ENGINEERING | AND | SCIENCE

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Caltech on TV . . . page 3

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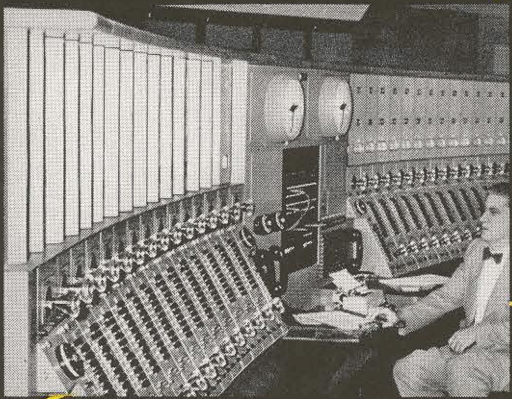

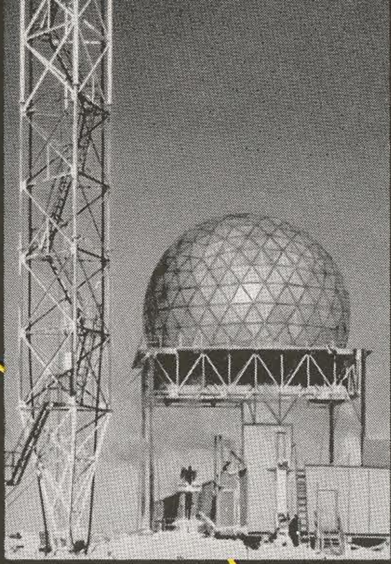

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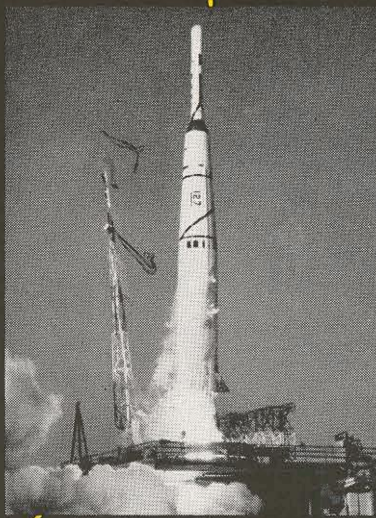

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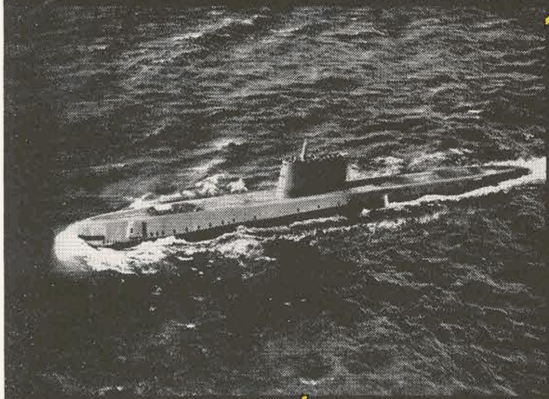

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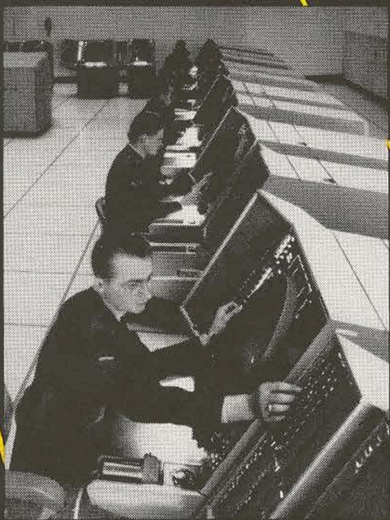

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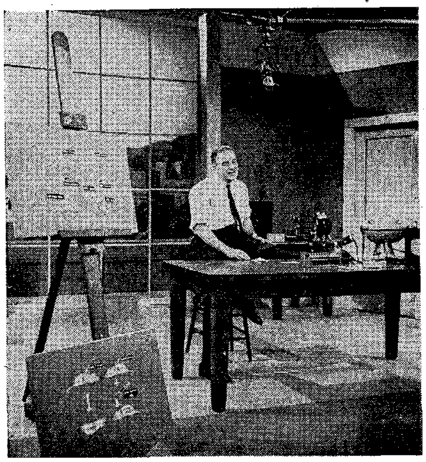

On Our Cover

Ray D. Owen, Caltech professor of biology, faces the NBC television cameras as he discusses "Facts for a Friendly Frankenstein." His talk (see page 16) was the second on Caltech's TV series, *The Next Hundred Years,* which was shown in Los Angeles on KRCA-Channel 4 from November, 1958 through May, 1959.

Dr. Owen, who has been at Caltech for 13 years, is the son of a Wisconsin farmer and gravitated naturally toward courses in agriculture in school. One of his high school teachers, however, introduced him to biology and genetics, the field in which he has since gained international recognition. From high school he went on to Carroll College in Waukesha, Wisconsin, working part of his way through as a Fuller Brush man. After receiving his PhD at the University of Wisconsin, he stayed on there as assistant professor of genetics and zoology for three years. At Caltech, Dr. Owen teaches and conducts research in immunology – the subject of his article on page 16.

Atomic Age Answers

Now that Caltech has got its feet wet in TV, it is taking on a radio program as well. "Atomic Age Answers," featuring research at Caltech, starts on June 19 over KFI, Los Angeles, and will be on every Friday night from 8:30 to 9 p.m. for 13 weeks.

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Books

Nuclear Magnetic Resonance

by John D. Roberts
McGraw-Hill $6.00

Reviewed by Harden M. McConnell

In this book John D. Roberts, professor of organic chemistry at Caltech, is primarily concerned with applications of high resolution nuclear magnetic resonance spectroscopy to problems of modern organic chemistry. Chapter I is a concise but remarkably clear qualitative introduction to the magnetic resonance phenomenon. Each of the following four chapters deals in turn with the principal characteristic phenomena of the high resolution spectra of molecules in liquids: Chapter II deals with nuclear shielding, Chapter III with indirect nuclear spin-spin coupling, Chapter IV with the effects of molecular kinetic phenomena on resonance spectra, and Chapter V is concerned with nuclear quadrupole relaxation and double resonance experiments.

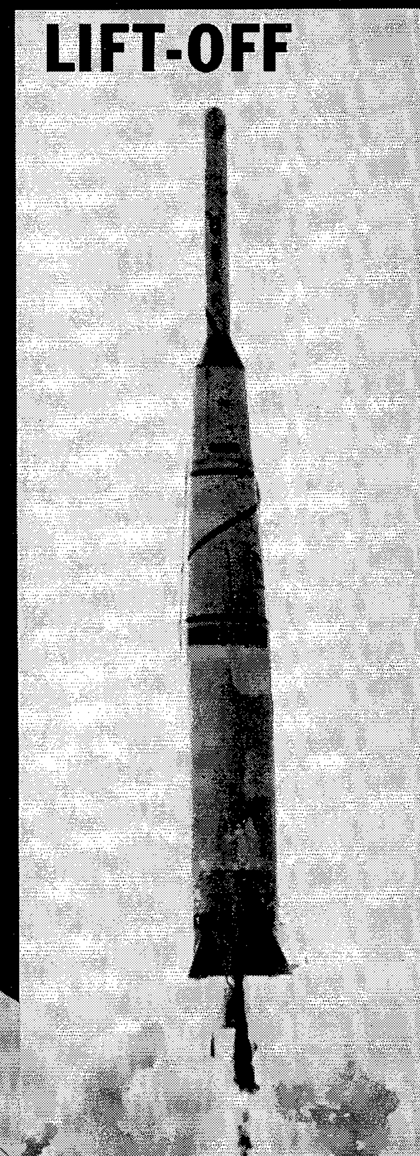
The exposition of each of these subjects is accomplished largely by means of illustrative spectra, many of which are taken from Professor Roberts' own research work.

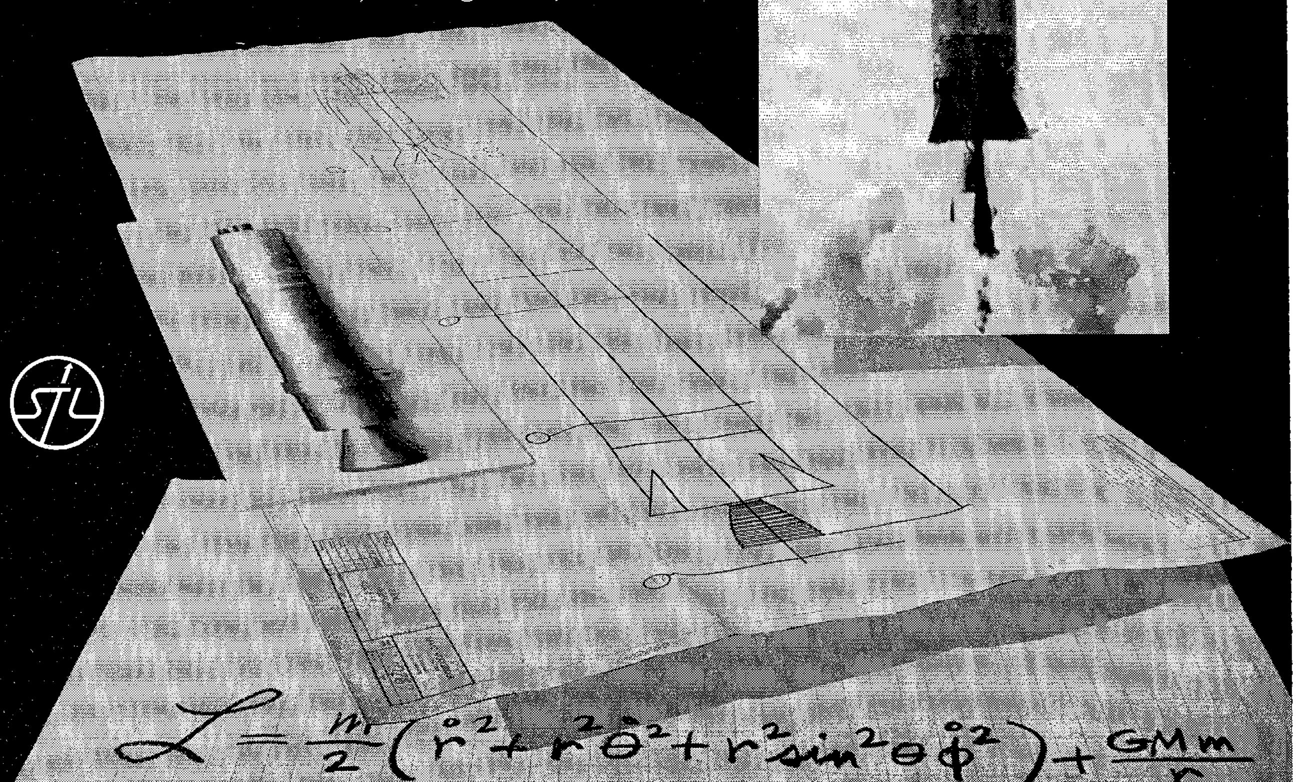
For organic chemists

As an introduction to the structural applications of nuclear magnetic resonance this is an excellent book for organic chemists, particularly since so many illustrations are given in terms of structures and concepts that the organic chemist is familiar with. A physical chemist may perhaps feel just a little frustrated in reading the book, however. This is largely because so many of the subjects that are discussed here could have been treated quantitatively with relatively simple mathematics and physical principles.

