E&S

ENGINEERING AND SCIENCE

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

December 1967

Westinghouse is looking for imaginative people to help make cities wonderful to live in.

There has never been such a tremendous need for building as there is today, and never such a permissive atmosphere for new ideas.

But it isn't enough to just build. We have to make cities easier to reach, easier to work in, efficient and, above all, attractive and exciting.

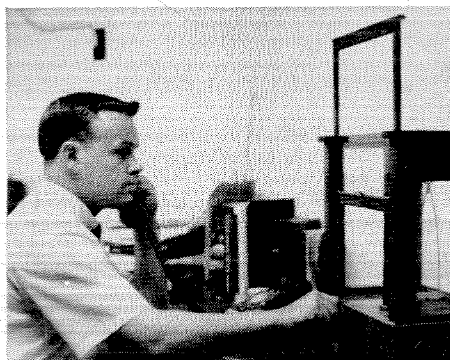
Westinghouse is developing new ways to heat, light and cool buildings — new ways to start from scratch and build complete new cities.

You name it, there's a project at Westinghouse that needs your talents. So what can you do about it? Talk to the Westinghouse recruiter when he visits your campus, or write Luke Noggle, Westinghouse Education Center, Pittsburgh, Pennsylvania 15221.

An equal opportunity employer

You can be <u>sure</u> if it's Westinghouse

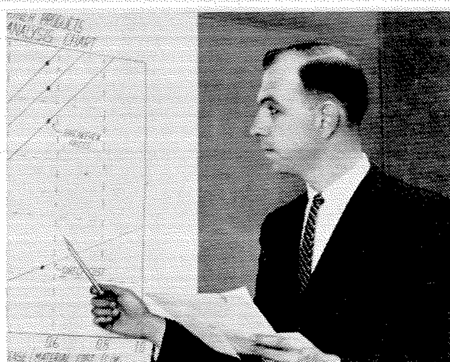
There is a growing need for nonferrous metals. To grow with it, contact Anaconda.



Robert Lindsay (BSME, U. of Kansas '64) is quality control supervisor of Anaconda Aluminum Company's plant in Louisville, Ky.

Joel Kocen (BS Commerce, Wash. & Lee '59; LLB, Wash. & Lee '61) left, is senior tax analyst at New York headquarters of Anaconda.

David Madalozzo (BSEE, Bradley '61) is plant engineer of the new Anaconda Wire and Cable Company mill in Tarboro, N.C.

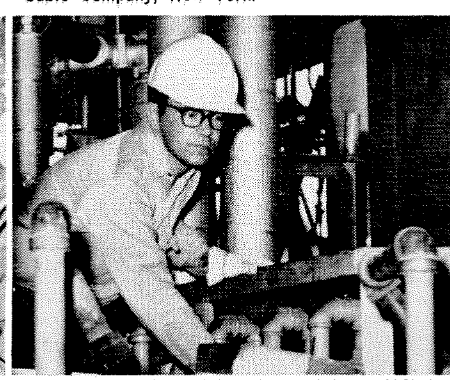


Alvin Cassidy (BA Econ., Bellarmine '54; MBA, U. of Louisville '59) is director of financial planning of Anaconda Aluminum Company, Louisville, Ky.

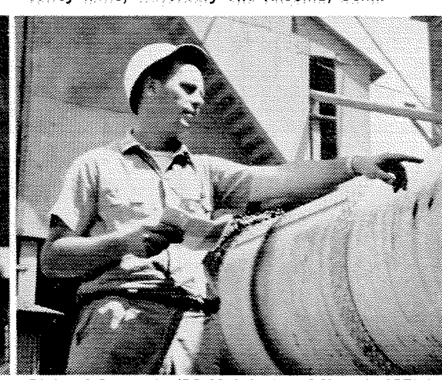
Robert Zwolinski (BSME, Rutgers '57) is chief mechanical engineer with Anaconda Wire and Cable Company, New York.

Willard Chamberlain (BE Metal. Eng., Yale '53) is manager of Anaconda American Brass Company's Valley Mills, Waterbury and Ansonia, Conn.

Robert Ingersoll (BS Geol., Montana Tech. '51 MS Geol., Montana Tech. '64) right, is senior geologist, Anaconda's mining operations, Butte, Mont.

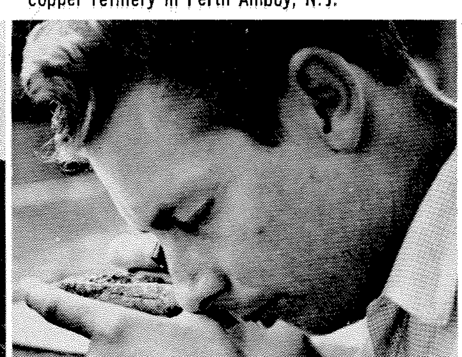


Thomas Tone (BS Mining, U. of Arizona '62) is foreman of the furnace dept. at the electrolytic copper refinery in Perth Amboy, N.J.

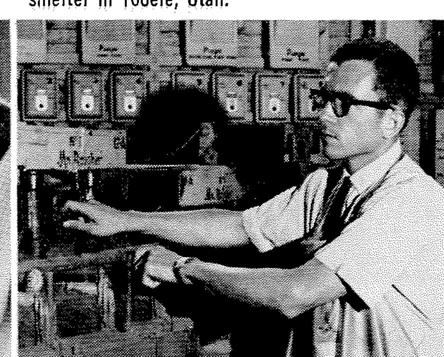


Richard Symonds (BS Metal., U. of Nevada '57) is superintendent of the lead plant at Anaconda's smelter in Tooele, Utah.

Jay Bonnar (BS Met., M.I.T. '57; MS Ind. Mgmt., M.I.T. '62) left, is research administrator of Anaconda American Brass Company's research and technical center, Waterbury, Conn.



Wilson McCurry (BSc, Arizona State '64) is an assistant geologist in Anaconda's new mines dept., currently working on development of the Twin Buttes mine near Tucson, Ariz.



Terrence McNulty (BS Chem., Stanford '61; MS Metal., Montana Tech. '63; DSc Metal., Col. School of Mines '66) is senior research engineer, extractive metallurgical research, Tucson, Ariz.

Anaconda American Brass Co., Anaconda Wire & Cable Co., Anaconda Aluminum Co.

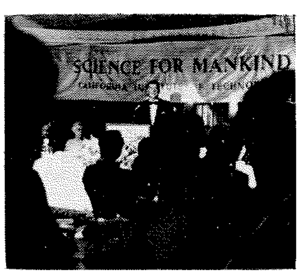
For information about your opportunity at Anaconda, write:
Director of Personnel, The Anaconda Co., 25 Broadway, New York, N.Y. 10004. Equal opportunity employer.

67122

E&S

ENGINEERING AND SCIENCE

DECEMBER 1967 / VOLUME XXXI / NUMBER 3



ON THE COVER

California Governor Ronald Reagan verbally launches Caltech's new $85 million development campaign at a kickoff dinner held at the Ambassador Hotel in Los Angeles on November 8. Eight hundred alumni and friends of the Institute heard the Governor's address, "Science for Mankind"—which is the theme of Caltech's five-year campaign, described on pages 13-16.

PICTURE CREDITS:

Cover, 13, 15, 16, 19, 28-30, 42-45—James McClanahan
31-34—Midge Quenell

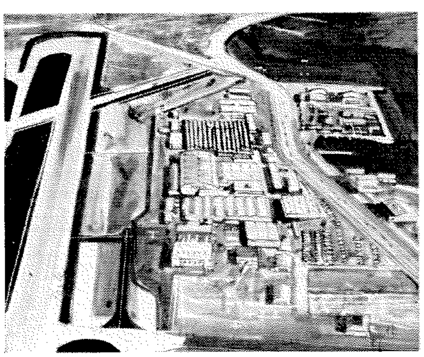
STAFF

Editor and Business Manager—Edward Hutchings Jr.; *Associate Editors*—Bruce Abell '62, Phyllis Brewster, Jacquelyn Hershey, Kathleen Marcum; *Photographer*—James McClanahan.

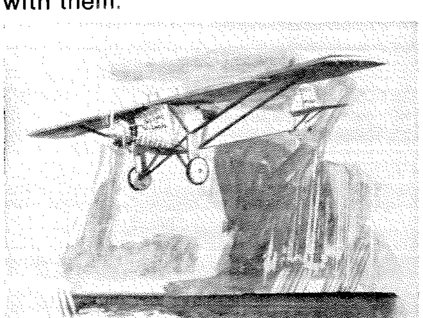
Published monthly, October through June, at the California Institute of Technology, 1201 East California Blvd., Pasadena, Calif. 91109. Annual subscription $4.50 domestic, $5.50 foreign, single copies 50 cents. Second class postage paid at Pasadena, Calif., under the Act of August 24, 1912.

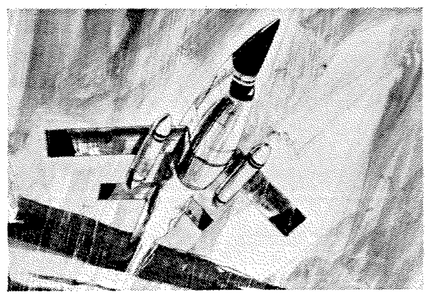
Here's what we mean when we say, "Ryan is a better place to work."

We mean that a pioneer aerospace company still headed by the man who founded it 45 years ago has *got* to be a company that cares about its people. T. Claude Ryan, founder and chairman, is still at the office every day. To him, Ryan employees are friends. Old ones and new ones alike. Ryan headquarters, combining engineering and manufacturing facilities, are on the shores of San Diego bay, where it all started in 1922.

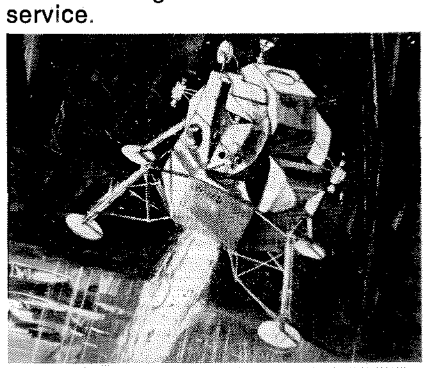


We mean that a company so rooted in aviation history is bound to be a leader in vitally important defense/space programs. The outgrowth of the original Ryan Airlines, Inc., that built the "Spirit of St. Louis" in 60 days from a standing start will always be ready to accept impossible challenges. And ready to listen to young men of vision who can dream up answers to those challenges. Ideas are given a chance at Ryan. So are the men who come up with them.

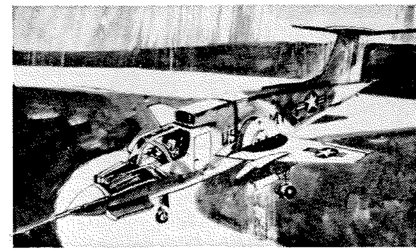




We mean that a company which led the world in the conception and development of jet-powered target drones is the kind of company where daring and untried ideas come to life. Over 3,000 Ryan Firebees, the most versatile aerial targets ever conceived, are in use with all three branches of our armed forces, helping to train our defenses against any airborne threat. A super-sophisticated, supersonic Firebee II will soon be flight tested and enter service.



We mean that a company whose heart has always been in the wild blue yonder would just naturally be there when man reached for the stars; that the products of its scientists, engineers and technicians would naturally play a key role in our race for space. Ryan landing radar systems made possible the first soft landing on the moon. And an advanced Ryan system will assure a soft landing for the first manned lunar visit. The men at Ryan already have their eyes on the space beyond the moon.



We mean that a company made up of men who taught themselves to fly straight up, while others said it couldn't be done, is the sort of place that puts no strings on a man's imagination. Or barriers in the way of way-out thinking. For over twenty years Ryan has been amassing an unmatched fund of technology in vertical and short take off and landing (V/STOL) aircraft. The list of accomplishments is long: Dragonfly, 1940. Vertijet, 1957. Vertiplane, 1959. The present day XC-142A tilt-wing and the XV-5A Vertifan. Ryan products can fly straight up. So can the men who work there.

We mean that a company with a strong and capable management—whose business success has led to majority ownership of large related companies — is the kind of concern that can match challenges with permanent opportunities. Ryan Aeronautical is majority owner of Continental Motors Corporation and its subsidiaries, suppliers of primary power for both piston and jet aircraft and agricultural, military, marine and industrial equipment. There is nothing provincial about Ryan. Including subsidiaries, it operates 16 manufacturing facilities in the USA and Canada.

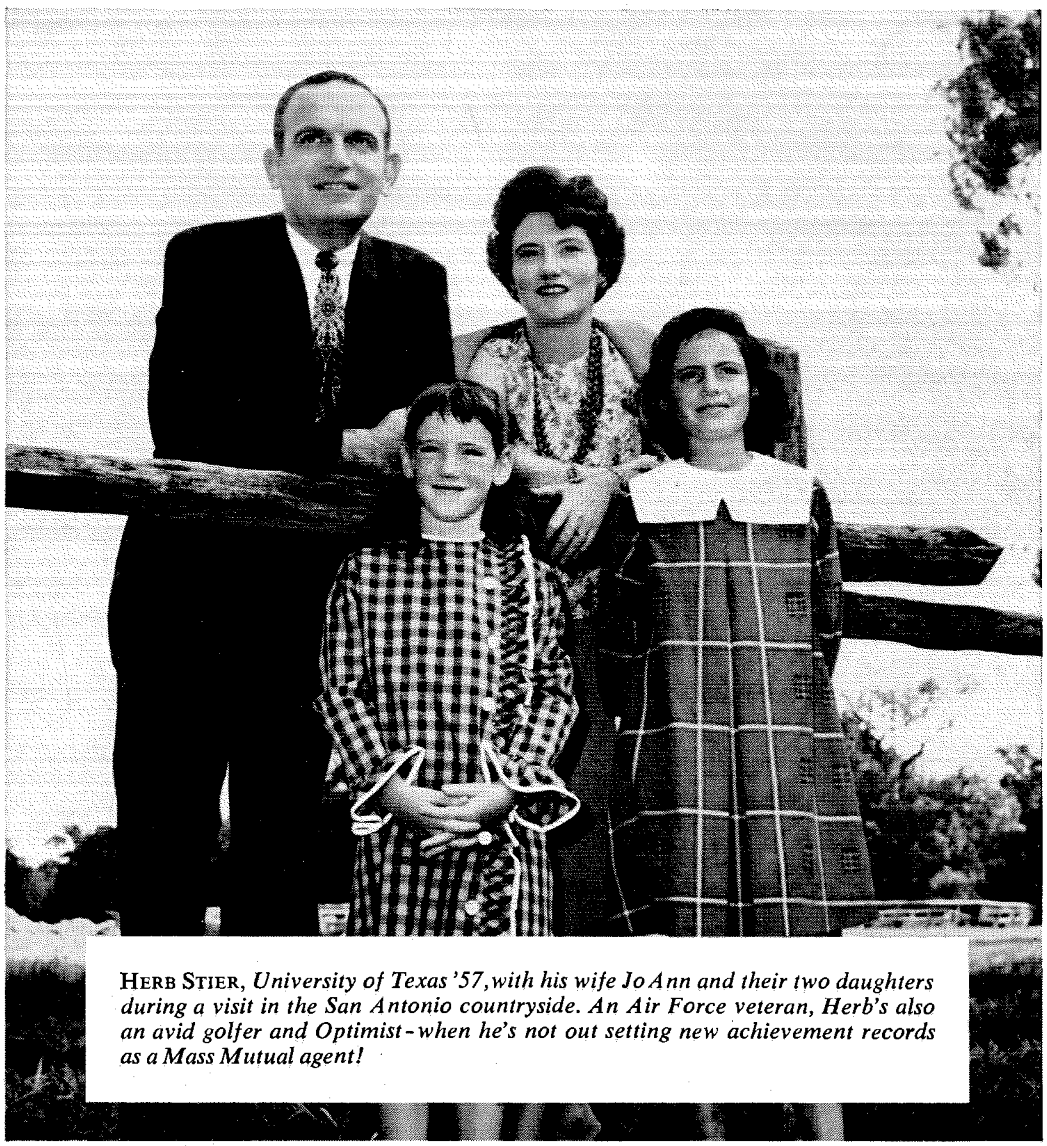
We mean, also, that *San Diego* is a better place to work—because it's a better place to *live*. It's the surfing, sailing, deep-sea fishing and golfing capital of the country. It's clean, uncrowded and friendly and you can lead the good life year 'round. Its great universities make education one of its largest industries. Ryan is an important and respected member of this dynamic community . . . a community on the move.

