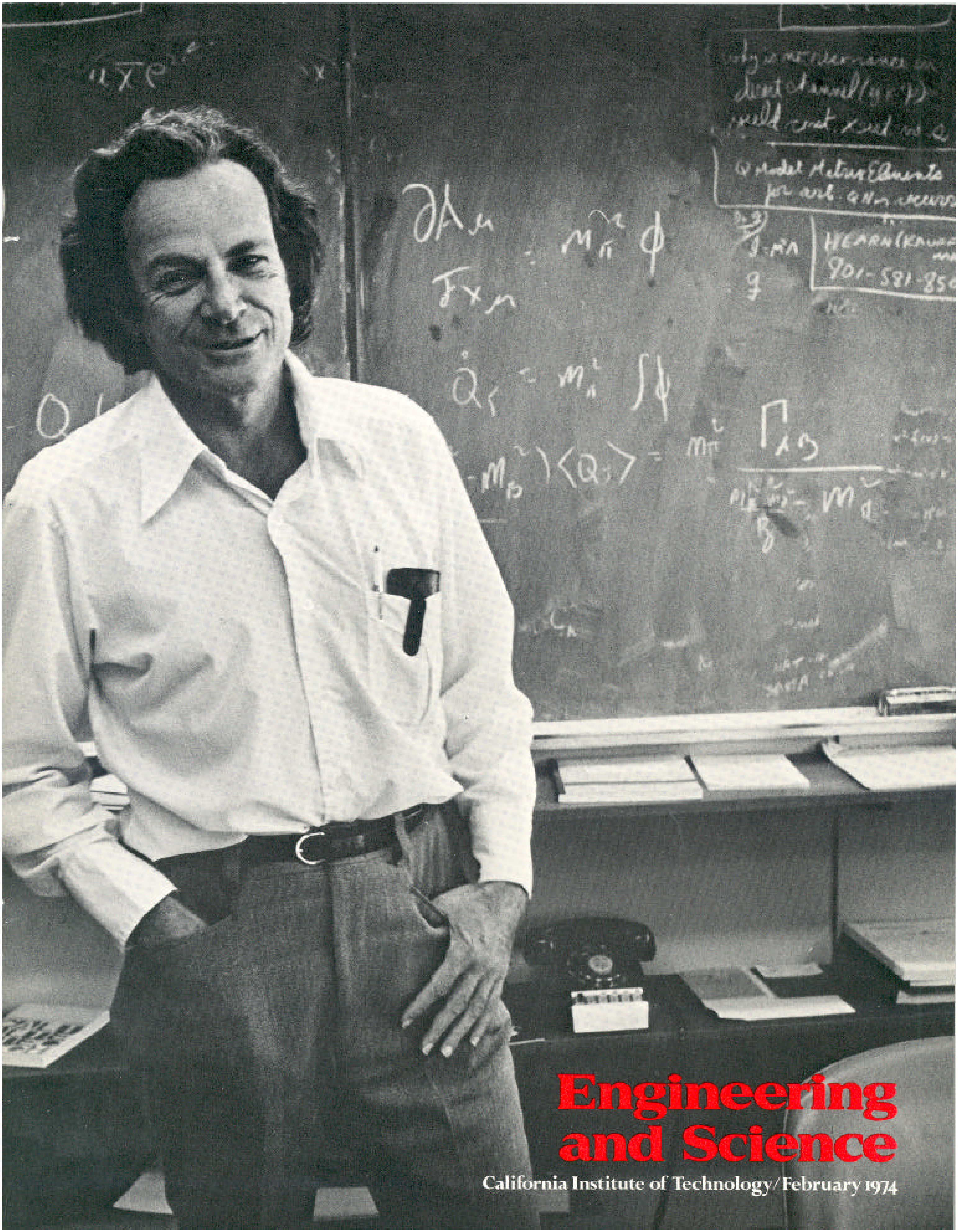
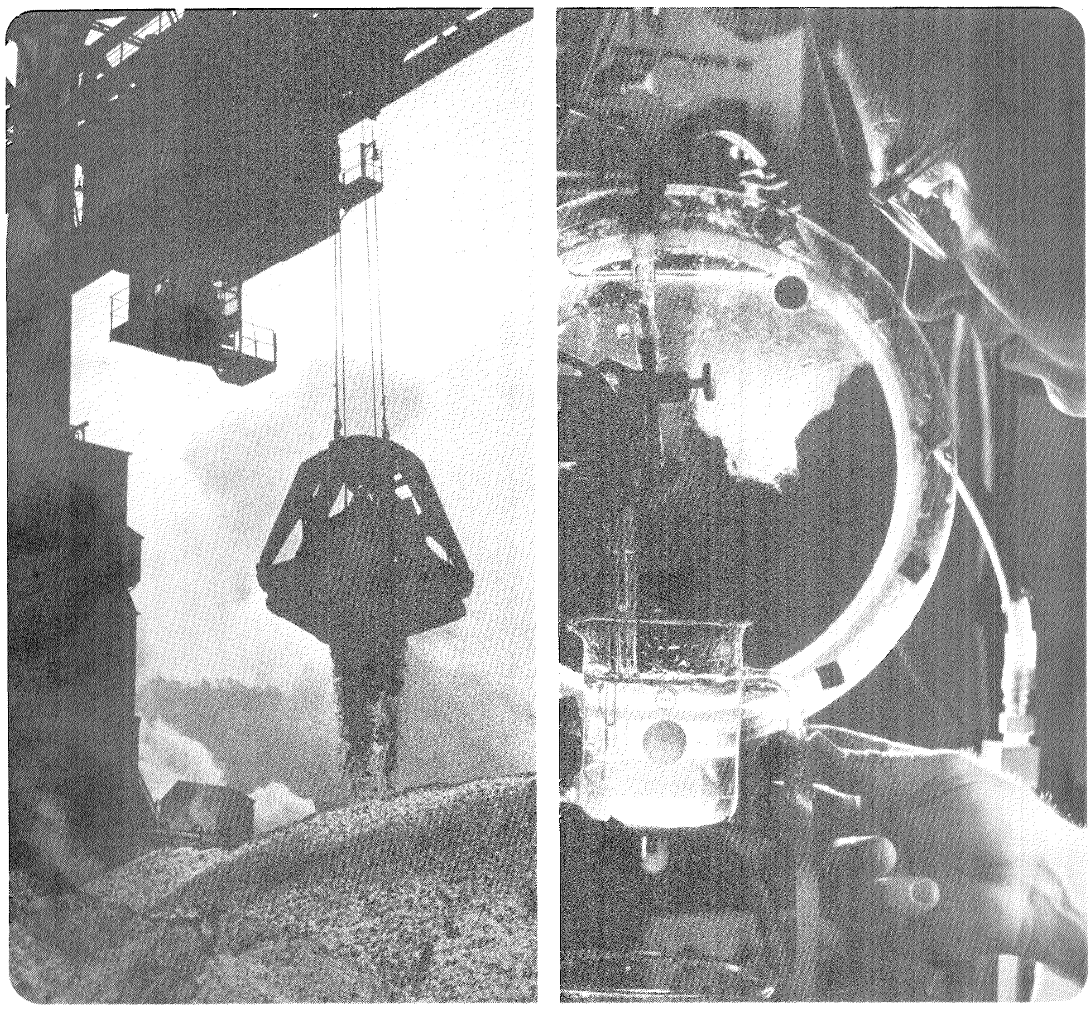
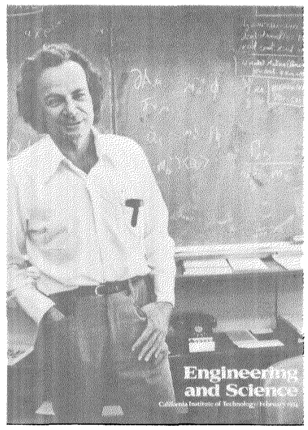


Engineering and Science

California Institute of Technology/February 1974



In This Issue



Fluent Feynman

On the cover—Richard P. Feynman, Richard Chace Tolman Professor of Theoretical Physics at Caltech and winner of the Nobel Prize in physics in 1965, has always been one of the most articulate and stimulating spokesmen for science. This ability is vividly demonstrated once again in a television interview conducted by Simon Welfare for Yorkshire Television Limited in Great Britain. Except for some abbreviation, the interview is reproduced almost verbatim in "Take the World from Another Point of View on page 10.

The color film from which this transcript was made was presented by Yorkshire Television as one of a series of documentaries on the world's outstanding scientists. The executive producer was John Fairley, and it was produced and directed by Duncan Dallas.

Traveling Man

Henry Abarbanel is one Caltech alumnus who gets around—as his travel article on page 14, "New China Hands—American Scientists Visit the People's Republic," demonstrates. Of course, even before that trip there were signs that he had peripatetic feet. In the last two years, for instance, he has traveled in Israel, the Soviet Union, and Iran—as well as Western Europe and a sizable part of the United States. Prophetically, the *Big T* for 1963 comments that in his four years at Caltech he was "known to dwell in seven places, on and off-campus, including lengthy four-term stays in Ruddock and Dabney. Although he didn't know where he was, an appeal to Heisenberg tells us that he knew where he was going."

He did indeed. He went on to get his PhD in physics at Princeton in 1966 and stayed on there for a year as an NSF postdoctoral fellow. After spending a year as a research associate at the Stanford Linear Accelerator Center, he returned to Princeton in 1968 as an assistant professor of physics. In 1972 he became a physicist with the theory group at the National Accelerator Laboratory in Batavia, Illinois; and he spent the spring term of 1973 at Caltech as a visiting associate in theoretical physics. He's back here once again now, for the winter term—occupying an office in Lauritsen, when he isn't someplace else on campus showing some of the 750 color slides of his China trip.

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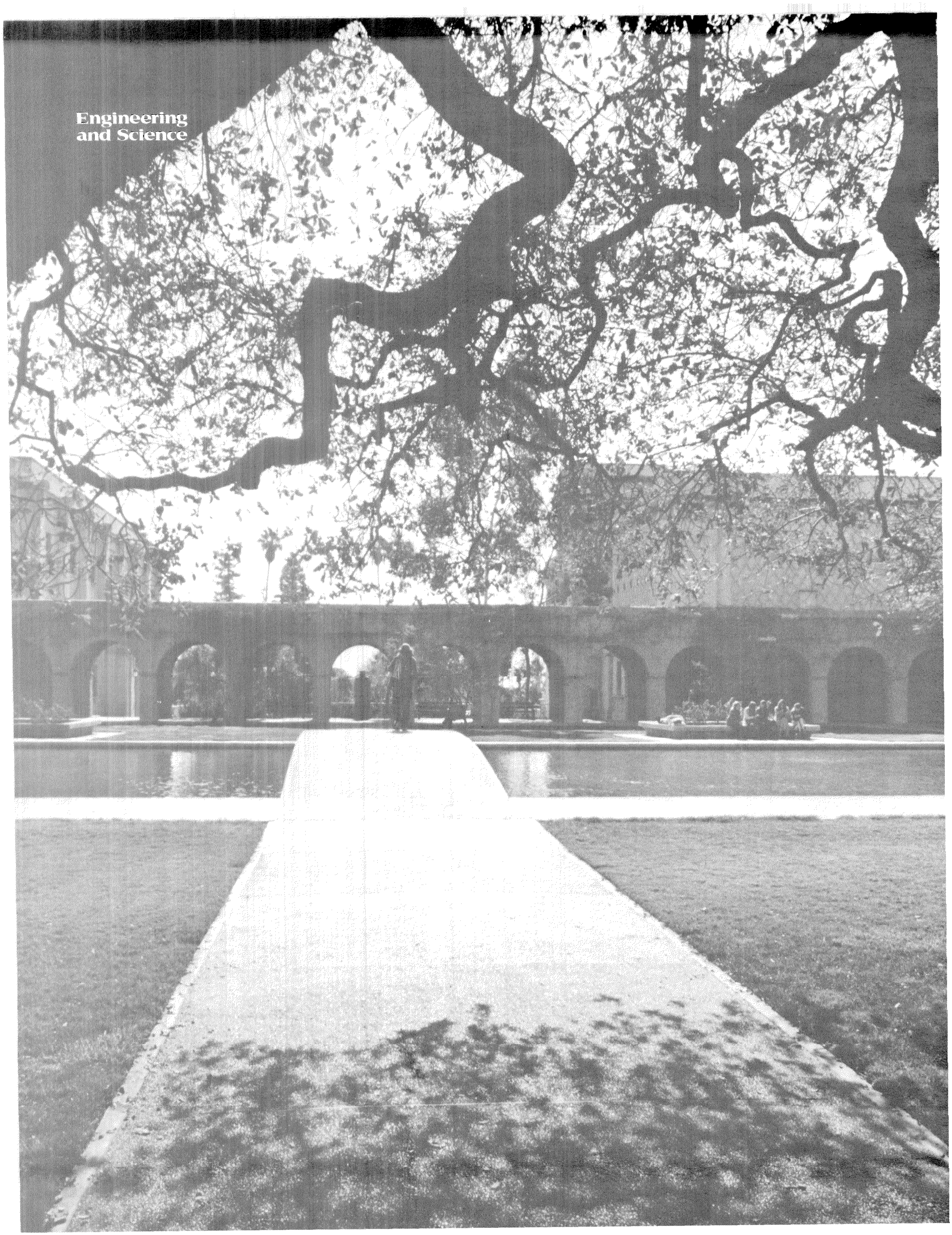

Engineering
and Science

Caltech at the leading edge...

The Institute's new development campaign to raise $130 million was announced on January 14 at a banquet attended by more than 700 civic and business leaders at the Beverly Wilshire Hotel. The goal of the five-year campaign is to raise $50 million in endowment funds, $40 million for current operating funds, $27 million for new buildings and endowments for their maintenance, and $13 million in trusts whose returns may eventually be used in many ways.

As an excellent beginning, $33 million of the $130 million goal already have been raised.

"Caltech needs $130 million in gifts and endowments to continue its unexcelled education of scientists and engineers and to continue the leadership role of its productive and very substantial research program," said President Harold Brown. "Excellence is not cheap, but it is well worth the cost.

"At a time when opportunities are extremely promising for major scientific advances, we face a shortage of funds. Simply put, we are barely able to keep up with inflation. The number of our graduate students has been severely reduced by cutbacks in federal support.

"We have curtailed spending, postponed construction of needed buildings, all but halted the hiring of new faculty, made stringent economies in administrative and support services, and increased tuition. Thus we have weathered until now the current financial storms, but not without damage.

"As we look ahead, the financial picture for education appears far from bright. After a careful appraisal of the situation and taking into consideration that we are determined to keep Caltech at the leading edge of science and technology, we have decided to seek the help of the private sector of our country in the amount of $130 million."

To improve Caltech's financial stability, the substantial sum of $50 million is being sought for additional endowment which, Brown emphasized, "is the strength of any great university." Invested endowment brings a dependable return each year, provides for growth of the principal, and allows freedom to innovate, to explore, and to plan ahead.