All in all, however, the interests of the general reader and the organic chemist are doubtless best served by Professor Roberts' qualitative but lucid introduction to the subject.

Harden M. McConnell, associate professor of physical chemistry, received his PhD from Caltech in 1951.





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WBoyle

"How pure can a research program be, and still command public support? How practical can it be allowed to become without losing the essential spirit of true scholarship?"

Problems of Financing Research at a Private University

by L. A. DuBridge

I wish to introduce this subject by talking about research problems at *one* private institution – namely, Caltech. I know that these problems will be found in other institutions – both private and public. And I know also that quite different problems may be faced by still other institutions – both private and public.

Caltech is a small private institution with a highly selected student body, restricted to about 700 undergraduate and 500 graduate students. When it was reorganized into its present form in 1920, it became devoted to the proposition that research and teaching should be inseparable activities in a school of science and engineering. Hence small teaching loads, adequate funds for research, and a small student body selected for its creative and research potential have always been the ideals – and these ideals have, to a substantial extent, been achieved.

A second pair of ideals was also adopted; namely, that all research activities should be of a basic nature aimed at the extension of knowledge – but, at the same time, the Institute would choose its fields of interest in such a way as to be of maximum service to the community and to the nation. Thus, at the same time that cosmic-ray research was begun in 1921, there was also initiated a program of research on the problems of high-voltage transmission of electric power. Structural organic chemistry and aeronautical engineering came along next. Later, genetics and jet propulsion – and so on.

In this respect Caltech and many other institutions face a serious choice. How "pure" can the research program be, as a whole, and still command community and public support? How practical can it be allowed to become without losing the essential spirit of true scholarship, the search for new knowledge?

There is, of course, no unique answer to this dilem-

This article has been adapted from a talk given by President DuBridge at the Symposium on Basic Research held at the Rockefeller Institute in New York City on May 14. The symposium was sponsored by the American Association for the Advancement of Science, the Alfred P. Sloan Foundation, and the National Academy of Sciences. The entire symposium record will shortly be published in book form by the AAAS.

ma. Yet every institution must find some answer which is both consistent with its own ideals and consonant with its circumstances and responsibilities.

Our aim at Caltech has been to lean over backward in the direction of basic or pure research, and I shall try to explain how we seek to maintain this posture under today's conditions.

First, we find that a small student body is a prime asset. If our teaching load were allowed to outrun our research capacity, we would then have a large teaching staff inadequately provided with research facilities or funds. The pressure would be great to accept any kind of research task for which funds were made available, just to keep the faculty busy. This, you will admit, could lead to unhappy results.

The problem of selection

But even under the best circumstances the selection of research activities and research fields remains a critical problem. The momentary glamor of a well financed but inappropriate project may have to be resisted in favor of the long-term benefits of more basic research activities. To assist in reviewing this situation our faculty and trustees invented the device of a faculty committee on sponsored research. Before an actual proposal for research support can be forwarded to any outside agency – private or government – it must be reviewed by this committee to be sure that it conforms to our ideas of what constitutes basic research. Inasmuch as this committee, with a rotating membership, has been in existence for many years (since 1946) its policies have been well established and are well known to the faculty. It does not often have to veto a project any more. But it has done so and can do so at any time.

This does not mean that there have been no "practical" projects. There have been many – even in the basic science fields. For example, a few years ago one of our biochemists, Professor Haagen-Smit, who had had one too many sniffs of the famous Los Angeles smog, went into his laboratory to see if he could artificially create that characteristic odor. With one eye on the Los Angeles motor traffic and the other on California sunshine, he was soon able to show that gasoline vapor *plus* ultraviolet light did produce a typical smog cloud, and he had soon elucidated the basic ideas of the chemistry of that particular type of air pollution.

However, it is in the engineering departments that the most difficult questions arise as to what is fundamental research and what is practical development which could be more appropriately done in commercial laboratories. Engineering is *applied* science, and engineering research must have some relevance to the practical needs of men. Yet, even here it is normally possible to distinguish the projects which are aimed toward a basic extension of engineering knowledge and toward new contributions to engineering practice, from those which are aimed solely at the perfection of particular devices or techniques.

Our computer laboratory does not aim principally at the improvement of computer circuitry, but rather at basically new ways of using the computer as an instrument to solve scientific, engineering and technical problems, and as a tool to aid in the development of applied mathematics. The aeronautics laboratory does not design airplanes; it learns about the properties of air flow.

One useful criterion which helps many decisions in this field is that to be acceptable in any area a research program must be one which is consistent with and contributes to the educational program. This means it must be one in which graduate students can participate. This means, among other things, it must not be "classified," either for reasons of trade secrecy or military security. Also, it must not be one which provides exclusive patent rights to the sponsor. As far as the *on-campus* program is concerned, these rules are now rigidly followed.

Does that mean we have no way of being of service in the field of national defense or industrial development? Not necessarily. When we have found it necessary or desirable – since the close of World War II – to undertake classified activities, they have been done in off-campus installations where restricted access does not inconvenience the teaching program or interrupt the free access to all parts of the campus.

We operate two such off-campus installations now: the government-owned Jet Propulsion Laboratory (now the principal laboratory of the National Aeronautics and Space Administration for space flight research) and the Cooperative Wind Tunnel (owned cooperatively by a group of aircraft companies). In both cases Caltech initiated the work of these laboratories during the war and has continued them ever since under a nonprofit management contract.

A number of years ago a temporary project was carried on in leased space about two miles from the campus. Thus we are enabled to preserve the condition of free access to all parts of the campus by faculty and students, which we regard as a precious asset not to be relinquished except in times of extreme emergency.

The problem of finance

How, then, is our basic research program financed?

Here again it must be emphasized that in our case the size of the faculty is determined by the total funds that are available rather than by the number of students to be taken care of. Nevertheless, our able research staff does have an insatiable appetite for more research funds and for continually expanding research programs. Hence, the problems of financing the rapidly rising costs of research and the rapidly growing program are severe indeed.

It may be of interest to list our sources of support.

In listing them I shall list support for both teaching and research, for I do not know how to determine at Caltech how many pennies of each dollar go to teaching and how many to research. This is not because our bookkeeping department is inefficient, but only because we purposely mix the two activities so thoroughly that separate budgeting is impossible even in *principle*.

Out of a total *campus* budget of 9 million dollars (in 1957-58), endowment income provided 32 percent; gifts and grants from nongovernment sources provided 20 percent; government grants and contracts (including overhead) provided 35 percent; and tuition and other sources provided 13 percent. During the past 10 years the total budget has doubled. The percentage (but not total volume) of government funds has declined (from 41 to 35 percent), that of private gifts has risen (from 13.5 to 20 percent), and the others have remained nearly constant.

We hope and expect that these various sources of support will retain the present relative positions in the future — that is, in round numbers: endowment, 30 percent; gifts, 30 percent; government contracts, 30 percent; tuition, 10 percent. Whether this is just the right ratio or not, no one can say. But one can say that maintaining *all* of these sources of support is of very great importance to any private institution.

It is, of course, just here that all private institutions have a common problem — that of obtaining income from a variety of sources to support both educational and research programs.

Erosion of funds

There is no question but that the relative importance of endowment income in the private universities has been declining in the nation as a whole. This has sometimes been mistakenly referred to as the "erosion" of endowment funds. Actually, endowment funds have not eroded at all; they have, as a whole, risen rapidly both in book and in market value and they have also increased in their earning power — when properly invested — nearly as fast as prices have risen. Every private institution which has been on its toes has also secured substantial fractional increases in its endowment funds in recent years, and these increases are continuing.

Yet, research and teaching costs have outrun endowment income, not only because the prices of specific products have been inflated, and not solely because salaries and wages have risen sharply, but because the equipment, materials, techniques and manpower for doing research and teaching have changed so greatly. Intricate and enormous machines and instruments, requiring large crews to build and operate them, were almost unknown before the war, even in industrial laboratories. Now they are commonplace.

Clearly, this radical change in research activities has not been financed by endowment funds. The change has been possible only because government funds have been available in substantial amounts.

Granted that some government funds have been misplaced and misused; granted that some have been used to support the kinds of things that universities should not be doing; it is still true that government funds have been the backbone of the growth of basic research in the universities in the postwar period. The chief trouble has been that government funds for basic research have not been available in large enough amounts, compared to the funds available for applied research or for testing and development. It is this fact that has forced many universities to take on development projects in order to have something going on that could be called research. A major problem of the future is to keep these funds for basic research growing at an adequate rate.

Government control

Increasing government support of research raises the question of whether or not the government will assume control of the universities if it provides funds for their research. The chief answer to this question is that it has not happened yet. The chief threat of control has come not from the government agencies who administer the funds, but from the panels and advisory committees (composed largely of professors!) who pass upon projects *and budgets* before they are accepted. Many of these groups have steadfastly opposed proper overhead payments on research contracts, have opposed including allowances for the salaries of professors working on the projects, have opposed block or departmental grants, and have required of the prospective research worker such elaborate and detailed proposals and reports that a type of bureaucratic committee control has grown up which suppresses daring ideas and takes administrative control out of the hands of the universities themselves.

All of these things are done with the most pious protestations, of course. "It isn't good for the universities to receive overhead reimbursement and thus become dependent on the government," they say. Or, "It is not good for the professor to have part of his salary paid by the supporter of his research." (Why not? Somebody has to give the university money to pay him.) Again, "Block grants are bad for they put too much power in the hands of the department heads." So a committee in Washington decides *it* is more competent to allocate the funds than the university officials!

