CALIFORNIA INSTITUTE OF TECHNOLOGY

Engineering and Science

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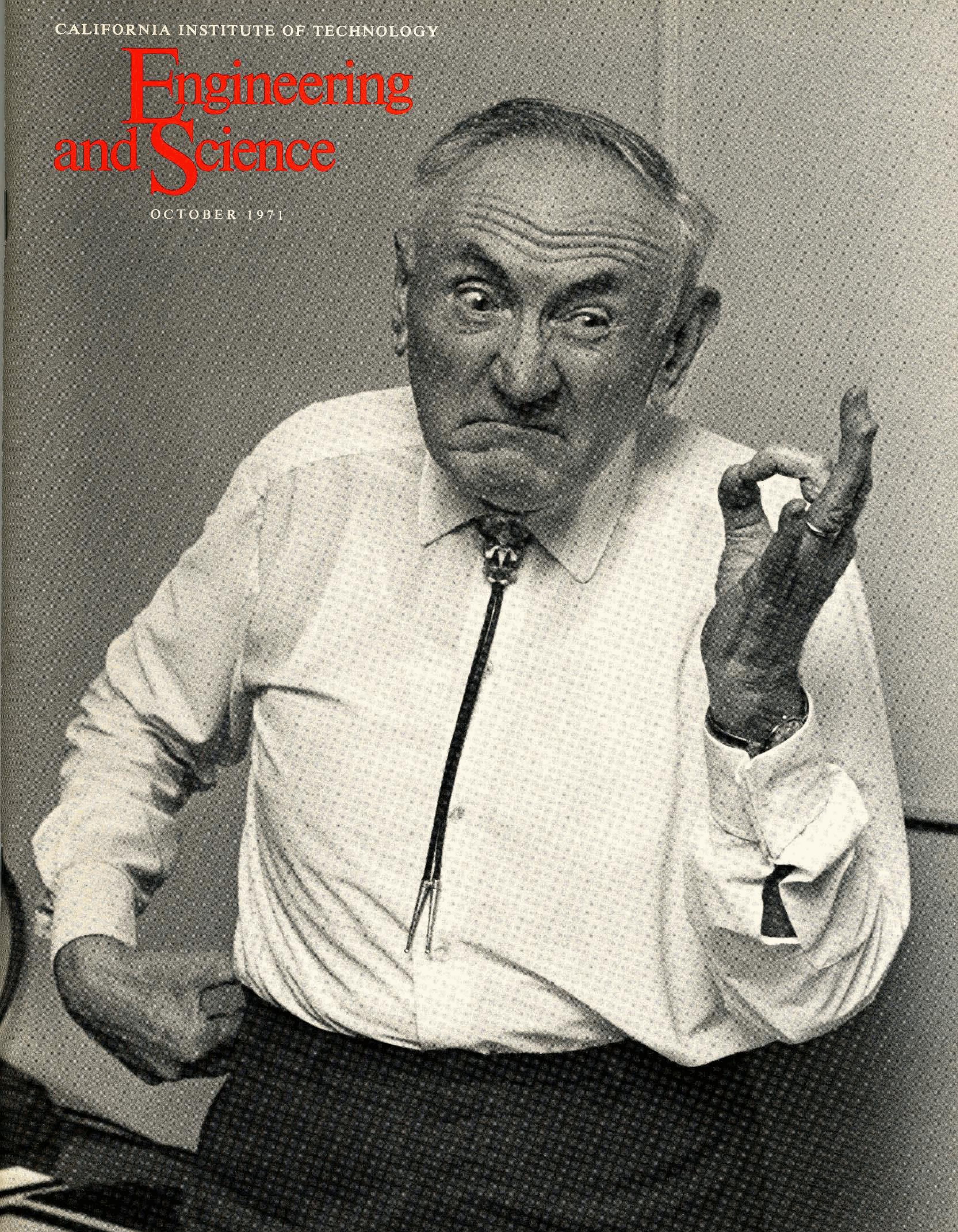

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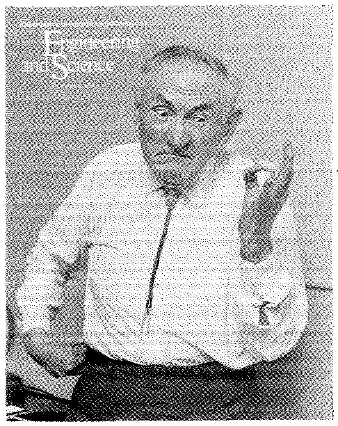

Engineering and Science

In this issue

Actions Speak Louder

On the cover—Fritz Zwicky, professor of astrophysics, emeritus, is giving a graphic demonstration of how to communicate without words. It's a talent shared by many successful teachers—as evidenced by the photographs of some colorful Caltech communicators ("Words Fail Them") on page 21.

Stirring Up the Dust

C. J. Pings is Caltech's vice provost, dean of graduate studies, executive officer for chemical engineering, and professor of chemical engineering and chemical physics. Several years ago he was also chairman of Caltech's Aims and Goals Committee, which in 1969, after long debate, issued a nine-volume report. In "Aims and Goals—What Ever Happened?" on page 6, Pings reconsiders the recommendations in that report.

Biological Blessings

"A Treatise on Doing Good" (page 11) is adapted from a talk given by James Bonner, professor of biology, on Alumni Seminar Day last spring.

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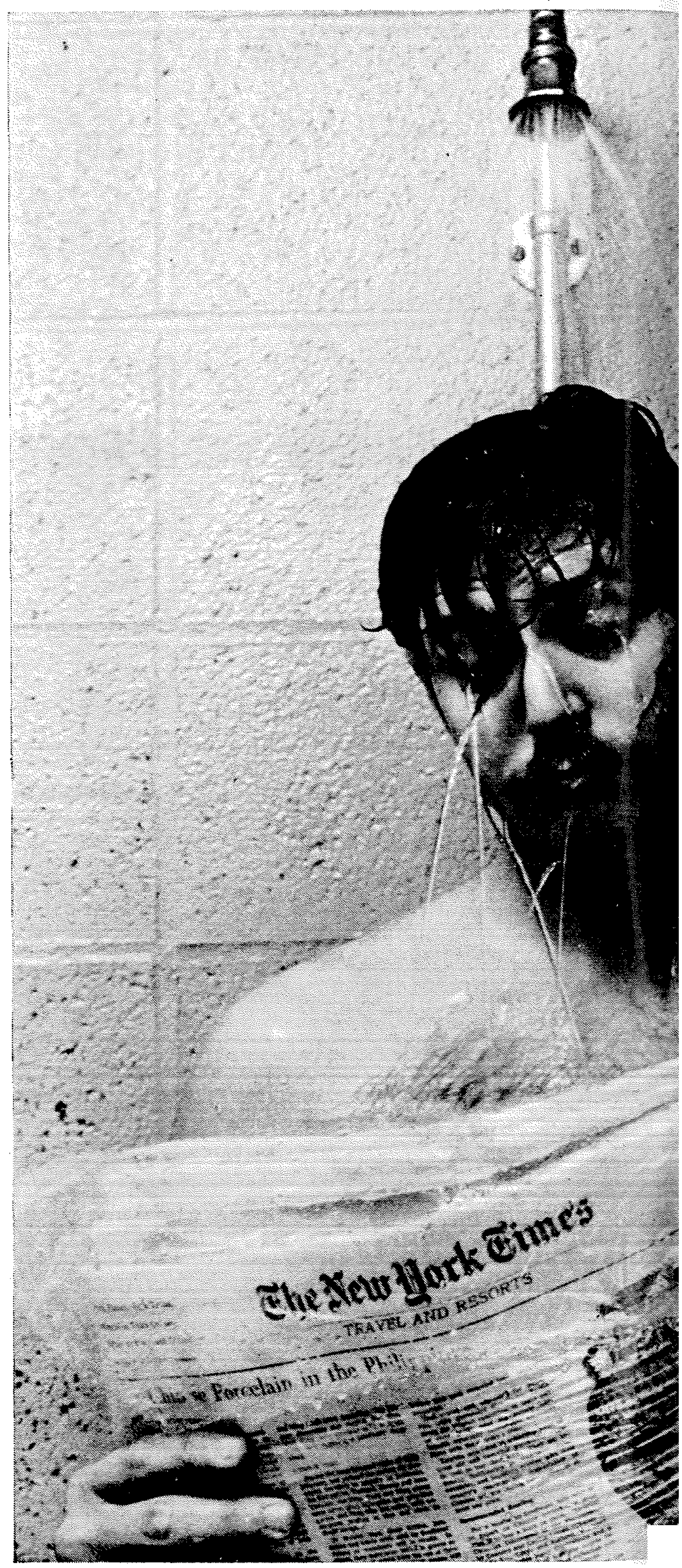
We keep the news fit to read.



Aims and Goals—What Ever Happened?

In June 1967 the chairman of the Caltech faculty appointed a committee of faculty members to study the question of the long-range goals and objectives of the Institute. In May 1969 the committee issued a nine-volume report. *Then* what happened?

A Foreword: A little ancient history

From the minutes of the meeting of the Caltech faculty February 27, 1967: "Professor C. A. Mead stated that in recent years he has come to the feeling that many of the major decisions affecting the long-range character of the Institute are made without sufficient involvement or communication with the majority of the faculty. To these faculty, items such as the new fund-raising development drive appears as a *fait accompli* without a clear discussion of the needs and requirements for such a drive or even of the desired direction for the Institute growth. Accordingly, he moved that the chairman appoint an ad hoc faculty committee to study the question of the long-range goals and objectives of the Institute."

A committee was appointed on June 1, 1967, by Jesse L. Greenstein, then chairman of the faculty. This group of 20 to 25 faculty members became known as the Aims and Goals Committee, and it met relatively frequently over a two-year period. The activities culminated in the publication of a nine-volume preliminary report in May and June of 1969. The results of the deliberations of the Committee were summarized in an article in the May 1969 issue of *Engineering and Science*. That article listed the some 70 specific recommendations of the committee on topics including general problems of growth and change, decision making at the Institute, undergraduate life and education, graduate students and research fellows, humanities and social sciences at Caltech, relations with the community, and JPL and other off-campus facilities.

In sending its report to the chairman of the faculty, the committee noted: "In preparing this report our objectives are rather modest. Primarily we are anxious to identify problem areas worthy of attention from either or both the administration and faculty. On issues so identified, we have attempted to indicate the range of views held by the committee members. In certain cases the views so assessed are tantamount to a consensus. On the other hand, we have not let the absence of a unified committee position deter the statement of a problem or an attempt to measure the spectrum of opinion on the subject.

"The ultimate disposition of this report will depend upon the will of the general faculty. Possibly our own reflections and the reactions of others will lead us to want to submit a revision as a final draft. In any event, we anticipate the dissolution of this committee before the end of 1969."

The committee was formally dismissed by the Faculty Board in February 1970.

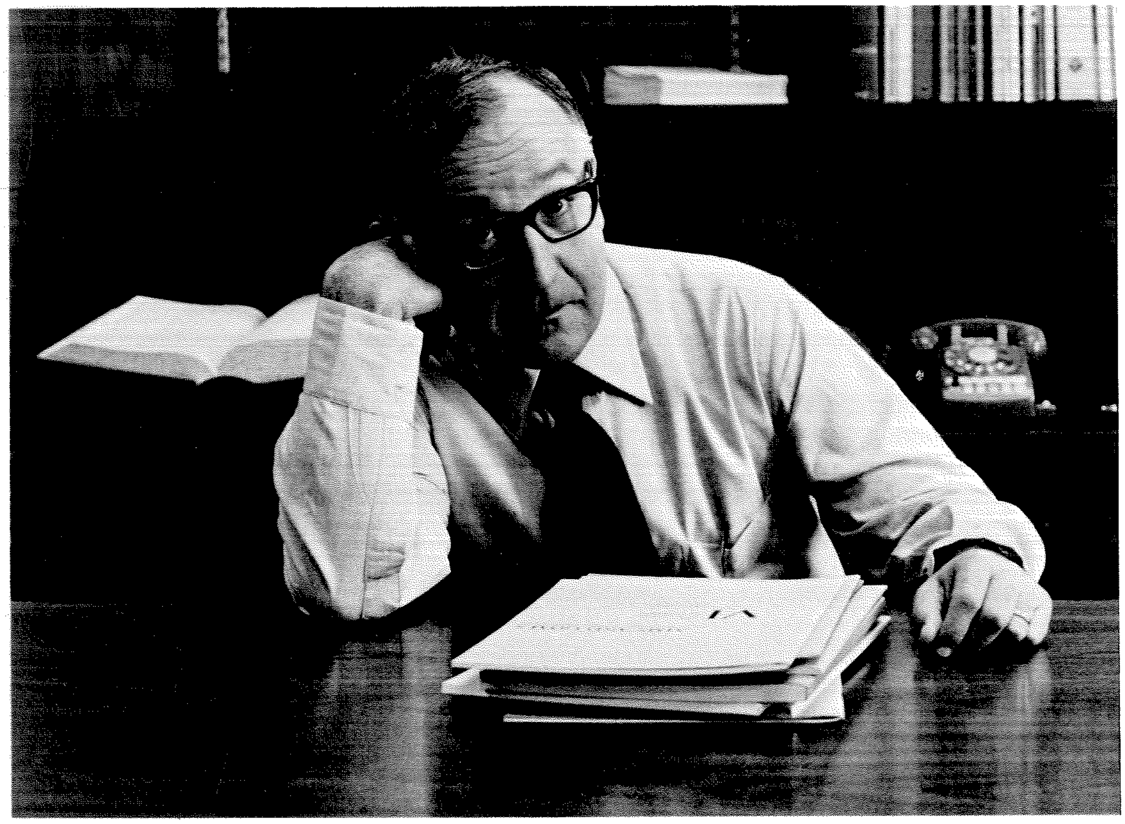
There can be no doubt that the activities and goals of the Aims and Goals Committee are of little current interest. In fact, reporting on their status now reminds me of the words of the contemporary American philosopher, Satchel Paige: "Don't look back. Something might be gaining on you." But I am also intimidated by the threat of the late George Santayana that "those who cannot remember the past are condemned to repeat it." In spite of the double-edged threat, I feel an up-to-date assessment may provide interesting perspective on the recent and current status of the Institute and its adaptation to the exigencies of our times.