In 1970-73 Caltech's endowment income amounted to 15 percent of its total revenue. The Institute hopes to increase endowment income to 20 percent, which is more in line with that of other leading private universities. Caltech's operating budget for fiscal 1974 is $44 million.

Noting that Caltech has one of the world's most distinguished faculties, Brown pointed out that the Institute has only 11 endowed professorships. Even extending that honor only to Caltech's most noted professors would require the addition of many more endowed chairs.

This outstanding faculty is being augmented by the Sherman Fairchild Distinguished Scholar program which, under a $7.5 million grant from the Fairchild Foundation, brings world leaders in various fields to the campus for periods ranging from two months to two years.

Caltech needs $40 million for current operating expenses —for education and research, and for more mundane but nevertheless vital expenses such as utilities and insurance premiums. Such funds would also be used for purchasing equipment and for modernizing some older buildings.

Equally important is the need for specific new buildings and for funds to support the research to be carried out in them. One pressing concern is for a laboratory building to house new joint projects in biology and chemistry related to medical science. Biologists and chemists would be brought together in this structure, some of them working in conjunction with researchers at Caltech's Jet Propulsion Laboratory and at nearby hospitals.

A new building is needed to house research in earthquake engineering and the environment, including several research projects in environmental engineering science.

Another urgent requirement is for a new astrophysics building. The development of several new branches of astronomy, as well as new discoveries in both optical and radio astronomy, makes it important to bring specialists in these fields together in one facility.

Funds are also being requested for improving physical education, health, and nonacademic facilities for students, and for necessary campus landscaping projects.

While the development campaign is primarily designed to meet the needs of the next ten years, it also calls for raising $13 million in trusts that will produce funds for future activities at the Institute.

The chairman of the new campaign is Harry J. Volk, a Caltech trustee since 1950 who is chairman of the Union Bank and chairman and chief executive officer of Union Bancorp. He presided at the kickoff banquet. Thornton F. Bradshaw, president of Atlantic Richfield Company, was the principal speaker. His address, "The Things Which Men Can Do," follows.

The Things Which Men Can Do

The greatest raw material the world possesses is human talent. And the greatest hope we have for the creation of a better world is the profitable use of that talent

For most Americans, I would guess, the energy crisis appeared at first to be just one more of those relatively minor but nonetheless deeply annoying personal trials that seem to be characteristic of our time. Lining up for gasoline, watching the TV picture shrink during a brown-out, reading something in the paper about still another utilities rate hike—when were they going to solve these problems and get things back to normal?

But gradually the annoyances began to blend into an emerging reality that was neither small nor temporary. Something indeed had gone very wrong. Our economic-social game plan—in essence producing more of everything into the indefinite future—was clearly out of whack. The frantic rate of material growth that we had come to consider normal was not only exposed as anything but normal but also clearly not sustainable. In other words, the throwaway society expired of sheer overindulgence—A.D. 1973.

Thus we have entered, mostly unaware and surely unprepared, the new era of scarcity. And the question that faces all of us, particularly those of us in the university world, is what our response to this challenge will be—because it is certainly the most profound challenge our generation and the next will be called upon to deal with.

The purely physical side of the problem is not difficult to perceive, though it wasn't widely understood until the Arab oil embargo—our economic Pearl Harbor—occurred in October. With or without the embargo, however, and whether or not you buy the theory that the oil companies are conspiring, the United States is emphatically short of petroleum and all other usable forms of energy.

Energy is the cause célèbre of the moment, of course, and the issue that has earned me and my colleagues in the industry a number of hard looks and harder words. I am afraid we are going to have to get used to that because the energy problem is going to be with us for a long, long time—even if the Arabs have a change of heart tomorrow and start all-out pumping. I won't get into the reasons for saying that. If you read anything more oriented toward current events than the *National Philatelic Review* you know the specifics of the energy debate as well as I do. It's a well-covered story.

This address was given by Thornton Bradshaw, president of Atlantic Richfield Company, at the dinner that announced the beginning of Caltech's campaign to raise $130 million.

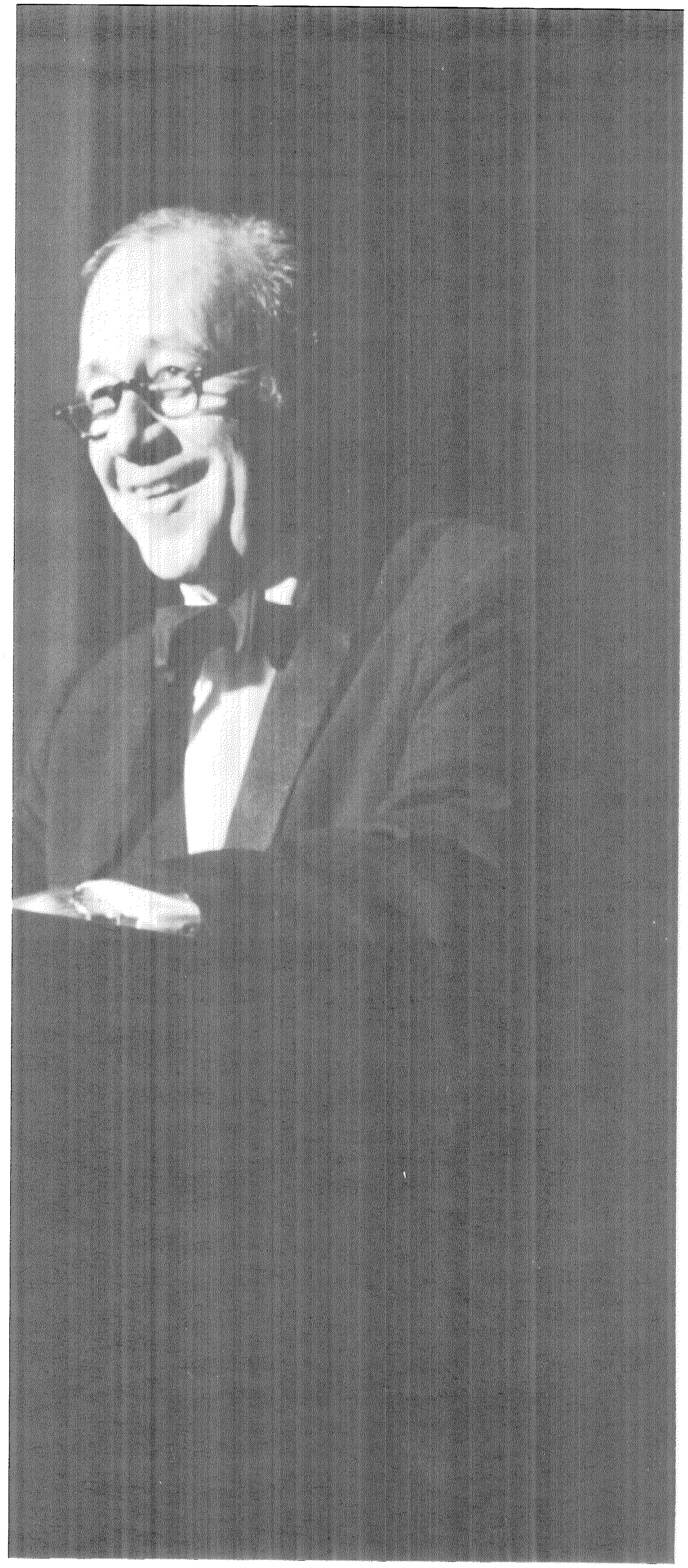
But energy is only one item on our vanishing commodities list. We seem to be running out of practically everything. Food is scarce and expensive. Arable land is low. And we're apparently heading for a host of scarcities of raw materials, including bauxite, copper, lead, zinc, manganese, magnesium, and iron ore. The situation is producing a hoarding psychology. Johnny Carson talked about the paper shortage on his show recently, and the Safeway stores in the Baltimore-Washington area reported that the next day they were cleaned out of every piece of paper down to the last napkin.

But amid all shortages, the crisis of scarcity is certain to generate at least one surplus. I am speaking of prophets, and not the financial kind, though in certain cases that may happen too. I refer to the emergence of men and women who, in the words of the poet Archibald MacLeish, are "familiar with the shape of the future and willing to share their familiarity with others."

The trouble is, they usually are prophets of doom. MacLeish was talking at a university commencement in 1941, and his concern was with those who believed that the tide of Naziism that had engulfed Europe was an irresistible movement of history that could not be usefully opposed. "Such prophecies," MacLeish said, "are prophecies of defeat, prophecies of negation, prophecies not of the things which men can do but of the things which men cannot do."

I think we may take encouragement from the fact that those particular gloomy theorists were wrong. In fact, thus far at least, the prophets of doom have *always* been wrong. And some of them—most, perhaps—have been quite sincere. Thomas Malthus, for example, the English economist and demographer, predicted an unpleasant end to the species in an essay published in 1798. Since population must always increase faster than production, Malthus reasoned, people would always exist on the edge of

BY THORNTON F. BRADSHAW



starvation. While all the results aren't in, it does seem clear that Malthus was wrong, because he failed to foresee the new and more productive methods of agriculture that men would invent.

Much more recently the Club of Rome made its well-known judgment that the world had reached the limits of growth because each potential road to expansion was in some way effectively barred, either by a shortage of raw material, environmental problems, or some other factor. I believe that the Club of Rome's theory will turn out to be as erroneous as the Malthusian theory because it, too, ignores the great x-factor—man's remarkable ability to cope with his condition.

The historian Barbara Tuchman has this to say about the human factor: "As our century enters into its final quarter I am not persuaded despite the signs that the end is necessarily doom. The doomsayers work by extrapolation. They take a trend and extend it, forgetting that the doom factor sooner or later generates a coping mechanism.

I have a rule for this situation, too, which is absolute. You cannot extrapolate any series in which the human element intrudes. History—that is, the human narrative—never follows and will always fool the scientific curve."

Well, I don't know how the crisis of scarcity is going to resolve itself but, relying on the Tuchman theory, I do believe that there are many things which men, and women, can do—indeed must do—to convert what could very well be an impending disaster into an opportunity of a very real kind. But to do this we must not only examine the economic and social implications of shortage, but the moral implications as well. We must not only plan to live with less than we have had, but we must also closely examine the assumptions underlying our living patterns. In the process we may discover, or perhaps rediscover, a philosophy of life that we had lost amid the discarded wrappings of the throwaway society.

It is quite clear that an era of shortages of energy and raw materials will change the present status of nations—the haves, the have-nots, and the dispossessed—and will change ways of life within those nations.

In a world of energy shortages and raw-materials shortages the highly developed, highly interdependent societies clearly have the most to lose. The United States is entering into a period of economic pause due to the energy cut-back. We don't know how severe it will be.

We are short somewhere between 2.5 million and 3.5 million barrels of oil a day, and the impact of that shortage will translate inevitably into personal inconvenience and in some cases real hardship. And yet, given time, given a whole-hearted adoption of the conservation ethic, given a government energy policy transcending in intelligence and flexibility anything we have had in the past, and given a vigorous energy industry, we *can* cope. We can make it through the next three to four decades by developing fully and using carefully the fossil-fuel deposits that exist within our borders. And when they are gone, perhaps in 40 years or so, we hope that we will then be ready to turn to the essentially inexhaustible resources of solar and nuclear power.

Europe and Japan are far more vulnerable than we to the oil weapon—as their recent behavior toward the Arab nations (with the conspicuous exception of the Netherlands) has emphasized. The United States needs Arab oil to sustain a reasonable rate of growth during the next decade or so, or until our alternate sources of energy such as oil shale and tar sands and liquefied and gasified coal can begin to power our cars and light our houses and drive our factories. But Europe and Japan have *no* alternate energy sources. For them, it is Arab oil or economic paralysis.

The throwaway society expired of sheer overindulgence, and we have entered, mostly unaware and surely unprepared, the era of scarcity

And so the first large implication of the crisis of scarcity is an inevitable realignment of traditional have- and have-not nations and a redefinition of their economic powers. The U.S., with 6 percent of the world's population, will no longer have the freedom to use 35 percent of the world's energy.

We may find that something of a comedown but one with rich compensations. A more prudent use of energy can produce a controlled but reasonable rate of growth that will sustain our economic strength but do so with a greater degree of attention to the human factor. If uninhibited growth means a Los Angeles that is twice as big and twice as crowded and twice as polluted as it is now, then I don't want any part of it or of any other motorized megalopolis of the future.

But other industrialized societies will have more severe adjustments to make in this approaching realignment of the haves and have-nots. I do not expect the advanced nations of Western Europe to be suddenly reduced to a poverty-stricken impotence. Such a fate is unthinkable. But France, Germany, Italy, and the rest of Europe, as well as Japan, must nevertheless begin to address the problems of employment, transportation, and leisure in ways consistent with a reduced level of material prosperity vis-à-vis the rest of the world. The only industrialized nations I can think of that will avoid the effects of this kind of economic realignment are the U.S.S.R. and Canada because of the balance that exists in those nations between industrial capacity and availability of raw material. But the rest of the industrialized nations, including the U.S., must plan ways in which to provide a quid pro quo to the countries that have raw materials to export. If Britain wants Arab oil, for example, she must give in return not a currency which is easily debased but a service of some kind, probably technological assistance.

If she wants copper from Zambia, she must be prepared to do the same, acutely conscious that the exchange is no longer between a superior and an inferior culture but between two increasingly equal parties bargaining with each other in the world marketplace on even terms and against a background of mutual respect.

Maintaining an economic balance between consuming and producing nations will obviously require considerable restraint on the part of the consumers and particularly on the part of the United States. Whatever balloons may have been floated to the contrary, the hard fact is that there is no conceivable way other than a full-scale depression for this country to achieve energy independence by 1980. Even if we are able to limit our growth to an annual average of 3.5 percent instead of the 4.5 percent of recent years, we can expect to do little more than slightly depress the rising curve of demand and thereby lessen to some degree the amount of oil we will have to import from the Middle East.

Finally, the industrialized nations must change the thrust of science in order, first, to provide new energy and raw material forms and, second, to provide the basis for the new life style. Much of the burden for this shift will necessarily fall on centers of research such as Caltech. I will have more to say about that development in a moment.

In underdeveloped countries that are rich in raw materials —primarily in the Middle East and in Africa though to a degree in the Far East and South America—other problems are beginning to surface in the realignment process. One of them, not surprisingly, is money. They literally have too much of it, at least in terms of their own internal investment needs. We have developed figures showing that, if the Arab nations produce oil according to our projected requirements, by 1976—two years hence—

they will have built up a floating balance of about $150 billion. By 1980, again assuming that they produce all the petroleum we ask, monetary reserves in Arab hands will amount to more than $300 billion.

Since loose investment capital in such incredible volume would wreak havoc in even the strongest of the world's monetary systems, we must take what measures we can to limit oil imports. Excessive reliance on Arab oil also poses security threats that we are only too aware of. But whatever limitations we attempt to impose, the Arabs will be selling us oil, and a lot of it, for years to come, though probably not in the amount we would like. They will also be selling it to Europe, Japan, and developing nations that can afford it. And so the question arises as to how countries such as Saudi Arabia will handle their new affluence. And the political power that comes with it.