As a longtime faculty member myself, I can pray fervently that both I and my faculty may be delivered from dictatorship by government faculty committees. Give me a good smart administrator to deal with and I can dispense with faculty advisory committees, *except when they deal with purely scientific affairs* and not with administrative or fiscal matters. Scientists, when they get into government, are their own worst enemies. When they have control over activities of their colleagues — through the administration of research grants — they become autocrats of the most difficult kind.

These are serious matters. The rapid rise in research activities has required the universities to expand their plants, their business offices, their maintenance facilities and their libraries. Research grants or contracts which have not borne their share of these costs have been parasites on other sources of funds. It is quite all right to talk about the desirability of the university "sharing the cost" of research with the sponsoring agency. But what with? Endowment funds, as we have said, have scarcely kept pace with rising costs of carrying on the same operations, to say nothing of adding new ones.

Corporate executives, I find, get understandably glassy looks in their eyes when they are asked to give money to a university to cover indirect costs of research being sponsored by government agencies because these agencies cannot afford, or are not allowed, or simply refuse, to pay the full costs of the research which they take credit for supporting. Corporations and individuals alike have trouble understanding why they should be asked to underwrite those costs. So the universities don't ask them to. They ask for "unrestricted funds," or funds for "general support." But of course this is just a euphemistic way of requesting the same thing — money to pay the costs of research which others are pretending to support.

Now I must say that corporations as a whole have been exceedingly generous in responding to this appeal for unrestricted funds, and this has saved many an institution, including my own, from going broke in recent years. Or rather, I should say, unrestricted corporate support has enabled us to abandon our prohibition against accepting funds from government agencies which do not pay full costs. We now can accept such funds in limited amounts and still remain solvent.

Problems of government support

The principal problems in connection with the government support of research are:

1. To increase the funds available for basic research;

2. To persuade all government agencies to pay full costs of the research they support (including the prorated share of the faculty salaries);

3. To enlarge the degree to which block or departmental or general grants are made available for strengthening an *area* of science rather than only a particular project; and

4. To persuade the Bureau of the Budget and other fiscal and auditing agencies to modify radically the cost-accounting practices which they now insist upon and which are inappropriate to educational institutions. (With some difficulty I restrain myself from a further discourse on this latter subject, which is even now a subject of strenuous and difficult negotiations between the universities and the government.)

Private funds

What, then, about the nongovernment sources of support for research in private universities?

The problems here are many, but, though they are not easy, they are not impossible. Granted that the government will continue to support a substantial share of university research — especially the large and expensive projects — private funds still play a critical role. Individuals, corporations and foundations should continue and expand their contributions to endowment funds, operating funds and building funds. Private sources are free to follow the theory that the strength of the basic research program in this nation is primarily dependent on the strength of the institutions that carry on such research. Hence, the most important way to finance research is to finance the institutions — to provide what they need in order to acquire facilities, pay adequate faculty salaries, and maintain the plant in order to attract and support the best research people. Especially is it important to provide the long-term support essential to a real scholarly atmosphere in which new ideas are likely to thrive. New ideas must be born *before* clever and startling research proposals can be submitted to the government. Private funds, wisely given, can enhance the intellectual ferment in our great centers of learning and thus create the environment in which new ideas will arise.

I would not be honest if I did not point out that there are troubles in the administration of private funds for research also. The indirect costs of privately sponsored research are just as great as for government sponsorship. As I have already suggested, the universities have found it embarrassing to pass the hat elsewhere for these costs. So they have done two things: (1) sought more funds — given largely on an annual basis — for "unrestricted" purposes (i.e., to raise salaries and pay overhead); and (2) asked private sponsors of all projects to pay their prorated share of these costs.

Private foundations have been understandably reluctant to do either of these two things. They wish to see their limited funds going for direct, recognizable costs of identifiable projects. Besides, they could point to plenty of institutions where the president or treasurer was a bum but the biology professor was a whiz. They wanted no funds to be diverted from the professor. And obviously, too, their money would "not go as far" if a quarter to a third of it was allocated to indirect costs. "Better to supply 15 hungry men with bread than only 10 with butter too."

I do not pretend to offer any easy formulas for solving this problem. Many foundations and other private agencies have found ways — a variety of ways — to assist. I am only setting forth the problem and asking that we all face the fact that those great research institutions of this country, the private universities, no longer have — if they ever did —"funds of their own" to disperse freely. All their funds are gifts (except, of course, tuition fees). Furthermore, a large share of these gifts now come on an annual basis and not in the form of permanent endowments. Professors on tenure, who resist having their salaries paid partly from project funds because they are on an annual basis, should become aware of the fact that other sources of funds are on an annual basis too and, whether we like it or not, that's the way things are these days. This does not mean the professors will not be as surely paid; it only means that *every* possible source of funds must be tapped.

There are some who will bemoan the fact that the universities have allowed themselves to reach such a terrible state. And I admit that universities have been more concerned about national welfare than with their own financial security. The private universities could have pulled in their necks and refused to expand their research until endowment funds had been secured to underwrite it. Some, indeed, did so. But if all had done so and left it to the state universities to become the only research centers, the private university in this country would have been doomed to oblivion. And that would not have been good even for the state universities.

Paying the bills

But the private institutions as a whole met the challenge and took the risks. Fortunately, the largest sources of new funds did pay full costs, and these helped to carry the other projects which did not. Annual unrestricted gifts were sought and found also — and somehow the bills got mostly paid — that is, all were paid except the professors' salaries. *They* had to wait — partly because the professors themselves did not realize the new turn which university financial problems had taken.

If we now raise our eyes from the specific research problems in a specific university to the broader problems of academic research in America, what difficulties do we see? There are many, of course — fiscal, administrative, jurisdictional, political. Some people worry about the "balance" of our research effort — that we will spend too much money on space and not enough on cancer, or vice versa. (Incidentally, I have frequently seen cases of general agreement on how much is "not enough"; I have never seen a generally accepted way of learning how much is "too much.")

Great segments of science and technology now have enormous popular appeal, and special purpose groups can whip up considerable enthusiasm for spending huge sums on this disease or that — or on nuclear power or oceanography or radio astronomy or other perfectly respectable areas, both basic and applied. Hence, so-called "categorical" funds grow and multiply — both in private and government circles. Of course, one can say that if there are only enough categories, with plenty of funds in each, then full freedom of choice is again available.

But is it?

I shall forever pity the physicist who is anxious to learn about the puzzling behavior of liquid helium II, wasting his time trying to decide whether this is solid state physics or nuclear physics, or maybe oceanography, and whether he should submit proposals to ONR or OOR or NSF. And how can he write a detailed proposal when he is just exploring, when he is just curious?

Fortunately — in precisely this situation and others like it — the Sloan Foundation has indicated that it was interested in supporting inquiring minds, and would be glad to have such minds worry about any questions on earth they pleased.

The final challenge

Here is the great challenge to universities and to all who support them: Are we attracting the cream of the nation's inquiring minds to our campuses, and are we there giving them full encouragement and support in pursuing whatever lines of endeavor interest them — preferably with no questions asked? That is a difficult challenge, possibly an impossible one. But unless we have inquiring minds that are really free to inquire — even in fields outside the cognizance of any Washington or New York committee — then we can never reap the full benefits and satisfactions of free and unfettered scientific research.

And now, as I bring this paper to a close, I realize that I have spent too much time on what seem like dirty administrative problems. I would have enjoyed it much more if I had been describing the magnificent achievements in scientific research the past 10 years have witnessed. From the center of the earth to outer space; from the nucleus of the atom to the nucleus of the cell; from the theory of solids to the evolution of the universe; from the structure of proteins to the geography of Antarctica; from cybernetics to astronautics, great new areas of science have seen astonishing advances. Thousands of young men and women have found fruitful and satisfying careers in scientific research and America's universities, private and public, have become national assets of prime importance — not only because they aid in the advance of welfare and security, but because they are the congenial homes of the inquiring minds, the great stimulators and supporters of that restless and adventurous thing, the human spirit.

Academic Procession, 1959

The Month at Caltech

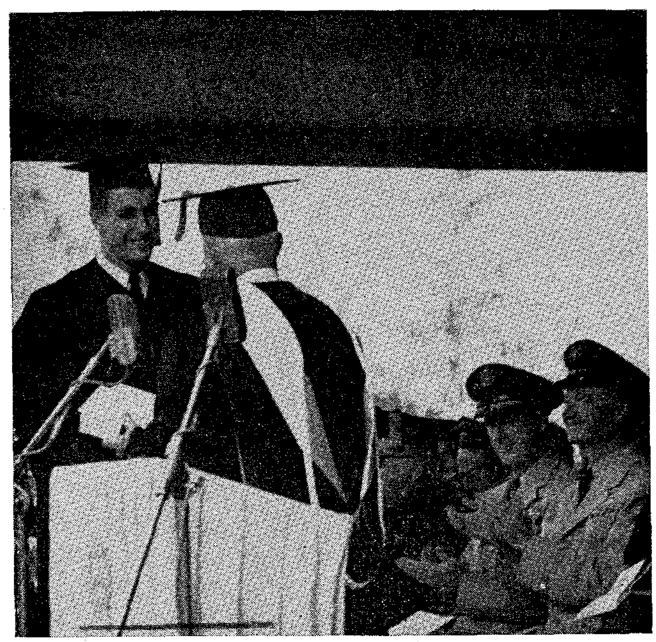
Commencement

At Caltech's 65th annual commencement on June 12, a total of 498 students received degrees – 147 Bachelors of Science, 141 Masters of Science, 60 Doctors of Philosophy and 13 Engineers.

Of the 49 men who graduated with honors, 7 received both academic honor and Student Body Honor Keys: Gerald J. Arenson, Walter S. Baer, Keith S. Brown, Jr., Charles R. Johnson, Robert V. Lange, David M. Milder and Anthony Leonard. Honor Keys were awarded to 14 seniors in all.

The Frederick W. Hinrichs, Jr., Memorial Award for the most outstanding senior this year went to Keith S. Brown, Jr., who is shown at the right, receiving his award from President DuBridge.

The commencement address, "Democracy In an Age of Science," was given by Sir Solly Zuckerman, professor of anatomy at the University of Birmingham, England, and deputy chairman of the Advisory Council on Scientific Policy in Great Britain.



Caltech and the Future

At last year's commencement ceremonies President DuBridge announced that the Institute had raised $5,000,000 of the $16,100,000 goal set for the Caltech Development Program.