Assessment of the effectiveness of the Committee's impact upon the campus must, of course, be largely subjective, and I can hardly be regarded as a dispassionate observer. Furthermore, it is obviously difficult to assign cause and effect. Many of the changes called for by the Committee have taken place, but undoubtedly would have done so even if the Committee had never existed.

The Committee report first received formal and thorough review from the administration of the Institute. The Institute Administrative Council, for example, spent at least one full working day thoroughly discussing all recommendations directed wholly or in part at the administration. In addition, the document was called to the attention of the Board of Trustees, and I am sure that Chapter IV of the Aims and Goals Report, "Decision Making at the Institute," prompted a panel discussion on that topic at the National Trustees meeting held in Palm Springs in October of 1969.

Second, the documents were made available to various student groups, but to my knowledge no formal review was undertaken by the undergraduate student body. However, ASCIT officers have subsequently taken it upon themselves to urge a number of the adaptations and student reforms called for in the Committee report.

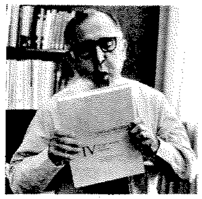
Third, and perhaps surprisingly, one group has clearly defaulted so far on the matter of undertaking any formal review of the recommendations of the Committee: *the faculty*. At the time of the disbanding of the Committee in



Neal Pings, chairman of Caltech's Aims and Goals Committee, reconsiders the Committee's objectives and achievements.

February 1970, detailed recommendations were given to the faculty board for referral of various points to stipulated standing committees or special committees of the faculty. That review has not been carried out, nor is it likely to be done. In several cases this inertia of the faculty's political system has probably resulted in the loss of easy opportunity to open further inquiry on important topics. But it is my personal opinion that, in a variety of diffuse ways, the Aims and Goals Committee has nevertheless affected the attitude and actions of the faculty, perhaps in some cases in ways that are more fruitful than formal review of the Committee's report.

Some significant changes in the Institute which were at least anticipated to some extent, if not caused, by the Aims and Goals Committee have taken place. Perhaps paramount is the seemingly general, tacit acceptance of the Committee's reiteration of the fundamental principles of operation of the Institute: special emphasis on small size, and quality and excellence in a selected few areas of intellectual inquiry. It is conceivable that reemphasis of this position actually caused reduction in scale—and



Some of the Committee's recommendations regarding the governance of the Institute actually seemed bold at the time.

stretch-out in pace—of developments in the areas of social science compared to plans envisioned by some in 1966. However, growth and diversification in those areas have gone ahead on a very sound basis. The addition to our faculty, during the last two academic years, of a half dozen promising young scholars in the areas of political science and economics is particularly noteworthy.

A procedural matter recommended by the Aims and Goals Committee was adopted almost immediately by the administration: a more formal identification of the Institute Administrative Council, the central governing body for the campus. The identity of membership of that group and its role in establishing Institute policy are now clear.

The Committee made several other recommendations regarding the governance of the Institute, some of which actually seemed somewhat bold at the time. For example, "Graduate and undergraduate students should be more effectively involved in the decision making process of the Institute." Mind you, at the time that recommendation was made, the *Aims and Goals Committee itself had no student representation.* Only one year later, the faculty had formally amended its bylaws in order to allow significant student representation in all the elected faculty committees. Undergraduate and graduate student representatives are invited to every faculty board meeting and to many faculty meetings. They do not vote in those meetings, but frequently enter into discussion, particularly on topics related to student affairs. Student participation has been almost uniformly useful and constructive. Indeed, certain of the faculty committees now have the attitude that they simply cannot hold a meaningful meeting without the designated student representation. These changes have all taken place in the spirit of cooperation, without formal demands, and with no acrimony. Incidentally, I believe that this is one change that clearly would have taken place whether or not the Aims and Goals Committee had existed. However, the acceptance by the faculty of this reform over a relatively short time period may well have been aided by the Committee's recommendations.

The Committee made a number of recommendations on undergraduate life and education including, "The undergraduate operation is important and essential. The existing program has much to recommend it, but there are opportunities for major improvements which should be seized. Much greater flexibility in the undergraduate curriculum is needed. Individual options should be encouraged to offer several alternate means for satisfying their requirements. The common freshman year should no longer be regarded as essential for all students. Innovation, experimentation in all aspects of undergraduate education should be encouraged, supported and rewarded."

The climate established by such a recommendation probably provided encouragement to the chemistry faculty in its decision two years ago essentially to remove all formal requirements for the BS degree in chemistry. Students, of course, still take rigorous and demanding programs in the chemical sciences, but the details and amounts of study in various areas, sequence of courses, etc., are worked out between the student and a faculty adviser.

Last year the biology faculty created the Biology Scholars Program. "This program permits for a small number of biology juniors and seniors the formulation of individual academic programs combining course work and independent study adapted to each student's interest and requirements. Each program must be acceptable to and supervised by a faculty committee. Work is undertaken and evaluated on the basis of a written contract between the student and his committee of instructors."

This concept of specially designed courses of study has now been adopted on an Institute-wide basis with the beginning this fall of an Independent Studies Program. For the first time, a student may graduate from the Institute without necessarily affiliating with any of the conventional options or majors; rather, the student works out an undergraduate course of study with the advice and supervision of a three-man faculty committee. Such programs may involve particular combinations of existing courses but may also have a substantial component of independent research or specially arranged tutorial sessions. The program allows the individual student to propose courses that

The Committee recognized that its report would be an opportunity to give our new president some indication of faculty views and concerns.

may fall outside ordinary course offerings in order to accommodate his particular program of study or research. It is expected that during the fall term three undergraduates will be pursuing courses of study towards the BS degree under this Independent Studies Program.

In 1971 a new applied physics option became available to both undergraduate and graduate students. This is a program that cuts across conventional divisional lines with a group of faculty drawn from the divisions of physics, engineering and applied science, chemistry and chemical engineering, and geology. Graduate programs in environmental engineering science are now available, again cutting across divisional lines to permit close interaction among engineers, scientists, and social scientists.

The Aims and Goals Committee called for a review of the Institute's association with the Jet Propulsion Laboratory. This request was unfortunately misunderstood by some who apparently felt that the Committee held the belief that the result of such review would inevitably carry negative connotations. This was not the intention, and in actual fact such a review has taken place with generally beneficial results. There has been a significant increase in the number of research programs carried on jointly by JPL staff members and Institute faculty members. This without a doubt has been fostered significantly by substantial research funds made available both through the Director's office at JPL and from the President's office at the Institute. Other beneficial changes have taken place. Students and faculty from the campus may now come and go freely on the JPL grounds, with minimal identification procedures. Last year the faculty formally passed new rules for the first time permitting programs of study on the campus by Laboratory staff members.

The Committee was perhaps perceptive in anticipating some of the problems of our society and its impingement upon our educational institutions. "We foresee the possibility that a new type of national and international crisis (environmental degradation, for example) may require of Caltech something beyond a mere expression of opinion. In such a case, the Institute consonant with its widened sense of social responsibility may wish to involve itself more actively by sponsoring a major problem-solving venture analogous to the Institute's World War II activities." And, of course, the Institute has now made such a commitment in the form of the newly created Environmental Quality Laboratory. That group is at the present time nothing like the size of the World War II programs. Nevertheless, the birth of EQL clearly signals readiness on the part of the Institute's administration and faculty to devote some portion of our resources to problems of current great social concern.

Suppose for a moment we invert the process and ask what effect the Aims and Goals Committee activity might have had upon its members. The answer is obvious. We now have two dozen or so members of our faculty who are considerably better informed and more perceptive to the real problems of the Institute, both present and those that will be forthcoming. And that awareness has surely spread out among the faculty, both as a result of the Committee's report and perhaps more importantly from ongoing dialogue with those faculty members who served as Committee members.

I am sure that all members of the Committee felt at times that the chairman had driven them unmercifully and unreasonably toward the publication of a final report. I would guess that, by now, most members of the Committee and perhaps even many of the faculty in general are thankful and pleased that a report was published. There seems no doubt that the document did help to focus community attention on certain classes of problems. Furthermore, we recognized this as an opportunity to give our new president, Harold Brown, some indication of faculty views and concerns on a wide range of topics.

On the other hand, it was said a number of times during Committee deliberations that the Aims and Goals Committee would have served a significant purpose even if it had never issued a single memorandum, much less published the extensive report it did. This assessment was based on the feeling that this group of individuals, amount-

ing to almost 10 percent of our total faculty, which spent close to two years working together on institutional introspection could not help but develop some new understanding and appreciation of the problems of our university. Furthermore, the very process of inquiry carried out by that Committee affected large segments of the campus, causing individuals and groups to think out their role in the structure of things at the Institute in order to be able to respond intelligently to the request of the Aims and Goals Committee for information.

Enough time has passed now that a curious bit of history has become glaringly evident about the Committee members as individuals. A striking number of participants in the Aims and Goals Committee activities have subsequently assumed significant administrative positions, either at Caltech or at other institutions. The original Committee was scrupulously constructed so as to include no administrative officers. However, over the past four years 14 of us have succumbed to administrative assignments. At the Institute in the areas of general administration, faculty, and student affairs, there are currently some 24 administrative positions; during the present academic year, *13 are filled by former members of the Aims and Goals Committee.* Every man can have his own reaction to such statistics, but it is hard for me to escape the conclusion that the Aims and Goals Committee activity had a profound effect on many of its members. Almost all former members of the Committee have become influential in campus affairs, and many have responded to requests to assist with Institute administration.

Administrative involvement may or may not be judged significant. However, an informed commitment to the affairs of the Institute by a group constituting 10 percent of its faculty takes on an importance that will loom large many years after the Aims and Goals Committee, its activities, and its reports are forgotten.

An Afterword: A story with a moral?

Once upon a time (June 1967) the chairman of the faculty appointed a committee to study the aims and goals of the Institute. The chairman of the faculty (Professor Jesse Greenstein) was very wise, for he appointed to that committee no faculty members holding any administrative position at the Institute. The Committee labored and produced a report. Copies of that report now gather dust in many offices on the campus, and the Committee has long since been disbanded. However, four years later, members of that Committee have yielded in large number to requests to assume administrative positions either at Caltech or other institutions. Note the record of recent or current (in italics) positions held by members of that Committee.

Norman H. Brooks—*Academic Officer for Environmental Engineering Science*
Robert F. Christy—Executive Officer for Physics; Chairman of Faculty; *Provost*
Julian D. Cole—*Chairman, Department of Mechanics and Structures, University of California at Los Angeles*
Robert S. Edgar—*Provost, Kresge College, University of California at Santa Cruz*
Roy W. Gould—*Assistant Director, Controlled Thermonuclear Research, Atomic Energy Commission*
George S. Hammond—*Chairman, Division of Chemistry and Chemical Engineering*
George W. Housner—*Chairman of the Faculty*
Robert A. Huttenback—*Dean of Students; Acting Chairman, Division of the Humanities and Social Sciences*
Wilhelmus A. J. Luxemburg—*Executive Officer for Mathematics*
Cornelius J. Pings—*Vice Provost; Dean of Graduate Studies; Executive Officer for Chemical Engineering*
Robert L. Sinsheimer—*Chairman, Division of Biology*
David R. Smith—*Master, Student Houses*
Gerald B. Whitham—*Executive Officer for Applied Mathematics*
Robert Woodbury—*Dean of Students, University of Massachusetts*

So far the following members of the Committee have had the will power or good judgment to avoid such duties: Fred C. Anson, John F. Benton, Harry B. Gray, Floyd B. Humphrey, Herbert B. Keller, Thomas J. Lauritsen, Frederick B. Thompson, Rochus E. Vogt.