RYAN

An equal opportunity employer.

This is what we mean when we say, "Ryan is a better place to work." The 4,500 men and women now at Ryan know it is. And they invite your inquiry. Check with your placement office for our campus visit, or write to Mr. Harlow McGeath, Ryan Aeronautical Company, Lindbergh Field, San Diego, Calif. 92112.

It's one of the few frontiers still open where imagination's all the capital you need.



HERB STIER, *University of Texas '57, with his wife JoAnn and their two daughters during a visit in the San Antonio countryside. An Air Force veteran, Herb's also an avid golfer and Optimist - when he's not out setting new achievement records as a Mass Mutual agent!*

Trust a Texan like Herb Stier to describe the life insurance business as a challenging new territory just waiting to be explored!

But Herb's a man who should know. After college, he spent seven years in retailing—then joined Mass Mutual in 1965. A single year later, he ended up with more individual life policies to his credit than any other man in the company! Total sales... $1,789,974!

"It's a great business to be in," says Herb. You're on your own. You're selling a product that benefits the purchaser more than it does the seller. And you can be highly creative—you're free to put your own ideas, your own imagination to work where *you* think best.

"What's more, with Mass Mutual, you've got a great company behind you. You know, a lot of companies offer all kinds of help at the outset, but darned few are ready to commit the time and money that's really needed to get you on your feet. The people at Mass Mutual really put themselves out to make you successful.

"And let's not forget the personal rewards. Both my wife and I agree that we've found more in the way of friendship, pride of accomplishment, all-'round satisfaction than we'd ever have found elsewhere. Not to mention far greater financial success!

"If these are your goals, too, I'd suggest you write Mr. Charles H. Schaaff, President, Mass Mutual, Springfield, Massachusetts 01101. By the way, he started out as an agent himself!"

MASSACHUSETTS MUTUAL
LIFE INSURANCE COMPANY
SPRINGFIELD, MASSACHUSETTS • ORGANIZED 1851

LETTERS

Huachuca City, Arizona

EDITOR:

The other evening, upon arrival home, the answer from my wife to my often-asked question of "Any mail?" was "No, just a catalog." I gave it a quick glance, and several hours later I got around to taking it to the "file." Before I dropped it in the wastebasket, I noted in small letters that the *E&S*, which I had taken for representing a drug or mail order store, stood for *Engineering and Science*. I don't believe I have ever seen an uglier masthead. I suggest going back to the former one, if possible. The magazine is excellent, although I did miss Alumni News. Maybe you have transferred that to a newspaper I receive occasionally. *(We have—to the Caltech News, which is sent to all alumni.—Ed.)*

After I finish reading my engineering magazines, I like to leave them (the last issue) on the coffee table since they are both decorative and utilitarian. I have finished the last *E&S* (October), but it is not displayed—the prior issue of *Engineering and Science* is.

ROBERT G. MACDONALD '33

Phoenix, Arizona

EDITOR:

I would like to comment on the new format for *E&S*. Recent issues have been substantially longer. One of the things I liked about the old shorter format was that you did a measure of screening for me. I was able to pretty much read the entire magazine. Recent issues are sufficiently long that I find myself scanning from paragraph to paragraph and probably getting less out of each issue than I did before.

I would like to put in a plug for keeping the articles technically oriented but not highly technical, with equations, etc. This you have been doing. I would also like to suggest limiting the articles to two or three pages each and limiting each issue to two or three articles.

This is, perhaps, a lazy approach on my part, but I hope that *E&S* articles can be a technical narrative to introduce new technical concepts to us old grads and review other matters of technical interest going on at Tech.

I emphasize "technical" intentionally. In my opinion, most of the articles in *E&S* on non-technical subjects have left something to be desired.

DAVID C. LINCOLN '46

Inglewood, California

EDITOR:

In regard to the so-called "revolution" at Caltech *("The Revolution," by Barry Lieberman '68, which appeared in the October 1967 issue of* Engineering and Science, *described the recent movement by Caltech's undergraduates to improve their academic environment by proposing curriculum changes and requesting student representation on specific faculty committees.)* . . .

1. The Institute belongs to the people who created it by giving of their energies; they own it.

2. The Institute does not belong to the present group of students or employees, some of whom are faculty.

3. There are no natural "rights" of employees or students, only the rights the owners choose to give them.

4. An applicant for admission as a student or for employment may accept the policies and practices of the owners of the Institute or may exercise his freedom to go elsewhere.

5. If a student or an employee of the Institute chooses not to follow the owner's policies and practices, he has the freedom to get out.

6. Recognizing any one of the four propositions on the "ballot" would establish a dangerous precedent of allowing a group of persons to change the Institute's policies, which have yielded worldwide esteem. The group's only claim to fame may be their loud voices and their sloppy and dirty nature.

7. In regard to the supposed destruction of the students' enthusiasm as the price to pay for an education based on sound principles, it might be asked, "What good was Michelangelo's enthusiasm for creating his *David* unless he possessed a hammer and chisel and knew how to use them?"

8. In regard to the individuals who own the Institute, it might be said that it takes more than a gift of energies followed by relaxation and drifting off to dreamland; maintaining things of value requires constant monitoring and the rebuilding of parts that have decayed.

GEORGE M. SAWYER '51

BOOKS

The Gene: a critical history
by Elof Axel Carlson

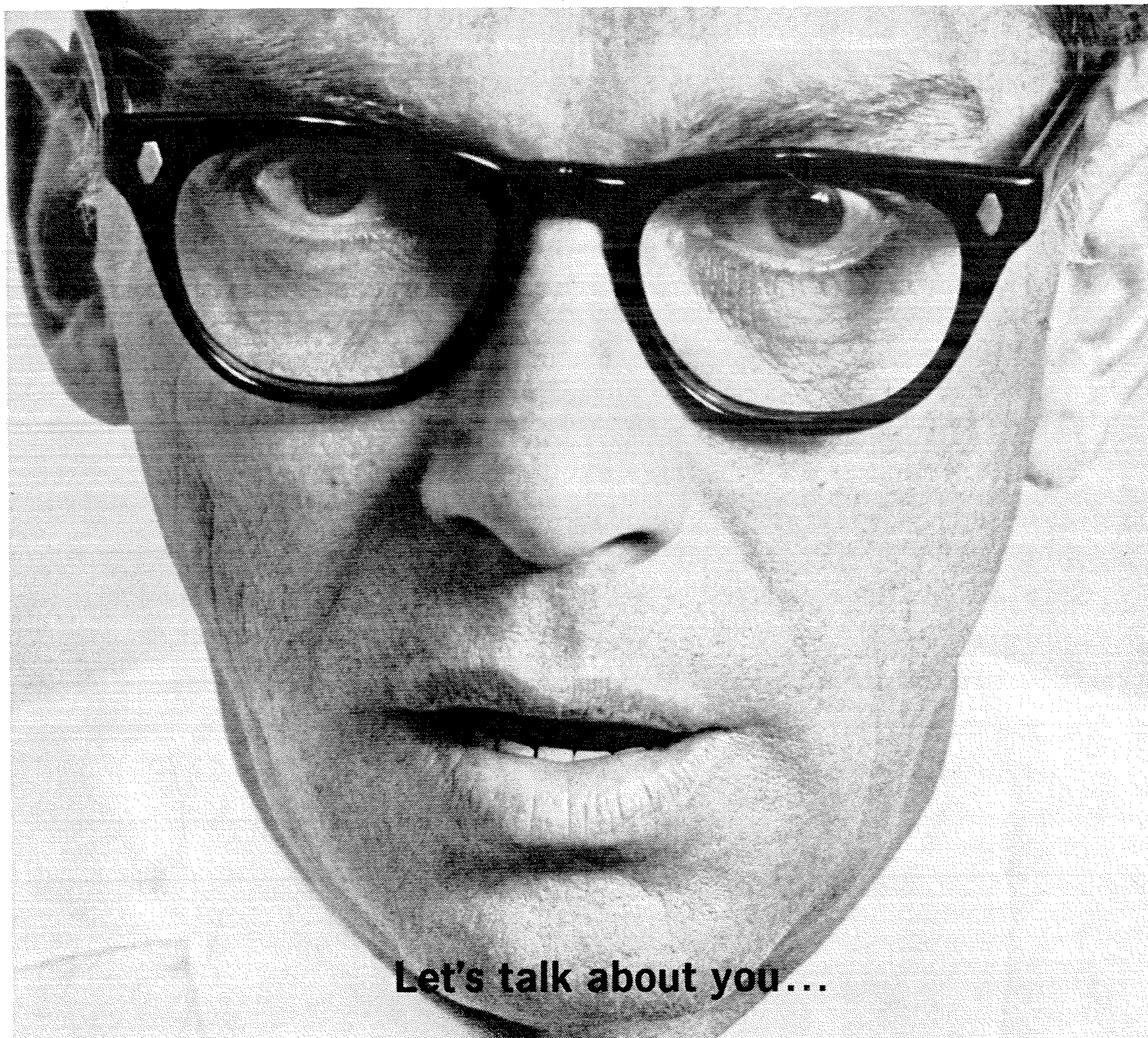
W. B. Saunders Co. *$9.00*

Reviewed by Robert S. Edgar, professor of biology

To this reviewer, a history of science brings to mind the image of either a dusty factual treatise or an anecdotal memoir. This book is neither. It is a scholarly yet absorbing and exciting account of the quest for the gene—for half a century the central enigma of biology.

Although this book could be difficult for a reader with little background in genetics, Carlson's writing style is lively and lucid. His story starts with the rediscovery of Mendel's work in 1900 and carries through the major recent triumphs of molecular biology to the present. Caltech played a prominent role in the fashioning of this history—Morgan, Sturtevant and the chromosome theory of heredity, Beadle and the control of enzymes by genes, Delbrück and the birth of molecular genetics, the discovery of pseudoalleles by Lewis, and the analysis of the fine structure of the gene by Benzer are major milestones in the quest for the gene.

Rather than using accounts of scientists still living who played a part in the story, Carlson has chosen to reconstruct the history of the gene from the published literature, and he quotes extensively. Within these unpromising boundaries he has created a dramatic and vital account of this major theme of modern biology. He makes a persuasive case for science as a basically human enterprise that progresses, as with social history, through the confrontations of opposing viewpoints. To latecomers like Carlson and this reviewer, the first half-century was a romantic time when heroes walked the earth, especially when contrasted to the present era characterized by the consolidation of molecular biology and its relentless triumphs.



ENGINEERING
AND SCIENCE
December 1967, Vol. XXXI, No. 3

University Basic Research

by Lee A. DuBridge

Granted that the fundamental arguments for pure research can be set forth in impressive array — how much monetary investment is justified each year, and how can it best be distributed?

The nation's program of basic research in science is at a critical juncture. Its future progress is by no means assured, and much will depend on the outcome of the debates now in progress. These debates are going on not only in scientific circles but also in the public press, in the halls of Congress, and in the offices and conference rooms of many government agencies. Pressures for reducing or leveling off research budgets are evident.

In this debate the advice and the views of many scientists will no doubt be heard. But the critical decisions will not be made by scientists, for important matters of public policy are involved.

Yet the scientific community must be involved in this debate. Scientists must look again at the goals, the potentialities, and the values of science and set them forth clearly and persuasively. These views must, in fact, be formulated so convincingly that non-scientists in high places will be able and willing to speak out for scientific advance as a vital national effort. It is often asserted that scientists are so prejudiced by their personal interests that they are no longer always to be believed. Nevertheless, the case for basic research in modern society—if there is one—must emerge from careful considerations set forth by scientists themselves, for no one else is likely to undertake the task.

It has, indeed, been well begun. It was begun over 20 years ago when the case for the federal support of science was first cogently set forth in the famous Bush report, *Science—the Endless Frontier.* The discussion has continued across the country, in Congress, and in the White House ever since. The recent definitive reports from the Committee on Science and Public Policy of the National Academy of Sciences have added much to the public record.

But obviously the task is not completed. Possibly it is scarcely begun. Here it may be well to start by trying to clear up a few misunderstandings.

First we must ask whether the case for or against basic research has changed in recent years or whether it merely needs to be stated in different terms. In fact, the basic case is unchanged. The arguments can be grouped under four headings.

1) Research—that is, inquiry into the nature of the physical and biological world—is a prime human urge. The advance of knowledge has *in itself* been an elevating, inspiring aspect of human history.

2) Basic research has uncovered knowledge which has made possible practical applications which have enormously affected human civilization.

3) This planet, on which 3 billion (soon to be 6 billion) human beings live, cannot become more habitable and a better place to be unless new knowledge is found to make possible new technologies and new ways of living. (The words *food* and *population control* illustrate what I mean.)

4) Scholarly inquiry is an indispensable role of institutions of higher education and has a unique function in educating the minds of the future.

Basic scientific research thus has cultural or human values which result from enlightenment of the mind, and it also makes possible the advance of

"University Basic Research" first appeared in *Science*, Vol. 157, pp. 648-650, 11 August 1967.

technology. It has become a necessity for the future.

The case for these values of science can be, and has been, documented time and time again. If people are tired of hearing of the great results of the researches of Galileo, Newton, Faraday, Maxwell, Einstein, and the rest, there are many other examples that can be set forth. I suggest that we set them forth, repeatedly and convincingly. This *is* the case that must be documented. Man *is* better off today than he was 300 years ago, and science has done much to this end by combating superstition and prejudice, by allaying hunger and disease, by laying the base for technological advance. If the world's troubles still seem tragic and complex, this is so not because we have too much knowledge but because we have not learned how to use all our knowledge effectively.

And here the scientist must face and answer a new set of questions. If our great investment in pure and applied science has failed to cure all the world's ills—if, indeed, they are getting worse—should we not, in investing our money, focus more precisely on the problems of war, of overpopulation, of urban living, or of achieving a stable economy and a better way of life for all people?

The answer of course is yes, by all means! Science never pretended to be a solution for all human problems. Science is a search for truth about the physical world. The truth so far attained has led to solutions of *some* problems. These solutions have come as welcome by-products of scientific knowledge—so welcome that we now spend eight times as much money on exploiting the applications of scientific knowledge as on seeking new knowledge.

This is fine. Applied science is important too. It is also inherently more expensive than pure science and more profitable in terms of immediate results.

But the world's problems go far beyond the problems of science and technology. They include problems of human understanding; of fulfilling human hopes and human desires; of understanding the social, economic, and political institutions which men have created: of using the knowledge we have more intelligently.

Every sensible scientist will see the need for urgently seeking to understand and solve these problems, too. The university is the seat of the scholarly inquiry and the source of the trained minds needed for understanding and solving them. The universities need more resources for developing these humanistic and social studies.

We as scientists may not have very effective ideas on ways to proceed to solve these social problems, yet we cannot withdraw from the field. We *are* human beings. We will suffer or prosper as other human beings do. Furthermore, many and possibly most of these problems have scientific and technological aspects. We can associate with our friends in the social and behavioral sciences and seek to help in areas where our help can be useful.

But society will not be well served if pure science is abandoned in this process or even substantially impeded in its growth. The values of science remain. All efforts and investments which the nation makes in tackling these other problems will pay off in their own right—just as our past efforts in science have paid off handsomely, even in purely economic terms.

Granted that the fundamental arguments for pure research can be set forth in impressive array, the question remains: How does one set forth to government representatives and the public just how much monetary investment is justified each year, and how it can best be distributed among subject matter fields, among projects, or among the 50 states.

Here the complexities of the problem begin to appear. And herein lie the challenges for initiating a fruitful discourse between the worlds of science and education and their various subworlds, the world of government officials and the world of influential taxpayers. No one of these worlds, of course, is a unified one; each contains individuals and groups with widely differing attitudes, beliefs, experiences, responsibilities, and concerns. We cannot expect to find unanimity within any of these worlds, much less full agreement between them. Yet, by some form of consensus and compromise, an agreement—or a decision—on national policy must be consummated.

A few points should be stressed.

1) The present annual investment in basic scientific research in universities (about $1 billion) is sometimes said to be "extravagant." But if we observe the results and observe the nation's scientific potential, we must conclude that this sum is a sound investment in the future. It is indeed an inadequate investment in terms of the opportunities which lie ahead and of the needs of the government agencies which support it. Every field of science sees opportunities unrealized.