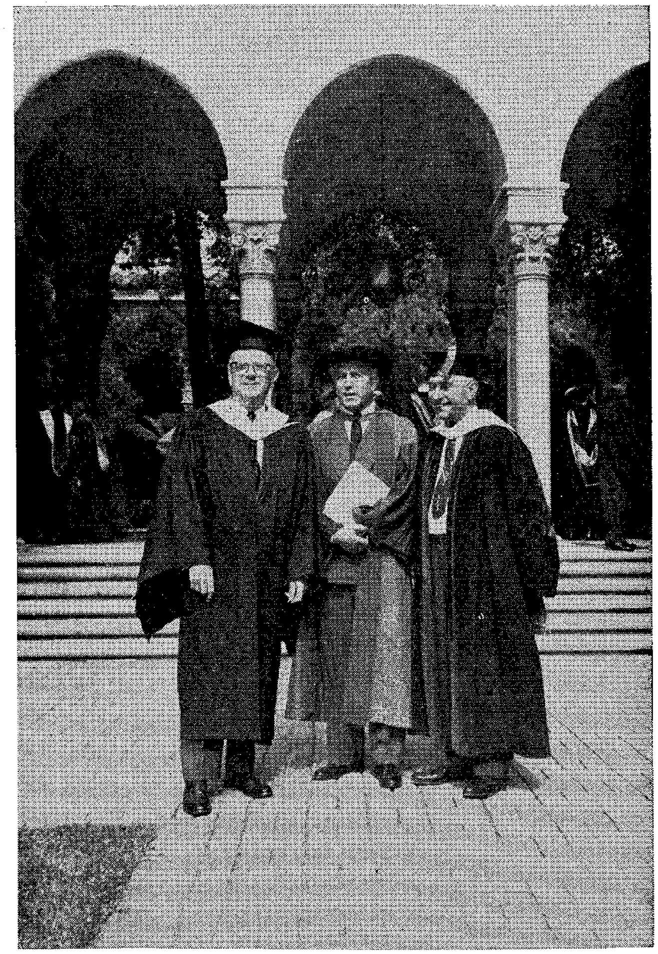
At the 1959 commencement this month President DuBridge was able to report that the amount pledged or assured now totaled $16,516,000. Though this meant that the original goal had been met — and in a matter of 18 months, at that — costs and conditions had changed so much in that same period that it would now take $19,350,000 to complete the program originally planned. To meet this new goal, then, the Institute must raise an additional $2,800,000.

Last month the eighth of the Institute's 18 new buildings was assured by a gift from Dr. Seeley G. Mudd of Pasadena — a new central library on the campus. At Dr. Mudd's request the building will be named the Robert A. Millikan Memorial Library, in honor of the man who was one of the founders of the modern Caltech, and who served as its chief executive officer from 1921 until 1946.

The earliest plans for the Caltech campus provided for a central library at the site which has been reserved for it for nearly 40 years, in the center of the western section of the campus. The new library will house the books and personnel that now occupy eight departmental libraries, though these libraries will still retain small working collections of widely-used materials.

At commencement this month President DuBridge announced gifts that would finance construction of six more buildings on campus:

An undergraduate house to be called the Lloyd House in memory of Ralph B. and Lulu Hull Lloyd, the gift of the Lloyd Foundation. Mr. Lloyd was a former trustee of Caltech; his son-in-law, Richard Von Hagen, is now a trustee.



Albert B. Ruddock, chairman of Caltech's Board of Trustees; commencement speaker Sir Solly Zuckerman, and Caltech President L. A. DuBridge.

The Carl F. Braun Graduate House, gift of the Carl F. Braun Trust Estate, named also for a former Caltech trustee, whose son John is now a trustee.

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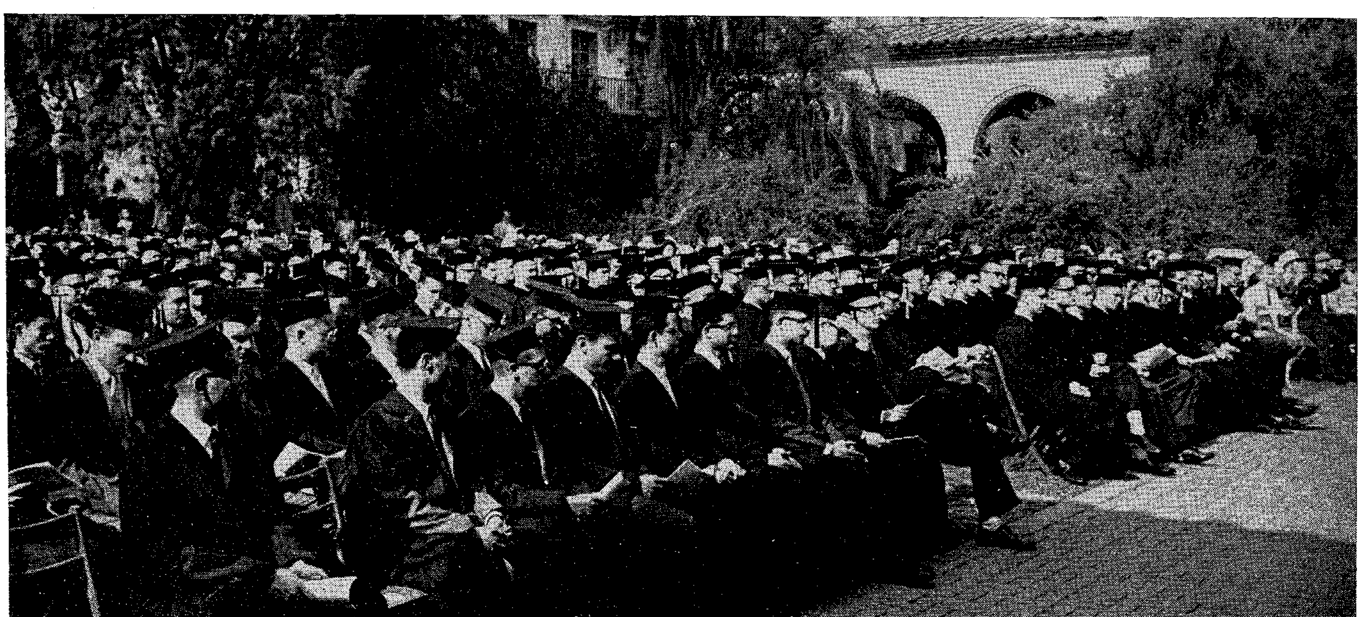


An architect's drawing of the Robert A. Millikan Memorial Library. The new central library, which will rise five stories above ground, is to house the books and personnel that now occupy eight departmental libraries.

A second graduate house – not yet named – which is the joint gift of Samuel B. Mosher of Los Angeles, and trustee Earle Jorgensen.

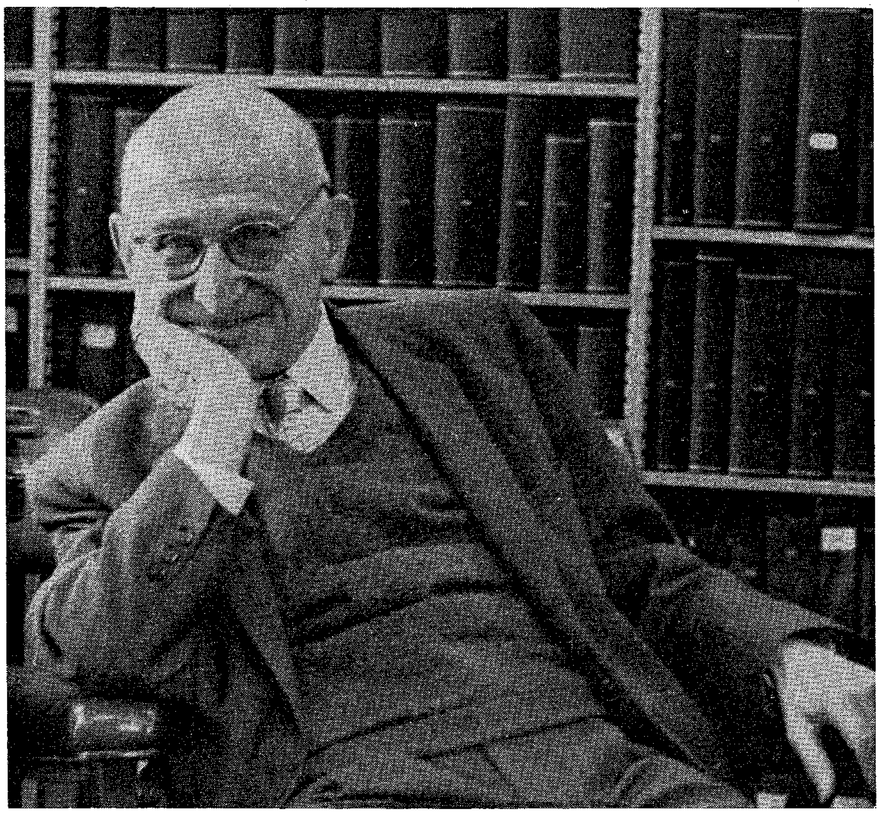
Two new laboratories of aeronautics and flight research – one a gift from an anonymous donor; the other, to be named the Theodore von Karman Laboratory (in honor of Caltech's distinguished professor of aeronautics, emeritus), is the gift of the Aerojet-General Corporation, a subsidiary of the General Tire and Rubber Company.

Four buildings remain to be financed: two undergraduate houses, a graduate house, and the campus dining hall; and approximately $500,000 remains to be raised to complete the Faculty Salary Fund, to cover additional land purchases, and other building costs not included in specific donations.

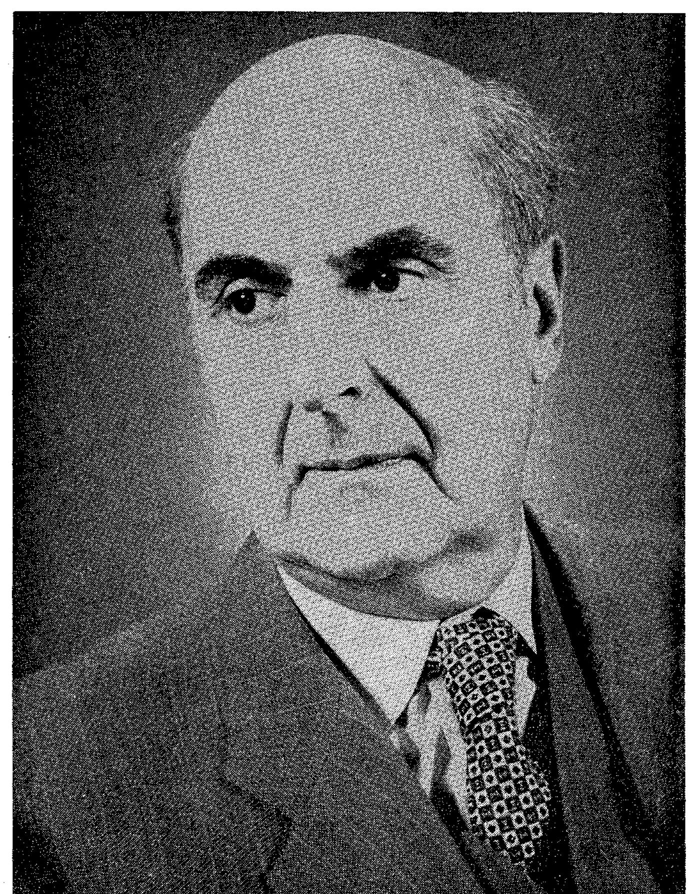
A NEW VIEW OF THROOP

The campus takes on a new look as construction workers make a 34-foot excavation in front of Throop Hall. The big hole will house the 10,000,000-volt electrostatic generator for the new Sloan Laboratory of Mathematics and Physics.