Will the raw-materials-rich countries make the same mistakes we have made, falling into the "more is better" trap? Or will they make more responsible and more livable decisions, particularly with regard to the needs of their third-world neighbors? The feeling is growing, even within the Middle East itself, that the oil-rich countries should be using their wealth to provide development capital for countries such as Egypt, Syria, and Jordan, rather than giving them weapons of war. An Arab Marshall Plan—perhaps a Faisal Plan—would siphon off funds which could not be profitably invested in the industrialized nations anyway and could take over some of the aid to developing countries which the industrialized nations, burdened by ever higher energy costs, could no longer shoulder.

Indeed it is the third world, where the deprived scratch out marginal existences in places such as India, Southeast Asia, and Central America, that is most gravely menaced by the crisis of scarcity. For the third world the problem may be very simply stated: In a developing shortage of materials and a developing scarcity of energy resources, how can poor nations avoid losing all hope for further advancement? With the international market pressuring the price of fuel ever higher, how can nations with neither resources nor industrial capacity obtain energy sufficient for their basic needs? These countries have no leverage to exert, no bargaining pressures to apply. They can only hope that the balance of humanity will respond to their condition and act forthrightly to remedy it.

There you have the triple implication of the crisis of scarcity—industrialized nations abruptly and permanently losing the base of their prosperity, cheap raw-material imports, while simultaneously having to cut back grossly wasteful life styles; emerging raw-materials-rich nations swamped by an embarrassment of riches and power; third-world nations threatened with the possibility of being priced out of the small percentage of the world market they are now able to control.

We must not only plan to live with less than we have had, but we must also closely examine the assumptions underlying our living patterns

But, as we have been frequently reminded in recent days, the Chinese character for the word "crisis" is made up of two others—one meaning danger, the other meaning opportunity. The crisis of scarcity thus presents an opportunity as well as a danger to all of us. For those of us in the industrialized nations it can mean the development of a life style more in tune with nature and with our basic needs as humans. If the fuel shortage means we can't go back to nature in a $15,000 recreational vehicle because it only gets five miles a gallon, we still can go back on foot, and undoubtedly find it more recreational in the bargain.

If the crisis forces us to pay more attention to our basic needs—needs such as clean air and water, reasonable material affluence, and an end to the throwaway society—then it will have proved to be an opportunity indeed.

If the crisis enables the raw-materials-producing countries to develop their full strengths and potential without aping the mistakes of the industrialized nations, it surely will help to correct the chronic material and political imbalance which is perhaps the single greatest threat to peaceful co-existence of the human family. Indeed, if the crisis awakens men to a fuller realization of their fundamental interdependence, then it can mean a renewal of hope for the third-world peoples. Selfishness and overindulgence having failed, we can perhaps turn to the task of fashioning a more just distribution of the world's goods.

In fact, I strongly believe that while the adjustments we face will be far from simply decided or easily made, the shortages of energy and materials are in the final analysis more opportunity than danger—particularly for private institutions of higher education such as Caltech. The greatest raw material the world possesses is human talent. And the greatest hope we have for the creation of a better world is the profitable use of that talent—through individuals and through human institutions.

Caltech is one of the institutions that has done great service in the past. With the proper level of support and continued encouragement, that record of service will prove, I am sure, only a prologue to far greater contributions to the scientific, social, and moral orders. I will always be grateful that I was here to share in the initiation of a new era of growth not only for Caltech but for the broad cause of human progress in which it serves. □

Take the World From Another Point of View

This is a Yorkshire Television interview with Richard Feynman, which was shown in Great Britain in 1973. Our article is an abridged—but otherwise unedited—transcript of the sound track, with the comments and questions of the interviewer in italics.

Take any crazy idea. It is hard to make up a very crazy idea—witches, for instance. And you talk about what people used to believe about witches, and you say, "How could they believe in witches?" And you turn around and you say, "What witches do we believe in now?"

What ceremonies do we believe in? Every morning we brush our teeth. What is the evidence that brushing our teeth does any good against cavities? And you start wondering. Are we all imagining that, as the earth turns and the orbit has an edge between light and dark, that along that edge all the people are doing the same ritual—brush, brush, brush—for no good reason? Have you tried to picture this perpetual line of toothbrushes going around the earth?

Take the world from another point of view. Now it may well be that brushing the teeth is a very good thing because it gets rid of cavities, but you can try to find out whether it does or doesn't. You ask your dentist. He says, "Of course." And you say, "What about evidence?" I have not found the evidence from dentists, because they just learned it in school. Now I am not trying to argue whether it is good or bad to brush teeth. What I am trying to argue for is to *think* about it. Think about it from a new point of view.

You see—I have had in my life a number of pleasant experiences. One of the earliest ones was when I was a kid and I invented a problem for myself—the sum of the powers of the integers—and in trying to get the formula for it I developed a certain set of numbers, the formula for which I couldn't get, and I discovered later that those were known as the Bernoulli numbers and they were discovered in 1739. So I was up to 1739 when I was about 14.

Then a little later I'd discover something, and I would find out that I just may have invented a thing which we now call operator calculus. That was invented in 1890 something.

Gradually I was inventing things that came later and later. But the moment when I began to realize that I was now working on something *new* was when I read about quantum electrodynamics. I read a book, and I learned about it. For example, I read Dirac's book, and he had these problems that nobody knew how to solve. I couldn't understand the book very well because I really wasn't up to it. But there in the last paragraph at the end of the book it said, "Some new ideas are here needed." And so there I was. Some new ideas were needed. OK—so I started to think of some new ideas.

Richard Feynman, Nobel Prizewinner, and his son Carl step gingerly down the wet cobbles of Millback, high in the Yorkshire Pennines. Feynman, professor of physics at the California Institute of Technology, retreats to this remote village near his wife's home for a special purpose. It is here he finds the time and solitude to sift the ideas that have made him the most feared and original mind in modern physics. Feynman is in the forefront of one of the oldest and most intriguing games of hide and seek in science—finding the ultimate constituents of the world. In this search Feynman is a celebrated maverick who was encouraged by his father, who was a New York clothing salesman, to confront conventional wisdom.

One Sunday all the kids were walking in little parties with their fathers in the woods. The next Monday we were playing in a field, and a kid said to me, "What's that bird? Do *you* know the name of that bird?"

I said, "I haven't the slightest idea."

He said, "Well, it is a brown-throated thrush." He said, "*Your* father doesn't teach you *anything*."

But my father had already taught me about the names of birds. Once we walked, and he said, "That is a brown-throated thrush. In German it is called the *Pfleegelflügel*. In Chinese it is called *Keewontong*. In Japanese a *Towhatowharra*, and so on. And when you know all the names of that bird in every language, you know *nothing*, but absolutely *nothing*, about the bird."

So I had learned already that names don't constitute knowledge. Of course that has caused me a certain amount of trouble since because I refuse to learn the name of anything. So when someone comes in and says, "Have you got any explanation for the Fitch-Cronin experiment?" I say, "What's that?"

And he says, "You know—that long-lived k meson that disintegrates into two pi's."

"Oh, yes, *now* I know."

I never know the names of things.

What my father forgot to tell me was that knowing the names of things was useful if you want to talk to somebody else—so you can tell them what you are talking about.

The basic principle of knowing about something rather than just knowing its name is something that you have stuck to, isn't it?

Yes, of course. We have to learn that these are the kinds of disciplines in the field of science that you have to learn—to know when you know and when you don't know, and what it is you know and what it is you don't know. You've go to be very careful not to confuse yourself.

How else did he try to mold your methods of thinking—the way you looked at the world?

Well, we had a lot of little games. Like at the dinner table he would pick up some little problem, and he would say, "Supposing we were Martians, and we came down from Mars to this Earth, and we would look at it from the outside." I can't explain exactly what he meant, but there is a way of looking at something anew, as if you were seeing it for the first time, and asking questions about it as if you were different. For instance, suppose you were a Martian who never slept. (They don't have to sleep, say.) And you come down to this Earth and you saw these people who have this funny property that every day for a certain amount of time they have to lie down and they're unconscious. Then the natural questions would be: How does it feel to get unconscious? What happens to you? Do ideas run along and suddenly they stop? Or do they just run more and more slowly? Or what *happens* to your ideas?

So I tried to answer the question: What happens when you become unconscious?

Do you find that these days when you are faced with a particularly difficult problem, when you are absolutely stuck, you still tend to say, "Let's look at it like a Martian would look at it?"

Sometimes. But there are a lot of things that people have done.

For example, Faraday described electricity by inventing a model (field lines). Maxwell formulated the equations mathematically with some model in his head, and Dirac got his answer by just writing and guessing an equation. Other people, like in relativity, got their ideas by looking at the principles of symmetry—and Heisenberg got his quantum mechanics by only thinking and talking about the things he could measure. Now take all these ideas: Try to define things only in terms of what we can measure. Let's formulate the equation mathematically, or let's guess the equation—all these things are tried all the time. All that stuff—when we are going against the problem, we do all that. It is very useful, but we all know that. That is what we learn in physics classes—how to do that.

But the *new* problem is where we are stuck. We are stuck because all those methods don't work. If any of those methods would work, we would have gone through them. So when we get stuck in a certain place, it is a place where history will not repeat itself. And that even makes it more exciting. Because whatever we are going to see—the method, the trick, or the way it's going to look—it's going

When you know the name of a bird in every language, you know nothing– but absolutely nothing– about the bird

to be very different from the way we have seen before, because we have used all the methods from before. So therefore a thing like the history of the idea is an accident of how things actually happen. And if I want to turn history around to try to get a new way of looking at it, it doesn't make any difference; the only real test in physics is experiment, and history is fundamentally irrelevant.

The most enduring legacy from his father was not just learning to question the physical world, but an enthusiasm for the inquiry, which—at 54—Feynman shares today.

It has to do with curiosity. It has to do with people wondering what makes something do something. And then to discover, if you try to get answers, that they are related to each other—that things that make the wind make the waves, that the motion of water is like the motion of air is like the motion of sand. The fact that things have common features. It turns out more and more universal. What we are looking for is how everything works. What makes *everything* work.

What happens first in history is that we discover the things that are on the face of it obvious. And then gradually we ask small questions, and then we dig in a little deeper into things that we need to do a little more complicated experiment to find out about. But it is curiosity as to where we are, what we are. It is *very* much more exciting to discover that we are on a ball, half of us sticking upside down and spinning around in space. It is a mysterious force which holds us on. It's going around a great big glob of gas that is fed by a fire that is completely different from any fire that we can make (but now we *can* make that fire—nuclear fire.)

That is a much more exciting story to many people than the tales that other people used to make up about the universe—that we were living on the back of a turtle or something like that. They were wonderful stories, but the truth is so much more remarkable. So what's the pleasure in physics for me is that it is revealed that the truth is so remarkable, so amazing, and I have this disease—like many other people who have studied far enough to begin to understand a little of how things work. They are fascinated by it, and this fascination drives them on to such an extent that they have been able to convince governments and so on to keep supporting them in this investigation.

As a theoretical physicist, Feynman in recent years has been concerned with the long-asked, almost childish question, "What are things REALLY made of?" "What makes up the world we see around us?" "Have we at last come to the foundation stone from which we can make anything—a tree, a human being—or must we go on looking at smaller and smaller pieces and going deeper and deeper into a bottomless pit?" Feynman is trying to knit together our scattered knowledge of the smallest pieces of matter to see whether they fit a pattern. The problem, although fundamentally important to all branches of science, seems far removed from everyday reality.

The world is strange. The whole universe is very strange, but you see when you look at the details that the rules of the game are very simple—the mechanical rules by which you can figure out exactly what is going to happen when the situation is simple. It is like a chess game. If you are in a corner with only a few pieces involved, you can work out exactly what is going to happen, and you can always do

that when there are only a few pieces. And yet in the real game there are *so* many pieces that you can't figure out what is going to happen—so there is a kind of hierarchy of different complexities. It is hard to believe. It is incredible! In fact, most people don't believe that the behavior of, say, me is the result of lots and lots of atoms all obeying very simple rules and evolving into such a creature that a billion years of life has produced.

There is such a lot in the world. There is so much distance

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New China Hands–American Scientists Visit

BY HENRY ABARBANEL

A Caltech alumnus (BS '63) reports his enormous enthusiasm –and severe reservations– about the new China

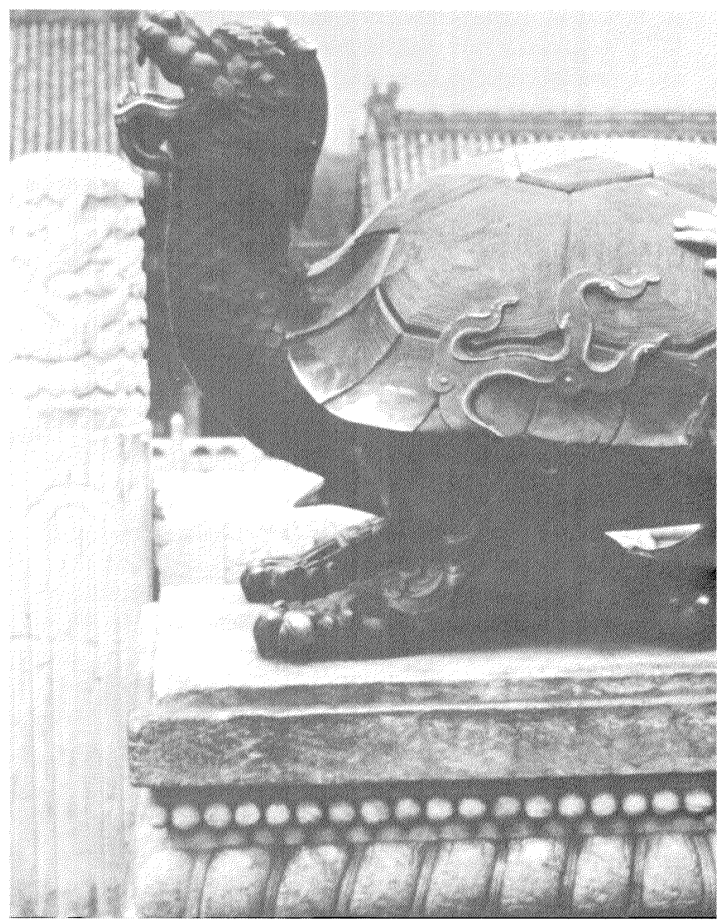
From the moment we left the hotel that evening, we were sharply aware of the quiet, historical nature of our little visit. As our cars turned left off Tung Ch'ang An Chieh and into the diplomatic area of the city, we could see the American flag flying over the Liaison Office, guarded by two alert members of the People's Liberation Army. We entered the building to join what was for most of us an activity which we would consider attending in no other foreign country: a Fourth of July party—given by the Chief of the American Delegation in Peking, David Bruce.