2) We have purposely, during the past 20 years, expanded the scientific community by training many young scientists at great expense. Do we not intend to put their talents to good use? Clearly, support of science must not stay at current levels; it must increase in order that we may capitalize on the trained talents of these young investigators, meet rapidly rising research costs, and exploit currently neglected fields.

3) We must clarify the role of basic science as compared to applied science, to engineering, and

The case for basic research in modern society—if there is one—must be set forth by scientists themselves.

to putting to beneficial use our new scientific knowledge. These are overlapping areas of endeavor with fuzzy boundaries. Yet each has its special and distinct place in our national effort; each depends upon the others. It is folly to neglect any one.

4) Most of the current federal expenditures for university-based research and education in science do not come from a direct effort to support such enterprises but accrue indirectly from government expenditures aimed at other national goals.

On this last point, for example, it is a matter of national policy—and of national necessity—that we improve our military technology. The Department of Defense spends large sums for this purpose. In the process it has found it necessary and desirable to encourage a comparatively modest amount of basic research in areas of science which seem to have immediate or long-range relevance to defense technology. When the Department of Defense finds, in a university, competent scientists who wish to undertake such research, is it not prudent to use their talents? Is it proper to regard such contracts as "handouts" or "benefactions" to the universities? Are the universities not simply performing a necessary public service?

The nation also has an established policy of advancing the technology of atomic energy for both military and peaceful purposes, of conducting a large program of space exploration, of seeking to improve the public health and to advance the conquest of disease. These and other missions in the national interest are assigned to appropriate government agencies for implementation. Each such agency turns, to a greater or lesser degree, to universities for relevant basic investigations. The scientists and the universities concerned welcome these research tasks whenever they fall within their realms of interest, enthusiams, or competence. A scientist and his institution are fortunate when it is found that the kind of research they wish to do also serves a national purpose, in that some mission-oriented government agency deems it relevant to its mission. These agencies are not authorized to give handouts to universities; they are not philanthropic institutions. They are properly charged with investing taxpayers' money in those research activities which promise to yield the greatest return. They have set up mechanisms for selecting with great care and great expertise just which of the many proposed projects they will finance. These tasks of selection have been performed with conspicuous success and integrity. It is not the fault of the agencies concerned if scientific competence has been found to be more plentiful in some parts of the country than in others.

Some 85 percent of the basic research funds allocated to universities has been placed by mission-oriented agencies in support of their own missions. In a sense it is only accidental if university science has been thereby strengthened.

Only 15 percent of the dollars for university research comes from the one agency which is authorized to support general basic research not visibly relevant to specific government requirements or goals. The National Science Foundation grants for research total only about $175 million a year. These grants go to hundreds of colleges and universities, large and small, throughout the nation, supporting important fields of science. The NSF has the most extensive array of expert committees and consultants of any agency, plus a large professional staff, to insure fruitful expenditure of funds. It seeks to be the balance wheel for the national science program. It has never had enough funds for this.

Now what is wrong with this whole picture? Basically, nothing! Yes, there have been administrative headaches on all sides. No system operates perfectly. Some abuses have crept in here and there. Not all experts agree on the areas of importance or on the relative merit and promise of various project proposals. It is not easy for a mission-oriented agency to judge which research areas are really "relevant" to its mission. Every scientific discipline contains many members (often a large majority) who feel that their subject is inadequately supported. And they can usually prove it by pointing to opportunities unrealized, to promising young scientists inadequately supported.

But is a major overhaul of the system either necessary or desirable? I know of no widely accepted proposals for such an overhaul. Most of the arguments and misunderstandings about the total effectiveness of the system are based on conflicting opinions as to the relative importance of the various objectives of the mission-oriented agencies. It is said by some that we are spending too much on space and not enough on cancer—or vice versa; too much on military development and not enough on weather modification or oceanography or atomic energy.

Now these national policy objectives are determined by the legislative and executive branches of the government on the basis of considerations having little to do with the progress of basic science. Military strength, the practical exploitation of atomic energy, the conquest of disease, the proper use of national resources are all judged by the government to have inherent value or to be necessary in their own right, and it is only proper that all relevant resources for implementing these objectives, including the resources of university science, be employed. That many university science and engineering activities in teaching and research have benefited from the services they have rendered to the mission-oriented agencies is undeniable—and very fortunate! It is also fortunate that a fairly broad-based program of research support has emerged, thanks to extensive cooperation among the agencies involved. Understandably, however, there are serious gaps.

The confusion about the relation of basic science to national-policy objectives is probably most evident in the space program. Is the purpose of that program to extend scientific knowledge or to enhance national prestige or to achieve other objectives? Obviously the space program has many aims and objectives, and there is wide disagreement as to which ones take priority. Those who feel (wrongly) that the *principal* aim of Congress in supporting NASA is the advance of basic science contend (rightly) that $5 billion a year could be more fruitfully expended in other ways. Those who believe that the principal objectives of the space program are to enhance national prestige or to satisfy a human urge for exploration, or to assure future military or economic dividends, argue that some or all of these objectives *are* being achieved and that the total result *is* worth $5 billion a year. Clearly the question is not a scientific one; it is one of public policy. And those in the Congress and the executive branch responsible for establishing public policy have decided that the expenditure is justified. Those who disagree are entitled to say so—and they do.

Scientists who insist that this $5 billion could be more profitably expended for other scientific enterprises may be right, but they miss the point. The $5 billion is not being spent primarily to advance science any more than the $50 billion expended by the Defense Department is. Yet in both cases a moderate fraction of the budget is necessarily used to advance science. In the space program the resulting technologies are providing a valuable tool for carrying on scientific investigations which would otherwise be impossible. Many scientists are welcoming the opportunity to ride piggyback on this great venture and thereby to greatly advance terrestrial, space, and planetary science.

However, it must again be stressed that neither NASA nor any other agency charged with implementing national policy is intended to be a philanthropic agency authorized to provide benefactions to university science departments. They are agencies seeking to get a job done, and they turn to universities only when the universities can render a service—a service usually rendered at less than cost.

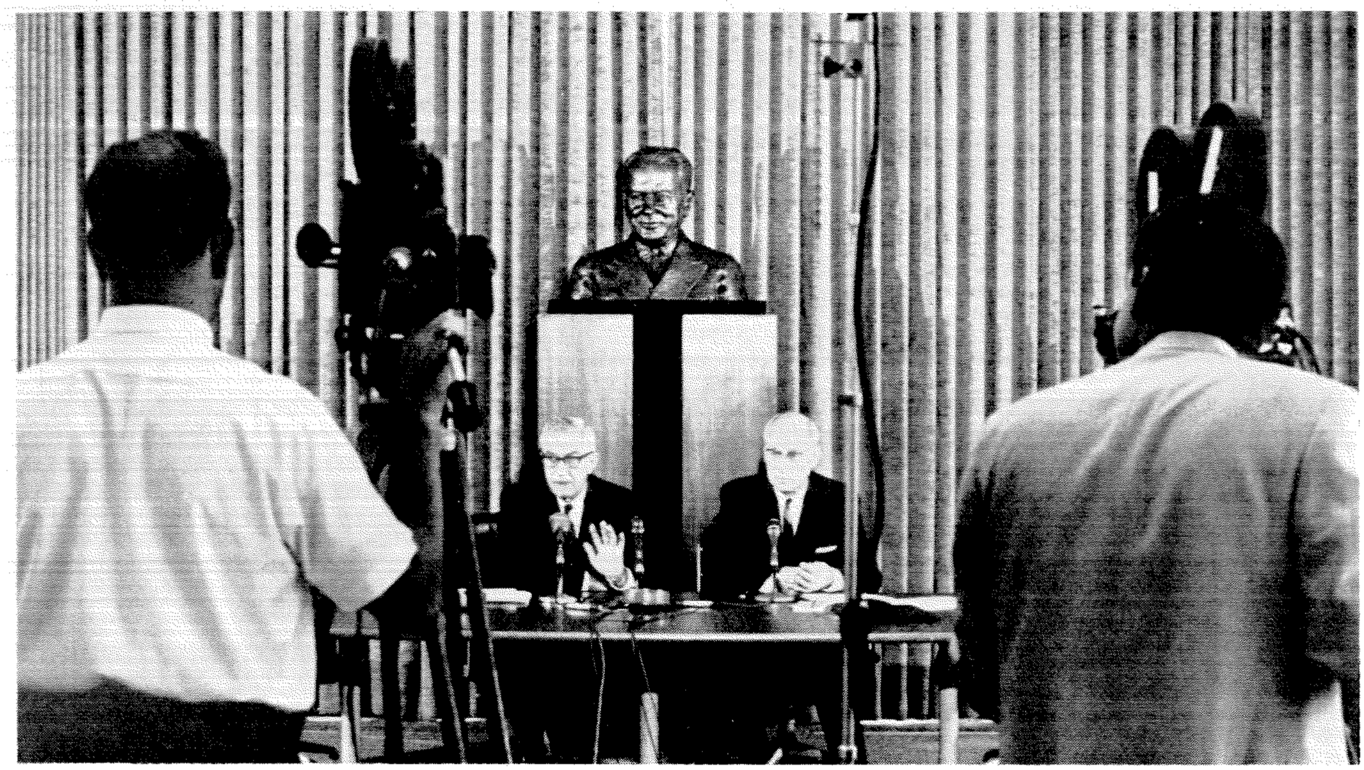
If the government wishes, as I believe it should, to develop a more adequate and more balanced program for strengthening American science per se, then it should charge suitable agencies, principally the National Science Foundation, with this particular task and provide funds for carrying it out.

As I have said, there is nothing basically wrong with the system. But there are serious dangers ahead in its current operations. The degree to which mission-oriented agencies of government will invest their precious funds in the rather long-range benefits to be expected from basic science will vary. Already there are pressures for concentrating on more immediate results. Project Hindsight will be used by some as an argument to this end, showing, as it does, that the results of undirected research appear in the form of new weapons only many years later. Mission-oriented agencies are, understandably, in a hurry. Can we afford to let the basic knowledge so necessary for future progress depend on the winds of political and economic pressures which blow hot or cold today?

A ready solution is at hand. The National Science Foundation *can* be depended on to look to the long-range future. It can be depended upon to recognize the cultural as well as the practical values of basic science. It can serve as the balance wheel to promote the broad advance of science—if its research budget is substantially increased.

The budget levels for NSF are determined by the Bureau of the Budget and by the House and Senate appropriation committees, agencies to which scientists at large and the general public have almost no access. The burden of presenting the needs of science thus falls almost solely on the members of the Board and the staff of NSF, aided only by the behind-the-scenes work of the President's Advisory Committee.

Here is a serious flaw in an otherwise viable system. Herein lies the need for a widespread public discussion of the issues—so that *all* congressmen and senators become aware of the real values and needs of basic science and of the critical role which can and should be played by NSF. Presumably, only wide public support will have the required influence on the appropriate committees and offices.



President DuBridge and Board Chairman Arnold Beckman announce Caltech's development campaign to the press.

SCIENCE FOR MANKIND: FIVE YEARS—$85 MILLION

On November 5, 1967, Caltech officially announced to the world what had been brewing behind the scenes at the Institute for some three years—a major development campaign to underwrite Caltech's programs for the future. The Institute intends to raise $85.4 million for three vital areas: facilities ($26.6 million for new buildings; $4.7 million for rehabilitation); endowment for faculty positions ($19.4 million); and operating funds to support research and study ($34.7 million).

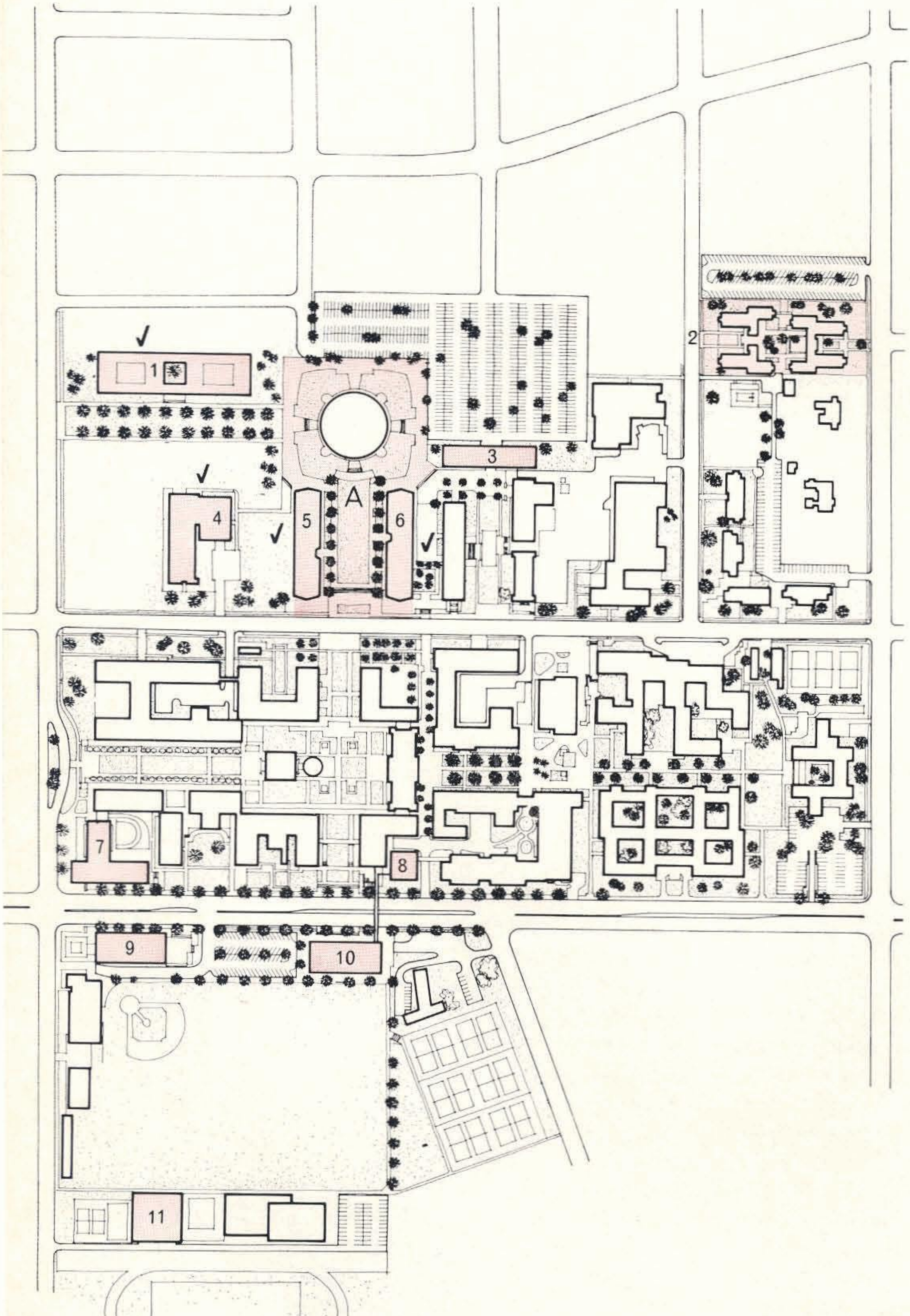
Throughout the busy month of November, Institute officials met with groups of Caltech friends and alumni to outline the development plans. The largest meeting was on November 8, when some 800 people gathered at the Ambassador Hotel in Los Angeles to hear California Governor Ronald Reagan explain the importance of private support for higher education in general and Caltech in particular. Special dinner meetings with alumni were held in 20 cities, and visiting speakers included Caltech trustee Simon Ramo (PhD '36), who is national chairman of the campaign; Ruben F. Mettler ('44, PhD '49), chairman of the alumni phase of the campaign; President DuBridge; Arnold O. Beckman (PhD '28), chairman of the Caltech board of trustees; and William Nash Jr. ('38, PhD '42) and Richard Schuster Jr. ('46), assistant chairmen of the alumni phase.

Caltech alumni, of whom there are about 10,000, had been expected to raise at least $2 million—without counting any major gifts of more than $100,000. Now that solicitation has begun and responses are rolling in, it appears likely that enthusiastic alumni will exceed the $2 million goal, and total alumni contributions, including major gifts, may approach $10 million before the campaign is over.