The moral of this tale is left as an exercise to be worked out by the reader.

A TREATISE ON DOING GOOD

It's not so hard for biologists to do societal good if the problems selected are simple enough.

by James Bonner

James Bonner's miniature replica of a section of the trunk of a rubber tree was presented to him at a National Rubber Conference in Kuala Lumpur, Malaysia.

My principal research is finding out how genes and chromosomes work, and in recent years my colleagues and I have discovered quite a lot. No doubt one day some of our findings may even be useful. But the fallout of public good is still in the future, and today there is increasing demand for science to be relevant, for it to solve or at least ameliorate social problems. A growing number of people are looking at science and scientists with a what-have-you-done-for-me-lately? attitude.

In response, we have the National Science Foundation setting up its Research Applied to National Needs Program; the National Institutes of Health announcing a goal of curing cancer by 1975; and Caltech establishing its Environmental Quality Laboratory to help solve urgent societal problems.

While such directions are being pursued on a high-priority level, let's remember that doing good can be effected in an infinite number of ways. There are all kinds of areas where it's not only easy, but takes relatively little time. Since I have had a few absorbing experiences as a consultant in the line of useful scientific activity, I would like to put into the record two of my modest attempts to do something useful.

I start with a historical digression. During World War II, I was requested by our government to help find out how to produce rubber. All rubber then came from the rubber tree, *Hevea*, grown mainly on plantations in Malaya and Indonesia. When the Japanese occupied these countries in 1941, our rubber supplies were cut off. The Emergency Rubber Program, to which I was assigned, carried out massive experiments on the cultivation of rubber-producing plants that would grow in the United States:

My experience with the Emergency Rubber Program did not produce a whole lot of rubber, but I did learn that no one knew how rubber trees make rubber.

guayule, goldenrod, Russian dandelion, and others. We also produced rubber from the usual rubber tree, *Hevea*, which grows wild in tropical Mexico and Guatemala. The rubber emergency was, of course, eventually met by finding out how to synthesize rubber substitutes chemically. The substitutes were much less satisfactory than real rubber but better than nothing at all.

My experience with the Emergency Rubber Program did not produce a whole lot of rubber—perhaps about enough to recap a couple of bicycle tires—but I did learn that no one knew how rubber trees make rubber. I took up this problem after the war, and in 1960 the Malaysian government invited me to the capital, Kuala Lumpur, to talk about rubber matters with rubber producers and with scientists of the Rubber Research Institute of Malaya, the biggest and best research institute in all of southeast Asia.

As a result of my first visit I was asked five years ago by the Malaysian government to become an adviser on all matters of development, and in 1967 I went to Malaysia again and spent a month looking over the situation to determine where the most good might be done. In Malaysia the rubber crop is the greatest contributor to the gross national product, a prime source of capital formation and of foreign exchange, and the principal factor in Malaysian development. Obviously, in view of the central importance of the rubber economy, the best place for me to do good was in rubber, and this made my biochemical research into the rubber-making process useful.

The rubber tree produces its rubber as a latex—that is, rubber particles suspended in an aqueous solution of proteins. Latex is produced and contained in long, pipe-like cells in the bark. Sugar, made by photosynthesis in the leaves, moves down to the bark through another series of "pipes" and leaks into the latex cells where various appropriate enzymes convert it to rubber. Eventually, rubber constitutes 35 percent of the latex.

At this level the rubber-making enzymes turn off, and the latex just sits there until the rubber tapper comes along to collect it. The tapper removes a spiral of bark from a third of the tree's circumference. The latex, under a pressure of about 10 atmospheres, squirts out of the cut vessels, runs down into a little spigot fastened to the end of the cut, and drips into a cup below. As flow continues, latex moves to the tapping cut from further and further away. It flows more and more slowly until, in about an hour, it coagulates at the cut.

After the flow ceases, water from within the tree flows into the latex cells, signaling them to produce enzymes. In about 48 hours rubber concentration is back up to 35 percent, and the tree is ready for tapping again. The tree may be tapped like this every other day forever. In this way over a million tons of rubber a year are produced in Malaysia, each acre yields an average of a half ton a year, and one billion dollars a year flows into the economy.

When the rubber tree is tapped, latex flows to the cut from as much as two feet away before it stops. Since the tree may be 50-60 feet tall, it is obvious that it would be nice to get more of the tree into the action. Two taps separated by six or eight feet are practical; in fact, they double the yield. But tapping from a stepladder consumes too much time. The question in 1967 was how to get more of the tree to supply latex, and to resynthesize each day, from a single tapping cut. We already had a hint of sorts.

In the late 1950's it had been found in Malaysia that application of the compound 2,4-D to the bark of the tree beneath the tapping cut caused latex to flow 10 to 15 percent longer than normal. In South Vietnam, at the time a considerable rubber producer, it had been found that applications of copper sulfate to the bark do exactly the same thing, and cause exactly the same sort of increase in yield. How can two such diverse chemicals cause the same end result? It would seem impossible.

To explain why it was not impossible requires another digression. During the years 1966-69 the division of biology at Caltech had worked on a crash program to try to find out how to harvest oranges mechanically. Florida faced a crisis because of a new law prohibiting the importation of Mexican labor to handpick the state's massive commercial crop of oranges. Our help was recruited by the director of the Citrus Research Division of the U. S. Department of Agriculture, a Caltech alumnus and former student of mine, William C. Cooper (MS '36, PhD '38).

We already knew that fruits or leaves fall off of plants in response to the gas ethylene. This substance, a plant hormone, travels to the base of leaf or fruit and turns on genes for making enzymes. The enzymes digest the adjacent cell walls, weakening the cells which join fruit or leaf to stem so that the fruit or leaf drops off. To solve Florida's problem we concentrated on trying to find out how to get oranges to produce ethylene to make themselves fall off the tree. Copper sulfate turned out to be

The world's ability to gobble up rubber is still increasing exponentially. Everyone appears to want wheels.

excellent for this purpose. Sprayed on fruit, and in particular in combination with ascorbic acid, it damaged cells, which caused the fruit to produce ethylene. It was already known that the application of 2,4-D in other plant tissues causes ethylene production.

Ultimately our group found a usable, totally non-toxic, biodegradable material—now approved by the Food and Drug Administration. Named cycloheximide, its spray on orange trees makes the ripe fruit fall off, but it doesn't affect either green fruit or leaves. Today Florida's oranges—and this means 200 million boxes a year—are increasingly being harvested by first spraying the trees with cycloheximide to decrease pull strength of the fruit, then blowing oranges off with a wind-blast, and finally picking them up with an oversized vacuum cleaner.

The problem is solved. Insofar as it is a societal problem—and it certainly was a Florida societal problem—a societal problem has been cured.

End of digression and back to Malaysia. Both 2,4-D and copper sulfate cause ethylene production in plants—although, to be sure, in different plants. Could it be that both agents cause *Hevea* bark to produce ethylene, and might it be that ethylene is the common agent through which both work?

We and our colleagues at the Rubber Research Institute of Malaya wrapped the trunk of a rubber tree in a big polyethylene bag. We brought a cylinder of ethylene gas from Bangkok, got a skilled tapper to tap the tree, and then injected ethylene into the bag. The result was spectacular! The latex flowed from the cut for several days. In fact, the tree oozed from every insect puncture wound. We concluded that we really had something.

But it is very unhandy to apply ethylene to trees in polyethylene bags, just as it's no use having the tree leak uncollectable latex. Better control of application had to be invented. The director of the Rubber Research Institute of Malaya, Dr. B. C. Sekhar, set up an interdisciplinary committee to tackle all the problems at once. It quickly developed that an excellent way to apply ethylene to *Hevea* is in the form of the compound ethrel (chloroethylphosphonic acid), which—in alkaline solution—decomposes spontaneously to form ethylene, HCl, and phosphoric acid. The ethrel is dissolved in palm oil, a local product, and applied with a paintbrush to a two-inch-wide strip below the tapping cut. As the chemical slowly diffuses into the bark, it is converted to ethylene, which causes the latex flow to continue for several hours rather than for one. It also results in latex draining from about six feet away from the tapping cut instead of from two. A single application is effective for at least two months; a second application may be made with equal effect; and the treatment costs 25 cents an acre. The yield of rubber per acre is doubled under the least favorable conditions and tripled under the most favorable.

In the fall of 1968 our experimental work was far enough advanced to justify the setting up of large-scale field trials. These were done in every Malaysian state, and with every important variety of rubber tree. The trials have been under way for several years, and no damage is evident to any of the trees.

I am happy to report that now the new technology is spreading like wildfire throughout the rubber tree area in Malaysia. It seems clear that this one innovation will, by itself, double the gross national product of Malaysia and thus help to speed the transition of that country from an agricultural to a modern, industrial, technological society.

But will all that increased natural rubber supply depress its worth? Not likely. The world's ability to gobble up rubber is still increasing exponentially. There are still more people without wheels than with them, and everyone appears to want them. Natural rubber's place in the world is assured. The United States is Malaysia's biggest customer, followed by Japan, Russia, and mainland China. In the United States airplane tires and all large heavy-duty off-the-highway tires must be made with *Hevea* rubber; so must most of the passenger car radial tires—and the use of radial tires is growing rapidly.

So my conclusions are: (1) It's not so hard for biologists to do societal good if the problems selected or presented are simple enough. Basically it's not difficult to make oranges fall off trees in Florida, and it will certainly save those Florida folks a lot of backaches; and (2) it would appear to be easier to do really meaningful societal good in a developing country with a technological problem than to do the same thing in a developed country. Imagine trying to double the gross national product of our own country in five years.

And finally—to try is good, to succeed sublime!

JOHN R. PIERCE

J J COUPLING

J. J. Coupling—glider pilot, science fiction writer, computer music composer, engineer, administrator, scientist, technical author, inventor, systems specialist, communications wizard, psychology buff, and pioneer satellite communicator—is back at Caltech. To stay.

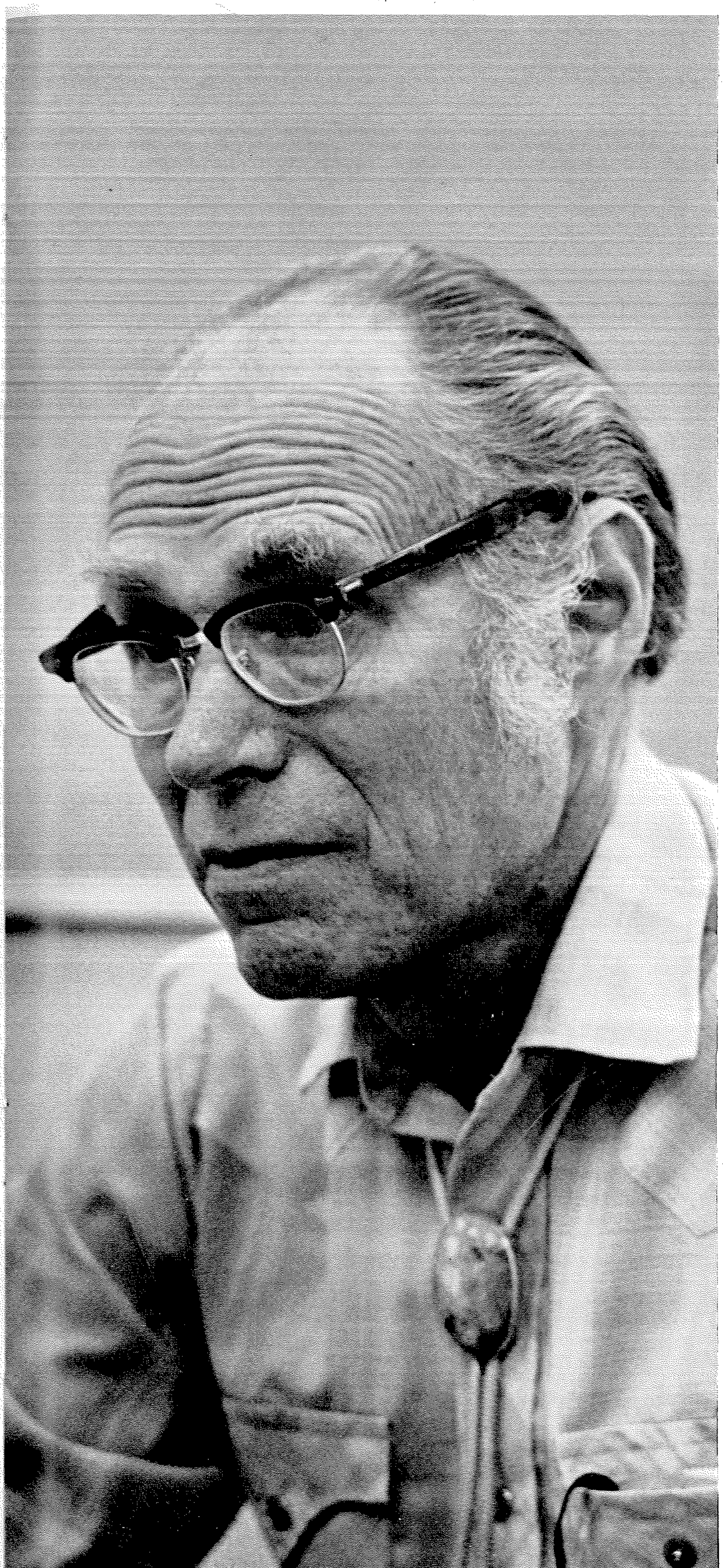
He has agreed to settle down in exchange for an office at 115 Steele Laboratory and a title: professor of engineering. The name on the door reads "J. R. Pierce," an alias Coupling has used off and on for more years than he likes to talk about and which he has distinguished considerably since 1936. That was the year he left Caltech with his shiny new PhD degree to begin a notable 35-year career at the Bell Telephone Laboratories.