The reception was simple, with excellent Chinese hors d'oeuvres and fiery mao tai liquor accompanying the conversation. American mixed drinks were also provided, and with a good old gin and tonic (all of us already understood the dramatic effects of 120-proof mao tai), I sat down to talk with Wu Yu-hsun, a vice president of the Chinese Academy of Sciences, one of our hosts in China, and Al Jenkins, the deputy chief of the American Liaison Office.

Jenkins is an "old China hand" who had spent considerable time in Peking before Liberation in 1949 and had been present at the last Peking Fourth of July celebration 24 years ago. He spoke a bit about the contrasts between the old China and the China he now saw. "The thing that has amazed me most," he said, "is that in China today no one is fantastically rich, but no one is desperately poor. When it rained yesterday, everyone had a plastic raincoat. Before 1949 only the rich could protect themselves from the rain."

My presence at that remarkable Fourth of July celebration was possible because of my good luck in being a member of the first American physics delegation to the People's Republic of China. My fellow travelers were Luis Alvarez of the University of California at Berkeley, and Jan Alvarez; Owen Chamberlain, also from Berkeley, and his friend June Steingart; Murph Goldberger from Princeton University, with Mildred Goldberger and their son Joe; Ned Goldwasser from the National Accelerator Laboratory, and Lizy Goldwasser; Francis Low of MIT and Natalie Low; David Pines of the University of Illinois, and his wife Suzy. Each of us had applied in one way or another to visit China, and the delegation was assembled by the Chinese government at the end of May 1973 and invited to come to China as the guests of the Chinese Academy of Sciences during a period of three weeks in July 1973.

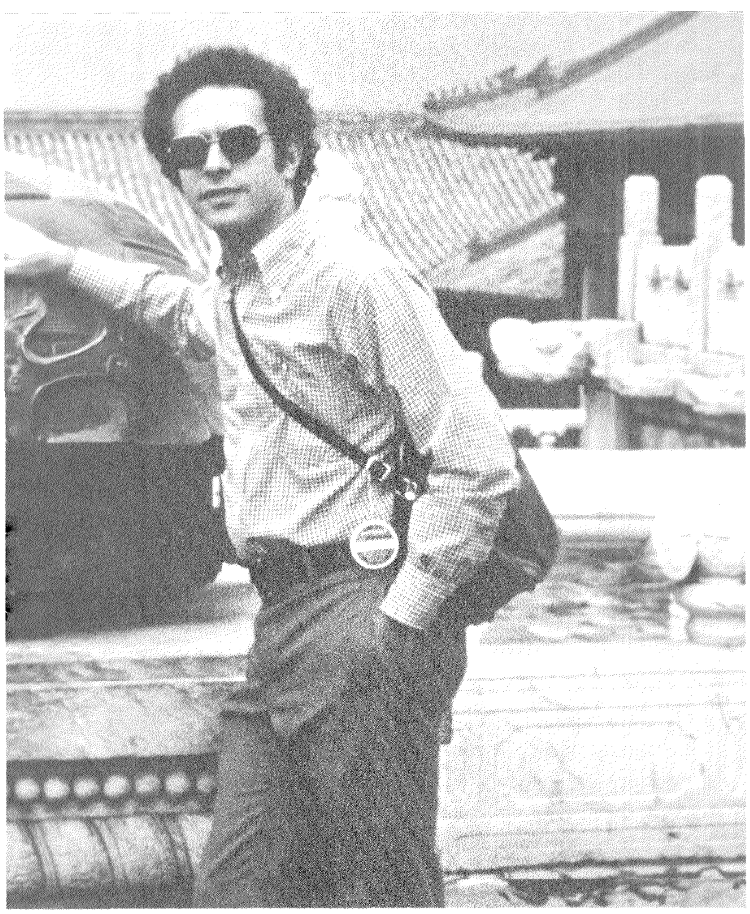
The purpose of our visit was certainly not clear to any of us. The scientific interest among the seven physicists is primarily in high energy physics. There were three theoreticians (Abarbanel, Goldberger, and Low) and three experimentalists (Alvarez, Chamberlain, and Goldwasser). Pines has worked as a theorist in both solid state physics and more recently in astrophysics. It goes without saying



the People's Republic

that we all shared an intense curiosity about both the standard tourist sights of China and the life and culture of the new China. Beyond the very beginnings of a satisfaction of that curiosity and the constantly repeated announcement that our visit served "to enhance the mutual understanding and friendship between the people of China and the people of America," no definitive purpose ever did emerge.

We had rather significant contact with our scientific colleagues in Peking, Shanghai, and Canton. And members of our delegation delivered lectures on their various interests in physics that were well attended and were followed by vigorous, informative question periods. In general, however, our journey consisted of rather more formal visits to factories, people's communes, research institutes, universities, hospitals, primary schools, national monuments, and museums.



In offering this brief account of some of the highlights of our trip, I feel I ought to make it clear from the outset that I am not a China expert. My command of the language is hardly notable: I speak perhaps 25 words in the "absolutely necessary" category with an accent that only a generous teacher might agree resembles the Peking dialect now taught in China. My conversations were, therefore, either through or with the interpreters accompanying us. I am a very amateur student of Chinese history since the Opium Wars of the 1840's and listen happily to anyone who speaks with even minimal authority about Chinese art. I am at best a "new China hand" who has been quite impressed by my one visit to the new China and who has at once both an enormous enthusiasm and severe reservations about it.

Even the most casual student of China has read of the poverty, disease, hunger, and pervasive deprivation that haunted the cities and countryside alike during the last years of the Ch'ing dynasty and the 38 years of civil strife that followed its fall in 1911. This is certainly on one's mind as he visits the cities and countryside of the new China. The impression that comes across most strikingly is that the people are now well fed, well clothed, and reasonably, if not elegantly, housed. Everyone except the severely handicapped and aged appears to be employed.

Wages are, of course, regulated by the State. In a city a beginning worker may earn 30-40 yuan ($15-$20) each month while a veteran worker will earn up to 120 yuan per month. From this income one must pay 3-4 yuan a month for an apartment of three to five rooms and approximately 15 yuan a month for each person for food. The diet consists of fish, chicken, pork, duck, and occasionally beef, rabbit, and delicacies, in addition to vegetables and the staple grain foods: rice in the South and wheat in the North. This food is brought into cities from the people's communes each day, and is sold in areas along the streets that appear to have been designated as neighborhood markets. The fact that we saw no refrigeration or freezing facilities in any of the homes or apartments we visited clearly implies that these marketplaces are frequently visited by housewives.

A digression on "Women's Lib": It is a modern Chinese

Henry Abarbanel may be around for a long time. Touching this bronze turtle in a courtyard at the Palace Museum in Peking is supposed to guarantee living for 10,000 years.

saying that at Liberation in 1949 "men were liberated once, but women were liberated twice." To a significant extent this is true. Women do seem to perform all tasks that employ men. We were told they receive the same salaries. They are, however, under-represented on the administrative bodies of China (called Revolutionary Committees) and in membership in the Chinese Communist Party. Further, when we asked who does housework and tends the children, the answer was, "The women, of course." From the point of view of several of us, it seemed that Chinese women would probably someday be liberated a third time.

Peasants (synonymous in China with farmers) own their houses on the communes. These houses appeared to be very clean and, in the heat of the Chinese summer, were cool and comfortable. The peasant's income is received both in food—according to the annual production of his commune—and in cash. The amount he earns is based on a system of work points which are assigned by discussion among the members of his "production team." Private garden plots and the raising of domestic animals are permitted and are used to supplement the income and diet of peasant families. One family we visited on a commune outside Peking sold three pigs last year at approximately 60 yuan apiece. Added to a peasant family cash income of perhaps 400 yuan a year, this is significant.

Eighty percent of China's 800,000,000 people live on the 70,000 communes around the country. Thus, it seems worthwhile to describe in more detail the Double Bridge People's Commune about 10 km southeast of Peking. Our translator told us that this was a "poor" commune and that he was almost embarrassed to bring "distinguished foreign friends" there. My reading indicates that it is a typical commune. It was organized during the Great Leap Forward in 1958 by combining 46 neighboring villages which had been working as members of smaller co-operatives since shortly after the land reform of 1951-52. Forty thousand people live on the 90 square km of the commune. The administration of the commune is in the hands of concentric sets of revolutionary committees. At the center is a body of 40 members—only 6 of whom are women. The next division is into six "production brigades," which more or less coincide with the cooperatives existing before 1958. After that, the workers are members of production teams consisting of 500-1,000 people. It is at the level of the production team that the detailed decisions are made about who works where and who receives how much reward for what work. The revolutionary committees at each level are, in principle, separate bodies from the local communist party organization. In fact, of course, there is a large representation of party members on the various revolutionary committees. Among other reasons, this is to be anticipated since the party chooses its membership from the most industrious and articulate part of the population. Precisely that kind of person could be expected to be elected to the revolutionary committees.

The members of a production team are thoroughly involved in each other's lives. After leaving school to work, and before marriage, men and women live in sex-segregated dormitories with fellow team members. Each Chinese citizen is strongly "encouraged" to attend six hours a week of study sessions of "Marxism-Leninism-Mao-Tse-tung Thought"; and these study groups are organized among members of a production team. (When we asked, in a Peking neighborhood, whether one could choose not to attend these "voluntary" study sessions, we were told it was possible, but that "the comrades will come to talk to you" to persuade you to join. As far as we could tell, everyone attended.)

Marriage is very straightforward in China. A couple must first receive permission from their production unit. Then they go down to a local police station and register—and that's it! Permission for a couple to marry, by the way, is not always forthcoming just for the asking. A young American-Chinese student studying for the summer at Fu Dan University in Shanghai told us that when he spent some time on a local people's commune, he arrived in the midst of a big controversy over the refusal by his production team to allow a couple, each aged 25, to marry. Controversy is perhaps an inappropriate word. The production unit had made its decision several weeks before, and now the male comrades were talking to the young man—and the female comrades to the young woman—to convince them of the validity of the "decision of the masses." There was no question of the decision's being reversed by discussion—only how long it would take the comrades to persuade the couple to accept it. The same couple probably would be allowed to marry, if they still want to, in two or three years, when they are more "mature." For reasons of population control, women are encouraged to marry at around 25-27 and men at 28-30.

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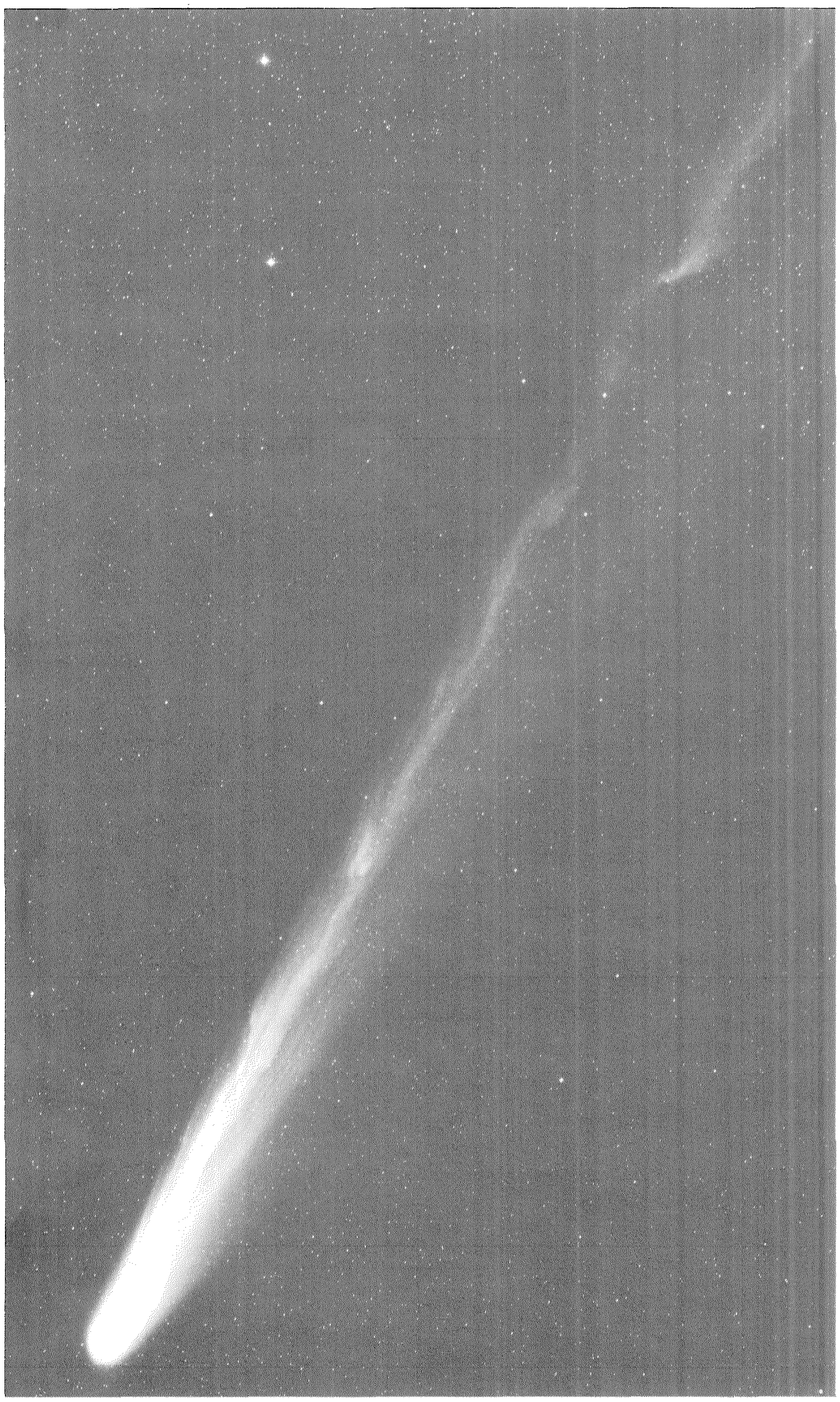
The Month at Caltech



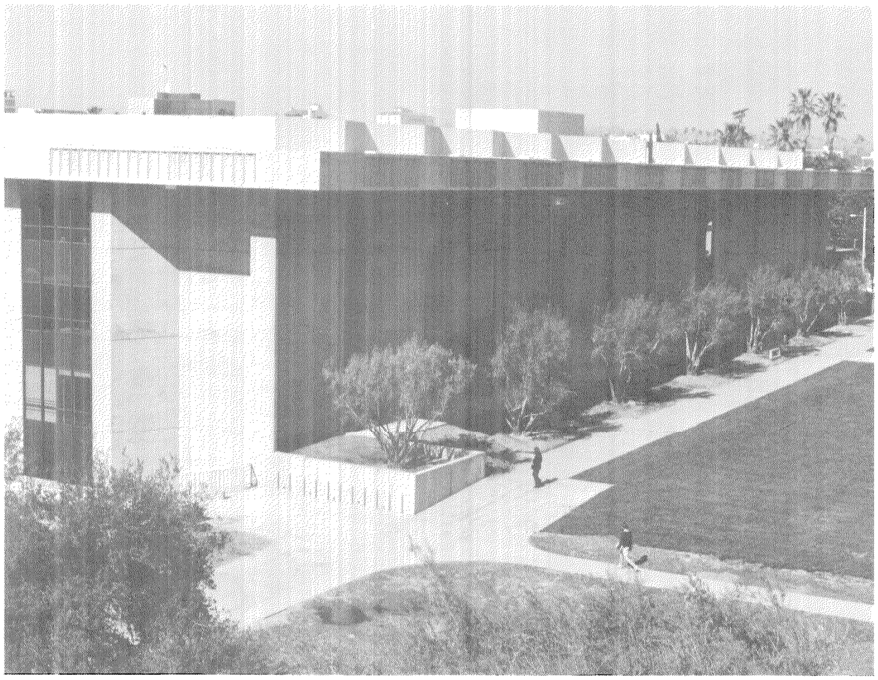
Portrait of a Visitor

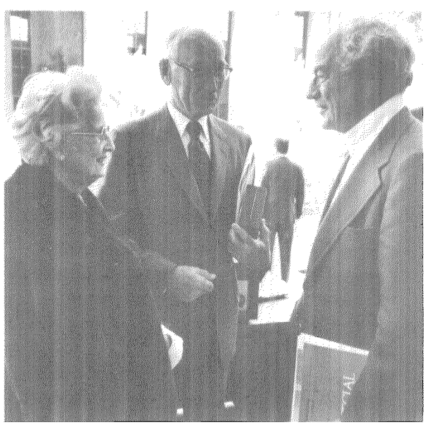
For millions of amateurs, Comet Kohoutek didn't live up to its advance billing as the celestial spectacle of the century. Still, it did provide some dramatic photographs for astronomers, plus a lot of scientific information that they will be analyzing and discussing for a long time.