Professors Emeritus



Beno Gutenberg, who retires this month as professor of geophysics, has been a member of the Caltech faculty since 1930. A native of Darmstadt, Germany, he was professor of geophysics at the University of Frankfurt before joining the Seismological Laboratory here. Dr. Gutenberg has played a major role in the investigation of size, location, occurrence, and cause of earthquakes in the Pacific coastal region and throughout the world in general.



Laszlo Zechmeister, professor of organic chemistry, retires this month after 19 years at Caltech. A native of Hungary, Dr. Zechmeister received a Diploma of Chemistry in 1911 and a Doctor of Engineering in 1913 from the Federal Institute of Technology in Zurich, Switzerland. Before coming to Caltech in 1940, he was professor of chemistry and director of the chemical laboratory of the medical school at the University of Pécs in Hungary. Dr. Zechmeister is internationally known for his work in the field of chromatography.

Ray D. Owen, professor of biology, and two of the mice used in his experiments. The darker mouse is an untreated control; the other is lighter because a heavy dose of x-rays has killed the pigment-producing cells in its hair. This mouse survived the lethal dose of radiation because normal blood-forming cells were transplanted into it.

by Ray D. Owen

Facts for a Friendly Frankenstein

When a car or bicycle or washing machine needs repairing you take it to a mechanic with the idea that if he finds a part that is worn out or broken, he will almost always be able to replace that part.

Imagine how important it would be if it were also possible to replace parts of human beings that had worn out, or that had been destroyed by disease, or gone "wild" as in particular kinds of cancer. Within the next hundred years – perhaps rather early in that interval – it is very possible that a lively market will develop for good used parts for the human body.

Of course, the kinds of substitutions of parts now possible are very limited. If a person needs a blood transfusion, it is a simple matter to transfuse the right kind of compatible blood into his veins. But unless his body is able to make the blood he needs, he will require another transfusion soon, and then another. The transfused blood doesn't settle down and make more blood like itself. It is a "dead-end" tissue; it is used up and disappears.

Somewhat similarly, if a person needs to grow bone in a particular place, it is possible to take part of another person's bone and put it in that area, and new bone will often grow there. But this can be done with bone that has been boiled, frozen, or dried. Dead bone works because it provides only the inert scaffolding onto which the host's cells grow, producing more bone of their own.

In fact, there are very few kinds of tissues that can be transplanted successfully from one individual to another, to grow and function in their new home. The reason for this is that the animal body has a kind of machinery to recognize things that are foreign to it, and it responds by destroying these foreign things. This machinery protects us from disease; it aids our recovery from disease; it prevents, generally, *Research in tissue transplantation points the way to a used-parts market for the human body. A transcript of a talk given on Caltech's TV Series, "The Next Hundred Years."*

our being reinfected by the same kind of disease-producing organism once we have recovered from a particular disease. This is the machinery of immunity. It recognizes the foreign, invading germ and responds by destroying that germ. When we have a foreign tissue transplant from another individual, the body isn't capable of making a moral judgment as to whether the foreign material is going to be good or bad for it; it recognizes simply that the material is foreign, and responds by destroying it.

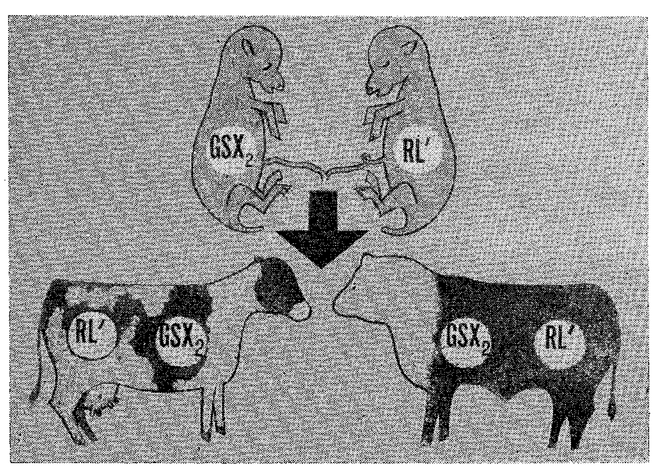
It *is* possible to transplant living, growing, surviving tissue from one person to another — if they are identical twins. Identical twins are so much alike, having the same heredity, that their bodies do not recognize each other's tissues as foreign. But in the ordinary case, if a person has a burn and needs a skin transplant to cover it, the surgeon will take skin from somewhere on that person's own body, because only that skin will be accepted.

So the problem in developing a market for good used parts for the human body is: How can we evade or control the immunological reaction — the recognition and response to foreign material — when there is need for a tissue or organ transplant? We don't have the answer now. But we have some rather promising leads.

One of the leads is, in part, derived from some observations made with my colleagues at the University of Wisconsin about 15 years ago. We were working on blood groups of dairy cattle and a very interesting and unusual case came to our attention. It happened that, on a farm in Maryland, a breeder of purebred Guernseys bred a Guernsey cow one morning to the Guernsey bull on the farm. By accident, that same day the cow was bred again to the beef bull — a white-faced Hereford — on the same farm. At the end of the proper period, the cow gave birth to twin calves. They were a remarkable pair of twins because, while one was a female and looked as a Guernsey should, the other was a bull and had the dominant white-faced marking of the Hereford.

It seemed evident, just from looking at this pair, that they were twins with different fathers. But when we tested their bloods, we found that their blood types were identical. This was hard to believe because they could not have been identical twins; they were of opposite sex, and they apparently had different fathers.

Studying them a little further, we found out why their bloods gave the same reactions. There were two different kinds of blood cells there, just as there should have been for two different individuals. One kind of blood cells was marked with the characteristics we call R and L′, inherited from the Hereford bull. The other kind was marked with the characteristics S and X_2 which came from the Guernsey. This second kind of red cells had G, inherited from the cow, while the first kind did not have G. The cow had therefore evidently produced two eggs, one with G and the other without G, and one of the eggs had been fertilized by a Hereford sperm (RL′), the other by a Guernsey sperm (SX_2). Both of the twins had a mixture of both of these kinds of blood cells. Now,



These remarkable twin calves, one marked like a Hereford, one like a Guernsey, have identical blood types—even though they are of opposite sex, and apparently had different fathers. The mixture of blood cells resulted from the reciprocal transfusions of blood which twin cattle give each other continuously during much of their embryonic lives.

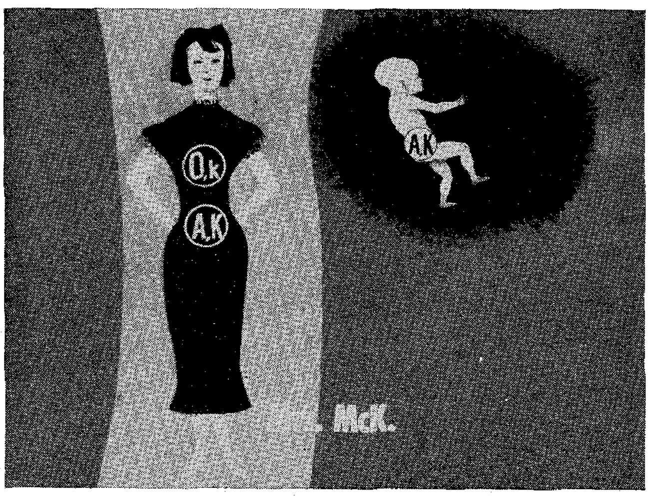
that shouldn't have been so surprising either, because it had been known for a long time that twin cattle usually have a common circulation; their blood vessels join, and they give each other reciprocal transfusions of blood continuously during much of their embryonic lives.

So, we might even expect to find that two calves born as twins have mixed blood. But the surprising thing was that, when we tested these twins again six months later, and again at the end of the year, and again over several years, they stayed the way they had been at birth.

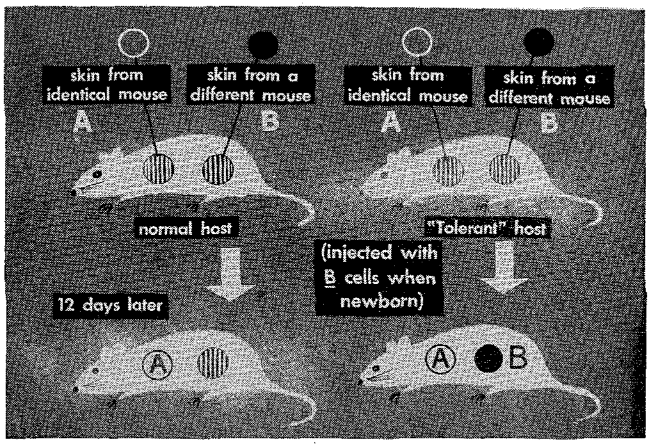
In other words, it wasn't just a matter of blood transfusion, with the transfused blood disappearing. There had been a persistent transplantation of blood-forming tissue between these calves while they were embryos. And this is interesting because it means that when a transplanted tissue is introduced to an individual while he is still very young (in the embryo, in this case) his body is not able to recognize the tissue as foreign, and doesn't respond to it and destroy it. Instead, his body continues to accept this material as his own.

A little while later some people in England showed that it was possible to make skin grafts between non-identical twin cattle. And more recently some Scandinavian workers performed successful kidney transplants. So bovine fraternal twins really lack the ability to recognize what is different in each other.