At that time he was known simply as John R. Pierce. That's what he was christened back in 1910 in Des Moines, 17 years before his father—once a traveling salesman in ladies' hats and later a partner in a millinery chain—retired and settled in Long Beach. "John R. Pierce" also appears on his three Caltech diplomas, 84 patents, 13 books, scores of technical articles, two record albums, a marriage license (shared with his musician wife, Ellen), and assorted other personal documents, including his acceptance letter at Caltech.

Still, Coupling has been around too long to be intimidated by the competition from Pierce or to accept total eclipse gracefully. J. J. surfaced after Pierce went to Bell Laboratories and developed second thoughts about how his own name on stories and articles in science fiction magazines (he was already a veteran contributor) might affect his employers. He plucked the pseudonym "j-j coupling" from atomic physics (it describes certain reactions in atoms), and it has since appeared as the by-line on numerous articles and fantasies carried by such magazines as *Astounding Science Fiction.* It was this magazine that in 1952 published Coupling-Pierce's "Don't Write: Telegraph!" a pre-Sputnik treatise on space communications that foreshadowed much more concrete accomplishments in satellite technology by Pierce and His Bell Laboratories colleagues.

Pierce's first publisher, Hugo Gernsback, created the world's first science fiction magazine, *Amazing Stories,* and later edited *Science Wonder Stories,* which printed Pierce's first science fiction story—"Relics of the Earth in March 1930." Writing for Gernsback didn't seem to interfere with Pierce's other literary pursuits—stories, articles, and poems in campus publications. It didn't hurt his scholarship either; he graduated with honors in electrical engineering. William Smythe, professor of physics emeritus, taught Pierce for three terms of electromagnetic theory and recalls him as a fast-moving blur who was "very original and had a lot of sidelines" but through it all remained "one of the top students." This was no small accomplishment considering that his classmates included Simon Ramo, William Fowler, Dean Wooldridge, and the Clauser twins, Francis and Milton.

Francis, now chairman of the division of engineering and applied science, supplied the decisive blandishment, but the campaign to lure Pierce away from his comfortable Murray Hill, N. J., office onto the Caltech faculty began at least 10 years ago under Clauser's predecessor, Fred Lindvall. Pierce steadfastly refused to be wooed, so Clauser's shock was understandable last June when he answered his phone and heard Pierce matter-of-factly announce, "You know, I think I'd like to come to California." The act wasn't as precipitate as Pierce's account makes it seem, although he does admit that his habit of "acting quickly once I've made up my mind" is sometimes fused with impulsiveness by his associates. For the record, he has been a regular visitor to the campus since he joined Bell Laboratories, and he and his wife spent "a satisfying week" in Pasadena last April when Pierce gave



J. J. Coupling, otherwise known as John R. Pierce, is back at Caltech. To stay.

a talk on "20 Years of Computers and Music." They were back again in June "to look at houses" and decided for Caltech on the plane ride home.

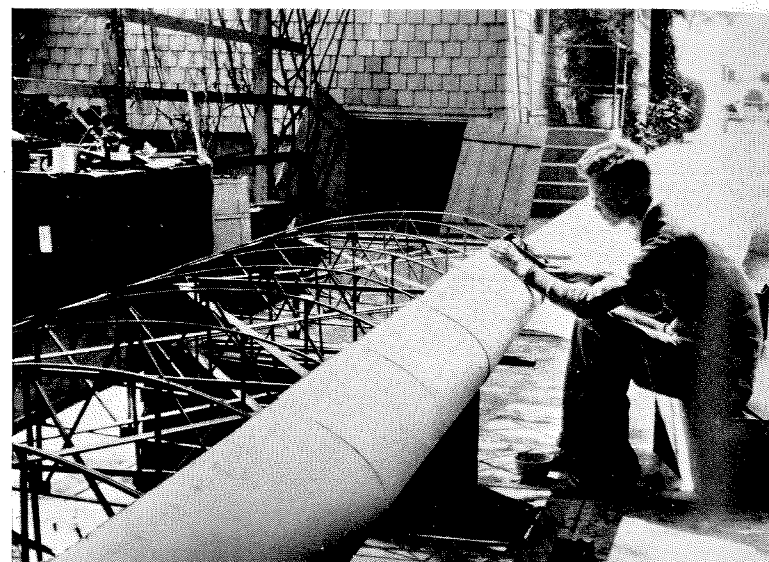
Pierce is a man of consuming intellectual curiosity and protean interests. As executive director of Bell Laboratories' Communications Sciences Division, he took advantage of the "unusual things dumped in his lap" to establish a reputation in areas pretty far afield from electrical engineering.

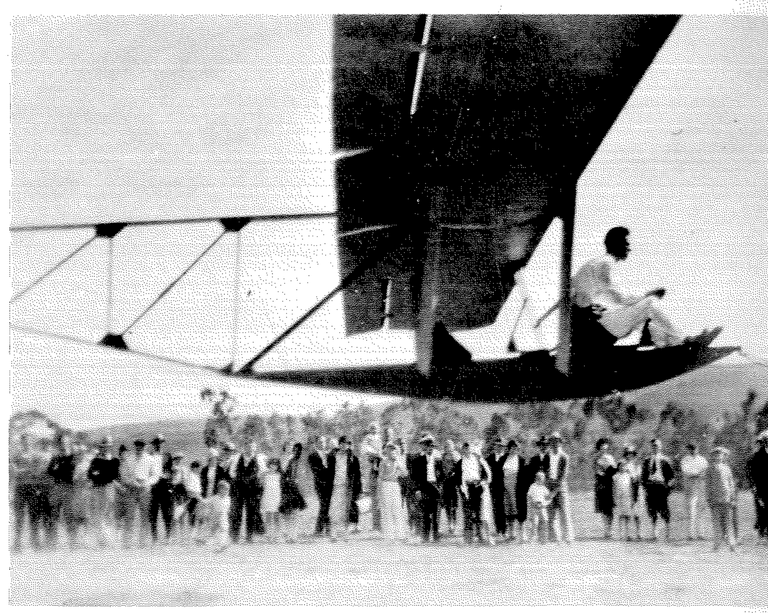
Working with composer James Tenney, he digested enough musicianship ("I can't carry a tune") to compose electronic ditties that appeared on two Decca recordings, "The Voice of the Computer" and "Music from Mathematics." Pierce has collaborated on a book on speech and hearing, and he has also published papers ("not major") in experimental psychology. Science, art and communication, and a history of science in New Jersey are other subjects that have had his literary attention—and contributed to his grand total of 13 books.

If this partial bibliography doesn't convey something of the essential eclecticism of John Pierce, then consider his house, a Japan-inspired creation, complete with formal garden, ornamental pool, and Japanese gardener. Pierce's romance with Japanese culture began many years ago when he admired some native prints in the rooms of Harvey Eagleson—one of Caltech's notable professors of English from 1928 until his death in 1967—who heightened the interest by suggesting that Pierce read the eleventh-century Japanese novel *The Tale of Genji*. The effect was profound. A few years ago Pierce converted his wife during a three-week visit to Japan which left them both "completely charmed."

Pierce's energy, his peripatetic curiosity, and his boundless appetite for knowledge bubbled up very soon after the Pierce family moved to St. Paul in 1911 when John was just a year old. It took a decided scientific bent. Before he could read himself, he listened by the hour as his mother, a milliner, read him technical books on all subjects, especially electricity. When young John learned to read for himself, he consumed all the scientific literature in sight, "good and bad." This included science fiction.

Back in 1929 gliders were hand-built, flimsy contraptions gotten aloft by being towed—preferably on a downhill slope—behind a bucketing tin lizzie. In spite of the problems, John Pierce built this craft, flew it, and produced a how-to handbook out of his experience.





Not surprisingly, scholarship came easy for Pierce. He graduated from Woodrow Wilson High School in Long Beach in 1928, compositely recollected by classmates as "wiry, serious, brilliant, thoughtful." The preferences that would forge his adult life were becoming pretty well established—a love for science, particularly the applied side, and certain knowledge that he was a gifted science scholar. Later, when pondering why he chose engineering over history or literature or one of the other areas he has since proved adept in, Pierce was prone to attribute it all to a background that from childhood was one of "gadgeteering." He did seriously consider writing but decided that since his "brains were more suited for engineering," he would choose the more "practical" route and retain writing as an avocation and safety valve when the equations began to close in on him. "I was right, you know," he says pensively.

Pierce hasn't always been that right, but he has never let discouragements stop him, either. Take the time he and two high school classmates decided to build their own glider, a prospect for which they were about as well prepared as Scrooge was for Marley's ghost. They turned to in the garage of Apollo Smith, later a classmate of Pierce's at Caltech, and manufactured a contraption of bicycle spokes, wagon wheels, and piano wire that crashed on its maiden flight. But they kept at it and eventually produced a version that not only got airborne, but also won a few silver cups at a San Diego glider meet in 1929. Pierce went aloft "more from pure ignorance than from courage." It was in this period of glider madness that he got his first literary commission from Gernsback. *How to Build and Fly Gliders* ($1 per copy) made its appearance late in 1929.

This debut coincided roughly with Pierce's matriculation at Caltech and the Black Tuesday collapse of the stock market, events which Pierce insists are unrelated. Some seven years later, Pierce, who says he had evolved into a young and cynical scholar, was packing to report to Bell Laboratories' main research facility at 463 West Street on New York City's waterfront. One of the last items to go into the suitcase was his PhD dissertation on what later became known as a sampling oscillograph. It came as something of a shock to Pierce when he recently examined the document and realized that he has been a physicist in engineer's clothing for the past 35 years. Electrical engineering was part of physics back in the 1930's.

Bell put him right to work on vacuum tubes, something he knew next to nothing about. After thoroughly grounding himself in the subject, he began—predictably—to emerge as one of the organization's most creative thinkers and imaginative inventors. Some of his results he remembers as "good for absolutely nothing." Others had significant practical value, particularly his electron gun (now the Pierce gun) which focuses and controls a high-current stream of electrons and has been a key technological link in the evolution of the traveling-wave tube. During this period, Pierce's personality was causing almost as much stir among his colleagues as his genius. His quick mind made him impatient with those who were slower on the uptake, and he got a reputation for abruptness if not rudeness ("considerably mellowed now," he believes). His literary bent also reemerged in such aphoristic gems as "Nature abhors a vacuum tube." Later, as one of Bell's most successful and honored scientific administrators, he would growl, "Paperwork is all right if you hate it enough."

It's not easy to separate Pierce's personal scientific approach from the problem solving philosophy that Bell Laboratories has applied so successfully, perhaps because each had a lot to do with shaping the other. Both emphasize research on tractable problems where useful results can be anticipated. Both respect a step-by-step approach in which the previous step is thoroughly understood before the next is undertaken. Both have enjoyed brilliant results by bringing together small interdisciplinary groups of scientists and engineers and providing them an easy informal working atmosphere. It was in this kind of environment that a team headed by Pierce labored 10 years to produce traveling-wave tubes that would provide reliable amplification for microwaves. These have been of great worth to the Bell System in particular and the communications industry in general, and are used in communication satellites, one of Pierce's later interests.