This photograph is the first to be released by the Hale Observatories after the comet rounded the sun on December 28—at a distance of about 13 million miles—and headed outward toward the farthest reaches of its orbit. It was recorded at 7:35 PDT on January 12, when research assistant Charles Kowal focused the 48-inch Schmidt telescope at Palomar on the comet for a three-minute exposure.

Since the tail of a comet is always blown away from the sun by the solar wind and light pressure, Kohoutek's tail is now at its leading edge. Actually, Kohoutek has two tails. The one that resembles a corkscrew is composed of ionized gas; the cloudy streak beside it is made of dust. The overall length of Kohoutek and its tails is at least 13 million miles.

At the time this picture was taken, the comet was streaking away from the sun at the rate of more than 100,000 miles per hour toward the aphelion of its very long elliptical orbit—so long, in fact, that its next good picture-taking session is about 80,000 years away.





Beckman Behavioral Biology Laboratories

Caltech's new Mabel and Arnold Beckman Laboratories of Behavioral Biology were dedicated on January 14. President Harold Brown presided at the ceremony, and three of the happiest participants were the Beckmans and Robert Alexander, architect for both the new building and for its fraternal twin, Baxter hall, across the mall.

Taylor-made

Theodore B. Taylor, BS '45, recently showed up as the subject of a three-part profile ("The Curve of Binding Energy") in *The New Yorker* for December 3, 10, and 17.

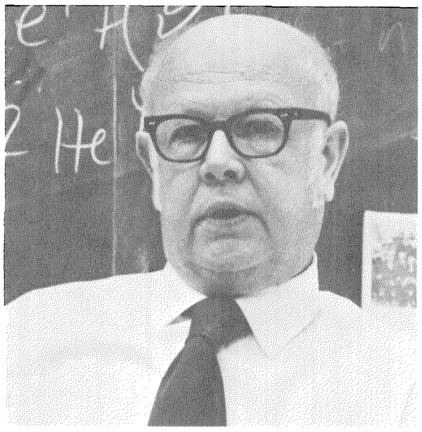
The profile follows Tayor's life from his childhood in Mexico City through his education at Exeter and Caltech, his stint in the Navy, and his brief stay at UC Berkeley. He then became a conceptual designer of nuclear bombs in the Theoretical Division at Los Alamos Scientific Laboratory—designing Davy Crockett, Hamlet, and the Super Oralloy Bomb.

In 1957 he went to work for General Atomic in San Diego in a civilian laboratory set up to make creative use of atomic energy. Project Orion was his main interest there, requiring the design of a spacecraft as large as a 16-story building, carrying 150 people, and powered by nuclear explosions of small bombs detonated about a hundred feet below the spacecraft. But the limited test-ban treaty of 1963 forbidding nuclear explosions in space also caused suspension of work on Orion.

Taylor now heads his own firm, International Research and Technology. Its main purpose—a subject that is intensively and exhaustively pursued in the profile—is to promote safeguarding the fissile material produced in the nuclear-powered fuel cycle. Taylor believes that theft of this material by people who want to make atomic bombs for personal use is quite possible.

The profile provides considerable information on the nuclear age—from its inception to its current awesome proportions—and includes mention of the contributions of Caltech's provost, Robert Christy.

Faculty Honors, Awards, and Appointments



William Fowler

Allan Sandage

Clarence Allen

William Fowler

William A. Fowler, Institute Professor of Physics, gave the George Darwin Lecture to the Royal Astronomical Society in London on December 14. His talk, "High Temperature Nuclear Astrophysics," summarized the work being done in this field at Caltech's Kellogg Radiation Laboratory.

The George Darwin Lecture was endowed in 1926 by Sir James Jeans, who stipulated that it be on some subject of interest to astronomers and that the lecturer, if possible, should be someone from outside the British Isles. The lectures have been given almost annually since 1927, and 7 of the 43 speakers have been Caltech faculty members or staff members of the Hale Observatories—Edwin P. Hubble, Walter Baade, Albrecht Unsöld, Ira S. Bowen, Robert F. Christy, Sir Fred Hoyle, and Fowler.

Allan Sandage

Allan R. Sandage, staff member of the Hale Observatories, has received the Elliott Cresson Medal of the Franklin Institute "for his skill, dedication, and keen insight in conceiving, conducting, and interpreting astronomical observations, and especially for his fundamental contributions to observational cosmology."

Sandage is a Caltech alumnus (PhD '53) and has been a staff member of the observatories for more than 20 years. His research is concerned with the structure and age of the universe—a subject he discussed in "Opening the Last Frontier" (*E&S*, March-April 1973).

The Franklin Institute, which awards the Cresson Medal, is a research and educational organization founded in 1824 in Philadelphia.

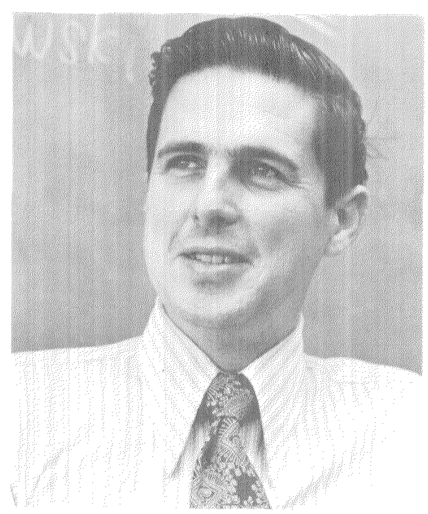
Clarence Allen

Clarence R. Allen, professor of geology and geophysics, was elected president of the 10,000-member Geological Society of America at the society's annual meeting in Dallas. Allen is in charge of the Southern California Seismological Network at Caltech's Seismological Laboratory and is an authority on earthquakes and fault systems. He is a 1949 graduate of Reed College, earned a Caltech MS in 1951 and PhD in 1954, and has been on the Institute faculty since 1955.

Robert Vaughan

Robert Vaughan, assistant professor of chemical engineering, has been awarded a $25,000 grant from the Camille and Henry Dreyfus Foundation of New York. (The Institute also received $3,000 to help cover the costs of administering the grant.) Vaughan is one of 16 young scientists selected from 101 candidates nominated by American universities and colleges as outstanding teachers and scholars in chemistry, biochemistry, and chemical engineering.

Vaughan, 32, will use his grant to support his own research in solid state and surface chemistry and also to help support undergraduate research projects he is involved in. He is the fourth Caltech faculty member to be awarded a Dreyfus grant since the award was created in 1970. Robert Bergman won an award in 1970, Jesse Beauchamp in 1971, and John Seinfeld in 1972.



Robert Vaughan

Robert Bacher

Lester Lees

Irving Bengelsdorf

Robert Bacher

Robert Bacher, professor of physics, has been elected president of the Universities Research Association, Inc. URA includes 51 member universities in the United States (plus the University of Toronto) and operates the National Accelerator Laboratory in Batavia, Illinois, under a contract with the U.S. Atomic Energy Commission. Bacher has been a member of URA's board of directors since the organization was formed in 1965. He was chairman of Caltech's division of physics, mathematics and astronomy from 1949 to 1962 and vice president and provost from 1962 to 1970.

Stuart Ende

Stuart Ende

Thanks to a $7,000 grant from the Graves Award Committee, Stuart A. Ende, assistant professor of English, will spend next summer in London. He will be doing research at the Keats House, the residence in which John Keats lived during his most creative period. It is now a repository for the poet's papers, particularly those that deal with his literary relationship to other poets. Ende is interested in the influence of Milton and Wordsworth on Keats's development, and he plans to write a book on the subject.

Graves awards are made to promising young faculty members under the age of 36 to increase their effectiveness as humanities teachers. Ende is 31. The funds for the Graves awards are administered by Pomona College under the auspices of the American Council of Learned Societies.

Lees and Bengelsdorf

Los Angeles Mayor Tom Bradley recently appointed two Caltech faculty members to his Energy Policy Committee—Lester Lees, director of the Environmental Quality Laboratory and professor of environmental engineering and aeronautics; and Irving Bengelsdorf, lecturer and director of science communication.

The committee includes representatives from business, industry, labor, environmentalist groups, science, and the academic community. They are making suggestions to the mayor on both short- and long-term programs for alleviating the energy crisis in Los Angeles.

As head of EQL, Lees is in the thick of developing programs to combat the problems of environmental pollution; he has been particularly interested in subway rapid transit systems.

Bengelsdorf was science editor of the *Los Angeles Times* for several years before coming to Caltech. Prior to that he was senior scientist for the U.S. Borax Research Corporation, Anaheim, and research group leader for Texaco-U.S. Rubber Research Center in New Jersey.

Doris DuBridge
1900-1973

Doris DuBridge, wife of Caltech's former president, died on November 18 at Laguna Hills, California, after a long illness. She was 73.

Born Doris May Koht in Reinbeck, Iowa, she graduated in 1921 from Cornell College in Mount Vernon—a social sciences major with particular training in nutrition, sewing, and institutional management. It was at Cornell that she met and became engaged to Lee DuBridge; while he did his graduate work at the University of Wisconsin, she taught school. They were married in 1925.

The DuBridges were first at Caltech from 1926 to 1928. They returned to the Institute in 1946, and for the next 22 years Doris DuBridge's college training stood her in good stead. Generations of students and countless other men and women—about 2,500 a year—were her guests. All of them found their hostess gracious, friendly, interested in what interested them—and dedicated to Caltech. Of course, she manifested those characteristics in many other ways as well. For example, she expressed her concern for students—and their wives and children—by serving as a member of the board of the Caltech Service League for many years, and she spoke several times to groups of students' wives on how to ease the strains of helping to "put hubby through" college. She called it earning their PHT. Mrs. DuBridge was also active in the community—as a member of the Pasadena Philharmonic Committee, the Women's Committee for the Pasadena Symphony Association, ARCS, the YWCA, and the San Marino PEO.

Her husband, a son, a daughter, and five grandchildren survive Mrs. DuBridge. Contributions in her memory may be made to the Doris DuBridge Memorial Fund at the California Institute of Technology.

Kenneth Eels

In 1966 the DuBridges and the Beckmans joined in the celebration of Lee DuBridge's 20th anniversary as Caltech's president.

Kenneth Eells
1913-1973

Kenneth Eells, former Institute psychologist, died on December 8 at his home near Springville, California. Dr. Eells, who was a native of Washington, received his AB in economics at George Washington University in 1937. His AM (1942) and his PhD (1948) were earned at the University of Chicago in the field of tests and measurements. He is nationally known for his work at that time on intelligence and cultural differences, and for the intelligence tests he devised—called the Eells Games—which were one of the earliest attempts to provide fairer evaluation of minority-group abilities.

After working for several years in various areas of statistical analysis, Dr. Eells became associate professor of psychology at San Diego State College, and from 1952 to 1955 he was a psychologist with the U.S. Naval Personnel Research Field Activity in San Diego. He returned to Chicago in 1955 to become counselor and associate professor of psychology at the University of Illinois. In 1961 he accepted the Caltech appointment, and he remained at the Institute until ill health forced his retirement in 1969.

Dr. Eells was coauthor of a number of books concerning evaluation of secondary schools, social class in America, and cultural differences in intelligence. The subjects of his many articles in professional journals ranged from methods of evaluating and reporting educational progress to assessing the prevalence of the use of LSD and marijuana. His booklet, *Drugs and the Caltech Student,* was first published in 1968. It was not only useful to the Institute community but was so widely requested by other colleges attempting to formulate reasonable, informed policies relating to drug usage that it had to be reissued in 1969.

Take the World from Another Point of View...

continued from page 13

between the fundamental rules and the final phenomena that it is almost *unbelievable* that the final variety of phenomena can come from such a steady operation of such simple rules.

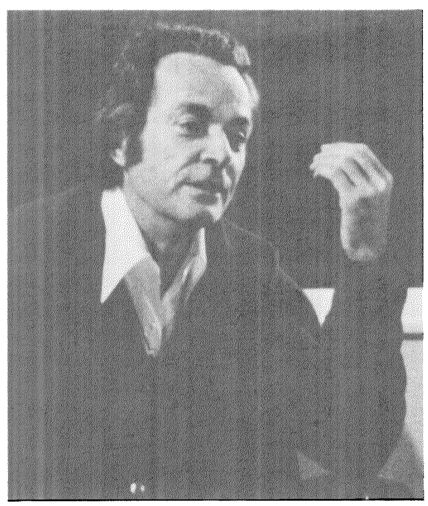
Do you have to build the most complex scaffolding to find out the simple rules?

But it is not complicated. It is just a lot of it. And if you start at the beginninng, which nobody wants to do—I mean, you come in to me now for an interview, and you ask me about the latest discoveries that are made. Nobody ever asks about a simple, ordinary phenomenon in the street. What about those colors? We could have a nice interview, and I could explain all about the colors, butterfly wings, the whole big deal. But you don't care about that. You want the big final result, and it is going to be complicated because I am at the end of 400 years of a very effective method of finding things out about the world.

In the search for the ground rules of the physical world, John Dalton worked out a complicated explanation over a hundred and fifty years ago. He assumed that everything we see is made out of tiny atoms, that they are immutable and indestructible, and that atoms of different chemical elements—like lead or copper—have different weights. Too small to be observed, the atoms combine with each other to form complicated molecules, and vast collections of these molecules are recognizable to us as tables, trees, or whatever. But in the final analysis atoms were to be the smallest constituents of matter, ultimate and unchangeable.