FACILITIES

The campaign may actually be overdue; Caltech has been bursting at its seams for several years. A steadily growing graduate student body and the extension of study into new fields are the main reasons. Dabney Hall of the Humanities, built to meet foreseeable needs in 1928, can't begin to house the staff or classes of that division today. Geophysicists are housed both on and off campus and need a place to work together. Planetary scientists, a growing and important part of geology at Caltech, are crowded into corners and basements of buildings completed 30 years ago, 20 years before their field even came into existence. Astrophysicists and astronomers are unable to work together as they should because some are located at the off-campus Observatories' headquarters and others are on cam-

CALTECH'S GROWING CAMPUS



Key

A. The Court of Man
1. Astrophysics
2. Graduate Residence Halls
3. Engineering
4. Chemical Physics
5. Behavioral Biology
6. Humanities and Social Sciences
7. Geophysics and Planetary Sciences
8. Applied Mathematics
9. Business Operations
10. Cyclotron Building
11. Physical Education

Off-campus

Radio Astronomy (Owens Valley)

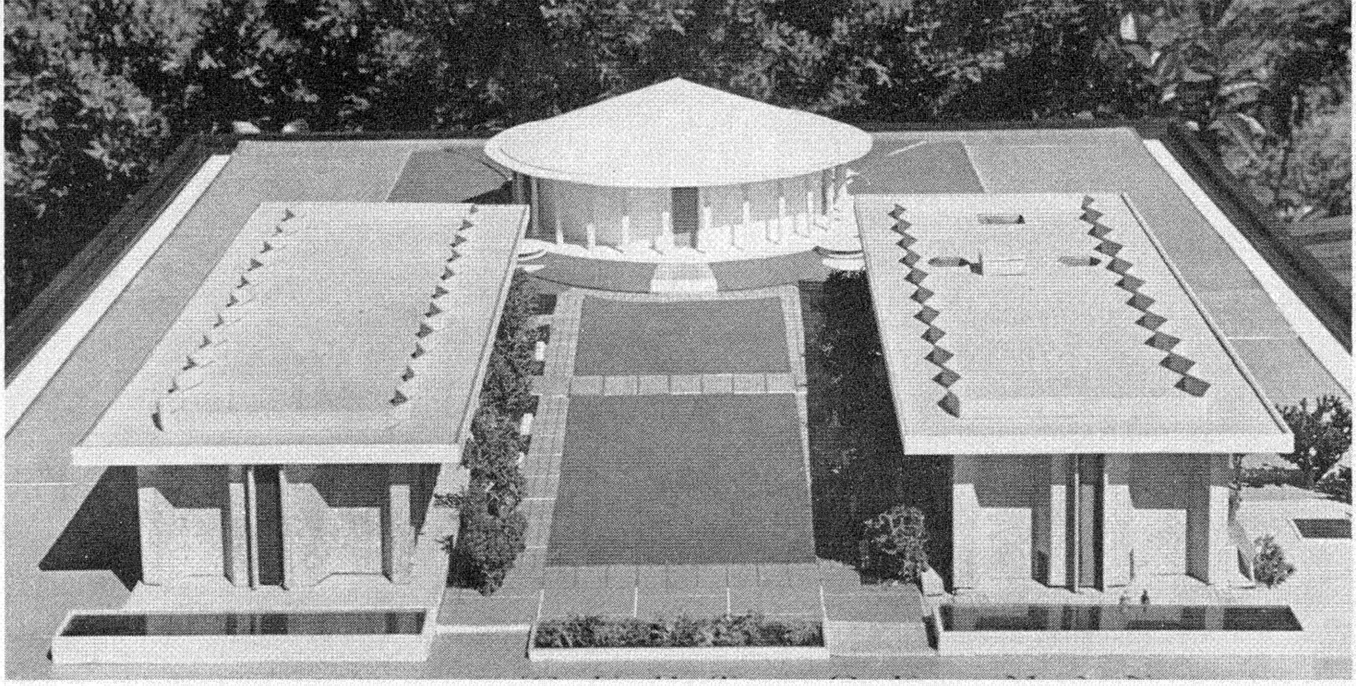
60-Inch Telescope Dome (Palomar)

Legend

Existing Buildings

Proposed Buildings

✓ Funded Buildings



Beckman Laboratory of Behavioral Biology (left) and Donald E. Baxter, MD, Hall of Humanities and Social Sciences (right) will soon flank Beckman Auditorium (built in 1964) to form the new Court of Man.

pus. Chemists, particulary those in the developing field of chemical physics, and biologists who are beginning to study bases of behavior need space badly.

The increasing number of graduate students (731 today, up 306 since 1957) has severely taxed the already limited off-campus housing situation. The four graduate houses have been filled for years. Athletic facilities too are overcrowded now that the student body numbers 1,429. New buildings will ease these burdens.

Caltech's business operations, which also serve JPL, are crowded into Throop Hall (built in 1910); they need much more space.

The squeeze is somewhat less critical in the engineering areas, primarily because six new engineering buildings have been added in the last ten years. Even so, that division foresees the need for more space within a few years.

FACULTY ENDOWMENT

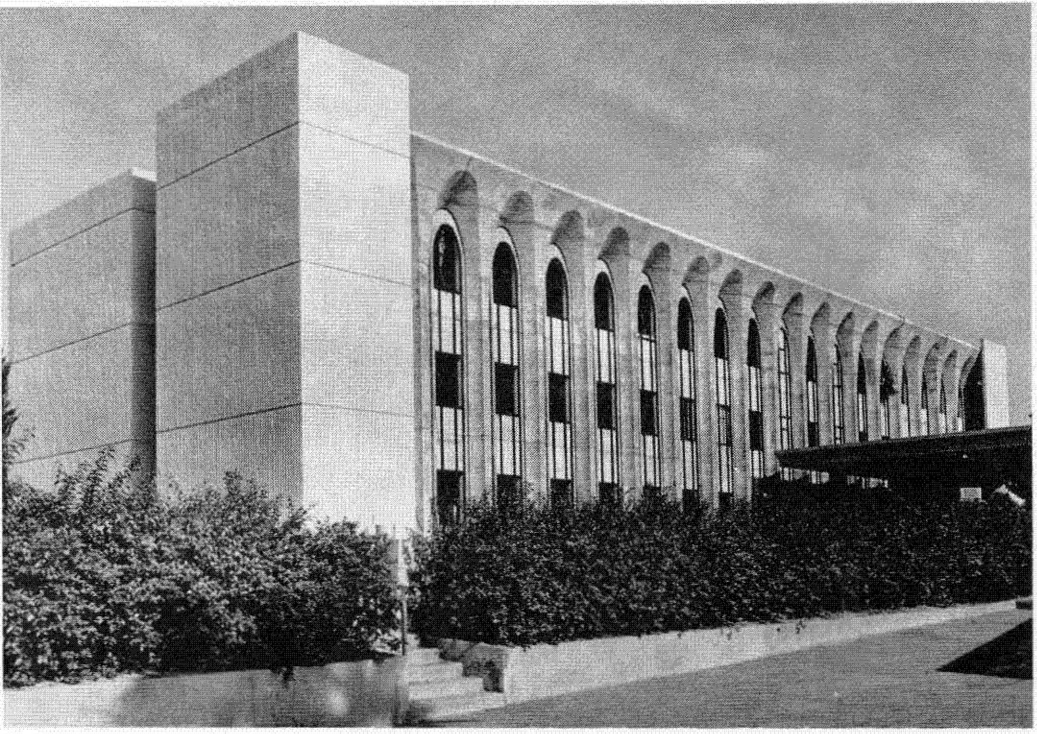
Competition grows keener each year for the great minds that make great universities. Caltech can still offer potential faculty members the benefits that go with working at a small, highly creative institution—and they are not to be discounted—but those benefits must be backed up by competitive salaries. For that reason Caltech is focusing particular attention in this campaign on raising money to endow professorial salaries, including at least 15 new chairs at a minimum of $750,000 each. Caltech now has only seven named professorships. One new chair, to honor Clark B. Millikan, has already been assured by the Aerojet-General Corporation.

OPERATING FUNDS

The largest item in the campaign is to many the least glamorous—operating funds. It takes millions of dollars each year to run Caltech, and as Caltech expands its work that amount rises accordingly—without a corresponding increase in revenues. The $34.7 million needed over the next five years represents $21.7 million in new support and $13.0 million of "normal" private support that Caltech would expect to receive without a campaign.

According to Dr. Ramo, the success of the campaign will depend in large part on a dedicated volunteer force. He has formed a "Committee of 100"

Proposed geophysics and planetary sciences laboratory at the corner of Wilson and California.



A. A. Noyes Laboratory of Chemical Physics is now nearly completed. It will be occupied in early 1968.

to bring Caltech's needs before a select group of individuals, corporations, and foundations throughout the country. As of December 1 the Committee has been largely responsible for the $21.2 million, 24.8 percent of the goal, now pledged. Additionally, 83 geographically divided alumni groups with some 800 alumni volunteers have, in only two months, passed the $700,000 mark on their way to a minimum goal of $2.0 million.

MAJOR GIFTS FOR BUILDINGS GIVEN OR PLEDGED:

$2.2 million from an alumnus (who prefers to remain anonymous) for a laboratory of chemical physics, to be named in honor of A. A. Noyes. Construction of this building is nearly complete.

$2.8 million from Mrs. Delia B. Baxter for the Donald E. Baxter, MD, Hall of Humanities and Social Sciences, in memory of her husband.

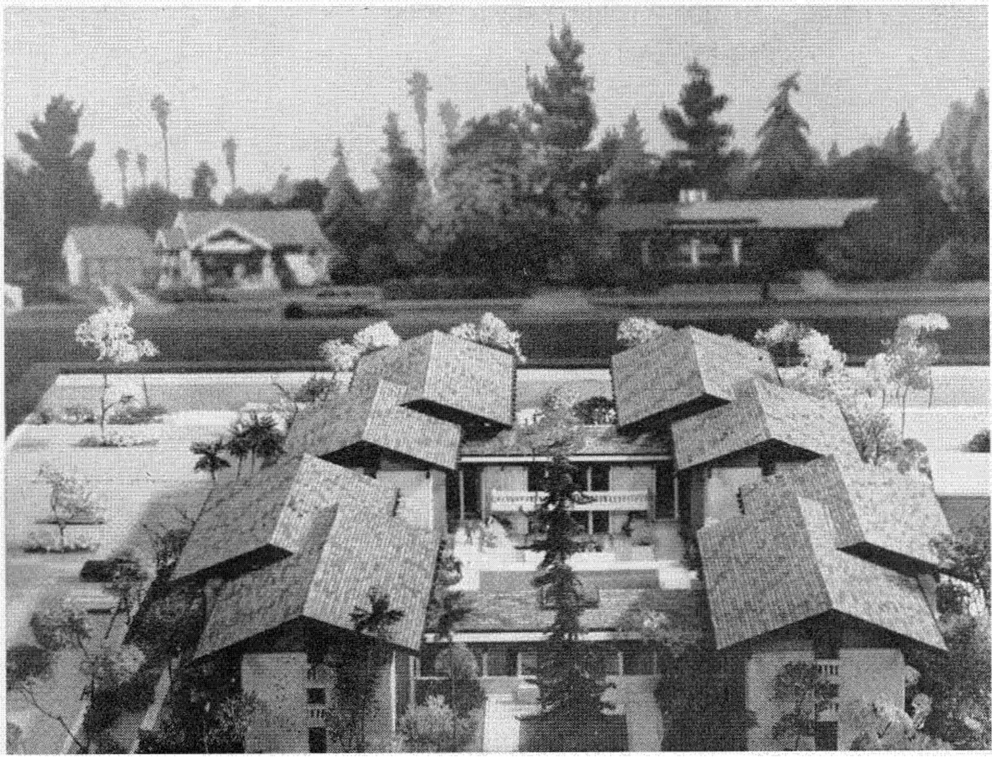
$2.2 million from Dr. and Mrs. Arnold O. Beckman for a laboratory of behavioral biology.

$450,000 from Caltech trustee Earle M. Jorgensen and Mrs. Jorgensen for a laboratory and living quarters for the Owens Valley Radio Observatory.

$2.8 million provided by Caltech trustee Seeley Mudd for an astrophysics laboratory to be built in conjunction with a building funded by the Carnegie Institution of Washington to house headquarters for the Mt. Wilson and Palomar Observatories.

$250,000 from the Oscar G. Mayer family for construction of a building to house a new 60-inch telescope at Palomar Observatory.

A complex of four new residence halls which will accommodate 200 of the growing graduate student body.



EARLY DEVELOPMENT IN ANIMAL CELLS

by Albert Tyler

A Caltech biologist and his associates add some pertinent information to our knowledge of early embryonic development

Our study of developmental biology at Caltech is concerned primarily with the activation of the egg—the way in which a chain of events is set into motion that transforms the egg into an adult. The problems on which we concentrate deal with the "turning on" of the synthetic processes that take place during early embryonic development, when new substances—particularly new proteins—are made for the new individual.

The work of molecular biologists during the last decade has revealed the basic steps that any cell employs in synthesizing new proteins: DNA (deoxyribonucleic acid), containing all the hereditary material, makes an RNA (ribonucleic acid) that has all of the information that the DNA has but in inverted form. This complementary RNA then serves as the template to make the protein.

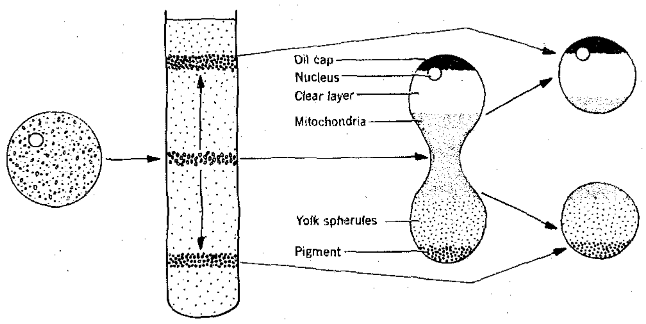
There are many different DNA's in a cell, each capable of specifying a different protein. The DNA's are always found in the nucleus, though not exclusively. In the nucleus of any particular cell, most of the DNA is inactive—not doing anything except replicating when the cell divides. But a portion of the DNA in any particular cell—let's say the nearly mature red blood cell—is active, producing the messenger RNA to make the specific proteins (principally hemoglobin in this case) characteristic of that cell. This messenger RNA goes out of the nucleus into the cytoplasm, associates with some particles there called ribosomes, and forms a structure called a polysome (polyribosome). The various amino acids are then assembled on that structure to produce the new protein.

In most species of animals the ripe, unfertilized egg is a resting cell. It is not engaged in much manufacturing activity. Immediately after fertilization, however, active protein synthesis begins. How does this come about? Is there a signal given to the nucleus to uncork some of its DNA so that messenger RNA—and new proteins—will be produced? Or is the messenger RNA already there, and are the ribosomes inactive and unable to be assembled into the polysomes?

We explore these problems in various ways. For example, we have examined the polysomes and ribosomes of sea urchin eggs: We separate them by centrifugation in tubes containing a solution of some viscous material, like sucrose, in various concentrations. Depending on whether these particles are single or grouped together (as they must be when protein is being synthesized), they will sediment at different rates and can be collected separately. When we explore these smashed-up cells, we find that before fertilization the cell has ribosomes mostly in single form, and after fertilization many ribosomes are joined together as polysomes. They are joined by messenger RNA.

This is one kind of experiment we use to study the turning on of protein synthesis in fertilization. We also know that the machinery in the *un*fertilized egg is quite capable of synthesizing protein. This has been shown with cell-free, protein-synthesizing systems that we prepare in the laboratory from homogenized sea urchin eggs. When we provide such systems with a particular set of instructions for manufacturing proteins—in the form of a simple synthetic ribonucleic acid, such as polyuridylic acid—a very simple protein, polyphenylalanine, is produced; and this occurs as actively in the systems prepared from unfertilized eggs as those from fertilized eggs.