Pierce met Austrian-born Rudolph Kompfner, the original inventor of the device, in England in 1945. Kompfner later came to Bell Laboratories and worked on the traveling-wave tube project. Though Pierce has become more widely associated with the breakthrough, the two are close friends whose mutual deference over credit sometimes puts one in mind of Alphonse and Gaston. Kompfner says that he invented the traveling-wave tube but that Pierce "discovered" it (that is, recognized its worth). Kompfner was also a key member of another Pierce team that recorded what may be his single greatest success as scientist-engineer-administrator. Working with scientists at NASA and JPL, Pierce's group proved conclusively that satellite transmission was both possible and practical, a point Pierce had championed for years before finally taking all the principals into a real test in 1960.

The star of the experiment was Echo I, a 100-foot mylar-skinned aluminum-coated balloon designed to inflate after launching and go hurtling around the earth at 16,000 miles per hour. It would be tracked by computer-driven antennas (a heresy at the time) and, it was hoped, would reflect a radio transmission from JPL's Goldstone station down to waiting receivers manned by Pierce's people atop Crawford Hill in New Jersey. With a staff that never exceeded 40 and a budget of about $7 million, the Bell scientists worked furiously to ready their computer programs and radio equipment. They grafted on new technology—a maser amplifier—and some that was all but forgotten—a frequency feedback modulator developed in 1933 by Bell's Joseph Chafee.

Next they tested the system with "moon bounces" and by tracking the small suborbital Tiros weather satellite. Then, on August 12, it was time. A perfect Thor launch sent Echo I into orbit, wheeling through space like a great bright star. Sweating and cursing, applying frequent manual corrections, the Crawford Hill group locked on its target and gave Goldstone the word to start broadcasting. Brief silence. Suddenly, with eerie clarity, the recorded voice of President Dwight D. Eisenhower filled the room with the sweet sound of success. Pierce told *The New York Times* that the effort was "something of practical value." It was indeed, and he put it to further use in the development of Telstar.

Echo was the kind of project Pierce dotes on: definable, useful ends, step-by-step problem solving, a small number of competent people brought together in relaxed shirt-sleeve camaraderie. Sheer magnitude is about as popular with him as "Mammon Worship" and "Organizational Ecstasy," both of which he views as dangerous heresies. The first holds that money can accomplish anything ("it cannot"), while the second says that simply creating an organization will cause something to happen ("it will not"). Pierce likes an environment where clever people are doing "particular and incisive things." He thinks Caltech is very good in this way. That is what attracted him here.

He doesn't expect to teach during this fall term; he will spend that time talking to faculty and students in an attempt to see where he can contribute "meaning and usefulness." Clauser thinks two probable areas are communications and systems engineering, where Pierce's credentials are impeccable. Pierce would seem an ideal choice to spearhead a move into such fields and raise the Institute's program to prominence.

If he runs true to form, Pierce will emerge from the turmoil of getting settled at Caltech and exceed everyone's expectations but his own. That seemed to be on his mind September 13 when he delivered the dedication address for the new Earle M. Jorgensen Laboratory of Information Science. He called his talk "The Challenge of the Doable" and ended by saying, "One must find challenging do-able things to do, and then one must do them." Not even J. J. Coupling could come up with a better phrase to describe the career of John Pierce.

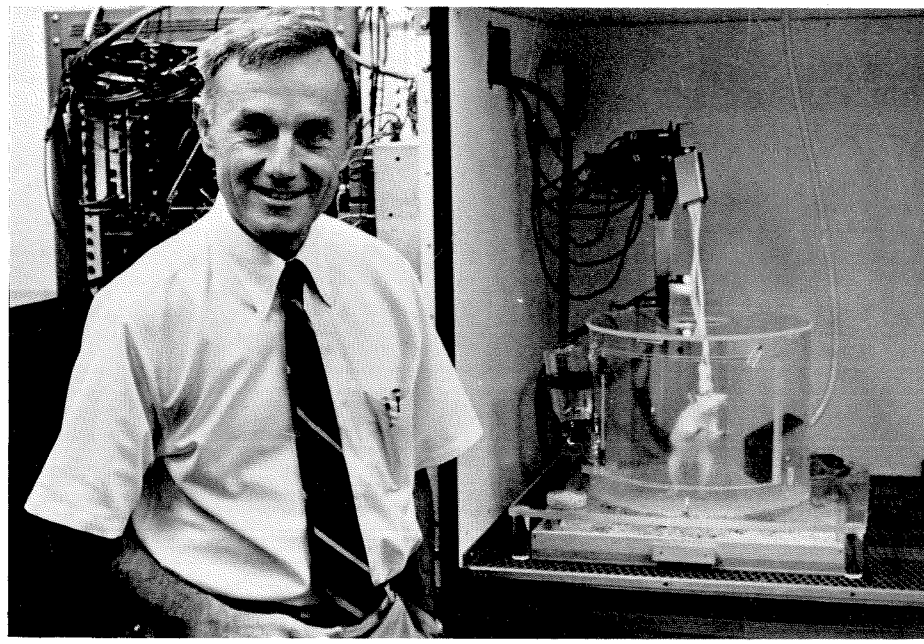
—Harry Bain

Research Notes

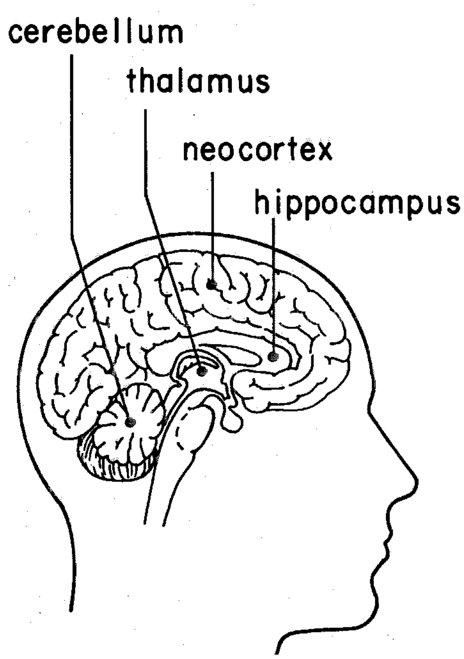
Learning about Learning

The brains of laboratory rats may seem unlikely—or at least unflattering—places to look for information about human brain function, but a learning experiment being conducted by James Olds, Bing Professor of Behavioral Biology, is providing key insights into the location of the brain's memory storage areas. And since the brains of rats and men share the same gross features, much of the knowledge gained from studying rat brain function is probably applicable to the human brain as well.

Olds and his colleagues have developed a method for monitoring individual brain cells during the act of learning—a technique that pinpoints where and when learning takes place while the rats are experiencing a simple learning situation. So far the research group has observed four main areas of memory storage in the brain (and there may be as many as six). Probably different *kinds* of learning take place simultaneously in each of these areas, but much of this activity is redundant, and the same facts are often written down in several places in the brain.



The reactions of the occupant of this transparent rat's nest help provide James Olds with data about learning centers in a rat's brain, and—by projection—in the human brain.



The brains of rats and humans are structurally enough alike to function in a similar manner.

Olds lists the four memory storage areas so far noted as the posterior thalamus, the neocortex, the hippocampus, and the cerebellum. The learning that takes place in the posterior thalamus is thought to be temporary and of a nonspecific nature. Olds compares this area to a computer's accumulator that fills with information about one learning task, then quickly empties and fills again with data about another task. The neocortex, on the other hand, responds more specifically. It is believed to be where memorization of actual objects occurs and where stored neuronal models are formed. Olds likens it to a computer's memory bank that retains specific information for long periods of time. The hippocampus, located above the thalamus, is thought to serve as a memory device much like a tape recorder, and the cerebellum at the lower back of the brain is probably the chief site for learning skills.

The research is based on observations of individual brain cells of wide-awake and freely moving rats before, during, and after learning. In a three-hour operation, nine fine-wire electrodes are implanted into each animal's brain to record the electrical conversation that goes on between the brain's cells.

Once the rats are "wired," they undergo two one-day testing periods in which three stimuli—two auditory signals and a food reward—are used to elicit responses. In the first phase the tones and food pellets are presented randomly, and responses to the tones are monitored so that a picture of the brain's reactions can be established. From the outset some parts of the brain ignore the signals, while other parts respond from the beginning and never ignore them.

In the second, or conditioning, phase one of the auditory signals is paired with the awarding of a food pellet, and the other tone remains meaningless. The animal soon learns the relationship between the stimuli and behaves accordingly. He goes for the food when he hears one tone, and he ignores the other one.

The experiments are regulated by a computer that makes the auditory signals and releases the food pellets at a prescribed rate. The computer also keeps track of the rate of electrical responses (recorded as spikes on a graph) generated by the "tapped" brain cell before and during the onset of the signal. The computer then establishes when the rate in brain cell electrical activity changes. Rate changes caused by the signals occur in some areas of the brain during the first phase of training, and these rate changes are termed old responses. Others, called new responses, may occur only after training.

Some new responses are considered secondary because they occur as long as 30 to 200 milliseconds after the signal is sounded. The primary new responses come much earlier—6 to 20 milliseconds after the signal. Olds assumes it is at the point of the primary response that the resistance of a synapse—a chemical junction between two brain cells—is lowered enough during learning to permit a nerve impulse to be transmitted across it. He thinks these synaptic gaps work in an opening-closing manner, much like an electric switch, sending impulses through or stopping them.

Although Olds' work has highlighted the general outlines of how the brain learns, the entire process from stimulation to response is not fully understood. No one really knows yet what happens to the message after it gets to the end of the input pathway. It seems to get lost in the central nervous system for one-tenth to one-fifth of a second, and then it goes racing down an output pathway almost as fast as it came in. There are probably many steps in the brief middle interval.

Olds, who is widely known for his discovery 18 years ago of the pleasure centers of the brain in rats (*E&S*, May 1970), reported his latest findings at the 79th annual meeting of the American Psychological Association, held in September in Washington, D.C. Collaborating with him are biology research fellows John Disterhoft and Richard L. Hirsh, and graduate students Menahem Segal and Carol B. Kornblith. The work is supported by the U.S. Public Health Service and the National Institutes of Health.

Extragalactic Chemistry — the quest for OH in space

When an important first in radio astronomy drew national attention to Caltech and its Owens Valley Radio Observatory last summer, the scientist who appeared least ruffled was the very scientist most responsible—34-year-old research fellow Leonid N. Weliachew.

By detecting the presence of OH, the diatomic hydroxyl radical, in galaxies M-82 and NGC-253, Weliachew demonstrated for the first time that chemical processes are occurring in galaxies other than our own Milky Way.

His announcement, reported in the July 15 *Astrophysical Journal*, fueled widespread interest in the enduring question of whether it is possible for life to originate in the gas and dust clouds of interstellar space. Some scientists view Weliachew's discovery and similar finds in our own galaxy as strong evidence that such life-building is going on.

Weliachew, who is visiting Caltech from Meudon Observatory in Paris, seems as unmoved by that prospect as he was unprepared for the excitement that greeted his disclosure. He insists that he doesn't know enough chemistry or biology to have an informed opinion about life "out there." As far as finding OH is concerned, he shrugs it off as much less earthshaking than news accounts made it appear. In fact, he confides that *not* finding the molecule would have been a more legitimate reason for astonishment than finding it.

This is because current theory, which Weliachew accepts and which his success has done much to strengthen, offered no grounds to doubt the existence of extragalactic OH. Since A. H. Barrett of MIT's Research Laboratory of Electronics, and J. C. Henry, M. L. Meeks, and S. Weinreb of the MIT Lincoln Laboratory first detected OH in our own galaxy in 1963, radio astronomers have discovered more than a dozen intragalactic molecules.