At the turn of the century we evolved our present picture of the atom—light electrons surrounding a heavy central core or nucleus. Once the atom was shown to be destructible, attention turned to the nucleus, and during the thirties it was found that bombarding one nucleus with another led to a release of energy and the breaking up of the nuclei. This process, which takes place in nuclear accelerators, is photographed in a liquid bubble chamber.

Take a liquid—liquid hydrogen or some other liquid—and expand it so it is ready to boil at low temperature and it has to boil and it has to form bubbles some way, and any little piece of dirt or any little disturbance in it will form a bubble. In that condition, if a particle comes flying through from some machine, it leaves a track, it tears up the atoms along its track. We can't see that, but when the liquid tries to boil, the bubbles form around these charged particles which are left, and we can take a picture of the bubbles. So the simplest picture would be of a string of bubbles. But if the particle on the way through hit the nucleus of another atom, then



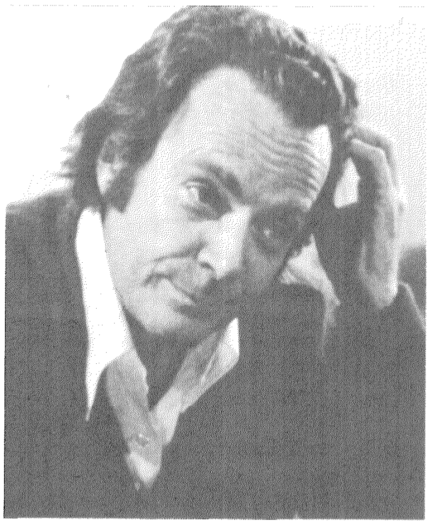
you see a string of bubbles in a kind of a Y. Or instead of a Y you may see an even more complicated track—three or four coming along and then one of them going into two—and you know that some particle went along and disintegrated. Now these things are going nearly at the speed of light, so a short distance of a few centimeters corresponds to a tenth of a billionth of a second. That is, if a track comes out and goes along and then bifurcates into two, you know you made a particle disintegrate into two in less than ten-billionths of a second. So you see it is not very difficult to find out about these things with clever techniques.

Since the war, with evidence from bubble-chamber photographs, physicists have explored the nucleus of the atom. The results have been spectacular and confusing. The harder the nuclei were bombarded against each other, the more they disintegrated into even tinier particles until literally hundreds were known. In the last ten years some order has been made out of seeming chaos by arranging the particles into patterns. Each pattern has 8 or 10 members related by nuclear properties like spin and mass. To the physicist, these patterns imply the possibility of even smaller particles not yet identified but already named. The key to the question of what makes up the physical world, then, lies in the understanding of the nature of these nuclear patterns.

We are getting close because we have a number of little theories by which we can understand these patterns. One picture, which describes what particles you are going to find rather well, is that all these particles are made up of something else which we happen to call quarks. Now a quark is an object which comes in three varieties. It is either an A type, a B type, or a C type of quark. The particles that we find are two big classes, and one class we can understand as being made out of three quarks. And depending on the different proportions —how many A, B, and C's—and how they are moving around each other, we *count* how many states we would get from putting three objects together that can be made in so many ways—27 different ways, each one being three. We find groups of particles in groups of 27 analogously and so on.

It is a little more complicated and a little more subtle, but it is *like* that. And then when we allow for their motion *around* each other, we find the higher energy states. And even semiquantitatively there seems to be a relation between the states and the rates with which one turns into another, and so it looks like they are made out of just three quarks.

Then there is this other class of particles which we call mesons. The first class is called baryons (the words aren't going to do you any good), but the other class, the mesons, we have to understand as being made of one quark and one antiquark. An antiquark is a negative particle, with all the charge properties the exact opposite of a quark.



We make a quark and an antiquark, put those together, and we understand the meson state. Put three quarks together, and we understand all the others. So we have made really great progress in analyzing these patterns. So much so it looks very much as if, to me at least, that we are very close to understanding *this* part of physics—this strongly interacting system.

But what is the main barrier, still?

The main barrier is that we don't understand it quantitatively. We do not exactly understand the laws. I mean, we do things like I'm talking to you about, but a little more carefully, counting how many states we should get, and so on; but we don't know exactly how they move and exactly what holds them together, and so on and so on. Also, there are little paradoxes with this quark picture. It helps to give us the behavior at lower energies of what kinds of particles to expect. So you would expect that a particle would be made out of only three parts. But we have done some experiments at very high energy, hitting a proton with an electron —which can only be interpreted by supposing that the number of particles inside is really infinite—if there *are* particles inside. It can't be done with just three. You can calculate, and it doesn't come out right. So *there* is a difficulty.

Furthermore, the idea that there are just three particles is contradictory to the ideas of relativity and so on, which imply the existence of particles and antiparticles. And when there are three, it should be possible for the forces to produce pairs of particle and antiparticle in various numbers so there should not just be three but many more. So the infinity is not a paradox, by itself. The *three* is more of the paradox. Why is it so *simple*? Why can we get away and understand so much when there are just three—when there should be an infinite number, probably, in there, both theoretically and experimentally?

Another thing (it is a little technical but very paradoxical) is that we once had a rule for atoms that no two electrons can occupy the same state. It is called the exclusion principle. And we thought that we understood that that was necessary according to quantum mechanics, and relativity—it has to be. But with the quarks we find the exact opposite rule. Two particles *tend* to occupy the same state. The exact opposite seems to be contradictory with the principle.

There are ways of escaping this all the time, but only by complicating the picture. But the simplest picture of just three, which explains everything, is self-contradictory. Furthermore, some people suppose that maybe these quarks can come apart. That would mean the prediction of new states which would consist of only one quark, say. If there were such a state, it would have to have a charge of ⅓ the normal charges of our objects, for example—or ⅔. We don't find experimentally any such particles. Now everybody is looking for them, but it looks as if—if they exist at all—they have to be extremely heavy. Then the problem is, if they are extremely heavy, compared to a proton, say, how is it when you put three of them together you get a light object—one that is *not* heavy like a proton?

There are technical ways of arranging it, but they are always complicated. The situation is—as it always is when we are near the answer—it looks much simpler than it has any *right* to be; and we have to understand that simplicity and why we think it must be more complicated. Our minds are complicated, somehow. Just like the orbits of the planets, which were supposed to be circles, which looked simple. Then they found experimentally they weren't circles, so they made circles on circles on circles and got more and more complicated, and it turned out that it was really much simpler. It was a force varying inversely as the square of the distance which made ellipses and so forth. It was a different way of formulating rules entirely, which was beautiful. So now we have our wheels within wheels. It looks simple, and nature is no doubt simpler than all our thoughts about it now. And the question is, what way do we have to think about it so that we understand its simplicity? That is where we stand now.

On holiday, Richard Feynman is paid a neighborly visit by Yorkshireman Sir Fred Hoyle, the astronomer, cosmologist, and science fiction writer. At first sight there seems little in common between the study of galaxies and nebulae billions of miles in diameter and millions of light years old and nuclear physics where particles exist for only a million-millionths of a second. But the formation of stars and galaxies is determined on a massive scale by the behavior of the very nuclear particles Feynman studies. Hoyle and Feynman share an interest in the foundations of physics, and exchanging ideas in the

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Take the World from Another Point of View . . .

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local pub is always as profitable as it is enjoyable.

FEYNMAN: You agree that the quasars are in real trouble. That the very big redshifts—
HOYLE: I think so. I have had this uneasy feeling now for about five years. It looked crazy for a while, but evidence is piling up all the time.
FEYNMAN: Every piece of evidence is the same problem; each one makes a new problem. If there were any cause for a redshift as big as that, other than recession, we would be all right.
HOYLE: That's right.
FEYNMAN: But in the present physical laws there doesn't seem to be any place for such a redshift. And at the same time the same kind of laws predict the kind of peculiar phenomenon of black holes, which is really confusing. And it could be that either the gravity is wrong or one of the physical laws is wrong too.
HOYLE: I am not arguing at the moment that the physical laws are wrong. But you would agree that one has to push it through along these lines.
FEYNMAN: The best way to progress I would think is maybe to try to be as conservative as we can. Try to be as conservative about the physical laws as possible in explaining the phenomenon. If you continuously *fail,* then you gradually realize that you have got to change something. But if we start out saying we've got to change something, there are so many ways of changing. Most often you don't have to change anything. Most of the time we succeed in ultimately explaining these damn things in terms of the known laws—but the cases that fail are the interesting ones.
HOYLE: Yes. It's like the story of the chap under the single lamp in the street, where a passerby says, "What are you looking for?" and he says, "I am looking for my key," and they search for it for a few minutes and at the end of these few minutes the passerby says, "Are you sure you lost it here?" and the man says, "Not at all. But unless I lost it here, I'll never find it."
FEYNMAN: It is interesting that in many other sciences there is a historical question, like in geology—the question of how did the earth evolve to the present condition. In biology—how did the various species evolve to get to be the way they are? But the one field which has not admitted any evolutionary question is physics. Here are the laws, we say. Here are the laws today. How did they get that way?—we don't even think of it that way. We think: It has *always* been like that, the same laws—and we try to explain the universe that way. So it might turn out that they are *not* the same all the time and that there *is* a historical, evolutionary question.

HOYLE: But how do you see it going? It is hard to speculate.
FEYNMAN: You're the speculator. You and I think differently. I think of the possibilities, but I am afraid to put things in. When I see the dark, I always think of the dark as too *big* for me to guess at. It is not much use in guessing. But you are different, and I would like to discuss with you sometime how you do that, because I am really a little afraid to make specific guesses. I am afraid to make specific guesses because the moment I make that guess I can see seven other alternatives—so, since I see these other alternatives, I don't know which one to piddle with.
HOYLE: My choice is very simple. I don't set any requirement that the answer be right. It is just what I am interested in. That's the difference.
FEYNMAN: That's the difference. I am not trying to find out how nature *could be* but how nature *is.* See what's right.
HOYLE: Well, I don't think you'll ever find it, you see. I—
FEYNMAN: Your idea is to find out what nature *could be.*
HOYLE: No, no—what I think is *interesting.*
FEYNMAN: Even if it's wrong?!

Common ground is enthusiastically explored. But is it only shared experience and knowledge that form a bond between working scientists and separates them from us, the interested layman, or even the artist? . . . Are you really saying, Dr. Feynman, that you have more in common with, say, a paleontologist or someone in a branch of science very far removed from yours than you would with a playwright or a poet?

Absolutely. Especially if he is a good paleontologist. Because if he is a good paleontologist, he is not just looking at old rocks. He is looking into the history of the earth. He is looking when he is standing and looking at his own hand, and he is thinking of how it evolved with five prongs and so on.

Or the size of the brain? I can talk about stuff like dolphins have bigger brains than we have and they have a signaling system. And we start to discuss all that they know about dolphins, and we complain about the way that the United States Navy has been doing its experiments, and it's not right, and we ought to find out more about dolphins—and we could just go on and on.

When I talk to a playwright or something, I find—because I don't go to plays, or something—I don't find it easy

to talk to them. I don't get much out of it.

I was going to say that you can talk to scientists of other fields, presumably, because you both read the scientific magazines and hear the scientific gossip.

No, because we don't have to have magazines or gossip. We think originally. We think of a new idea. We talk to each other, and we try to look at something from a new point of view, and we delight each other in a new point of view. And when you are talking to somebody else who is trying to think of something new, different—and he has thought about the whales or the dolphins and he has some little thing that he has thought of that is a little different than the thing that you thought of—and so when you are talking back and forth, he is excited about your point of view and you are excited about the observations that he has made. And our backgrounds give us a slightly different point of view. Like I specialize in physics, and he specializes in paleontology; and so his information on, say, dreams might be deeper, more evolutionary. For example, he might know about animals. He might have thought about what other animals dream and what the signs are and a lot of things that I haven't thought of. I can't make it up now because I am not a paleontologist, but I believe, yes, I find always that a good man—I take it all back.

I take it all back. A *good* man—I have talked to good men in other fields. There are certain kinds of men in *every* field that I can talk to as well as I can talk to a good scientist. I met a historian, a writer of history from France once, and I had a marvelous conversation with him. Maurois, his name was. André Maurois. And then I met an artist, Robert Irwin, who is a very important artist, and I could talk to him at the same depth of excitement.

So I take it all back. If you give me the right man in any field, I can talk to him. I know what the condition is. That he did whatever he did as *far* as he can go. That he studied every aspect of it as far as he could stretch himself. He is not a dilettante in any way. And so he talked deep, as far as he can go, and therefore he is up against mysteries

all the way around the edge, and awe. And we can talk about mystery and awe. That is what we have in common.

After discussing working problems, it is natural that Feynman and Hoyle would savor that most thrilling pleasure of all, the moment of revelation.

HOYLE: You *try* all sorts of things, and you are hopeful about trying it—and you have a moment in a complicated problem when quite suddenly the thing comes into your head and you are almost sure that you have got to be right.
FEYNMAN: Yes. And then you try to figure out what the conditions were at that moment so you can do it again. For example, I worked out the theory of helium once and suddenly saw everything. I had been struggling and struggling for two years and suddenly saw everything. I can remember everything about it, by the way. It's psychologically funny—you can remember the color of the paper you were writing on and the room and everything else, and then you wonder what was the psychological condition. Well, I know that at that particular time I simply looked up and I said, "Wait a minute—it can't be quite that difficult. It must be very easy. I'll just stand back, and I'll treat it very lightly. I'll just *tap* it, boomp-boomp." And there it *was*. So how many times since then I am walking on the beach and I say, "Now look, it *can't* be so complicated." And I'll tap-tap—and nothing happens. The delights *are* great, but the secret way—what the conditions are—
HOYLE: It's that missing bit in the brain, isn't it, that suddenly lights up and—
FEYNMAN: Yes. And I have *no* idea. I've thought about it. Some man suggested I think about it once because if I could only figure out the formula for what condition to be in to get good ideas, I'd be much more efficient and more happy. So I've often paid attention to what the condition is, and I've never found any correlations with *anything*. By the way, it's the delight that is *ab*solute ecstasy. You just go absolutely wild.
HOYLE: How long does it last for, really?
FEYNMAN: It's not very short. It's a very big moment—
HOYLE: Three days?
FEYNMAN: Yes. About. It's a very big moment—and then there are lesser pleasures as you work out more things and more people *notice* it and—
HOYLE: But the high peak—you're on the high peak for about three days.
FEYNMAN: That's right. Like the supernova, I suppose—no, that's *four* days; that's better. But I was going to say that it is the *hope* of that kind of goal—
HOYLE: That keeps you going.
FEYNMAN: That keeps you going through the doldrums.
HOYLE: Keeps you going to the end.
FEYNMAN: I think that what I learned from my father as a child was that, if you did work a little bit at these things, there would be the time that one should get this. And I had to learn that first, or I would never have been able to do it.
HOYLE: And then afterwards you wonder, now why the devil was I so stupid that I didn't *see* this.
FEYNMAN: Yes. That's not only true of you, it's true of the history of the sciences. You can always look at a particular moment in history and wonder why they hadn't thought of it earlier. It's because we're dumb, somehow.
HOYLE: It's most mysterious. It just means that however good you may get comparatively, compared to—
FEYNMAN: Apes.
HOYLE: Apes, that's right—that you're still very *bad* at it.
FEYNMAN: Absolutely. We're doing the best we can.
HOYLE: In a kind of stumbling way.
FEYNMAN: Yeah.
HOYLE: And with this depressing and sobering thought—
FEYNMAN: Well, it's been fun. □

New China Hands
Visit the People's Republic

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Sitting in front of his shop on one of Peking's main shopping streets, this cobbler resoles a sandal. His tool is a knife, which he heats to apply new rubber.