One conclusion drawn early from this work (later shown to be erroneous) was that the unfertilized egg is inactive because it does not have messenger RNA, and that upon fertilization the nucleus produces the necessary messenger RNA. To examine this proposition, we prepared non-nucleate fragments. This is done by placing sea urchin eggs in a



In studies of early development, the centrifugation method is used to produce large quantities of non-nucleate fragments from eggs. Eggs are subjected to a centrifugal force of about 10,000 times gravity, causing them to pinch apart into two sections—one with a nucleus, one without—that can be examined for their ability to manufacture new protein.

centrifuge tube with a sucrose solution of increasing density from top to bottom and subjecting the eggs to a centrifugal force of about 10,000 times gravity for about 15 minutes. The eggs then stretch out, because their light contents go up and their heavy contents go down. They become dumbbell-shaped and pinch apart into two fragments, one of which has a nucleus and one of which does not. The two kinds of fragments form separate layers, which are collected separately and explored as to their ability to manufacture new proteins when development is initiated by artificial means.

The results of these experiments show that, even without the nucleus, the fragments can synthesize new proteins—and do it just as well as the nuclear fragments or the whole egg. The non-nucleate fragments contain the instructions for early development, although in an inactive, or masked, form. It is masked messenger RNA that is the subject of much of the present exploration in our laboratories.

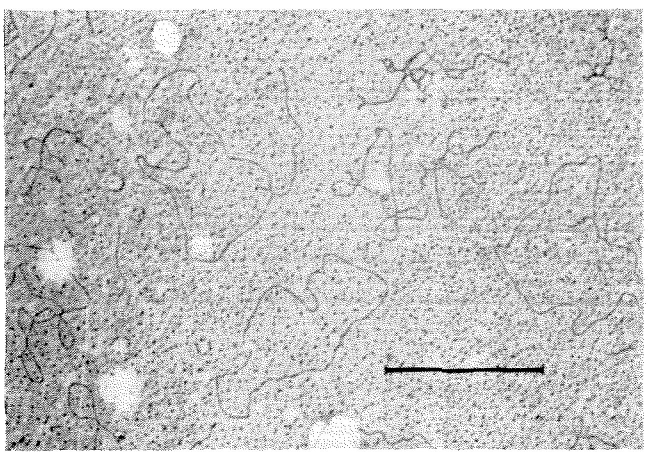
The inference that there is a masked messenger RNA is based on the supposition that there is not any other DNA outside the nucleus that might be present in the fragment and that might be activated upon fertilization. However, we know that there *is* other DNA outside the nucleus. At the same time we know that, upon fertilization, this DNA does not get immediately activated; it is not responsible for the bulk of the proteins that are synthesized in early development.

The evidence is supported, too, by the fact that the antibiotic dactinomycin, which inhibits DNA-primed RNA synthesis, permits protein synthesis and early development to proceed normally. Thus we find that the instructions (in RNA's) for early development are almost all present in the unfertilized egg. It also appears now, from work in various laboratories throughout the world, that the production of inactive messenger RNA is a common process at all stages of development. Thus the developing embryo anticipates events that are to occur at a later time by producing the working blueprints in masked form.

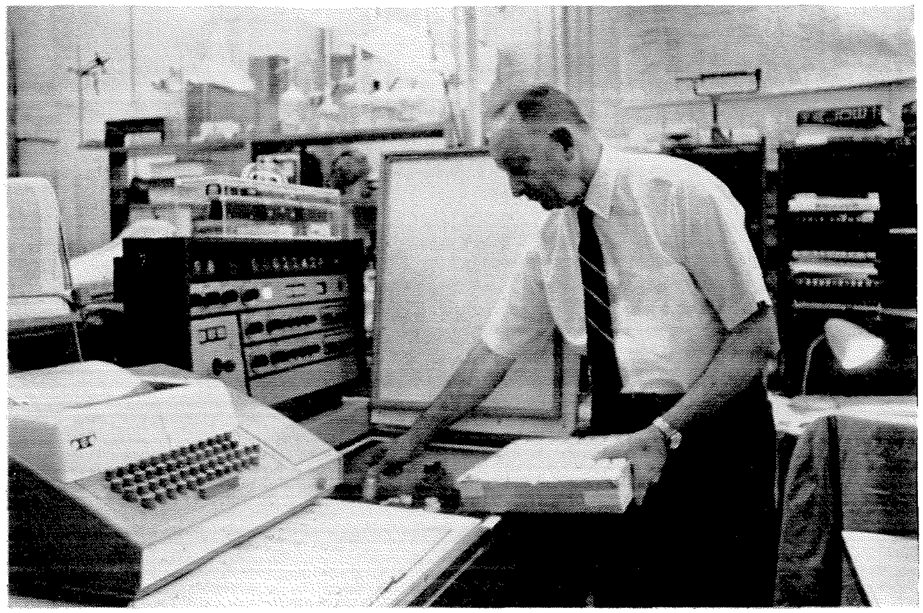
The DNA outside the nucleus is of great interest in itself. In recent years investigations with various kinds of animal and plant cells have shown that DNA occurs in the minute, rod-like particles called mitochondria that contain many of the cell's enzymes. My colleague Lajos Piko (now chief of the developmental biology laboratory at the Veteran's Administration Hospital in Sepulveda, Calif.) and I have been studying the cytoplasmic DNA of sea urchin eggs for some time.

There are about 200,000 mitochondria in a sea urchin egg. Probably the human egg-cell has about the same amount. The DNA of the mitochondria is somewhat different in density from the DNA of the nucleus. We can separate the two by the method of buoyant density centrifugation, on Cesium Chloride gradients, developed primarily by Jerome Vinograd, Caltech professor of chemistry and biology.

About a year and a half ago, researchers in Amsterdam found the mitochondrial DNA of mouse and chicken cells to be in the form of circular molecules about 4.5 microns in perimeter, instead of the long strands of nuclear DNA. At about the same time Dr. Piko and I found the mitochondrial DNA of sea urchin eggs to be in the form of circles of approximately the same size. Other workers have since found such circular DNA of similar size in other kinds of cells. We have shown also that this DNA can function as effectively as can nuclear DNA for the synthesis of RNA in an *in vitro* system. Our analyses indicate that there are on the average



Electron micrograph of DNA from the mitochondria of the sea urchin egg. (The line represents one micron.) Mitochondrial DNA occurs in the form of double-stranded circles of close to 4.5 microns in perimeter.



Albert Tyler, Caltech professor of biology, places vials containing radioactively labeled proteins and nucleic acids into a scintillation counter to measure the amount of synthesis that has taken place in a particular experiment.

about 1.3 circles of DNA per mitochondrion. Since no partial circles are found, we conclude that most mitochondria contain only a single circle of DNA, and some may have more than one.

Circular DNA was originally discovered at Caltech by Robert Sinsheimer, professor of biophysics, in a bacterial virus. Subsequently, Dr. Vinograd and his co-workers found it in the polyoma virus and other tumor viruses. The present information indicates that closed circular DNA is a normal feature of the cytoplasm of many, and probably all, organisms. In fact, measurements have shown the circles to be mostly of similar size in many kinds of organisms. Not all of the circular DNA, however, is in the form of the 4.5 micron circles. Recently Dr. Vinograd and his colleagues found a proportion in the form of double-size circles and many in the form of interlinked circles of standard size forming chains of two, three, four, or seven. These were found in HeLa cells (cultured cells derived from a human tumor) and in lymphocytes from leukemic patients. We have also found these double-size and catenated forms in sea urchin eggs, so we can assume that they are not simply a feature of tumor or other abnormal cells.

It appears, then, that the mitochondria have their own genetic machinery, although their precise contribution to development and heredity is still largely unknown. Because DNA is sensitive to mutations, mitochondria could be involved in various losses of functional capacity such as occur in the aging process. This could be true if mutations occurred that altered or inactivated the functions of these submicroscopic energy-releasing entities. For the problems of the start of development we think that the exploration of this cytoplasmic informational material may provide us sometime with some further clues as to the nature of the controlling influences. We already know that a large supply of mitochondrial DNA is a general situation for the start of development in all animals, and the relative amount of cytoplasmic DNA decreases as development proceeds. It also appears that the mitochondria manufacture proteins that move out into the surrounding cytoplasm, and that they in turn may accumulate certain proteins made in the surrounding cytoplasm.

The studies going on in developmental biology in many laboratories throughout the world have given us some preliminary insight into the factors that control early development. On the more practical side, these studies may be expected some day to lead toward more effective methods of both quantitative and qualitative control of reproduction and development. Society has become increasingly aware of the importance of quantitative control to more readily limit family size to that which is manageable, and to prevent populations from disastrously outgrowing resources. For qualitative control, the methods that have been considered until recently have been those of eugenics (namely selective breeding), which are objectionable to many people. Now, however, such control can be envisaged by non-eugenic methods, such as the use of instructional RNA's at the various stages of development, presumably with the greatest effects at the start of development. In such ways we can hope to produce better offspring—better in the sense that they are better able to cope with the exigencies of the environment, stronger, more resistant to disease, brainier, and better able to get along with one another peacefully.

EARLY DAYS AT CALTECH

by Theodore von Kármán

In a chapter from his posthumously published autobiography, one of Caltech's great men recalls his first impressions of the Institute.

Theodore von Kármán's autobiography* was about three-quarters completed when he died on May 7, 1963, five days before his 82nd birthday. Lee Edson, his collaborator, finished the book, which was published this fall.

Their collaboration grew out of an article about Von Kármán that Edson had written for the *Saturday Evening Post* in 1957. "Von Kármán and I became friends," says Edson in his introduction to the book. "I visited the great house in Pasadena whenever I had a chance, occasionally to do another story, but mostly to sit around the long dining room table with Von Kármán and his friends, drink Jack Daniels bourbon, and laugh over anecdotes and reminiscenses from Von Kármán's rich and colorful past. One day during one of these visits he asked me if I would be interested in helping to write his autobiography.

"This wasn't as easy a decision as it sounds. Some of Von Kármán's old associates felt that it was undignified for a scientist to write his life story, which stressed self instead of work, and that in any case it should be written by a professor of aerodynamics, not a science journalist. To my delight, Von Kármán refused to heed such advice. He thought that an academician would not be able to construct a humanized version of his life, but might place emphasis on matters not of interest to the general public. Von Kármán once told me with a smile that he had already created a vast body of work with the help of aerodynamicists, and very little of it was of interest to the general public."

"We have a fifty-fifty arrangement", is the way Von Kármán described this collaboration. "Lee writes and I read . . . (The book) is me in good English."

*THE WIND AND BEYOND: Theodore von Kármán with Lee Edson.

IN THE EARLY 1930's Caltech's reputation in scientific teaching and research was distinctly on the rise. This was due mainly to Millikan and his highly selective planning. In the four years that had elapsed since my first visit, this remarkably farsighted administrator-scientist had continued to seek out highly qualified and inspiring teachers.

Some of Millikan's methods were bold and unorthodox for universities of that day. In 1927, for instance, he brought in C. C. Lauritsen, a topnotch physicist, by offering him the facilities of a high-voltage laboratory which he had earlier persuaded Southern California Edison Company to set up on the Caltech campus. Such industry-university tie-ups were quite rare in the United States, and universities in any case never stooped to go to industry; they insisted industry come to them. But Millikan's approach paid off for Caltech. Lauritsen built in his lab the world's first million-volt x-ray tube, which became the father of all high-potential vacuum devices and brought the electric industry to Caltech.

Similarly in 1928 Millikan lured Thomas Hunt Morgan, then the leading geneticist in the United States, from Columbia University where he had spent 24 years. Morgan had hardly heard of the small engineering school in distant California, but Millikan persuaded the Rockefeller Foundation to furnish money for Caltech to build the nation's first laboratory devoted solely to the study of heredity. Morgan was offered the directorship. Unable to resist, he uprooted himself and his family from New York and settled in Pasadena.

Some faculty members questioned Millikan's judgment in hiring a biologist for the faculty of an "engineering school," but subsequent events showed that Millikan's decision was a wise one. Caltech contributed considerably to fundamental knowledge in genetics and developed a reputation as a scientific institution of the first rank. Morgan himself received the Nobel Prize for Medicine in 1933, thus bringing further renown to the Institute.

In my first interview with Millikan when I arrived at Caltech, he told me with pride of Thomas Hunt Morgan's famous work with Drosophila, the fruit flies whose quick rate of reproduction enables scientists to study many generations in a few weeks and thus draw conclusions about human heredity that might otherwise take hundreds of years to develop. Millikan hoped to see similar fundamental developments in aeronautics and fluid mechanics.

"We do not have the funds to develop all the engineering sciences here," he explained, "but I am convinced the aircraft industry will be attracted to southern California. So with your help and the Guggenheim Foundation I think we can make Caltech the nation's center of aeronautics."

I liked this direct approach and his optimism, because I thought it would not only encourage the growth of aviation but would stimulate progress in aviation science as well. And because Caltech was very young as well as small and selective (only 160 freshmen were admitted each year), it would be an excellent place for me to establish and develop the ideas of education that I had brought from Europe.

This proved to be the case. I remember that one of the things I noticed first in the United States was the lack of reverence for the teacher and the very few teachers who commanded real respect. A student came to me one day and said he had studied mathematics at the University of Chicago. When I asked him who his teacher was, he said he didn't remember. I found this response shocking. Who could forget the great Felix Klein or David Hilbert of Göttingen? I felt that if this were typical, it represented a real deficiency in American education. To what extent it might be remedied I wasn't sure.

Another characteristic of education I noticed when I arrived at Caltech was that the teaching plan was somewhat conventional. Each day so many pages of study were assigned from a textbook. The teacher wrote equations on the blackboard. The student copied them fervently in his notebook while he tried to understand as much of the reasoning as he could. There were frequent examinations in some courses. Therefore it was the memory, not creative impulses of the mind, that was being trained. Of course under such circumstances the teacher would be barely remembered.

My years of teaching had given me a different view of the art. In Germany, as I've indicated earlier, my courses began with the basic concepts, so the students would quickly develop a feeling for the principle at work. For me the principle was most important, not the detail, and I subsequently emphasized this in class at Caltech. How does the electron "feel" in its environment? What makes it behave as it does? What makes the wing lift in the air? First in each case came the physical "picture" with only the essentials, like a caricature. Then came the mathematics.

I seldom had used tests as drills in Aachen, and I saw no reason to change this approach at Caltech. Some of the students didn't like this. In fact, I was surprised to learn that the students in one of my classes were actually worried because I had not given them any tests during the semester. They didn't know how they stood in my estimation and were afraid to have me judge them on the basis of just one end-of-term examination. Faced with this insecurity, a delegation of students approached me with a request. Could I furnish a hint of the topics that would be covered in the final examination?

"Why just a hint?" I said. "I will be glad to give you the entire examination."

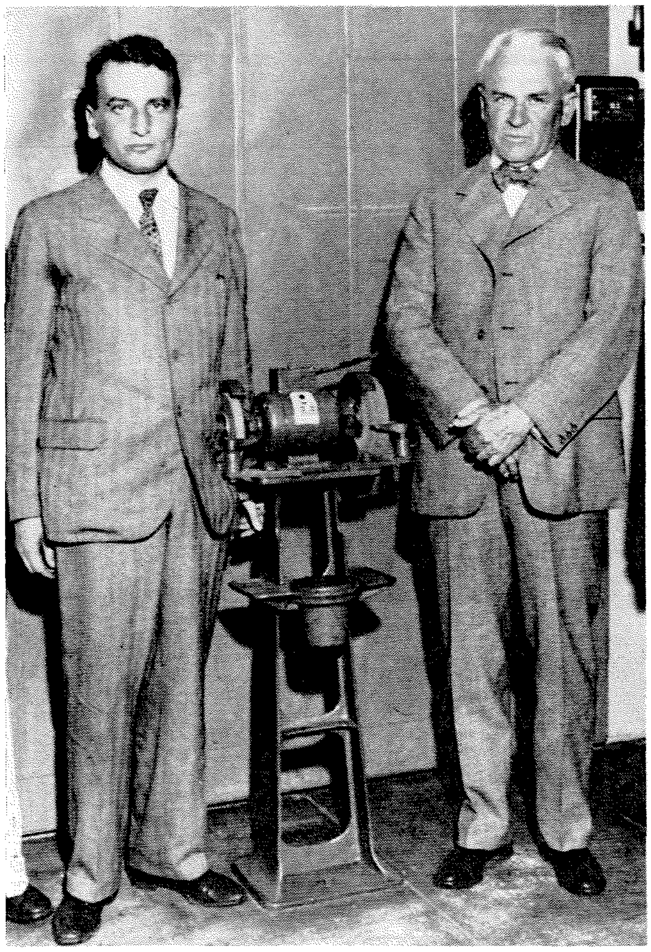
They must have thought I was fooling or playing a trick. They stood in front of me speechless. I wrote out the questions and handed over the list, but I could see that the men were still worried.