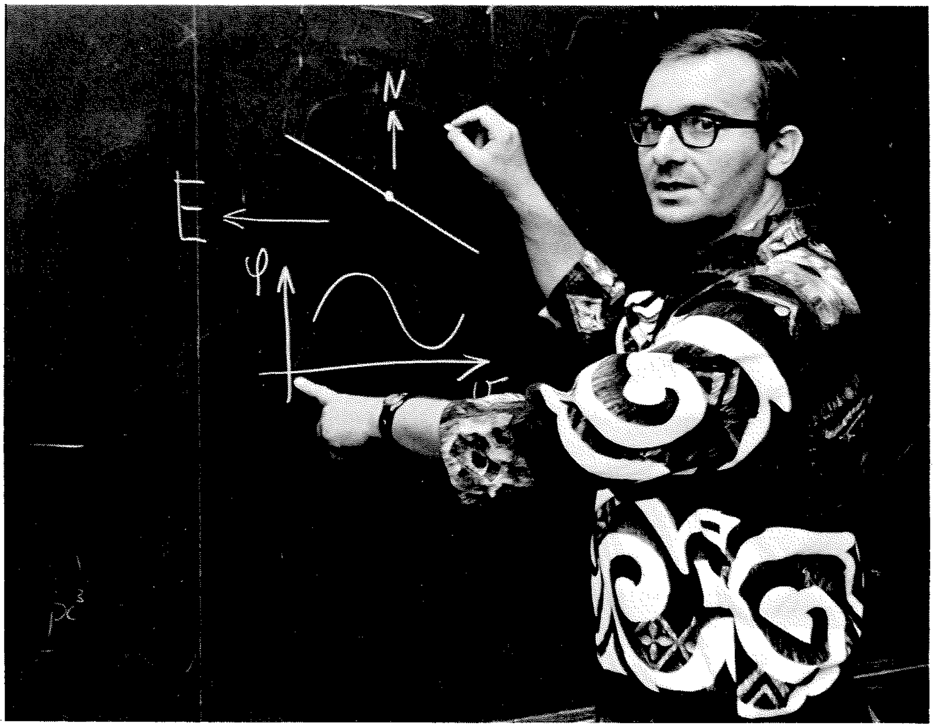
The fact that some of these are the precursors of amino acids, the building blocks of living things, was fascinating for the theoreticians in the field. Even more fascinating was the probability that their existence in our galaxy strongly suggested their existence in others. Weliachew says he simply designed an experiment to test that assumption.

His success had none of the serendipity of which great scientific legends are made. It resulted from a deliberate search, backed up by careful planning. One of the first tasks was to identify the galaxies that would be the most suitable candidates for the study. Weliachew's interest was in those about 10 million light years (6×10^{19} miles) from earth, which have an apparent size that is most suitable for study with the Caltech interferometer.

M-82 and NGC-253 emerged as the most promising targets for the search, because both emit strong radio signals from their centers and contain galactic dust clouds which are needed to shield the OH molecules from destructive ultraviolet radiation. Detection is possible only while the molecules are floating freely in space, in an equilibrium between one of several formation processes and eventual destruction. Once attached to a dust particle, they defy observation.

Weliachew knew it would take hypersensitive instrumentation to achieve the signal-to-noise ratio required to elevate his findings beyond the realm of pure chance and make them scientifically acceptable. Such a sensitivity edge should allow him to succeed where radio astronomers at Meudon, Green Bank, and other observatories had so far failed in the quest for extragalactic OH.

He was confident that a new instrumentation configuration at Caltech's Owens Valley Radio Observatory would supply the answer and made arrangements to use the equipment. His experiment, supported by the National Science Foundation and the Office of Naval Research, would be the first since the big dish antennas at the facility were beefed up by the addition of two delicately sensitive parametric



Leonid Weliachew diagrams motions in the inner regions of M-82, an irregular exploding galaxy and one of two galaxies in which he detected the presence of OH.

amplifiers. By October 1970, Weliachew and the equipment were ready.

With their receivers turned to the 18-centimeter wavelength at which OH is "visible," he simultaneously directed two big dishes first toward one galaxy, then toward the other. This synchronized use, called interferometry, can give two or more antennas the resolving power of one giant dish with a diameter equal to the distances between them.

Weliachew returned to Owens Valley in February 1971 to complete the experiment. There were four observations in all, each eight to ten hours long. Three were with the twin 90-foot dishes 1,600 feet apart, and one employed a 90-footer and the 130-foot dish, 3,500 feet away.

Weliachew's efforts produced just what he expected they would. The telltale spectral fingerprint of OH showed up twice in each galaxy, its signature readily identifiable as faint absorption dips against the brightness generated by radio signals emanating from deep within M-82 and NGC-253. This indicated that as the signals passed through clouds containing OH, the molecules absorbed their characteristic OH wavelengths from the signal pattern.

By finding OH in "nearby" M-82 and NGC-253, Weliachew has strengthened the case that it probably exists in a great many other galaxies as well. This suggests that natural laws operable in our own cosmic neighborhood are also at work elsewhere in space and contributes a new plank for theoreticians in the discipline to build on.

His findings also show that M-82, NGC-253, and our own Milky Way contain roughly one OH molecule for every million atoms of hydrogen, the most abundant and widely distributed interstellar element. In our galaxy, molecules that absorb radio waves should be detectable at concentrations well below one molecule per cubic yard. A much greater concentration would be required to detect a molecular fingerprint in other galaxies.

Weliachew has a busy schedule ahead of him when he returns to Meudon in December. In addition to studies on hydrogen line emission and absorption in external galaxies, and formaldehyde absorption in our own galaxy, he will be writing up the results of two years of research at Caltech. And he'll probably have to get used to being called Vell′-ya-chef again after finally adjusting to the Americanized Well′-ee-uh-chu.

Scientific detachment notwithstanding, he is "happy over-all" about his well-reported first. A few years ago when he was commuting between an engineering job at Meudon and doctoral studies in physics at the University of Paris, a career in radio astronomy wasn't the uppermost thing in his mind. ("Nothing about it attracted me.") But colleagues won him over by emphasizing the ideal fit of his electronics background and experience at Meudon. A positivist, Weliachew has been content to accept the symbiosis and make the best of it.

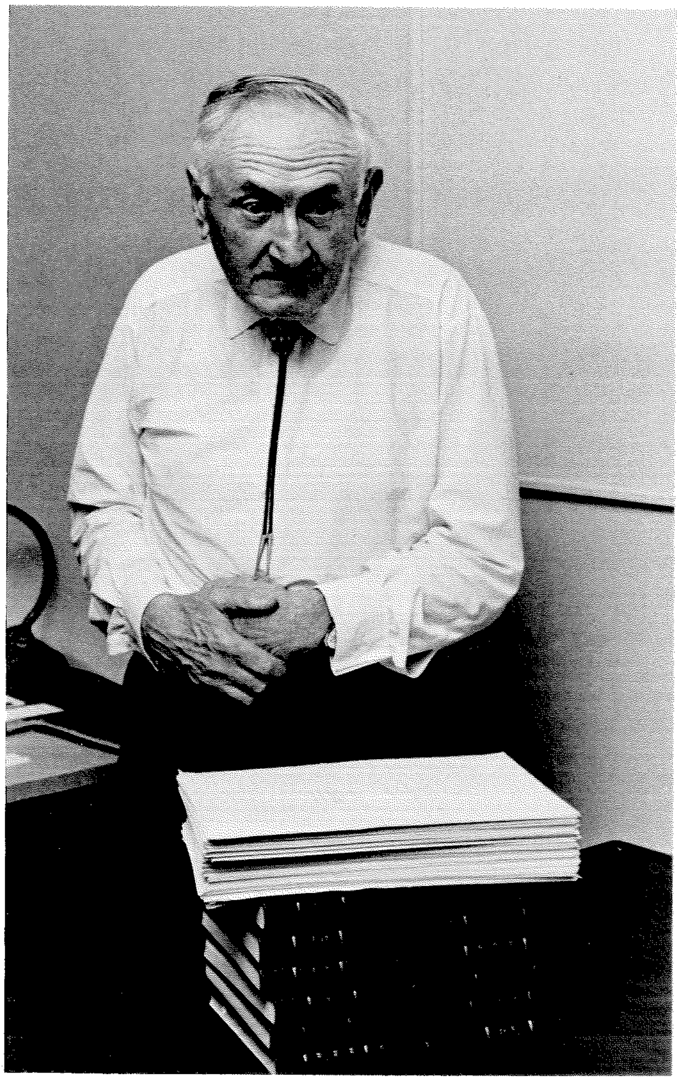
WORDS FAIL THEM

The educational process may still be founded on the lecture system, but the photographs on these pages are mute evidence of the fact that, for some of the best teachers, words are not nearly enough.

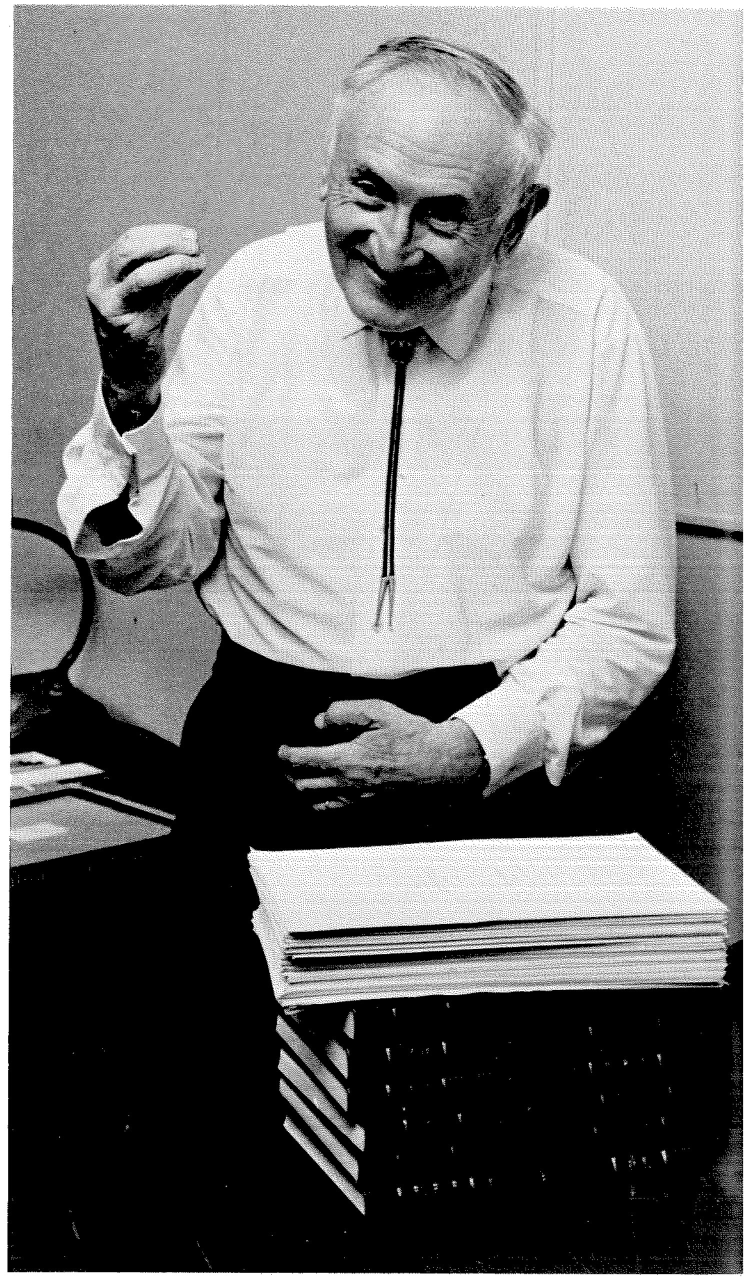
As Caltech's director of choral music, Olaf Frodsham is in the business of talking with his hands, so any seasoned glee club member can sight-read this gesture to mean that Frodsham is not entirely displeased with what he hears, thinks it might possibly be getting a little better as it goes along, could even come close to being pretty good in time—only for Pete's sake cut down on the volume, *please.*

As one of the principal investigators of lunar materials for NASA, Gerald Wasserburg, professor of geology and geophysics, is currently concerned about the future of the moon samples after the Apollo program is terminated. In fact, he says, if we don't make a long-term commitment and definition of policy for the storage and handling of lunar materials for future generations, well—mark his words.