One's life in China, then, can be seen to be very much involved in the lives of one's fellow workers—indeed, so much involved that privacy as we understand it appears to be absent from Chinese life. (The fact that in the Chinese language there is no really acceptable translation of our word "privacy" seems consistent with this observation.) A society which is organized with such mass involvement and with the intense level of social pressure prevalent in China is also able to be organized by a central authority to achieve impressive social and economic tasks. In my observation the present government, while having made some well-publicized mistakes such as the Great Leap Forward, has used this aspect of Chinese society to enormously benefit the majority of the population.

In such a situation it is natural to ask whether the people are happy. Well, to be frank, how could any visitor ever really find out? In my opinion, the questions of personal privacy and volition are *at this time* almost secondary in China, which has only barely emerged from the degradation that large segments of its population can vividly remember into a thriving country which provides every citizen with food, clothing, medical care, housing, and employment. Probably the people are happy. The fact that I (and probably you, the reader) find the social pressure and "persuasion" by comrades unacceptable must be quite irrelevant. Needless to say, it would be rash of me to conjecture how long the Chinese people are likely to remain "happy" on these standards.

It was my feeling that life in China, though it was rather well organized, tended to be rather drab. Young men and women are married only in their middle to late twenties. Before that, contact between the sexes is restricted to on-the-job or in-the-classroom activity. When a couple begin to date, they are engaged to be married. We asked our student friend in Shanghai what his dorm mates did to entertain themselves. He replied that they mostly play cards.

Other forms of entertainment consist of going to the opera to see one of the modern Peking-style revolutionary operas. Typical of this genre of "proletarian culture" is *The White-Haired Girl*, a straightforward story about a girl whose father is killed by a landlord and who runs away to the hills to escape him. Her boyfriend joins the Red Army, eventually comes back, kills the landlord, and discovers his girlfriend (her hair turned white from her experiences surviving in the mountains) wandering about the village. The accompanying music is hardly what one would call great, but is simple, sturdy revolutionary support for the story line.

It is not necessary to go to an opera house to experience these operas since films of them are enjoying very long runs in the neighborhood cinema theatres. Of course, one can go to the song-and-dance routines of the People's Liberation Army (PLA) or to the acrobatic shows for some variety. Radios were present in many places, but I have no real idea of what the fare is. I saw only one television set; it was in a lounge of our hotel in Peking. The evening we turned it on it was featuring the PLA dance show we knew to be playing in town.

Because we were so obviously *wei guo ren* (foreigners) and could not speak Chinese, approaching even the not insignificant number of Chinese (especially younger ones) who spoke some English was rather difficult. Of course, some rather formal contact could be established through our excellent interpreters, but it was most unsatisfying. Two clever members of our delegation had thought to bring along a dozen Frisbees between them, and playing Frisbee in the squares and parks of cities and on the people's communes proved to be a remarkable ice-breaking device.

Our first game of Frisbee was played in Tien An Men Square (the "Red Square" of China) in Peking on a warm summer evening. Within five minutes a crowd of, at minimum, 500 had gathered to watch these weird *wei guo ren* fling about a UFO. After ten minutes, at least a thousand people had gathered so tightly that what is normally a one-dimensional game with at least a line of sight to other players had become a zero-dimensional game. Tossing a Frisbee in the general direction of a spot radiating English can be fun but is not conducive to accurate throwing. By this time, however, one is really "mingling with the broad masses" and, exercising our fluent Mandarin, we would smile and say to the closest people: *"Ni how! Women shr mei guo ren!"* (Hello! We are Americans!) Often, as repetitions of the words *"mei guo ren"* would go floating through the crowds, someone would yell "Hello," or perhaps "Good-bye," and contact of a friendly (albeit not deep) sort would have been established. At this point we would begin handing the Frisbee to various members of the crowd and coaxing them to toss it to us. The roar of laughter and delight that followed a lousy Chinese toss was understandable in any language.

I think the height of Frisbee diplomacy occurred on our last morning in Shanghai. Four or five of us asked to go to a local park to "mingle with the masses" and, of course, to play Frisbee. Our hosts wishing, as usual, to show us the most beautiful park, not the most crowded, drove us off to the outskirts of the city where we were given free run of a magnificent, rather empty, park. We announced that this slightly missed our mark and after soothing ruffled feathers, were driven back into town to the People's Park. On the way a passing train stopped our cars and left the other side of the road completely free—for Frisbee-playing, naturally. Out we

The day will come when Shanghai-built Frisbees will begin to flood Western markets, and you will know where it all began

popped and for 15 minutes tossed the Frisbee both among ourselves and to people standing in trucks also waiting for the train. The real coup was a truckload of 30 or 40 People's Liberation Army men, who, as a rule, did not mingle much with *wei guo ren*. In fact, our first Frisbee game in Peking had been broken up by a nervous PLA man who was guarding the gate in front of which the game was proceeding. But on this occasion, they were completely captive. One Frisbee tossed into the truck and all formal decorum vanished as they vied for an opportunity to throw it back. After the train passed, we returned to our cars to the cheering of truckloads full of new Frisbee lovers, PLA men included.

At the People's Park our success was magnified. After the game took its usual zero-dimensional turn, I called several times, "Hey, Joe!" to Joe Goldberger, who had disappeared in a sea of Chinese. At that juncture an oldish man came up and insisted I let him throw the Frisbee; he was the only Chinese person who was so bold. I suppose he thought yelling, "Hey, Joe!" was part of the symbolic ritual in which we were engaged, for no sooner did he have the Frisbee in hand, than he yelled, "Hey, Joe!" and tossed it perfectly to Joe's outstretched hands. At the end of the game we presented him the Frisbee, as was our custom when we found a good player. He insisted we return the next day so he could give us a gift, but alas, we were leaving that afternoon. When Shanghai-built Frisbees flood Western markets, you will now know where it all began.

Peasants on a commune in Hunan Province are thrashing rice using a homemade wooden thrashing machine. The stalks will be dried and used to feed pigs.

Beyond these amusing interactions our primary social intercourse was at the banquet table. We were entertained at a magnificent banquet by the Revolutionary Committee of every city and village we visited. This would be an occasion of gourmet delight as well as a tedium of toasts and counter-toasts of welcome and declarations of "mutual friendship between the peoples of America and China." At the rate of a banquet every other day, the ritual rapidly became very wearing. Several of our party developed "small-banquet fever" which disabled them just before a not-so-important banquet; recovery from these illnesses was generally quite rapid.

Our most serious task in China was establishing contact with our scientific colleagues. We visited a variety of scientific and educational institutions in Peking, Shanghai, Canton, and Dalien. These included the Peking Physics Institute of the Chinese Academy of Sciences, the Academy's Chemical Physics Institute in Dalien, Fu Dan University in Shanghai, and others. On each visit we would, after the traditional "brief account" of the institution given during the consumption of enormous amounts of tea, tour laboratories and workshops. A free exchange of questions and answers characterized the discussion at each institute. The Chinese were clearly as anxious to communicate to us what they could do, had done, were doing, and planned to do as we were to find out. Our suggestions and criticisms were requested in each laboratory, and occasionally our advice on future programs was solicited.

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New China Hands Visit the People's Republic

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What is most clear is that fundamental science research in China appears to have been more or less at a standstill from the beginning of the Cultural Revolution in May 1966 until about a year ago. My impression of the physics laboratories we visited is one of vigor, enthusiasm, and high-quality personnel, but rather unsophisticated equipment and very little in the way of concrete results. For example, we saw two cyclotrons: one at the Institute of Atomic Energy outside Peking (built by the Soviets and producing 24 MeV alpha particles), and the other at the Institute of the Nucleus near Shanghai (completed by the Chinese in 1964 and modeled closely on the Soviet-built machine). The first of these seemed not to be in use; the experimental areas were, in a word, empty. The Shanghai machine has been employed for a variety of experiments since 1964, but since publication of journals was suspended from 1966 to 1972, none of the research has been published—although we were told about (but not shown) internal documents which circulate among the researchers to keep their Chinese colleagues informed.

The major scientific work in Chinese physics (aside from, one must suppose, weapons research) seems to have been applied research and development of useful things. We saw an impressive variety of particle detectors designed and built at the Peking Institute for Atomic Energy. We visited several workshops where oscilloscopes were being constructed or integrated circuitry was being put together or crystals being grown and doped for use in transistors. The emphasis is on "integrating theory with practice" and "serving the people," if I may use the apt slogans of the Chinese themselves.

It was my impression that many of the Chinese scientists we encountered felt that soon they would be encouraged to take up less product- or mission-oriented research and that fundamental science would blossom again in China. Usually this expression of possible future developments would come in response to our queries about how China would be able to maintain any excellence in science without the stimulation of basic research.

Members of the Revolutionary Committee in Shaoshan entertain at a "light" lunch.

On the right is Nobel Prizewinner Owen Chamberlain from UC Berkeley.

Our Chinese colleagues in high energy physics seemed very bright and extremely well informed. They receive in Peking, Canton, and Shanghai all the important and respectable journals from the U.S. and Western Europe. Also they seem to read them quite avidly. In questions asked during and after our several lectures it became clear that many members of the audience had thorough and deep knowledge of the subjects covered in our lectures. They, of course, do not have access to the "private communication" level of research that (at least in physics) plays a healthy role in the stimulation of ongoing work. But, that understood, the Chinese physicists seemed every bit as well trained and as able as our colleagues in the West. Clearly, one may expect China to develop into a major source of productive and valuable ideas in all fields of science once the decision is reached and carried out to spend their still-limited resources in this manner.

I am personally very enthusiastic about the possibility of developing extensive scientific collaboration and exchange with our Chinese counterparts during the next decade. We may, very temporarily, find ourselves in the role of educator as Chinese science regains its strength, but I expect that this will be a brief interlude to complete intermingling of the scientific communities.

I feel that the model of how Chinese-American scientific contact may develop is that of the U.S.-Western European experience, *not* the U.S.-Soviet example. It is very inaccurate to extrapolate from the fact that Marx and Lenin are ideological heroes in both the U.S.S.R. and in China to any possible similarities in their cultural and scientific attitudes. The disparities are enormous, and I sense a real, viable future in American-Chinese scientific relations—one that will be achieved at a much more reluctant pace in U.S.-Soviet agreements. As Professor Tsien San-Tsang, the director of the Peking Institute for Atomic Energy, expressed it to us: "I feel that your visit is like the first neutron in a chain reaction."

I am confident that he is correct, and that he had *controlled* fission in mind. □

Letters

Caltech's Perfect Student–Helmar Scieite

DEAR EDITOR:
Last summer (August 6) *Time* ran a story on Helga Sue Gromowitz, an imaginary high school student dreamed up by kids to confuse the faculty and administration. I thoroughly expected to see a follow-up in their "Letters to the Editor" from somebody at Caltech, because I well remember the composite Caltech student of legend, created by a group of the faculty to confound another faculty member who swore no one could get an A in his course. It's been a long time since I have read of one of Caltech's pranks and this one would be fun to see again.

(Ms.) LEE JONES
Assistant to the Chancellor
Johnston College
University of Redlands

Memo to Kay Walker
From Ed Hutchings

As I recall, this was a joke played on Fritz Zwicky (now professor of astrophysics, emeritus) sometime in the '30s. See what you can dig up. You might start by asking some faculty members who *were* here then and *are* here now—Bill Smythe, John Pierce, Tommy Lauritsen, Willy Fowler.

Memo to EH
From KW

The facts seem to be classically simple.

The joke was played in the '30s on Fritz Zwicky, who taught an extremely difficult course in analytical mechanics at that time. An ingenious group of plotters submitted an admit card for a fictitious student, had him enrolled in the class, turned in exams for him, and earned an "A" at the end of the term.

Simple. But why was it done? Why Zwicky? Who did it? When? How could the deception last a whole term? How did "they" get an "A"?
Here are a few answers:

1. Dr. Smythe, who was already teaching here then, says the pranksters were grad students, and they probably included Tommy Lauritsen and Willy Fowler. He gave me the outline of the story I've given you—plus a few details such as that the fictitious student went in Zwicky's class book because Zwicky never learned his students' names. When exams came along, two or three of the grads worked on different sections of the test and turned in—in one handwriting—almost perfect papers, and got "A's" on all of them.

2. Dr. Lauritsen was not one of the perpetrators; it was before his time. But he had a name for me: Hjalmar Sciate. Lauritsen always thought that the plotters were professors, probably led by Smythe himself.

3. Willy Fowler, who got a "B" from Zwicky, has thought all these years that the faculty was responsible for the fictitious student, whose name Fowler spells as Hjalmar Sciatti.


L. Sprague de Camp, 1929

> This story was on the press when Fritz Zwicky died of a heart attack on February 8 at the age of 75. We print it now because we think he would have liked it. We regret that he had no chance to reply to it because, as always, his reply would have been colorful and resounding. A tribute to Dr. Zwicky will appear in our next issue.

4. John Pierce's version of the student's name is Hjalmar Sciete, and he wasn't in on the hoax. He suggested that Carl F. J. Overhage, MIT professor of engineering, might have been one of the students who took the tests.

I am writing to Dr. Overhage.

Memo to EH
From KW

Carl Overhage says his recollections of the Hjalmar Sciete caper are rather dim and that John Pierce gave him too much credit—he had a hard enough time taking Zwicky's exams on his own.

He also says, "I have a persistent hunch that the roots of this joke go back to some undergraduates. If you really want to leave no stone unturned, write to L. Sprague de Camp and John B. Hatcher."

I'm doing so.

Memo to EH
From KW

L. Sprague de Camp says he wasn't in on the Hjalmar Scieite hoax, but thinks

Jack Hatcher was one of the perpetrators, or at least knew some of them.

I'm waiting to hear from Dr. Hatcher.

Memo to EH
From KW

Aha!

Please peruse the following—

Letter from
John B. Hatcher

DEAR MRS. (not Ms.?) WALKER:
Are you really serious, and willing to work on this? You are probably in for a difficult time, since there are the most extraordinary versions—memories dim, people elaborate, things get quoted wrong, and I even remember once hearing of someone I never heard of who was taking credit for the whole affair. But if you do your homework, you can probably make an important contribution toward getting the record straight.