Not long ago a similar case was found in a human being (below). A "Mrs. McK." came into a British blood bank to give a pint of blood. When the sample was typed, it was found that Mrs. McK. had unusual blood. Her blood behaved mainly as type A, but not all her cells had the A antigen. Quite a large proportion behaved as though they were O. And the O



Mrs. McK, a British blood donor, was found to have an unusual mixture of blood cells. Investigation revealed that she was born a twin, but her brother had died in infancy. Cells from the brother, that had been transplanted into Mrs. McK's body when the twins were embryos, still survived.



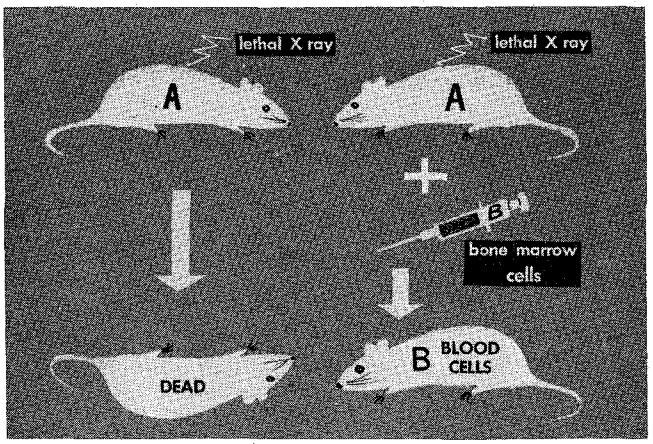
If we put on a mouse of strain A (left) some skin from another member of the same strain, this skin will grow and become accepted, while skin from another line of mice, B, proves incompatible. But if the A mouse had been injected when it was newborn with cells from strain B (right), a transplant of B skin would be completely accepted.

cells lacked another antigen called Kell that was present on the A cells. Her blood was apparently a mixture. Mrs. McK. was asked (with the twin cattle in mind), "Are you by any chance a twin?" "Yes," she replied, "I was a twin, but my twin brother died more than 20 years ago when he was a baby." It was possible to do a complete job of blood typing on the long-dead twin brother because descendants of his cells that had been transplanted into his twin sister still survived in her body, giving rise to blood cells in large numbers. Here again, a successful transplant had occurred because the recipient at the time was an embryo. Of course, Mrs. McK. and her brother were fraternal twins; there is no implication that Mrs. McK. has two fathers.

A few years ago a group of workers in England found a way of putting this kind of situation on a controlled, laboratory basis. These were the same workers that did the skin transplants in twin cattle, mentioned above, but in this work they used mice and chickens. Their procedure is shown above.

If we put on an albino mouse of strain A some skin from another member of the same highly inbred strain, this skin will grow and become fully accepted, just as we would expect when donor and recipient are identical. If we put on skin from another line of mice, B (a colored line this time) then the skin becomes established at first, but within a period of 10 or 12 days the recognition and response machinery has destroyed it and all that is left is a scab where the incompatible skin transplant was put.

Now, suppose the A mouse had been injected when he was newborn with cells from strain B. Cells from a different individual come into the very young animal just as they did in the case of the twin cattle. When an animal that has been treated in this way grows up and is given a B transplant, the skin is com-



If a mouse is given a sufficiently high dose of radiation it will die in a week or ten days. But if, after the x-ray, the mouse is injected with bone marrow cells from another mouse, then it lives.

pletely accepted. The host is "tolerant," so we get a white mouse with a disk of luxuriant, colored hair growing on the tolerated skin transplant.

Does this phenomenon suggest any recipe for *human* practice? Looking ahead in a rather starry-eyed way to the next hundred years, we could say, "Perhaps." It may even happen that when two babies are born, cells will be exchanged between them while they can still accept them, so that each of these babies grows up as a walking "tissue bank" for the other. However, this may well be a situation with dangers in it that we don't recognize, so we would hesitate to attempt such applications to human babies as yet.

There may be special cases where these experiments could be justified. For instance, there are certain kinds of anemia where the person is genetically unable to produce the amount of blood that he needs because of an inherent defect in his blood-forming tissue. If, when this person is a baby, we inject normal blood-forming cells into him from another individual, it might well be that these would be accepted as a transplant to provide a source of normal cells to take the place of his own defective ones.

Actually, the first steps in this research have already been accomplished with mice. Dr. Elizabeth Russell of the Roscoe B. Jackson Memorial Laboratory in Bar Harbor, Maine, by making transplants, has succeeded in saving the lives of mice that are genetically severe anemics.

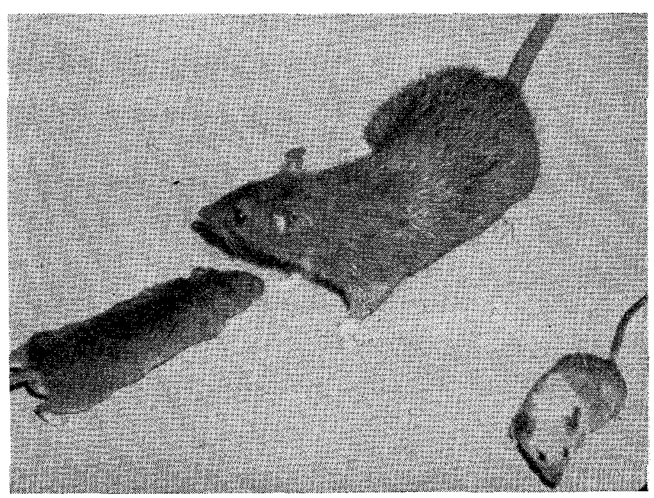
When you look at the broader picture it is obvious that the treating of very young babies in this way is not a general solution to the problem we are discussing. If you need a tissue transplant now because something is badly wrong in you, it doesn't help to say you could have been injected with some kind of cell when you were a baby. What we need to solve this problem is a way of suppressing and controlling the immune response in a normal adult. And it is with that in mind that a great deal of searching is going on now in laboratories all over the world.

Again, we have some leads. One of these is illustrated at the left and deals with very large amounts of x-ray irradiation, or with particular kinds of chemicals which mimic the effects of radiation on animals. If, for example, a mouse is given 900 or 950 roentgens of total body radiation (a very high dose) it will die in a week or 10 days. But if, after the x-ray, this mouse is injected with bone marrow cells from another mouse, then he lives.

This has two points of significance for us. The first is that the life of the mouse has been saved by this kind of treatment. Looking toward a future in which we can expect increased use of high energy irradiation, and possible catastrophes from this, we would be very much interested in saving the lives of individuals who have been exposed by accident to these killing rays.

The second point is that the x-rays have had the effect of permitting the individual to receive a tissue transplant that his body would ordinarily reject. The x-rays, or the chemicals that mimic the effects of x-rays, have inactivated the animal's ability to give an immune response; the recognition and response machinery has been destroyed. So he accepts the tissue transplant that will save his life.

Some examples of animals in this kind of experiment are shown below. First (at the left) there is an ordinary mouse — the well-known mouse-colored mouse. Recently, at Oak Ridge National Laboratory, the second mouse, of this same strain (at the right) was given a lethal dose of x-rays and then injected with bone marrow from a rat (in the center). The second mouse doesn't look really normal because, for one thing, the x-rays have killed the cells in his hair that produce pigment, so the hair is almost white. The x-rays have also had some other effects



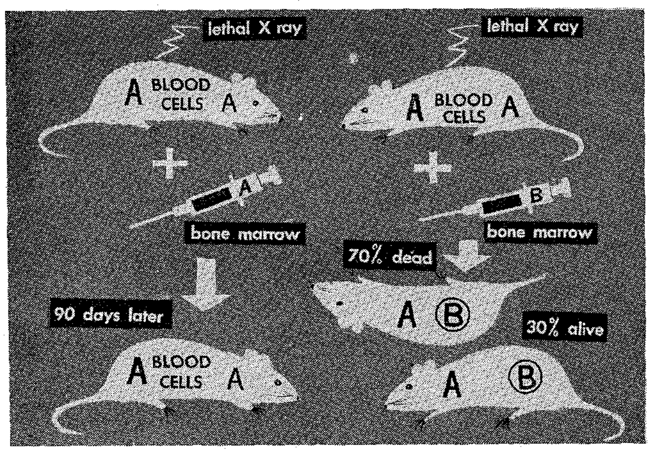
The mouse at the right is of the same strain as the one at the left. Though it looks far from normal, it is remarkable that this mouse is alive at all, for it has been given a lethal dose of x-rays, then an injection of bone marrow from a rat like the one shown in the center.

on the mouse which the injection of bone marrow has not corrected, but the main thing is that this mouse is alive and is reasonably well and happy. And within him are rat blood cells. Now, a rat is a very different kind of animal than a mouse — a different genus and species. It is remarkable that this mouse can live with all of his red blood cells derived from an animal so foreign to him.

This is only one part of the whole story. It is true that the control mouse died from radiation; the bone-marrow-injected one lived. But a lot depends on what has been injected into the irradiated mouse. If a mouse of type A is given a lethal irradiation and then is given A bone marrow (below), he lives almost a normal life for a long period of time. But if he is given a lethal dose of x-ray and then a *foreign* kind of bone marrow (from another kind of mouse or from a rat) then in time he begins to run into trouble. In fact, these mice begin to die off after 30 to 90 days. In 90 days after rat-marrow injection, only 3 out of 10 of these mice are alive. Some may live for a long time, but many of them die. They die from some kind of incompatibility reaction, and we are right back again to the problem of tissue transplantation.

It is believed now by some that the host recovers from the effects of x-ray, becomes able to recognize and destroy foreign matter, and in the process, dies. Others believe that the injected marrow has the ability to recognize that the host is foreign and to react against the host and cause his death. And some people, like myself, believe that there is something of both of these directions of reaction in the delayed death phenomenon.

But the important thing, I think, is that if we are considering extending this kind of treatment to human beings, then we will have to control the delayed death reaction. It may be very useful to save the life of a man by injecting bone marrow from another



If a mouse of type A (left) is given a lethal irradiation, and then is given A bone marrow, it lives almost a normal life for a long period of time. But if it is given a lethal dose of x-ray and then (right) is given B bone marrow—from another type of mouse—its chances of survival are reduced.

human being. But we are not doing a very good job if the individual dies from the effects of the treatment after a few months. So, if we are to apply this kind of treatment to human beings, who are very diverse indeed, we have to solve the problem of the delayed incompatibility reaction — and this is a problem for the future.

What are the prospects, then, in this field for the next hundred years? We now have blood banks for blood transfusions. We have some tissue banks for keeping tissues like bone, that don't have to live and grow in a new host. I think we can predict that in the relatively near future we will develop tissue banks for storing the kinds of tissue that need to live and grow in the foreign host. When we do, the vista that opens before us is overwhelming.