"This isn't fair," one of the students spoke up finally, expressing what was in everyone's mind. "If we all know the answers, everyone will get 100."

THEODORE VON KÁRMÁN 1881—1963

Theodore von Kármán, professor of aeronautics and director of Caltech's Guggenheim Aeronautical Laboratory from 1930 to 1949, was born in Hungary in 1881. His childhood, his student and teaching years at the University of Göttingen, and his early work in fluid mechanics were marked by his brilliance as a mathematician and scientist. At age 31 he was invited to head the new Aeronautical Institute at the University of Aachen, and during his 18 years in that position he not only established the school as the world's leading aeronautical institute, but also contributed greatly to the development of German aviation.

Prompted by the rise of Nazism in Germany, in 1931 Von Kármán accepted Robert Millikan's invitation to become director of Caltech's new Guggenheim Laboratory, which soon replaced Aachen as the leader in its field. During his 19 years at Caltech, he distinguished himself in the fields of supersonic aerodynamics and rocketry and helped found the Aerojet-General Corp. and the Jet Propulsion Laboratory. He is recognized by his colleagues as the man who has contributed more to the fundamental understanding of atmospheric and space flight than any other single person in our time.



Theodore von Kármán and Robert A. Millikan, 1930.

"And what is your definition of 100 percent?"

"All correct answers."

"Here we differ," I told him. "There is no such thing as an entirely correct answer to any question in engineering. It is the way the problem is treated and developed. A student who has completed an intelligent analysis, with the proper emphasis and approach, but who comes out with a wrong answer because of a mechanical slip in multiplication, would receive a much higher rating from me than a student with the correct answer but no imagination in his approach."

Not all my colleagues agreed with my views. We usually argued these matters at Caltech's *Stammtisch*, to which I was invited by Epstein and Tolman soon after my arrival. It was an exclusive gathering of a dozen or so faculty members who met regularly at various restaurants in Pasadena. Few engineers were ever invited. There was a strong difference in philosophy between those who believed that teaching should be directed toward theoretical understanding and those who believed in practical application.

In our group one wing of the argument (I hesitate to classify it as right or left) was represented by the late Eric Temple Bell, an eminent mathematician who headed the math department and as a sideline wrote murder mysteries under the name John Taine. Bell was strong on theory, not much interested in application.

Bell and I had differences of opinion on how to teach mathematics. I wasn't satisfied with the mathematical training of engineering students at Caltech and elsewhere in the United States, because it seemed too abstract. The students were not shown how to apply mathematics to practical problems, and this application was my main objective in teaching. But I couldn't change Bell's point of view. So one day I decided to compete with him and give a math class myself. (We had great latitude in these matters at Caltech.) The courses stimulated curiosity, and no wonder. Some bulletin boards listed them—for a while at least—as E. T. Bell's Mathematical Analysis and Kármán's Useful Mathematics.

The most eminent member of our group during the thirties was undoubtedly Nobel Prizewinner Carl David Anderson, who made important discoveries in cosmic rays. He worked in my laboratory, not because I knew anything of physics, but because he needed a great deal of power to operate his electromagnet, and we had the only source of power which could supply his needs. An introvert, he shunned large groups, preferring to work with only a few close associates.

He built his famous cloud chamber in our laboratory. This chamber is an apparatus into which high-energy particles are introduced. When these particles collide with atoms of the air inside the chamber, they knock out electrons, leaving the particles electrically charged. Vapor condenses around these particles, making them visible as a thin line of fog, called a "track." The negative and positive charges can be deflected in opposite directions by a magnetic field, so it is easy to determine whether the track is negative or positive. I remember that Anderson was quite excited the day in 1932 when he discovered in his chamber the first track of electrons with a positive charge. At first he thought it was a mistake, as did others who had seen similar tracks, since electrons are negative; but when Carl repeated the work, he always got a track with a direction indicating a positive charge. Finally he realized that he had discovered a new particle. The particle was called a positron, a positive electron.

Anderson wrote to the American journal *Science* announcing his discovery. Then for a time he could not reproduce his results, and he grew worried. He thought of writing the editor not to print his letter, but it was too late. The article was in the press.

I think this was rather fortunate for Anderson because shortly afterwards Sir James Chadwick in Cambridge made observations similar to those of Anderson's. If Carl had publicly revoked his announcement, Chadwick might have received the credit for the positron and possibly the Nobel Prize. As I've said earlier in this book, small things exert great influence on men's lives. Chadwick, incidentally, did get the prize in 1935 for discovery of another elementary particle, the neutron, which is now famous because it is used to trigger A-bombs.

The chief and guiding genuis at Caltech was, of course, Robert Millikan. But, interestingly, he never allowed himself to be called president of the Institute. His title was Chairman of the Executive Committee. In fact he told me once that Caltech was the only American university that had a really democratic organization because decisions were made by committee rather than by a single top executive. The committee consisted of four businessmen and four faculty members who were in control of all budgets, appointments, promotions, and salaries. This setup was quite unusual at that time. Millikan himself called his administration a "mean course between the role of the Tzar and that of the academic proletariat."

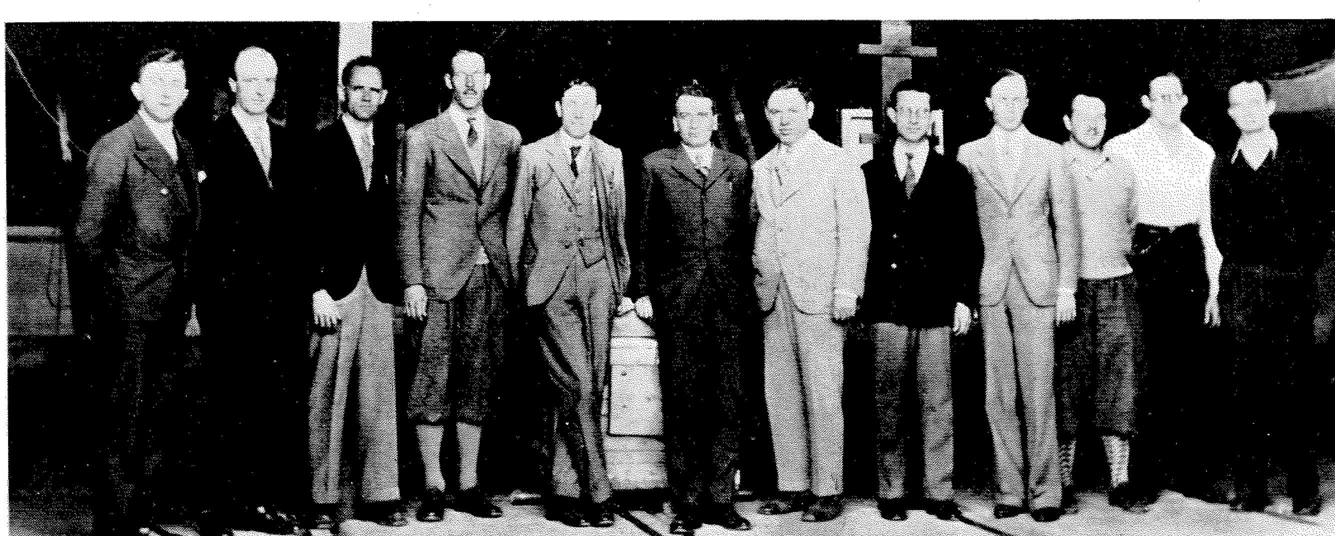
In practice this meant that if you went to Millikan, say, for money for your laboratory, and he did not want to give it to you, he would always say: "If I could do it, I would, but the Executive Committee won't let me." He reminded me at times of certain world leaders who blamed bad decisions or lack of decisions on their politburos. In jest I once mentioned this similarity. "Well, at least we have no Gestapo," he said, smiling.

There was considerable liberality and independence of thinking at Caltech, which I am glad to say has lasted through the years. For despite Millikan's one-man rule he was tolerant to a wide variety of ideas, particularly in matters of religion. He liked Thomas Hunt Morgan, for instance, knowing he was an avowed atheist. I once asked Morgan how, in the absence of scientific proof for or against, he was so sure that God did not exist. Morgan countered: "I don't understand how you, Kármán, and your friend Einstein, don't see that God is not supreme but is only an anthropomorphic construction of the human mind."

There is no better example of Millikan's tolerance than his attitude toward the occasional digs in his direction. I remember one faculty meeting at which Morgan presided. He introduced speakers in several of the scientific disciplines. After biology the program called for discussion in astronomy. Morgan rose, looked around the assemblage, and said solemnly: "I think I'd better give the chair to my friend R. A. Millikan—he is nearer to Heaven than I am." Millikan joined in the ensuing laughter.

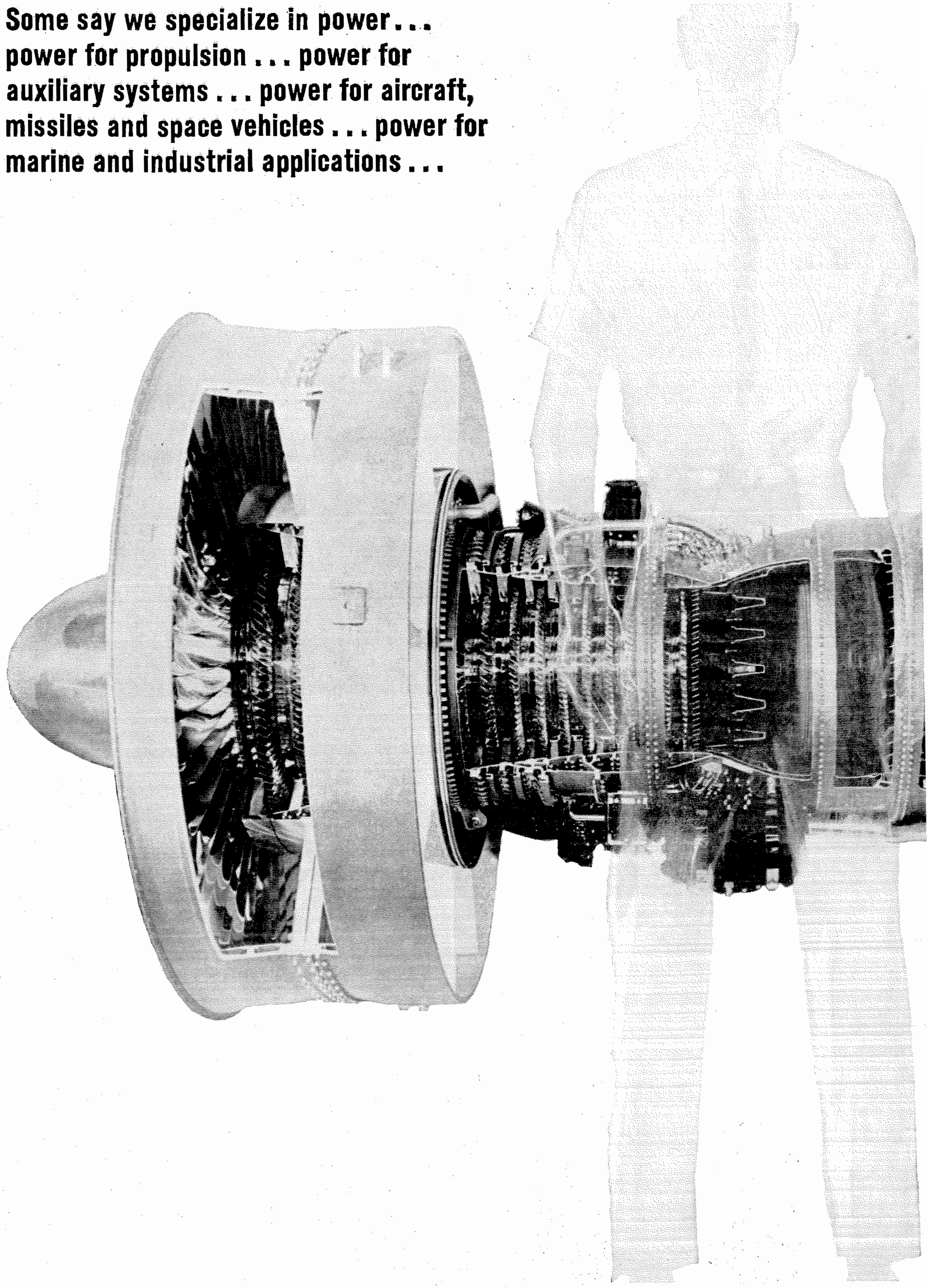
Millikan's basic hope was to bring science and religion together. To him the purpose of science was to develop a "knowledge of the facts, the laws, and the processes of nature," while religion more importantly would "develop the consequences of ideals and aspirations of mankind." This was a point of view I shared.

But Millikan's desire to bring the two together succeeded in a way that he never contemplated. I recall visiting a so-called science museum in Moscow. One atheistic show started with photographs of the Mt. Wilson Observatory and its findings, accompanied by some words about the heavens by Dr. Edwin Hubble, Mt. Wilson's great astronomer, who made impressive studies of the galaxies. I think Millikan would have been amused, as I was, to find the Institute, founded by a minister and run by a devout Protestant and son of a minister, was used as an introduction to Soviet antireligious propaganda.

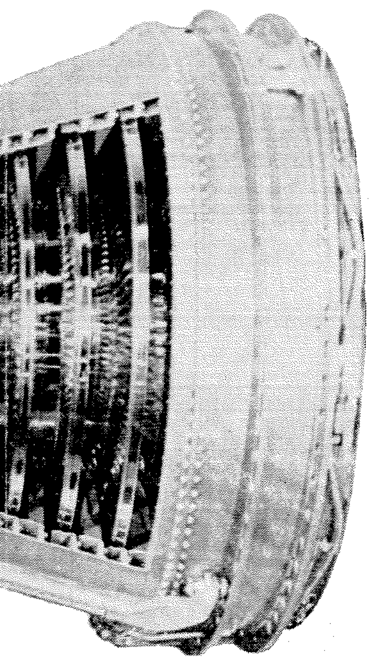


Von Kármán (center) and staff members of the Guggenheim Aeronautical Laboratory at Caltech in 1930.

Some say we specialize in power... power for propulsion ... power for auxiliary systems ... power for aircraft, missiles and space vehicles ... power for marine and industrial applications ...



. . . they're right. And wrong.



It might be said, instead, that we specialize in *people*, for we believe that people are a most important reason for our company's success. We act on that belief.

We select our engineers and scientists carefully. Motivate them well. Give them the equipment and facilities only a leader can provide. Offer them company-paid, graduate-education opportunities. Encourage them to push into fields that have not been explored before. Keep them reaching for a little bit more responsibility than they can manage. Reward them well when they *do* manage it.

You could be one of the reasons for Pratt & Whitney Aircraft's success . . . if you have a B.S., M.S. or Ph.D. in:
MECHANICAL • AERONAUTICAL • ELECTRICAL • CHEMICAL • CIVIL • MARINE • INDUSTRIAL ENGINEERING • PHYSICS • CHEMISTRY • METALLURGY • CERAMICS • MATHEMATICS • STATISTICS • COMPUTER SCIENCE • ENGINEERING SCIENCE • ENGINEERING MECHANICS.

And *we* could be the big reason for your success. Consult your college placement officer—or write Mr. William L. Stoner, Engineering Department, Pratt & Whitney Aircraft, East Hartford, Connecticut 06108.

Pratt & Whitney Aircraft

CONNECTICUT OPERATIONS EAST HARTFORD, CONNECTICUT

DIVISION OF UNITED AIRCRAFT CORP.

An Equal Opportunity Employer

The Mapping of a Molecule

by Richard E. Dickerson

Caltech chemists are beginning to work out the structure of cytochrome c, a molecule which is essential to virtually all life on earth

One of nature's smallest biological engines, a molecule which is essential to virtually all life on earth, is gradually emerging from the invisible world to the visible. With a technique known as x-ray diffraction, a Caltech team has succeeded in enlarging the image of the engine about one hundred million times.

The "engine" is a molecule of a protein called cytochrome *c* and is shaped like an egg one ten-millionth of an inch across. For comparison, if the molecule were the size of a hen's egg, then a man to the same scale standing on the earth could reach halfway to the moon. An analysis of approximately 4,500 diffraction data from crystals of cytochrome *c*, with and without labeling of molecules with platinum and mercury, has led to the calculation of a low resolution map in which the general plan of the molecule is visible.