Let me put down what I remember, and point you to some source data and people who can confirm a few things; I'll try to be meticulous and indicate my own haziness as best I can. . . .

First of all, you've got the name all wrong—and that was the basic, original point of the whole thing that started it all ! ! ! The name is

HELMAR SCIEITE

and don't you *dare* let *any misspelling* by a single iota, quark, or whatever get perpetuated.

The time *was* ca. '29-31. You can confirm the exact time by old records, as follows: You dig into old transcripts, and find out *when* Carl Thiele took Zwicky's Advanced Analytical Mechanics—*it happened then.*

It all began when some of us were sitting around with the usual undergraduate gripes, and there was talk of Zwicky. He seemed to take an intense, almost sadistic pleasure in picking on a hapless student, and regardless of said student's protestations of lack of preparation, ignorance, etc., get him up at the blackboard and make him do a tough problem. In today's phrasing Z would let him turn slowly, slowly, in the wind, aided by caustic comments as to his mental deficiencies and how easy the problem was.

It was mutually agreed that something should be done, but in those days we didn't revolt—we tried to match the punishment to the crime. Zwicky was reputed to have an intense pride in being correct, but it had been noted that he had difficulty in pronouncing Carl Thiele's name. (He varied from Theel to Tilly, with versions in between, but typically he just mumbled it.) So we decided to give him something more to think about, and the name was born—Helmar Scieite. We figured Z'd never get that *iei* combination right (incidentally do *you* know how to pronounce it? We did!) The "Helmar" was derived from Delmar Larsen, who was our resident linguist, and responsible for the assertion that there has never been an iei in *any* language. And the substitution of Sc for Th, and the t for the l would, we thought, render a difficult task for Z plain impossible.


Carl Thiele, 1932


J. B. Hatcher, 1929

Who was "we"? Well, I was there; almost certainly Delmar Larsen; most probably Carl Thiele; and maybe Jackson Gregory. We all lived in Blacker House, and along the 2nd floor corridor going south from Harvey Eagleson's room, and we called it Hell's Kitchen. Bill Shockley was in that corridor, but I'm pretty sure he wasn't at the creation of Helmar—he was usually a little above such antics. Perhaps Glen Miller was there; it could have been a poker session, and he usually came around for them. My memory says 3-5 people; there could have been more, and I just don't remember. The main point is that it was a group (interdisciplinary!) effort.

Anyway a class registration card was procured (was theft necessary? I don't remember how hard it was to get them) and filled out, registering Helmar Scieite in Zwicky's course, and it was turned in the next semester with all the rest. So there was Z running through the cards calling the roll the first day. I was told he fumbled a bit on the Thiele again, but he out-foxed us on Helmar—he just passed the card by, and after finishing all the rest stood there with that one card left and simply asked if there was anyone else present whose name he hadn't called! He did this a couple of times—never even tried to pronounce it.

The final was the finale, and a real tour de force. With the honor system (does it still work?) it was standard for the professor to walk in, write exam questions on the board, and then go away, to return at the appointed end and collect papers. This time the idea was simple: Delmar went into the exam room and copied off the questions, and then doled them out, one to each of some five or so graduate students who had previously been recruited. And then each did a bang-up job on his single question, getting it perfect. And then Delmar copied them all off in his nice round hand, switching languages between questions, with interpolated insulting remarks like "This is a very stupid and trivial question—why waste examination time on such tripe?" or "This problem is all worked out in . . . (cited reference) . . . Can't you think of anything new?" etc., and this was turned in under Helmar Scieite's name.

Delmar Larson, 1932

Now I never did learn, to my own satisfaction, whether Zwicky tried to turn in a grade for Helmar. Since he wasn't really on the books, the registrar's office would have queried such a grade; or did Z go ask them about such a person earlier?

I tried to immortalize Helmar Scieite shortly thereafter, by making him the hero of a mystery story I wrote. *The Hell's Kitchen Murders* never got published, but circulated around the campus for some years—Harvey Eagleson had a copy, and I was told he used to read it to later generations.

I do know that Helmar was still alive and wrote a long letter to the editor of the *California Tech* dated 1 May 1969, suggesting a novel and sound approach to teaching some of the things the student candidates were worrying about in their statements running for office in the Feb. 6 issue.

Well, maybe all this will help. Lotsa luck,

J. B. HATCHER
(BS '37, MS '38, PhD '52)

Memo to EH
From KW

Carl Thiele says it's all true. He took Ph 103c, Analytical Mechanics, the third quarter of the 1931-1932 school year, and he reports that Zwicky gave everyone in the class epsilons except Helmar.

Here is the course description from the 1931-1932 catalog:

> PH 103 a,b,c. Analytical Mechanics. 12 units (4-0-8) first, second, and third terms. Prerequisites: Ph 5 a,b,c; Ma 9 a,b,c; or 10 a,b,c; reading knowledge of French.
> A study of the fundamental principles of theoretical mechanics; force and the laws of motion; statics of systems of particles; the principle of virtual work, potential energy, stable and unstable equilibrium; motion of particles, systems of particles and rigid bodies; generalized coordinates, Hamilton's principle and the principle of least action; elementary hydrodynamics and elasticity.
> Texts: Painlevé Cours de Mécanique, Vols. I and II.
> Instructor: Zwicky.

Do you suppose Zwicky *really* used a French textbook?

Letter from Delmar Larsen
to Ed Hutchings

I can confirm that Jack Hatcher's letter is as accurate as it is charming.

I have only one revision to make, respecting the alleged statement by me that the vowel sequence *iei* is unknown in any language. I do not remember

Fritz Zwicky, 1932

making such a statement, and indeed numerous exceptions would have come readily to mind such as the German adverb *beieinander,* the Portuguese substantive *fieira,* and the Greek substantive διειδοσ, with its English derivative "dieidism," not to mention, of course, more recondite examples. The particular sequence of letters was designed to introduce maximum ambiguity into the pronunciation of the name.

Memo to EH
From KW

It's really been fun to watch this story unfold, but for now I guess we've done all we can.

E&S Shares Some Mail with *The President's Report*

Houston

EDITOR:
In the Caltech *President's Report* for 1972-73, Robert B. Leighton described some research highlights in physics and astronomy at Caltech. In his story of man's attempt to probe the depths of matter, Dr. Leighton mentioned "the notion that matter, in all its infinite variety as we perceive it, is composed of but a small number of irreducible parts which combine in different ways."

Letters . . . *continued*

He traced these fundamental building blocks from the Air, Earth, Fire, and Water of the ancient Greeks to the 92 chemical elements of the chemists' periodic table. He continued, mentioning the proton and electron thought to be the basic constituents by the early nuclear physicists, and the whole succession of particles still called "elementary" later on. He mentioned that today these particles themselves constitute families called baryons, mesons, leptons, and photons. Dr. Leighton continued to mention the recent work in which families of baryons and mesons are described in terms of "quarks."

In reading his report further we find that some scientists have abstracted a model to account for the fact that "quarks" are never observed. In this model the "quarks" are stuck together by neutral particles called "gluons." Using the notion of "color," both the "quarks" and "gluons" are "color non-singlets and are therefore unobservable as separate particles." Further reading reveals terms such as "hadron," "parton models," and "bootstrap pictures."

After some reflection on this fascinating description of man's attempt to probe the depths of matter, it now seems to me that this elusive irreducible component of all nature should be aptly called the "puton."

NEIL R. SHEELEY JR. '60
ATM Experimenters Office

Rank Injustice

London

EDITOR:

A copy of the November/December issue of your review, which contains an article by James and Ingelore Bonner, headed "Notes on a Trip to the Soviet Union," has been passed to me.

In this interesting article, reference was made to the fact that, during the Bonners' visit to Moscow, they were informed that a Xerox copier in one office was not working because the Xerox engineer had not called. The inference drawn from this is obvious, and your readers could get a very wrong impression of the way in which we look after our equipment in the Soviet Union. May I now give you the facts of the situation.

By Soviet law, Xerox—through Rank Xerox in England—have to sell their Xerox copiers outright in the Soviet Union. Under this arrangement, the Soviet authorities are then entirely responsible for the maintenance of the equipment. Nevertheless, Rank Xerox have gone to considerable trouble and expense in training local Russian engineers to maintain this equipment. The Soviet servicing organisation is still in its infancy and is battling with difficult odds. This is the first time the Soviet Union has had an organisation of this type. It has been very difficult for them to recruit the right staff, and, again under Soviet law, these engineers have to be trained in Moscow—not with quite the same facilities we could give them in a Xerox training school.

I would be most distressed if I thought that your readers gathered from the implication in the article that we were neglecting our equipment in any country. This is far from being the case. We have two resident Rank Xerox engineers in Moscow, whose permanent job is the training and organisation of local service engineers—but we do have many thousands of machines in the Soviet Union, and their task is a difficult one.

I have, however, immediately despatched the information contained in this article to our Moscow office, and have asked them to look into the matter of this particular machine. So some good has come out of this, in that the matter has been brought to our attention and action taken.

G. S. PLANNER
General Manager - EEO

CHECK OUR SPECS BEFORE YOU BUY THEIR 4 CHANNEL RECEIVER.

	Sylvania	Pioneer	Sansui	Fisher	Harman-Kardon	Marantz
Model	RQ 3748					
Continuous (RMS) Power[1] 4 channels Stereo Bridge	50Wx4 125Wx2					
THD at rated output	<0.5%					
IM Distortion at rated output	<0.5%					
FM IHF Sensitivity	1.9μv					
50 db signal to noise ratio	2.8μv					
Capture Ratio	1.5db					
Price	$549.95[2]					

[1] All powermeasurements taken at 120 volts/60 cycles, 8 ohms, 20Hz-20kHz, all channels driven simultaneously.
[2] Manufacturer's suggested list price which may be higher in some areas.

If you're in the market for four channel, you already know you've got to spend a good bit of cash for a receiver. So it'd be a good idea to spend a good bit of time checking specs on everything available just to make sure you get the most for your money.

To make your search a little easier, we've prepared the blank comparison chart above with spaces for some of the best-known brands and most important specs. Just take it with you to the store, fill it in, and you'll be able to tell at a glance what you get for what you pay.

We took the liberty of filling in the Sylvania column with specs for our RQ3748 four channel receiver. We did it because we know we're not the best-known name in four channel, and we didn't want you to overlook us for that reason.

Because we think the RQ3748's specs are really worth remembering.

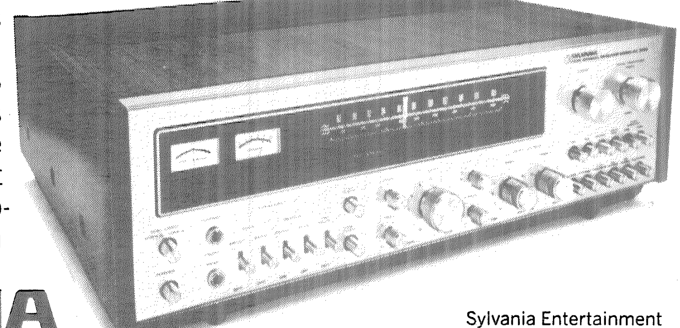
50 watts of RMS power per channel at 8 ohms, 20-20kHz, with all four channels driven. 125 watts per channel in stereo bridge mode. A THD and IM of less than 0.5% at rated output. An FM sensitivity of 1.9 microvolts. A discrete four channel receiver with matrix capabilities so you can use either type of quadraphonic material. And much, much more.[3]

We can offer so much because we have so much experience. We were one of the first in the audio field. And now we're applying all our knowledge, all our engineering skill to four channel.

Once you've proven to yourself which receiver has the best specs, move on down to that last line in the chart and compare Sylvania's price with all the others. Find out which one gives the most for your money.

We feel pretty confident you'll discover that the best-known names aren't necessarily your best buy.

[3] So much more that it won't all fit here. So send us a stamped, self-addressed envelope and we'll send you a four-page brochure on our four channel receivers.



GTE SYLVANIA

Sylvania Entertainment Products Group, Batavia, N.Y.

Sales and Service. Is this the kind of engineering for you?

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

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

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

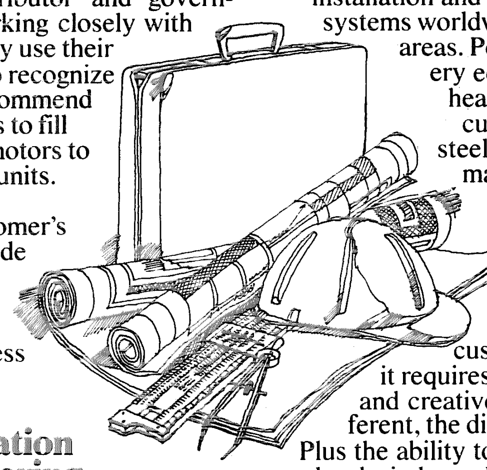
Basically, engineering at GE (and many other companies) can be divided into three areas. Developing and designing products and systems. Manufacturing products. Selling and servicing products.

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

We also have a handy guide that explains all three areas. For a free copy, just write: General Electric, Dept. AK-3, 570 Lexington Ave., New York, New York 10022.

Sales Engineering

Sales engineering is technical marketing. Sales engineers at GE are the important liaison between GE manufacturing facilities and utility, industrial, distributor and governmental customers. Working closely with assigned customers, they use their technical background to recognize customer needs and recommend GE products or systems to fill them. From small AC motors to huge turbine-generator units. Requires a thorough understanding of a customer's business, as well as a wide range of GE products. Plus the ability to work well with people and to recognize a good business opportunity.



Application Engineering

Application engineers are technical experts who work closely with the sales engineer and the customers' engineers. Their job is to analyze special problems and equipment needs of customers, then determine the optimum GE products or systems to meet them. There are two kinds of application engineers. The first works out of a sales operation and is adept at applying a wide variety of products to create a "system" that meets the customers' needs. The second works in a product manufacturing department and is a specialist at applying the products of that one department. Both must have in-depth knowledge of the customers' technical needs. They often consult with product planners and other marketing personnel to suggest ideas for new or modified products.

Field Engineering

Field engineers at GE plan and supervise the installation and service of large equipment systems worldwide in two main customer areas. Power generation and delivery equipment for utilities. And heavy apparatus for industrial customers such as paper and steel mills, chemical plants and machine tool manufacturers. They specialize in either the mechanical/nuclear or electrical/electronic areas. Since field engineers are often called to troubleshoot and correct a customer equipment problem, it requires the technical competence and creative ability to handle the different, the difficult and the unexpected. Plus the ability to take charge, lead people, and make independent, on-the-spot decisions.

Product Planning

Product planning is a marketing function. Product planners make sure a product line offers what customers need at competitive prices. They determine the need for a new or modified product, product availability, market size, cost structure, profitability, specifications and distribution channels. To do this, they work with market researchers, application and sales engineers, finance experts, marketing management, plus design and manufacturing engineers. Their engineering background is a big plus. This work requires self-starters who can coordinate a project and sell their ideas to management.

GENERAL ELECTRIC

An Equal Opportunity Employer