Think, for example, of a diabetic — a person who lacks the ability to make insulin in the islet cells in his pancreas. The diabetic goes through his life being injected repeatedly with insulin from animals. How much better it might be if, instead of injecting the insulin, we could provide the diabetic with normal tissue, itself capable of making insulin in the diabetic's body under physiological conditions.

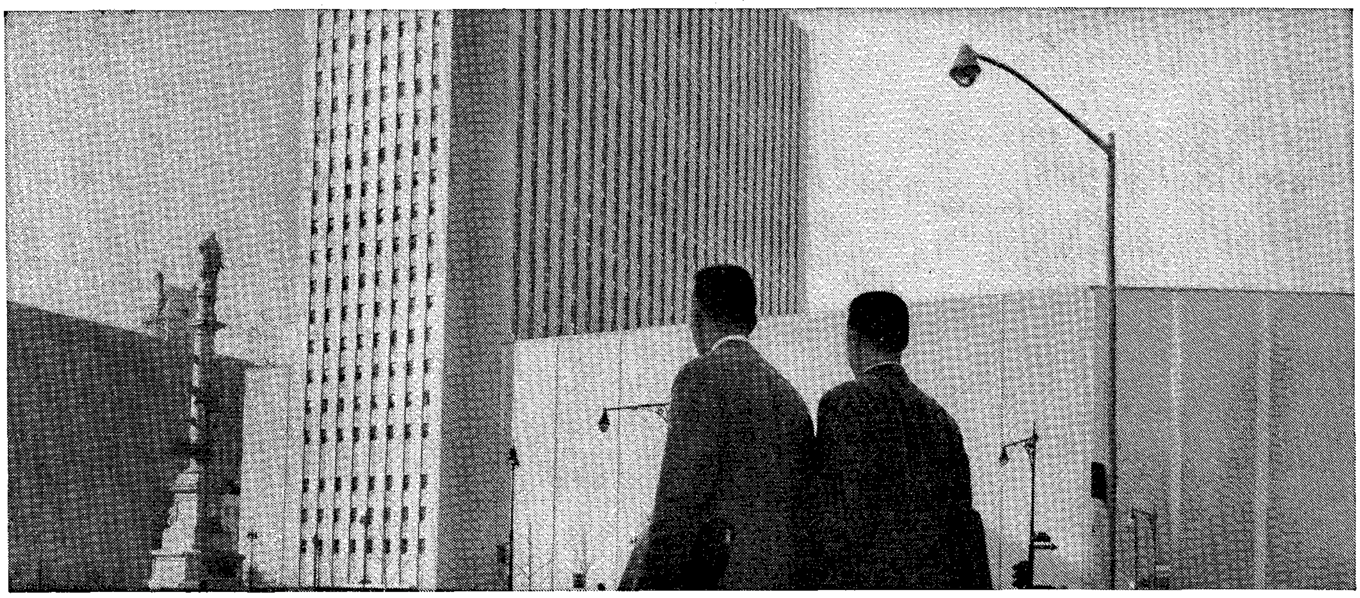
Or take the matter of transplanting healthy blood-forming tissues into the anemic individual. Or suppose we could destroy the diseased cells in leukemia (where a particular kind of cell goes wild) and replace them with normal ones.

Broader horizons

There are many examples that might be cited. But the horizon is even broader than that. If in the course of our search we find ways of controlling the transplantation-immune reaction, the way might open to treatment of many of the more serious aspects of important diseases. Many diseases have bad side effects from the struggle that is going on between the host's immune machinery and the foreign invading germ. In many allergies, as well, the immune machinery goes wrong and causes bad reactions. If we find a way to control this kind of reaction, the diseases of hypersensitivity may come under control, and we can do humanity a great deal of good.

Frankenstein created a monster. Mary Shelley, second wife of the poet Shelley, in the fantasy she published in 1818, had Frankenstein say, "The dissecting room and the slaughter house furnished many of my materials." Our aim, a used-parts market for the human body, is not to create a monster. Instead, we will serve desirable and practical aims — the needs of man. More than that, our effort will be to understand, and in this effort no one can predict what areas of human difficulty will yield to the understanding to be contributed by research in tissue transplantation in the next hundred years, or how far this research will help us to progress to ultimate comprehension of the essential mysteries of life.

New "post-grad" program helps engineers move ahead at Western Electric



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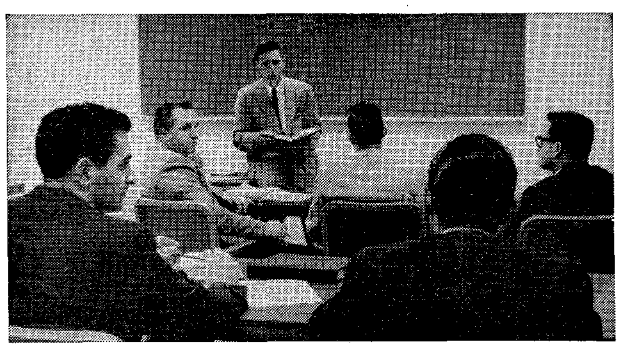

CLASSROOM SESSION at one of the centers takes up the first part of the three-phase program, Introduction to Western Electric Engineering. During this initial nine-week training period, new engineers are provided with a better understanding of Western Electric engineering methods and technical practices.

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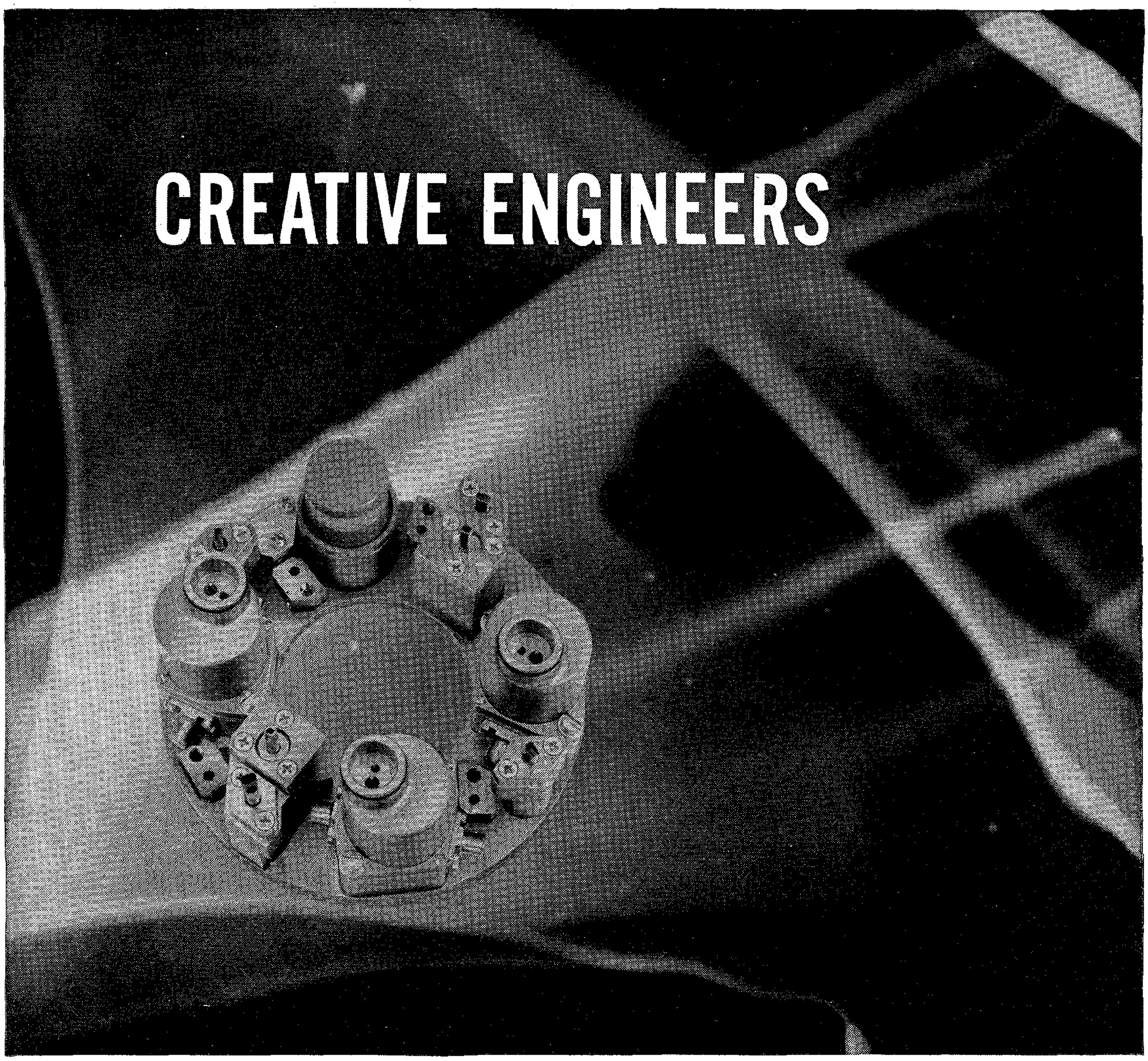

CREATIVE ENGINEERS

Personals

1925

Edgar E. Shafer, Jr., died of cancer on April 16, 1958. He had owned and operated his own chemical laboratory for petroleum products in Los Angeles. Ed was also an outstanding artist in both oil and water color and had exhibited for the past 20 years. He leaves his wife and four children—Margaret, David, Mrs. Jacqueline Loos, and Robert Eugene, a son by a previous marriage.

1930

Thomas T. Hiyama, head of the engineering department of Nippon Columbia, Ltd., in Japan, made a tour of U.S. electronic industries this spring. During a quick visit to Caltech, he explained that his company is one of Japan's leading producers of records, radios and television sets.

1932

Harry H. Bruderlin writes that "for several years I've been designing and building unusual houses in the $50,000 to $150,000 class, including one for a former Caltech inmate—*Millard Barton* '32. I have a number of patents, some of which are on the market. My hobbies are tennis, prospecting, and research on mental processes and physical basis of the mind. My wife and I have taken several trips to Mexico and toured some of the lesser known parts and have been doing Polynesian folk dances for fun and exercise. We still plan to go to the South Seas for a year or two someday. We have four children—two boys, 18 and 16, and two girls, 13 and 6."

1933

Col. Paul H. Kremmer, USAF (Ret.), MS, is executive advisor to the vice president of military relations at Ryan Aeronautical Company in San Diego.