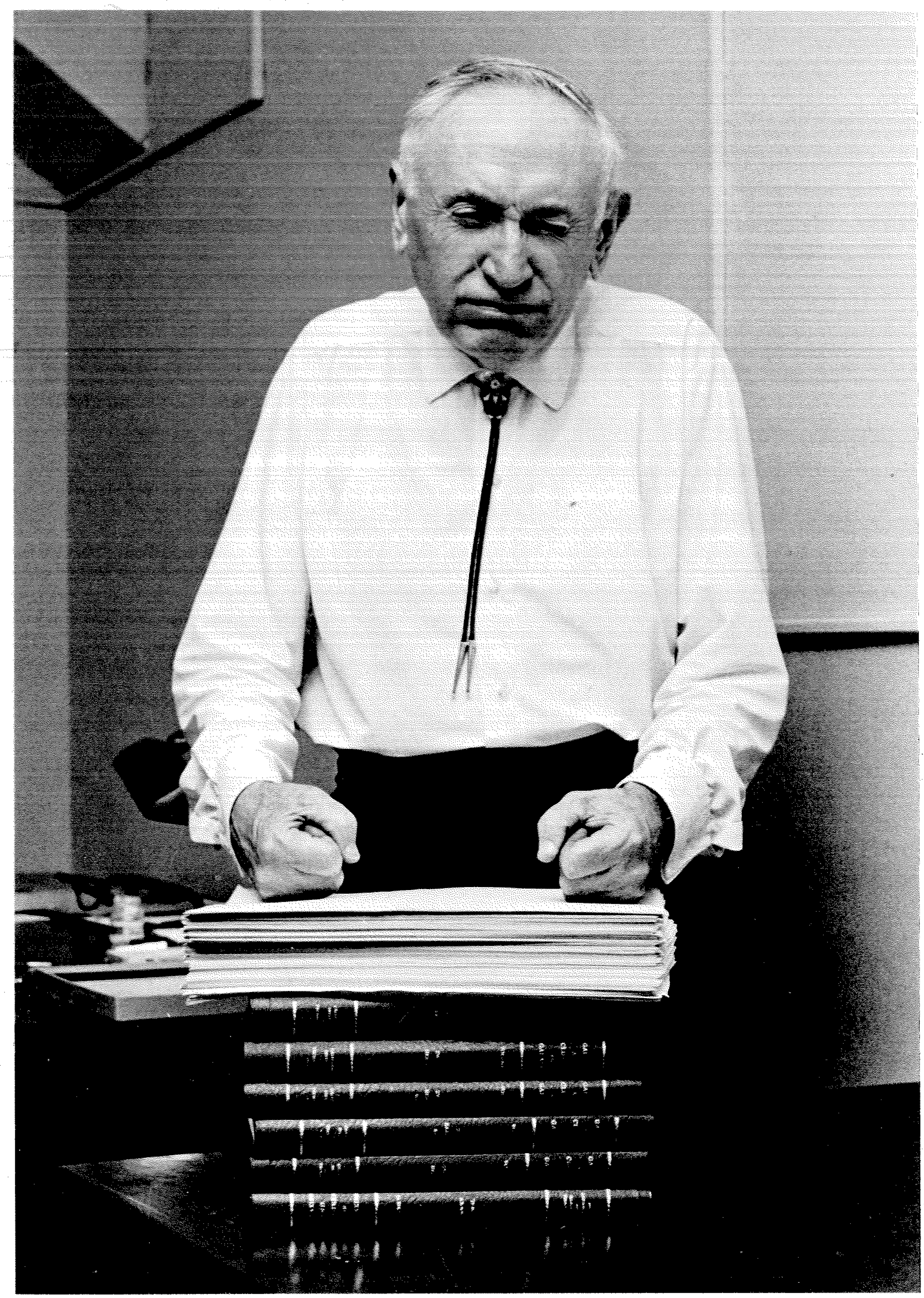
Derek Fender, professor of biology and applied science, and James Olds, Bing Professor of Behavioral Biology, have a common professional interest in studying the workings of the brain—and face a common difficulty in discussing the subject, which invariably involves such refined intricacies that words are better abandoned—as they have been by Fender (above) in describing the specially designed helmet he uses in his research and by Olds (right) in a graphic demonstration of how the brain makes decisions.



Fritz Zwicky, professor of astrophysics, emeritus, has so many firm opinions to deliver on so many subjects that mere words cannot possibly convey the depth of his convictions, and so . . . . .



they must be supplemented by considerable body English . . . . .



with a strong Swiss accent, of course.

The Summer at Caltech

President Harold Brown expresses his personal appreciation to Marion Jorgensen at the dedication of Caltech's new Jorgensen Laboratory.

Jorgensen Dedication

Caltech's new $1.6 million Earle M. Jorgensen Laboratory of Information Science was dedicated on one of the warmest September 13's in Pasadena history—109 degrees. Fortunately, there was some shade. Guests for the occasion sat under the trees in front of Winnett Center directly across San Pasqual Street from the new building, which is named for a long-time benefactor of the Institute. Earle Jorgensen has been a trustee since 1957 and also contributed funds for the Mosher-Jorgensen graduate student house.

Mr. and Mrs. Jorgensen were the major contributors of funds to build the new laboratory. Other donors included the Booth-Ferris Foundation, Bethlehem Steel Corporation, Mr. and Mrs. Donald Bren, Dart Industries, Inc., the Irvine Foundation, Kaiser Steel Corporation, Mr. and Mrs. William Martin, Mr. and Mrs. Kenneth Norris, Republic Steel Corporation, and Mr. and Mrs. Henry Salvatori.

Francis Clauser (BS '34, MS '35, PhD '37), chairman of the division of engineering and applied science, presided over the dedication. Like Clauser, the two main speakers were students here in the early 1930's, hold three degrees apiece from the Institute, and are now faculty members in the division. Gilbert McCann (BS '34, MS '35, PhD '39), who described computer science at Caltech, is professor of applied science. A brand-new professor of engineering, John R. Pierce (BS '33, MS '34, PhD '36), gave the main address, "The Challenge of the Do-able."

Jorgensen Lab's 30,000 square feet of floor area more than doubles Caltech's space for computer processing. It will house the man / machine interactions laboratory for study of the most effective ways that computer systems can extend man's capabilities. There are also facilities for computer research into management information systems, effective ways of integrating computers and research teams, and improvement of educational techniques. Offices, conference rooms, and space for card-deck storage complete the three-story building.

Independent Study

The Independent Study Program (ISP), thoroughly debated for nearly three years, has finally found its way into the Caltech catalog as a new academic option. The program is designed to take maximum advantage of the intelligence and curiosity of Caltech students by allowing them to combine existing courses with self-scheduled studies to meet personal educational goals.

Undergraduates are eligible for admission to the program any time after the first term of the freshman year. A student who wants to enroll in the ISP must write a proposal describing his goals, reasons for applying, a general plan for study while at Caltech, and a detailed plan for the next quarter. The student must also recruit three faculty members, representing at least two divisions, who approve of his plans and agree to act as an advisory committee. The advisory committee will bear the chief responsibility for overseeing the progress of the student, counseling him, and evaluating his performance and progress—in writing—each quarter.

The program is administered by the nine-member ISP faculty committee which considers each program proposed by a student in consultation with the prospective members of the student's advisory committee. If the program is accepted, a three-party written contract is drawn up and signed by the ISP committee, the three-man advisory board, and the student. This contract includes the agreed-upon content of the student's program and the methods for ascertaining satisfactory progress for those parts of the program that are not standard Institute courses. When—and only when—the ISP committee is satisfied that the terms of the student's contract have been met, he will be recommended for graduation.

In most cases the student's work will be graded on a pass-fail basis, and if he chooses this method, his credentials for graduate school or employment will be based on an extensive record or portfolio of his work under the ISP. If the student prefers the normal grading procedure, his grade-point average will be calculated as usual.

The ISP committee has been highly selective in screening candidates. Of the nearly 40 students who have applied, only three have been accepted so far. They are senior Lance Optican and sophomores Barry Cipra and Bruce Jacobson.

Optican was a physics major for three years before deciding to change his research to the human visual system with emphasis on the study of depth perception. Through the ISP he can pursue his new studies in biology without the complications inherent in switching options so late in his academic career.

Cipra, considered a particularly brilliant student as a freshman, has set up a tutorial scheme for his own education. His first term under the ISP consists of five self-designed tutorial courses in English, mathematics, and physics.

Jacobson is concentrating his research efforts on environmental biology and neuro-psychobiology.

Each of the ISP scholars has put together an impressive group of advisers who are equally impressed by the students and their plans. Optican's advisory committee consists of Carl Anderson, professor of physics; Max Delbrück, Albert Billings Ruddock Professor of Biology; and Derek Fender, professor of biology and applied science. Cipra's advisers are J. Kent Clark, professor of English; Richard Dean, professor of mathematics; and Richard Feynman, Richard Chace Tolman Professor of Theoretical Physics. Jacobson's group includes George Hammond, Arthur Amos Noyes Professor of Chemistry; Dan McMahon, assistant professor of biology; and James Morgan, professor of environmental engineering science.

The ISP faculty committee consists of Barry Barish (chairman), Fred Anson, H. F. Bohnenblust, Peter Goldreich, Floyd Humphrey, James Knowles, Gerry Neugebauer, Thayer Scudder, and William Wood.

Happy Birthday

From July 19 through 21 more than a hundred physicists and astronomers gathered in Cambridge, England, to give William A. Fowler a present for his 60th birthday—a symposium on supermassive objects in astrophysics.

At least a third of the invited guests had some past or present connection with Caltech, where Fowler is now Institute Professor of Physics. Most had close ties with Fred Hoyle's Institute of Theoretical Astronomy (IOTA) at the University of Cambridge where Fowler has been a visiting fellow each summer since 1967. (Hoyle is, in turn, a visiting associate in physics at Caltech.)

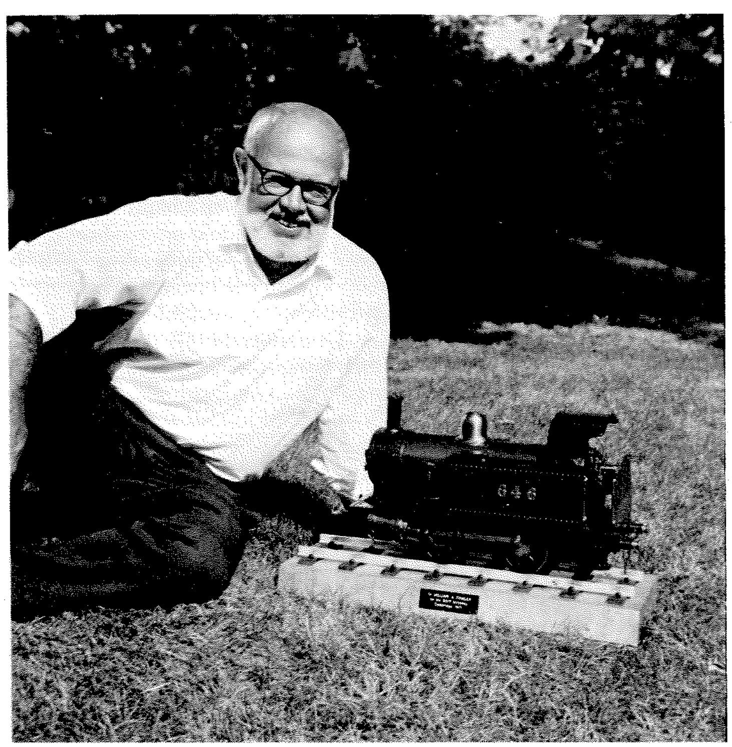
Fowler, who has been a Caltech faculty member since 1936, is credited with contributing more than anyone else to the understanding of why stars shine on nuclear energy and the origins of their chemical elements. He has already been widely honored for his contributions in low energy nuclear physics, astronomy, and astrophysics.

One of Fowler's Caltech colleagues, W. L.W. Sargent, professor of astronomy, was an organizer of the supermassive birthday fete. His associates in planning the symposium included Geoffrey Burbidge, internationally known astrophysicist from the University of California, San Diego; Martin Rees of the IOTA staff; and Donald Clayton of Rice University's department of space science. Clayton received his PhD in physics under Fowler in 1962.

Sargent and Kip Thorne, professor of physics, were among the symposium chairmen. Charles Barnes, professor of physics, gave a review of recent experimental research in astrophysics, much of which has originated in Kellogg Laboratory. Peter Goldreich, professor of planetary science and astronomy; and Gary Steigman, a research fellow in Fowler's Caltech stellar interiors and nuclear synthesis (SINS) group, also played a part in symposium activities.

The papers presented at the conference covered three important areas of Fowler's astrophysical interests: general relativity and cosmology, quasi-stellar objects and supermassive stars, and nucleosynthesis in stars—particularly massive stars. Fowler himself spoke at the closing session of the symposium about some of his and Hoyle's ideas on supermassive objects.

A summary of the conference, written by Virginia Trimble, appeared in the August 27 issue of the British science magazine, *Nature*. (Dr. Trimble, who received her PhD in astronomy at Caltech in 1968, is a staff member of IOTA.) A complete account of the proceedings will not be published because of the unique nature of the symposium. Its purpose was to encourage free discussion of new ob-



Just what he always wanted—William Fowler's 60th birthday present.

servations and ideas, some of which have been only partially developed. Participants were encouraged to be as speculative as they wished.