This molecule is one small part of a complicated factory, the mitochondrion, which converts food into usable energy for all of the body's processes. Dozens of these tiny factories are to be found working like miniature power packs in nearly every living cell. Cytochrome *c* itself is near the end of a production line (the terminal oxidation chain) which breaks down the fuel in small steps and saves the energy by storing it in molecules of adenosine triphosphate (ATP), which are then used to energize all plant and animal activity. The mechanisms by which this process is carried out are unknown, but finding out the structures of the machines involved is a step in this direction.

Cytochrome *c* is interesting not only because of its key role in energy production but also for what it tells us about evolution. Cytochrome *c* evolved shortly after oxygen-using, one-celled life appeared on earth roughly two to three billion years ago. All living things that have descended from these simple organisms have cytochrome *c*; and cytochome *c* from wheat germ, yeast, screw-worm fly, horse, and man are essentially the same.

The chemical makeup of cytochrome *c* is well known. The molecule has a molecular weight of 12,400 and is a chain of 104 links, each an amino acid with particular chemical properties. Emanuel Margoliash at Abbott Laboratories in North Chicago and Emil Smith at UCLA have studied the sequences of these links in the chains of more than 30 species including man, monkey, and other mammals; fish, birds, reptiles, insects, yeasts; and one plant, wheat germ. Some important parts of the chain are absolutely identical in all species; in other parts it seems to make little difference what kinds of links are present. One of our goals at Caltech is to find out where these constant and variable parts of the chain are situated on the molecule and why their influence on the molecule is so different.

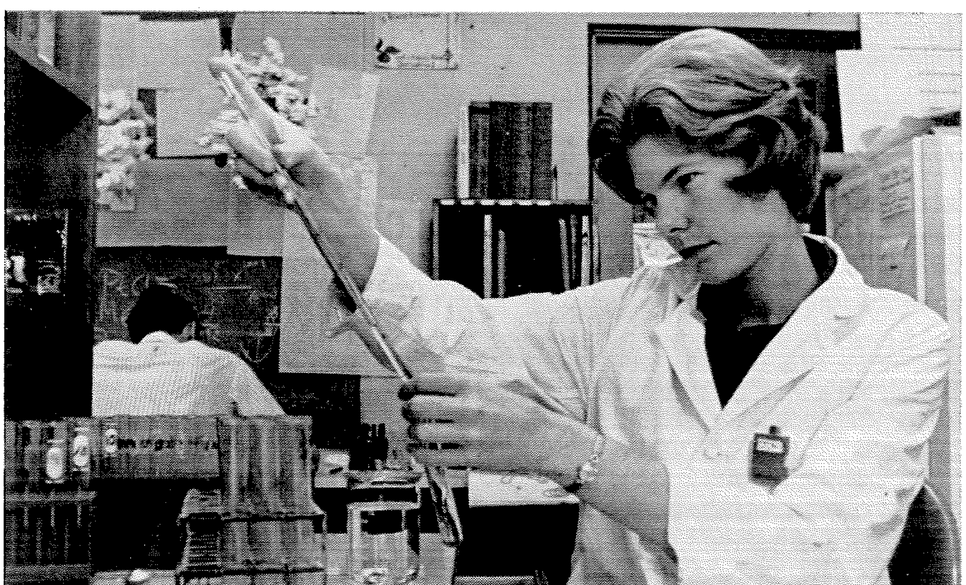
Margoliash and Smith have shown that the degree of similarity or difference between chains from two species checks exactly with their places in the evolutionary tree. For example, man and yeast differ by 44 links in the chain, man and horse by 12 out of the 104, and man and rhesus monkey by only two. Cytochrome *c* from man and from chimpanzee are identical. Darwin's theory of evolution is thus checked out using not only evidence which Darwin did not know about but also a substance whose existence was completely unknown in Darwin's time.

The heart of this tiny molecular engine is a heme group—an atom of iron surrounded by a cluster of atoms called a porphyrin molecule—very similar to that in hemoglobin. But instead of carrying oxygen where it is needed, as hemoglobin does, cytochrome *c* is designed to accept an electron from its predecessor in the mitochondrial energy chain and then to give it up again at the proper place. How it does this is not known. Some chemists think that the molecule shuttles back and forth from one site to another. Others have proposed that it stays in one place but rotates or wobbles so as to bring its iron-containing heme group close to the electron donor and acceptor in turn. Chemical and physical evidence suggests that the molecule opens up to some extent when it loses an electron and closes down when it receives one. In order to check this idea out and find the mechanism of oxidation and reduction of the iron, two independent x-ray analyses of the molecule are required—one in the oxidized and one in the reduced state.

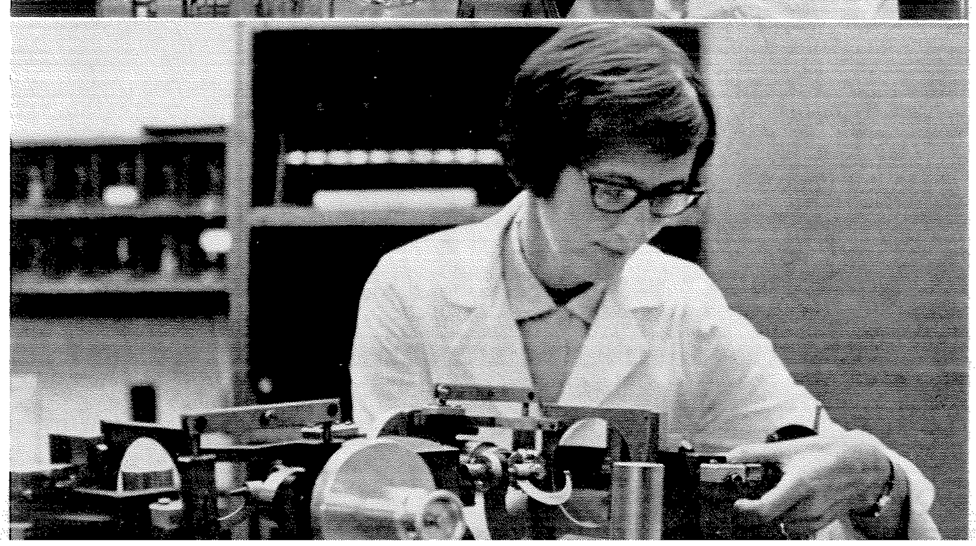
The richest source of cytochrome-containing mitochondria in mammals is the heart, the muscle that never stops working and the one that has the most continuous need for a power supply. The cytochrome for the Caltech structural work comes from horse hearts—about two and a half grams of crystalline cytochrome *c* from 35 pounds, or seven good-sized hearts. The protein must be separated, purified on a chromatographic column, and crystallized from ammonium sulfate solution. Crystals of oxidized horse-heart cytochrome are easy to grow in a matter of weeks. Those of other species are more difficult, and to date no species of the 30 or so which have been purified and analyzed at the Abbott Laboratories has crystallized well in the reduced form. This is an obstacle which will have to be overcome, of course, if the mechanism of oxidation and reduction is to be understood.

The first step in an x-ray diffraction structure analysis is to mount the crystal in the path of a narrow x-ray beam and then to move the crystal and some radiation detection system, either photographic film or counter, so as to collect the entire diffraction pattern of the crystal. On film the pattern will be a regular array of spots. The positions of these spots tell the investigator how the molecules are packed in the crystal (in this case a matter of only minor interest). But the *intensities* of diffraction in all of the different directions of diffraction lead to the important information—the atomic structure of the molecules doing the diffracting.

A complete structure analysis of a small organic compound may require measurement of only one or two thousand x-ray diffraction intensities. But the same analysis for a protein such as cytochrome *c* would involve 200,000 data. This means that for practical reasons a protein structure analysis is carried out in stages with increasing amounts of data and with successively higher resolution of de-



Cytochrome c is extracted from horse heart and is purified and fractionated on a chromatograph column. Here laboratory assistant Joan Varrum runs an assay on the fractionated samples.



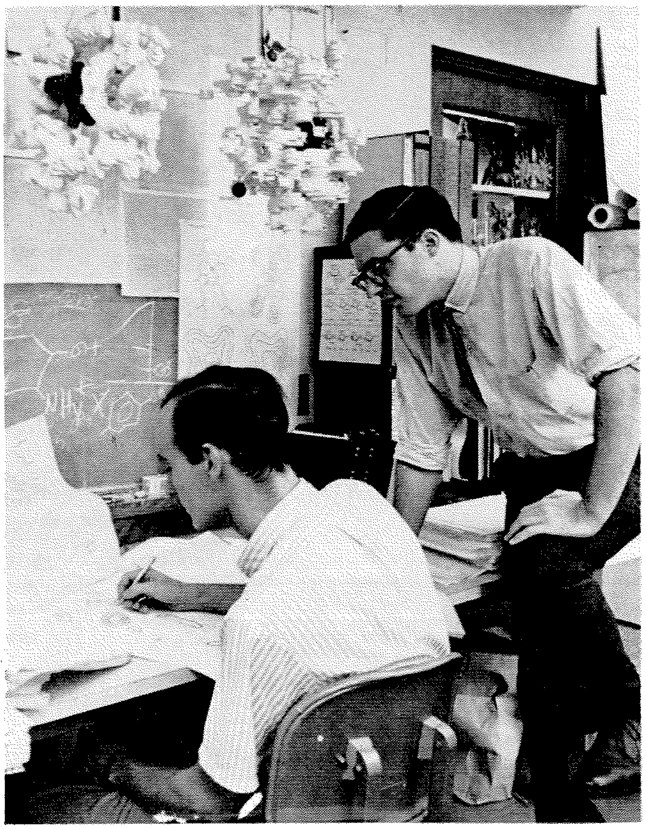
Crystallized protein is mounted on glass capillaries on an x-ray camera, and its diffraction pattern is collected. The crystal lies just above the crescent shaped beam stop near the center of the camera. Olga Battfay, laboratory assistant, aligns the precession camera.

Richard Dickerson assembles the plexiglass sheets which show the electron density of sections of the molecule. These sheets are used to plot the low resolution map of cytochrome c.

tail. It also means that automation, which is becoming more and more desirable in smaller structure analysis, is mandatory for proteins.

Richard Stanford, senior research fellow in chemistry and one of my collaborators in the Caltech protein structure group, has put together an automated, punched-tape-controlled, single-crystal diffractometer for collecting protein data. The paper master tape, produced at the chemistry division's remote computer console by the IBM 7094, tells the diffractometer where to position the crystal and proportional counter, and how long and under what conditions to measure diffraction intensity from the crystal. The results are punched out on paper tape for input to the remote console and subsequent analysis. The diffractometer can collect about 400 diffraction intensities per day and is similar in principle, if not in design, to the small-molecule diffractometer developed in chemistry by senior research fellow Sten Samson.

Each of the diffracted rays from the crystal has a phase as well as an intensity, but, as always with electromagnetic waves, all that we can observe with ease is the intensity. The phase information, unfortunately, is essential for the structure analysis. If a physicist wants phase information, he builds an interferometer. We do much the same thing, but in this case the chassis on which the interferometer is built is the cytochrome molecule itself. Extensive diffusion and reaction experiments have to be run until some way is found of labeling each molecule in the crystal at the same point with a heavy atom such as platinum or mercury. The interferometry experiment is then the comparison of total diffraction patterns of the protein with and without the heavy atom. This isomorphous replacement method, developed for proteins only 14 years ago by M. F. Perutz, is the key step which makes analysis



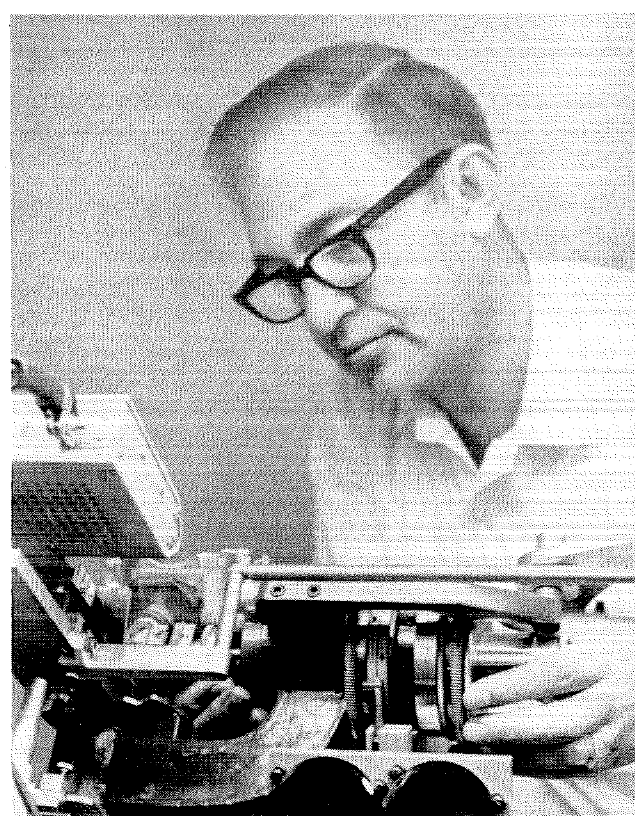
The electron density in the form of computer output is ultimately translated into solid models of molecules such as the ones suspended from the ceiling of the laboratory above the heads of Jon Weinzierl and David Eisenberg.

of such large molecules possible. Two such tagging groups have been found for cytochrome *c*, one containing platinum, the other, mercury.

The result of the x-ray analysis is the electron density at thousands of points through the molecule. This map must be plotted and interpreted in terms of a meaningful chemical structure. The current picture of the molecule is at a resolution of four angstrom units, which means that two features about four angstrom units (or 4×10^{-8} cm) apart would just be resolvable. At this resolution, benzene rings become shapeless blobs, and polypeptide chains become snaking ropes of density through the molecule. The over-all plan of the molecule is visible, though the details are not. But it appears even at this stage that the center of the molecule is filled with atoms of packed hydrocarbon-like amino acid side chains, forming a molecular "oil drop" in which the heme is immersed, sitting in a crevice in one side of the molecule. Enzymes and globular proteins that we find today have evolved to operate well in an aqueous environment. A common feature of those other proteins whose x-ray structures have been deciphered to date (myoglobin, hemoglobin, ribonuclease, chymotrypsin, and lysozyme) seems to be a local region of less polar, non-aqueous surroundings for the reactions with which it is involved. The chemistry of the heme iron will be greatly affected by the polarity of the medium around it.

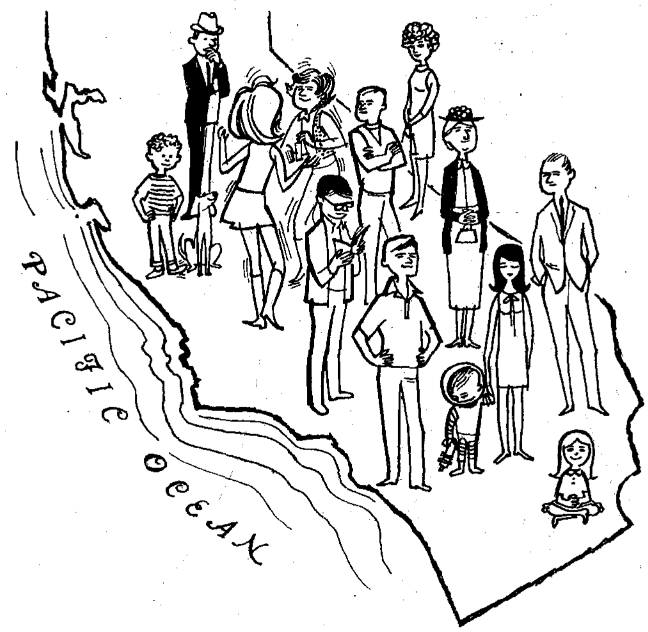
The main feature of the egg-shaped cytochrome *c* molecule is a crevice, running lengthwise, into which the heme group is fitted. The heme is firmly attached to the protein on one side of the crevice by two covalent bonds and by coordination of the iron with the nitrogen atom of a histidine side chain. On the other side of the heme, a polypeptide chain sweeps in a curve past the iron atom and extends another coordinating side chain to it. Some chemists think that this side chain is a particular methionine. If so, then this structurally vital part of the chain would correspond to that part of the chemical sequence which has been absolutely unvarying through a billion years of evolution.

