labor, would correspond to the work of 200 slaves. A simple turn of your ignition key, and several hundred horsepower—corresponding to a few thousand slaves—spring into action. The trouble is, of course, that the energy slaves are not very neat. Worse, they might ask that their wages be increased. Even worse, there might not be enough slaves to go around. What is the baby going to do when he doesn't get his "bottle" of fuel? I can tell you. He is going to kick and cry. That is how he got everything in the past. Why change a good racket?

The punishment for not solving either old or new problems may well be disastrous. Today (December 4, 1972) at 5:07 p.m. Eastern Standard Time, the demograph in the Department of Commerce building in Washington, D. C., showed that there are 210,234,507 persons in the United States. With an increase of 5 new citizens every minute, there will be a hundred million more of them by the year 2000. That is not far away, and the babies I mentioned earlier will want their food and play.

What Lewis Carroll's Alice foretold, when she said that she had to run twice as fast to stay where she was, is the effect of exponential growth: two times more power in ten years, two times more in another ten years—the relentless growth in population with all its dire consequences.

Measures designed to cope with the increase are timid and totally insufficient to keep up with the size of the problem. This goes for transportation, housing, education, health, and safety on our streets and in our homes. We can still change all this, but if we are incapable of adjusting ourselves to the pace of time, a power stronger than we will do it. The laws of nature will take over, and there is no mercy and no bargaining then.

continued on page 32

Measures designed to cope with the effects of exponential growth are timid and totally insufficient to keep up with the size of the problem. This goes for transportation, housing, education, health, and safety on our streets and in our homes. We can still change all this, but if we are incapable of adjusting ourselves to the pace of time, a power stronger than we will do it. The laws of nature will take over, and there is no mercy and no bargaining then.

The Sins of Waste . . . *continued from page 31*

We need to educate, to inform people, to present them with alternatives. We need to create public awareness of the pressing problems. We need to tell people that we *can* afford clean air and clean water, that cities don't have to look like overgrown parking lots—punctuated with towers that allow the inmates to look down upon the mess they made.

And I am not downhearted. A beginning has been made! All over the country, for the first time in history, plans have been drawn up about what to do about our problems. These plans have a tight schedule and an impressive program of enforcement. One can quarrel, and even be skeptical, about levels of control, thoroughness of implementation, and the time allotted for it. Nevertheless, the programs indicate for the first time what it is that has to be done and how gigantic the task is.

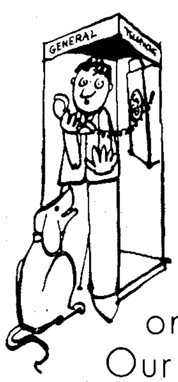
As my favorite statesman, John W. Gardner, once pointed out:

> There is something disheartening about the modern scene—the confusion, the disorder, the changing values, the constant push-and-pull of conflict, the vastness and impersonality of the systems that govern our lives.
>
> But at the same time, the possibilities of an improved life for mankind are more exciting than ever in the long history of the race. We hold in our hands the tools to build the kind of society our forebears could only dream of.
>
> We can lengthen the life span as they could not. We can feed our children better and educate them better. We can communicate better among ourselves and with all the world.
>
> We have the technology and the means of advancing that technology. We have the intellectual talent, and the institutions to develop it and liberate it. We have, or we can build, the systems and organizations, public and private, through which our common goals can be pursued.
>
> We have these things not because we are any smarter than those who came before us but because we can build cumulatively on their creative effort and achievements.
>
> Far less than any other generation in the history of man are we the pawns of nature, of circumstance and of uncontrollable forces—unless we make ourselves so.
>
> We built this complex, dynamic society, and we can make it serve our purposes. We designed this technological civilization, and we can manage it for our own benefit.
>
> To do this takes a commitment of mind and heart—as it always did. If we make that commitment, this society will more and more come to be what it was always meant to be: a fit place for the human being to grow and flourish.

And I add: No generation before us had a greater responsibility and no one had a greater opportunity to better our life on earth. Let us all join hands in this wonderful goal!

GTE Telecomunicazioni S.p.A., Via Turati 27, 20121 Milan, Italy   General Telephone & Electronics, 730 Third Ave., New York, N. Y. 10017, U.S.A.

We do more than gobble up coins.



General Telephone operating companies serve 11,500,000 telephones in North America.

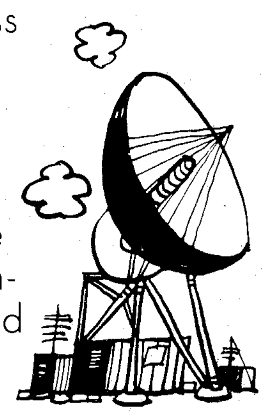
And even though we'll admit that has to add up to a lot of phones, we'd like to take this opportunity to remind you that General Telephone is only our first name.

Our last name is Electronics.

And that covers a lot of ground.

It covers GTE Sylvania, which, as you probably know, manufactures everything from flashcubes, flashbulbs, and lightbulbs, to television sets and stereo systems.

But did you also know that GTE Sylvania makes hundreds of electronic components for business and industry?



It covers GTE Automatic Electric, a major manufacturer of telephone equipment in the U. S., whose products include new computerized electronic switching equipment for telephone exchanges.

And it certainly covers the people who specialize in solving the problem of easy access to computer-stored information: GTE Information Systems.

And GTE International, not only a world leader in the construction of microwave transmissions systems and satellite communications earth stations, but with manufacturing and marketing operations in 30 countries to meet the demands of telecommunications, lighting and home entertainment markets.

And GTE Lenkurt, another one of our companies that specializes in the manufacture and installation, all over the world, of microwave, multiplex, carrier, and coaxial transmission systems for video, voice, and data telecommunications.

That should give you a brief idea of what we're doing when we're not gulping down all those coins.

And why we'd like to be known by our full name. GTE

GENERAL TELEPHONE & ELECTRONICS

HOW CAN A 5" WIDE TUBE HELP KEEP AN ENTIRE CITY FROM GRINDING TO A HALT?

What you're looking at is a cross section of a new kind of cable ...part of a revolutionary new system being developed by General Electric engineers and researchers.

It works on the theory of cryogenics. What's it got to do with keeping a city running? Plenty.

Put three of these cables inside an underground pipe, then cool them with liquid nitrogen to −320°F, and you've got an electric power line that could carry as much as 3,500 million volt-amperes.

That's about ten times more power than any conventional underground transmission line can handle.

This is important because of the soaring need for electricity. Demand may double in the next 10 years alone. Some electric transmission lines are already loaded to capacity. And land for more lines, particularly near the big cities, simply isn't available any more.

But a single cryogenic line could deliver enough power to keep a city of a million people running. And it could be buried beneath the ground where nobody would see it.

It's a clear example of how a technological innovation can help meet people's needs. A lot of times the effect of technology on society can be rather direct.

That's why, at General Electric, we judge innovations more by the impact they'll have on people's lives than by their sheer technical wizardry.

Maybe that's a standard you should apply to the work you'll be doing. Whether or not you ever work at General Electric.

Because, as our engineers will tell you, it's not so much what you do that counts. It's what it means.

GENERAL ELECTRIC