On July 20 about 160 men and women honored Fowler at a dinner in the Great Hall of Trinity College. Among the 30 guests at the head table were the Hoyles, the Burbidges, and the Fowler family (with Fowler himself seated directly below the famous Holbein portrait of Henry VIII). At the other tables were many of Fowler's oldest and closest friends—some from the Continent, including Paul Ledoux of the Institut d'Astrophysique in Liège, Belgium, and Livio Gratton of the Laboratorio di Astrofisica of Frascati, Italy.

Fowler was presented with a special gift, which he describes as "a dreamy 3½-inch-guage live-steam model locomotive!" According to reports, it was more than a week after the big celebration before Fowler—a long-time steam engine buff—had a chance to try out his locomotive and ride behind it on the elevated tracks of the Cambridge Model Engineering Society.

He has since applied for membership.

Harold Z. Musselman 1895-1971

Harold Musselman

Harold Z. Musselman, 75, director of physical education and athletics, emeritus, died on August 29. He first came to Caltech in 1921 at the invitation of Robert A. Millikan to be a coach and part-time YMCA secretary. Because of the growing athletic program, his YMCA duties were dropped after two years, and in 1924 he became coach and manager of athletics. He was made director of athletics in 1947, and—after 45 years of service—retired in 1966.

Hal Musselman was born in Kent, Illinois, in 1895. He graduated from Cornell College in Iowa in 1920, and later did graduate work at the University of Illinois and USC. During World War I he was an army sergeant, and in 1919 was a member of the U.S. baseball team in the Inter-Allied games in Paris.

At Caltech, Musselman was varsity baseball coach for 26 years, and he also served as varsity basketball and assistant football coach. He felt that any Caltech student who wanted to participate in intercollegiate competition should have the opportunity to do so, and he maintained an athletic program designed to make this possible. He also provided Institute athletes with opportunities in such sports as karate, soccer, rugby, cricket, and fencing.

For 11 years Musselman was president of the Southern California Intercollegiate Athletic Conference Coaches and Managers Association. He was a member of the Tournament of Roses Association for 19 years, and in 1932 he managed the Olympic cycling races at the Rose Bowl.

Caltech's first gymnasium was dedicated in 1955, and in giving a tribute to Musselman at the memorial services held in Pasadena on September 1, 1971, his fellow graduate of Cornell College—and president emeritus of Caltech—Lee A. DuBridge, recalled: "I never saw a happier man than Hal on the first day I visited him in his new office over there.

"Being an athletic coach at Caltech is hardly one of the easiest jobs in the world. Winning teams are few and far between, and only occasionally does a real star athlete decide to come to Caltech.

"And yet I have the impression that Hal enjoyed every minute of his 50 years of association with Caltech. The academic faculty members, of course, taught the students science, engineering, and the humanities. But from Hal they learned about sportsmanship, about fair play, about keeping a stiff upper lip in the face of defeat and discouragement—and humility in the face of success. He taught, by example, the qualities of friendship, respect for the other fellow, and the joys of keen and friendly competition. More than a dozen generations of Caltech undergraduate students will remember Hal Musselman with affection and respect."

John Hall, 1944-1971

John Hall, a graduate student in geology and the resident associate of Ricketts House, was killed August 1 during a mountain climbing expedition in Canada. He was 27.

At Caltech, Hall was doing research on stable isotope analysis with Samuel Epstein, professor of geochemistry. A graduate of Reed College in Oregon, Hall came to Caltech in 1967 after two years at Harvard Medical School. He received an MS degree here in 1970.

In the summer of 1970 he was the leader of a team of four "chambernauts" who were sealed in a simulated space laboratory for 90 days to test regenerative systems and provide other information for Skylab 1, which NASA will launch in 1973 (*E&S*, February 1971).

Hall, an experienced climber, was leader of a party that had just successfully scaled 19,800-foot Mt. Logan in the Yukon. The group had begun the first stage of an ascent up nearby Mt. St. Elias when Hall and three companions were buried under an avalanche.

Faculty and Administrative Changes 1971-1972

ADMINISTRATION

NORMAN H. BROOKS—*academic officer for environmental engineering science*
NORMAN H. HOROWITZ—*executive officer for biology*
STIRLING HUNTLEY—*associate dean of graduate studies*
ROBERT A. HUTTENBACK—*acting chairman of the division of humanities and social sciences*
JAMES K. KNOWLES—*academic officer for applied mechanics*
LESTER LEES—*director of the Environmental Quality Laboratory*
C. J. PINGS—*vice provost and dean of graduate studies*
CHARLES RAY—*acting director of the Booth Computing Center*
WILLIAM P. SCHAEFER—*registrar*
BRADFORD STURTEVANT—*executive officer for aeronautics*
GERALD B. WHITHAM—*executive officer for applied mathematics*
CHARLES H. WILTS—*executive officer for electrical engineering*

PROMOTIONS

To Professor:
CHARLES B. ARCHAMBEAU—*geophysics*
DONALD S. COHEN—*applied mathematics*
FRED E. C. CULICK—*jet propulsion*
FLOYD B. HUMPHREY—*electrical engineering*
TOSHI KUBOTA—*aeronautics*
JAMES W. MAYER—*electrical engineering*
ALAN T. MOFFET—*radio astronomy*
DUANE O. MUHLEMAN—*planetary science*
W. L. W. SARGENT—*astronomy*
BRADFORD STURTEVANT—*aeronautics*
OLGA T. TODD—*mathematics*
THOMAS A. TOMBRELLO—*physics*

To Associate Professor:
JESSE L. BEAUCHAMP—*chemistry*
ROBERT G. BERGMAN—*chemistry*
LOUIS BREGER—*psychology*
WILLIAM R. COZART—*English*
WILLIAM A. GODDARD—*theoretical chemistry*
D. L. GOODSTEIN—*physics*
RICARDO GOMEZ—*physics*
A. P. INGERSOLL—*planetary science*
GARY A. LORDEN—*mathematics*
FRANK J. SCIULLI—*physics*
EDWARD C. STONE—*physics*
DAVID B. WALES—*mathematics*
JAMES A. WESTPHAL—*planetary science*

To Assistant Professor:
GEOFFREY FOX—*theoretical physics*
H. H. KISILEVSKY—*mathematics*
G. R. ROSSMAN—*mineralogy and chemistry*

To Senior Research Fellow:
JOHANN ARBOCZ—*aeronautics*
ELSA M. GARMIRE—*applied science*

NEW FACULTY MEMBERS

Professors:
JOHN R. PIERCE—*engineering,* from Bell Laboratories
CHARLES R. PLOTT—*economics,* from Purdue University
JAMES P. QUIRK—*economics,* from the University of Kansas
JEAN-PAUL REVEL—*biology,* from Harvard University

Associate Professor:
DAVID M. GRETHER—*economics,* from Yale University

Assistant Professors:
JOHN FEREJOHN—*political science,* from Stanford University
ALEXANDER FIRESTONE—*physics,* from Lawrence Radiation Laboratory
THOMAS C. MC GILL—*applied physics,* from Princeton University
W. DAVID MONTGOMERY—*economics,* from Harvard University
WILLIAM H. WEINBERG—*chemical engineering,* from the University of Cambridge

RESIGNATIONS

JOHN H. BAHCALL—*associate professor of theoretical physics,* to the Institute for Advanced Study, Princeton University
DAVID W. BOYD—*associate professor of mathematics,* to the University of British Columbia's mathematics department
KENNETH D. FREDERICK—*assistant professor of economics,* to Resources for the Future in Washington, D. C.
ROGER C. NOLL—*associate professor of economics,* to The Brookings Institution in Washington, D. C.
JAMES M. VARAH—*assistant professor of applied mathematics,* to the University of Columbia's computer science department

ON LEAVE OF ABSENCE

ROBERT BATES—*assistant professor of political science,* to conduct research in central Africa
FELIX BOEHM—*professor of physics,* to do research at CERN in Geneva, Switzerland
NORMAN BROOKS—*professor of environmental science and civil engineering,* to Scripps Institute of Oceanography
FRED CULICK—*professor of jet propulsion,* to do research and writing
DEREK FENDER—*professor of applied science and biology,* to do research at other institutions
STEVEN FRAUTSCHI—*professor of physics,* to do research at CERN in Geneva, Switzerland
MURRAY GELL-MANN—*professor of physics,* to do research at CERN in Geneva, Switzerland
ROY GOULD—*professor of electrical engineering and physics,* to the research division of the United States Atomic Energy Commission in Washington, D. C.
HAROLD LURIE—*professor of engineering science,* to the Yankee Atomic Electric Company at Newton Center, Mass.
YORIKIYO NAGASHIMA—*senior research fellow in physics,* to do research at National Accelerator Laboratory in Illinois
JEROME PINE—*professor of physics,* to do research and study
G. WILSE ROBINSON—*professor of physical chemistry,* to do research in photobiology

Barnacles. They're uninvited—and expensive. So a new hull is being tested that could keep them at bay. And nickel's helping make it happen.

Shrimp boats are a-comin'—out of a harbor at San Juan del Sur, Nicaragua. And one of them is unlike any other work vessel in the world.

It has a new kind of experimental hull designed to fend off barnacles and other drag-producing marine growth *permanently*.

The Copper Development Association, sponsor of the project, estimates that the new hull material could reduce fuel consumption by as much as 15 to 20 percent. And, by totally eliminating hull scraping and painting, could slash maintenance costs up to 80 percent.

Most impressive of all, though, may be the savings that come through improved efficiency. At present, for example, a slowdown of even one knot because of bottom-fouling can cost a big tanker as much as $4,000 a month. And the loss of five profitable working days for a layover in drydock can mount up to $100,000 or more.

The new hull is a time-proven marine alloy of copper and nickel. It's the copper, really, that's anathema to the barnacles. The 10 percent of nickel is there to make the metal easier to weld and form, to give it the necessary strength, and to help protect it from pitting and corrosion.

Just as our metal is a strong helper, one that improves the performance of other metals, so International Nickel is a helper.

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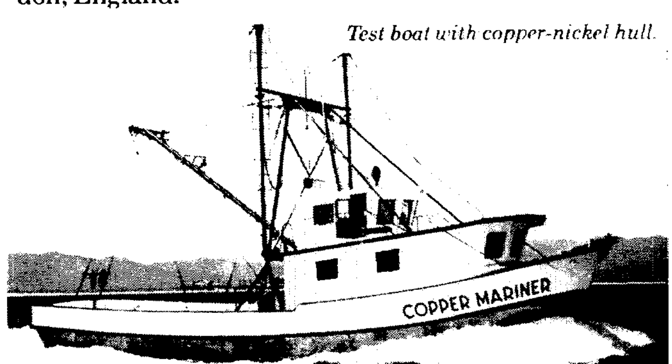
This kind of helpfulness, we figure, will encourage our customers to keep coming back to us.

And that helps all around.

The International Nickel Company, Inc., New York, N.Y. The International Nickel Company of Canada, Limited, Toronto. International Nickel Limited, London, England.

Test boat with copper-nickel hull.



INTERNATIONAL NICKEL HELPS

notes & news

Do corporations care?

Of course they do. WE certainly do! We have to operate profitably—that is, *successfully*—or we'll go broke, which would not be good news to more than 120,000 employees or their families. But there's a lot more to it. For example: caring for employees' health and safety; protecting the environment; hiring, training, and seeing to the progress of minority group members; contributing to civic betterment. It's good business to be a good corporate citizen.

Mindful mining

Mining and quarrying operations must be conducted in a manner mindful of Environment as well as Efficiency. We've always been an industry leader in modern technology and worker safety; today, similar attention is lavished on reclamation, conservation, reforestation, and waste water treatment. This is no idle boast; doubters are regularly invited to tour our mining operations.

Continuing education

At last report some 3,100 salaried employees of Bethlehem Steel were taking or had taken college-level courses at company expense under our Educational Assistance Program.

Ships ahoy

From Sparrows Point to San Pedro to Singapore it's full speed ahead for Bethlehem's Shipbuilding Department. We're at work on the largest shipbuilding basin in the U.S.—to accommodate vessels of up to 300,000 deadweight tons; we have orders for 120,000 deadweight ton tankers; we recently completed the country's biggest drydock, in San Francisco.

Don't belittle benefits

An average U.S. worker gets "fringe" benefits worth about 25% of his regular pay, according to a recent survey. Bethlehem is a leader in this area, providing life insurance; disability benefits; Blue Cross, Blue Shield, Major Medical; minimum of 9 paid holidays; liberal vacation and pension plans, and more!

Computer quiz

How many computers do we operate? Answer: Currently, about fifty, operated by 1,300 data processors.

Study up

A wealth of information appears in our booklet, "Bethlehem Steel's Loop Course." A copy is available in your placement office. If what you read appeals to you, sign up for a talk with our representative when he visits your campus. Bethlehem Steel Corporation, Bethlehem, PA 18016.

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