E. Ray Lockhart, MS '34, vice president of the Stone & Webster Service Corporation in New York, has been elected a director of the firm. He has been with Stone & Webster since 1941. Ray is also vice president of the Sierra Pacific Power Company in Reno, of the Savannah Electric and Power Company in Georgia, and of the Iowa Water Service Company in Iowa City. The Lockharts and their two children live in Garden City, L.I.

1934

Milton U. Clauser, MS '35, PhD '37, vice president and director of the Space Technology Laboratories in Los Angeles, is now serving on a research committee of the National Aeronautics and Space Administration. He is also a member of the Scientific Advisory Board for the United States Air Force.

1934

Raymond W. Traynor, physics and mathematics teacher at Burbank High School in Burbank, Calif., has been awarded a Shell Merit Fellowship to attend Stanford University this summer. He is one of 100 high school and science instructors in the U.S. and Canada selected to attend graduate-level seminars at Stanford and Cornell Universities. His training will include mathematics, chemistry, physics, educational techniques, and application of science and mathematics in industry.

1936

Louis N. Ridenour, Jr., PhD, vice president of Lockheed Aircraft Corporation, was found dead in his Washington, D.C., hotel room on May 21. Death was apparently due to natural causes.

Louis was the Air Force's first chief scientist and later served as chairman of the Scientific Advisory Board committee formed to survey Air Force research and development activity. His work led to the establishment of the Air Research and Development Command, an agency which now has a major share of responsibility for the nation's advanced weapons program.

He was at one time a consultant to the Secretary of War, and nine years ago he was appointed professor of physics and dean of the University of Illinois graduate college. He has been at Lockheed Aircraft since April 1955.

Louis leaves his wife Gretchen, and two daughters — Eleanor and Nancy — in Palo Alto.

continued on page 26

Personals . . . *continued*

1940

A. M. Zarem, MS, PhD '44, president of Electro-Optical Systems, Inc., has been elected chairman of the American Rocket Society's 23-member technical committee on non-propulsive power. The committee presented a report on auxiliary power at the semi-annual meeting of the Rocket Society in San Diego.

George J. Todd, MS '41, has been appointed test supervisor on the Space Technology Laboratories' Minuteman Program at the Air Force Flight Test Center at Edwards Air Force Base in Lancaster, Calif. He will also continue as manager of STL'S Edwards Field Office. George has been with the company since 1956. The Todds have five children.

1941

Col. Charles H. Terhune, Jr., AE, is now vice commander of the Air Force Ballistic Missile Division in Los Angeles. He has had 21 years of military experience, and has been deputy commander for ballistic missiles at the L.A. base since June 1954. The Terhunes, who live in Santa Monica, have three children—Donna, Terry and Charles III.

1943

David E. Shonerd, MS, '48, AE '49, is now assistant program director for the Minuteman intercontinental ballistic missile program of the Space Technology Laboratories in Los Angeles. He has been on the senior staff there since July 1958. The Shonerds and their three children live in Rolling Hills.

Abraham Fiul has been appointed associate manager of the systems design and analysis department of Space Technology Laboratories. He has been with STL since last April and before that was manager of preliminary design at Radioplane, a division of the Northrop Corporation. Abe and his wife have two daughters, live in Northridge.

John E. Cushing, PhD, professor of bacteriology at the University of California in Santa Barbara, has been appointed chairman of the department of biological sciences there. He is now at the University of Tokyo on a Guggenheim Fellowship, serving as a visiting lecturer and conducting research on blood groups of fish, whales and seals.

1944

George M. Wood, BS '44, MS '44, is now assistant branch manager of the Glendale sales office of the International Business Machines Corporation. He has been with IBM since 1955.

1947

Charoen Vadhanapanich, MS '48, writes that "after I received my PhD at the Florida State University in February 1958, I returned to my job at the Royal Thai Meteorological Department of the Thai Navy in Bangkok, and have been promoted to full commander. I was one of the delegates from Thailand to attend the International Civil Aviation Organization in Rome from January 4 to February 3 this year."

1949

Carl Price will be leaving Harvard this fall to become associate professor of plant physiology at Rutgers University.

David Hogness, PhD '53, and *A. Dale Kaiser,* PhD '55, are joining the biochemistry department of the medical school at Stanford University this month.

1950

James C. Goodwyn, formerly chief of systems analysis in the engineering division of the Martin Company in Denver, is now on the staff of the advance research projects agency division of the Institute for Defense Analyses in Washington, D. C. Jim had been with Martin for nine years.

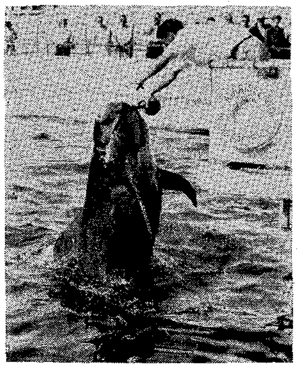
Richard D. De Lauer, AE, PhD '53, has been appointed director of the vehicle development laboratory of the research and development division of Space Technology Laboratories in Los Angeles. Dick is coauthor of *Nuclear Rocket Propulsion,* published last year by McGraw-Hill.

1953

Lt. Comdr. Herbert Poorman, AE, writes that "I've been at McDonnell Aircraft Corporation in St. Louis for almost three years. My primary effort is directed toward helping make the F101 and FYH weapons systems reliable and operationally maintainable. Flying a lot. The fishing in nearby lakes has provided fine family recreation throughout our tour here. The family is fine and growing fast (in size, not numbers)."

Alumni News

Alumni Seminar



On June 27, Marineland of the Pacific, southern California's showplace of marine life, will be host to the Annual Alumni Family Picnic. Marineland is a three-ring sea circus consisting of a Sea Arena, where visitors can see porpoise games and a sea lion show; the Whale Stadium, a 640,000-gallon tank housing the only black pilot whales in captivity; and the biggest fishbowl on earth, a 540,000-gallon tank containing over 200 varieties of sea life. Picnickers will also see the Jeweled Aquaria, displaying rare and beautiful fish; the Octopus Grotto; the Flamingo Garden, with graceful flamingos and comic equatorial penguins; Tropical Tank, with hundreds of colorful fish from Hawaiian reefs; Harbor Sea Pool; African Lung Fish; and wall exhibits featuring a variety of strange underwater specimens swimming in individual tanks.

Alumni, their family and friends will be admitted at reduced prices, by picking up tickets at the registration entrance. Ample free parking will be available. Those who bring their own lunches will enjoy eating on a spacious lawn which has been specially reserved for the Caltech group.

Marineland, which is open from 10:30 a.m. until sunset, is located directly on the coast, midway between Redondo Beach and San Pedro on Palos Verdes Drive.

See you there on June 27.

—Stan Groner '52
Chairman, Picnic Committee

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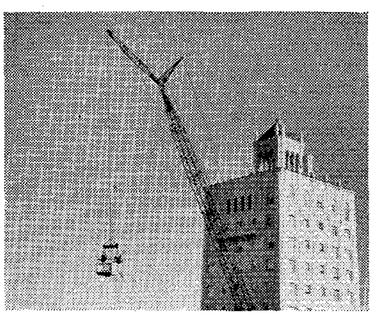
Though the building is not yet built, this is a view from one of the apartments.



One of a series

General Electric interviews Dr. Richard Folsom, President of Rensselaer Polytechnic Institute, to explore . . .

Teaching— A Career Opportunity For the Engineer

Leading educators, statesmen and industrialists throughout the country are greatly concerned with the current shortage of high-caliber graduates who are seriously considering a career in the field of science or engineering education. Consequently, General Electric has taken this opportunity to explore, with one of America's eminent educators, the opportunities and rewards teaching offers the scientific or engineering student.

Q. Is there in fact a current and continuing need for educators in technical colleges and universities?

A. Colleges and universities providing scientific and engineering educational opportunities are hard pressed at the present moment to obtain the services of a sufficient number of well-qualified teachers to adequately carry out their programs. Projected statistical studies show that this critical need could extend over the next 15 or 20 years.

Q. Why is this need not being met?

A. There are probably three main reasons. These might be classed under conditions of financial return, prestige associated with the position, and lack of knowledge and understanding on the part of the college student of the advantages and rewards teaching as a career can afford.

Q. What steps have been taken to make education a more attractive field to engineering students?

A. Steps are being taken in all areas. For example, we have seen a great deal in the newspapers relating educators' salaries to the importance of the job they are doing. Indications are that these efforts are beginning to bear fruit. Greater professional stature is being achieved as the general public understands that the youth of our nation is the most valuable natural resource that we possess . . . and that those associated with the education of this youth have one of the most important assignments in our country today.

Q. Aside from salary, what rewards can a career in education offer as opposed to careers in government or industry?

A. The principal rewards might be freedom to pursue your own ideas within the general framework of the school, in teaching, research and consulting activities. As colleges and universities are normally organized, a man has three months in the summer time to engage in activities of his own choice. In addition, the educator is in direct contact with students and he has the satisfaction of seeing these students develop under his direction . . . to see them take important positions in local and national affairs.

Q. What preparation should an engineering student undertake for a teaching career?

A. In college, the engineering student should obtain a basic understanding of science, engineering science, humanities and social sciences with some applications in one or more professional engineering areas. He should have frequent career discussions with faculty members and his dean. During graduate work, a desirable activity, the student should have an opportunity to do some teaching.

Q. Must an engineering student obtain advanced degrees before he can teach?

A. It is not absolutely necessary. On the other hand, without advanced degrees, advancement in the academic world would be extremely difficult.

Q. How valuable do you feel industrial experience is to an engineering or scientific educator?

A. Industrial experience for a science educator is desirable; however, with a senior engineering educator, industrial experience is a "must". An ideal engineering educator should have had enough industrial experience so that he understands the problems and responsibilities in carrying a project from its formative stages to successful completion, including not only the technical aspects, but the economic and personal relationships also.

Q. What do you consider to be the optimum method by which an educator can obtain industrial experience?

A. There are many methods. After completion of graduate school, perhaps the most beneficial is a limited but intensive work period in industry. Consulting during an academic year or summer is a helpful activity and is desirable for older members of the staff. Younger educators usually need experience in "living with the job" rather than providing consultant's advice to the responsible individual.

Q. Based on your experience, what personal characteristics are possessed by successful professors?

A. Primarily, successful professors have an excellent and growing knowledge of their subjects, are interested in people, and transmit enthusiasm. They have an ability to explain and impart information with ease. They generate ideas and carry them out because they are devoted to developing their fields of knowledge. They desire personal freedom and action.

For further information on challenging career opportunities in the field of science and engineering education, write to: Mr. W. Leighton Collins, Secretary, American Society for Engineering Education, University of Illinois, Urbana, Ill.

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