The present incomplete picture has encouraged us and has made us anxious to get on to the next stage, the high resolution analysis. In the coming year David Eisenberg, research fellow in chemistry, Dr. Stanford, the rest of the team, and I will be involved in collecting the data required for a map which will show the details of the path and the folding of the polypeptide chain from which the molecule is built. When the crystallization problem is solved, the reduced molecule analysis will follow.



Richard Stanford adjusts the automatic diffractometer which will be used for high resolution analysis.

A Perspective on Southern California



by Robert W. Oliver

A Caltech professor of economics, who is also a public servant, considers some problems and peculiarities of southern California.

By 1970 the population of the 14 southernmost counties of California—southern California, that is to say—will total almost 14 million people. Already today, in 1967, more people live in southern California than in any state of the union except for New York and, of course, California. In 1960 only 45 percent of the people living in California had been born here, and since 1960 native-born southern Californians have accounted for less than 40 percent of the net population increase. (Texas has headed the list of the states supplying people to California, followed by Illinois, Oklahoma, New York, Missouri, Iowa, Arkansas, Ohio, and Pennsylvania.) Nearly half the population of Los Angeles County, and presumably of southern California generally, is 25 years of age or younger; and almost 70 percent of the people currently migrating into southern California are under 34 years of age. In 1960, 48.5 percent of California's adult population (people over 21 years of age) had not graduated from high school, while 14 percent had not graduated from elementary school.

As one might expect of a rapidly changing, neo-frontier community, the majority of the people in southern California are ambitious, hardworking, self-reliant, self-confident, independent, and a bit arrogant. Correspondingly, they are non-tradition-oriented and anti-intellectual; they tend to be intolerant of failure, preoccupied with personal success, and not too concerned with the public sector of the economy and of the body politic. It may be that these are characteristics of Americans generally, but if so, they are emphasized in southern California.

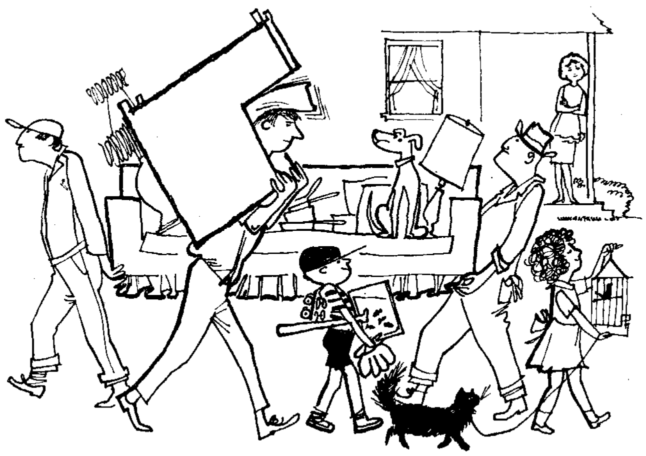
In most respects, of course, southern California is a dazzling success. The standard of living is high and rising for virtually everyone except the elderly and the underemployed in our much-publicized Negro ghettos. Business success is likely, largely because the economy continues to expand as the population grows. Success breeds success. But the forces which direct our destiny create problems.

An obvious consequence of the increasing concentration of people in southern California is the need for planning. We cannot go on using our land extensively the way we used our farmland nationally in the 18th century. We must pay more attention to the long-run viability of new developments; and as population density increases in our central city areas, we are going to have to provide for more open space and for more public buildings, including facilities for education and recreation. We must learn to enjoy more things together.

"A Perspective on Southern California" has been adapted from a talk given by Robert Oliver at the Bishop's Conference of the Episcopal Diocese of Southern California in April 1967. Dr. Oliver is associate professor of economics at Caltech and an elected member of the city council of Pasadena.

As southern California becomes a great urban area stretching from Santa Barbara to San Diego, we will have substantial human relations problems unless we learn to think of people as individuals rather than as members of particular races.

Another problem relates to the psychological instability of some who live in southern California. I have already indicated the large percentage of people who have moved here within their own lifetimes. In addition, as of 1960, only 33 percent of the people in southern California had lived in the same house for as long as five years.



As of 1960, only 33 percent of the people in southern California had lived in the same house for five years.

This kind of peripatetic existence may help to explain the disrespect for society of, for example, women who wear hair curlers in public places. It may explain why adults feel less responsibility for their neighbor's children or even for their own children. The children, in turn, may feel less a part of a family. If grandmother lives in Dayton, Ohio, or Des Moines, Iowa, and the children see her once a decade, their notions of responsibility are likely to be less than if grandmother lived around the corner or had a room of her own in the same house.

Young people may be affected in other ways. The typical teenager is frequently characterized as feeling that he must not allow himself to become too involved, to care too much about the school, or the church, or the society of which he is a part. He is afraid that if he does care he will be hurt by being snatched away from those he cares for. This attitude may even extend to matters of love, making it difficult for young people today to love deeply.

While California is blessed with an abundance of skilled and well-educated technical people, we are *on the average, and in a classical sense,* poorly educated. Unemployment in southern California is a function, in part, of the lack of education. So is our tendency to think of many issues in simple terms, to believe that there is a clear-cut correct solution for all problems. People who belong to the Communist Party, on the one hand, or the John Birch Society, on the other hand—to take two organizations at random—are illustrative of this point. An important function of education is to help people be aware of the rules of evidence, to avoid the mistake of starting with a conclusion and working backwards to the facts. A proper education teaches people not to accept something as true simply because it is in print. It induces a healthy skepticism.

Let me turn now, in somewhat greater detail, to a problem I happen to be particularly aware of as a councilman in the city of Pasadena, and let me relate this problem to the characteristics of southern California as a community. The issue might be called the crisis of local finance, by which I mean the extraordinary difficulties currently encountered by school districts and local governments in financing essential public services.

The problem stems in part from the regressive nature of the property tax, the major source of revenue for local jurisdictions. In 1959, those households in southern California whose incomes were $3,000 a year were paying 6.9 percent of their incomes for property taxes; those with annual incomes of $10,000 were paying only 3.6 percent; and those with $17,000 were paying 2.86 percent. In short, the property tax takes a larger fraction of the incomes of low-income families. It is small wonder, therefore, that local bond issues which will be paid off by property taxes are opposed most vehemently in most cities and in most school districts by those whose incomes are low. In the city of Pasadena almost every bond issue is approved 4 or 5 to 1 in the wealthier sections of the city while it barely breaks even in the poorer sections.

The other aspect of this problem is the increase in the financial needs of local jurisdictions relative to the incomes of those who pay property taxes, and this is directly related to the increasing population concentration and declining median age in southern California, as well as to the need for more and better education.

Over 21 percent of the population of southern California is now in our public schools as compared with 15 percent as recently as 1950. Most students stay in school longer than they did 15 years ago. More adult education is being offered. (Nearly 50 percent of the adults in southern California did not have a high school diploma in 1960.)

Put these together, and it is clear that an extraordinary expansion of the public school system has been required at all levels and that per-student costs have risen substantially. (The cost per student in elementary schools in Los Angeles County in 1963-64 was $413 a year; in high schools, $634; in junior colleges, $735. But the burden was not shared equally. In 1965, for example, Beverly Hills had a tax rate to support schools of only $2.62. The city of Los Angeles had a rate of $4.25, and the Little Lake School District had $7.15.)

City governments are not much better off than school systems. Their expenditures have not risen as rapidly, but the need has risen faster than actual spending. There is an acute need for more policemen and higher police salaries, for more counseling of those who commit crimes, and for more fire protection as we increase the amount of building per square foot of land. Even if we leave out of account the newer kinds of local spending—for urban renewal, for recreation, for health and welfare—the requirements for spending by city governments would be increasing absolutely and, probably, per capita.

This is happening, moreover, at the same time that the land area available to be taxed is decreasing. Taxable land decreases whenever a freeway goes through a city. Pasadena now has two freeways about to go through it, plus an enormous interchange which will take something like a hundred acres of taxable land out of the center of the city. When ordinary streets are widened, land is taken off the tax rolls. Tax-exempt institutions, like senior citizen homes and private welfare agencies, seem to be increasing. Caltech is continually expanding and taking land off the tax rolls of the city of Pasadena, yet Caltech expects the Pasadena fire department to put out fires and the police department to protect its campus.

To some extent, the state government helps local jurisdictions. The one thing the city of Pasadena seems able to do without any great difficulty is to widen its streets. Periodically the city engineer reports that we have enough state-collected gas-tax revenue to finance the widening of another street. But if somebody says, "Let's plant a tree," "Let's build a playground," or "Let's do things for people instead of automobiles," we don't seem to have the money.

Let me mention in passing some possible solutions. It has been suggested that we rearrange the taxing system in California so that the property tax is used exclusively by city governments—school systems being financed by the state sales and income taxes. The general structure of the tax system would then be somewhat less regressive. It would be more consistent with the venerable principle: He who benefits shall pay. Such a proposal came close to being introduced in the legislature in 1966 and was discussed by the Reagan administration this year. It clearly merits attention.

If somebody says, "Let's do things for people instead of automobiles," we don't seem to have the money.

Another revenue-sharing proposal very much in the air is that a larger portion of the income tax revenue collected by the federal government should be returned either to states or to cities, with or without strings attached.

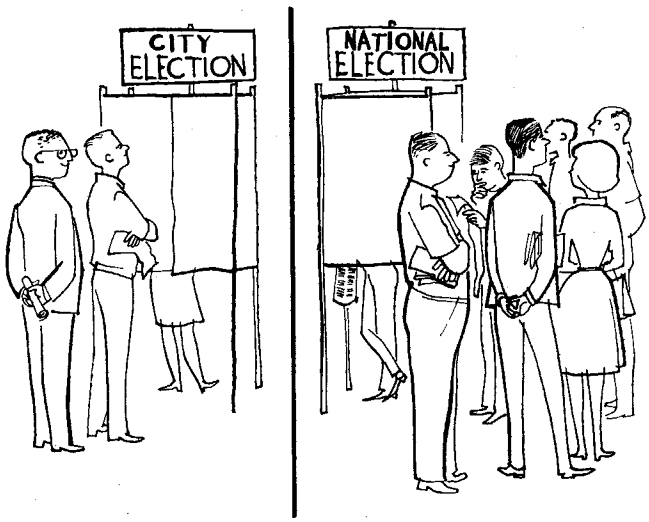
Since 1938, the federal government's share of total spending by all levels of government in the United States has increased slightly, if one includes expenditures for national defense, but its share of spending *for strictly civilian purposes* had decreased from 36 percent of the total in 1938 to 23 percent in 1964. If peace should break out in the world, the federal government could decrease taxes, hoping that the local and state governments would correspondingly make more use of the income tax, or it could continue to collect income taxes but return a substantial portion to local and/or state governments. This latter proposal, generally known as the Heller Plan because it was originally proposed by the now famous economist who was chairman of President Kennedy's Council of Economic Advisors, has become a part of the platform of the Republican Party. With substantial bipartisan support, it seems likely to be adopted in some form at some time in the foreseeable future.

An important unsettled question is: Should federal funds be provided as unfettered grants or only with strings attached?

Many people in southern California seem to assume that the former is better. Such an attitude is consistent with our predilections of independence.

We believe that the government closest to the taxpayer knows best how the taxpayer's money should be spent.

This is not obviously correct, however. In the city of Pasadena, only 25 percent of the voters turn out to elect city councilmen. This suggests that the



People are less concerned about what is happening locally than about what is happening nationally.

people are less concerned about what is happening locally than about what is happening nationally. And there is the so-called local "establishment." A prominent citizen once told me that, with one exception, he had personally selected everyone who had been elected to the Pasadena City Council in 20 years. He was probably exaggerating somewhat. In any event he required cooperation. But I think it's fair to say that a small number of people have decided who was to be elected to the Pasadena City Council much of the time.

There is nothing *necessarily* insidious about this. The people who put money into a local political campaign are people who have strong views about local affairs. They are people who devote a good deal of time to their city. They are prominent in local organizations that get things done. In short, they get their candidates elected because they care enough about their city to work for it. There is much to be said, furthermore, for a system whereby people can call their councilman on the telephone and say, "John, don't you think we ought to do it this way?" It is easier than calling Washington; it is a great deal easier than trying to argue about your income tax with some clerk from the Internal Revenue Service. Still there is a question about the ability of the local councilman to consider the welfare of the entire city as distinct from the welfare of the people who elected him. Local government can be "government by crony."

There is also a question as to whether local funds will be used for imaginative programs. In Pasadena, the special teaching help for children whose educational background is deficient is financed mainly by the federal and state governments. Federal grants to increase the open space in cities are available because Congress has decided that the cities have paid too little attention to open space. Federal grants are available to plant trees and grass and to preserve historic buildings, the things of history having been thought to be important by somebody in Washington. It took the forceful encouragement of the federal government to bring about a regional association of governments in southern California, thereby making it necessary for representatives of the cities of southern California to talk about regional problems and to hire a staff to carry out common planning objectives.

In short, many good programs are being carried out at the local level not only because they are being financed, but also because they have been conceived by the federal government. Thus, there is much to be said for a continuing federal-local government partnership.

Regardless of how the crisis of local finance is resolved, however, the more basic problems of a rapidly changing, highly mechanized, increasingly concentrated urban society will remain, and they will not be solved unless we increase somewhat our concern for the public good. The greatest challenges to our collective happiness—ugliness, noise, air pollution, crime, choked freeways, ghettos—require collective responses.

By economic standards, America is the most successful nation in the history of the world, and southern California is an exaggerated, small-scale model of America. The success of America has been due in large measure, moreover, to the hard work, individual initiative, and imagination of its people. Nevertheless, many Americans tend to underestimate the contribution to happiness of things people share, perhaps work together to obtain: such things as music and art, clean air, park land, public buildings, law and order, and educated people. Being quick to attribute the failure of others to an unwillingness to work, they devote too little attention to the ways and means of securing the American dream of equal opportunity for all.

We should remind ourselves periodically that Americans are wealthy not only because they work hard, but also because the land has been good and because we have had good government, good public institutions, and a traditional belief that society's obligation to us is not greater than our obligation to society.

A not-unbiased report from Caltech's undergraduate Ad Hoc Committee on the Admission of Women which says, in effect:

Bring on the Girls!

On October 9, 1967, the faculty Ad Hoc Committee on the Freshman and Sophomore Years presented a proposal to the Faculty Board to admit women to Caltech as undergraduates. As soon as this news reached the students, several independent organizations sprang simultaneously into action, each trying to figure out how to ensure that the faculty would become informed about student opinion on the proposal. The most notable of these organizations were the ASCIT Educational Policies Committee (whose title describes its function) and the ASCIT Executive Committee (charged with the investigation of major problems facing Caltech undergraduates). Before long the resources of these two groups were combined into a student Ad Hoc Committee on the Admission of Women.

Every Thursday afternoon the group met to discuss the advantages and disadvantages of the admission of women and the means of making the proposal more attractive and more practicable. It is rare that student interest can be mobilized and concentrated at Caltech, and the speed with which this mobilization and concentration took place after October 9 is unambiguous testimony to the urgency of the problem involved.

The great bulk of the work of the Ad Hoc Committee on the Admission of Women was concerned with such practical considerations as housing and a Dean of Women. But the committee also discovered a number of *need areas* to bring to the attention of the faculty.

The principal arguments of the committee in these need areas are: The systematic discrimination against all females in the admission policy at Caltech is morally unjustifiable. If we were living in the Middle Ages, it would be easy enough to understand this discrimination—it would simply be a product of our unshakable conviction that women are second-rate human beings, merely a derivative of a man's rib. But to carry the trappings of monasticism into the 20th century and to impose them upon an institute which purports to be in the vanguard of scientific knowledge is surely an intolerable anachronism.

Many people seem to feel there is something fundamentally wrong with life at Caltech; but, like the weather or an act of God, no one seems to do anything about it. They simply shrug their shoulders and say that the excellent education makes up for it. But this is the worst sort of insensitivity. The monastic environment at Caltech has a chronically depressing effect on many—perhaps most—of the students.

To expect a normal 18-to-20-year-old young man to live in isolation from womankind and to be happy is the most foolish thing imaginable. Yet the Caltech admissions policy systematically augments this isolation.

Not only does the absence of femininity at Caltech make its students unhappy; it also acts as a positive deterrent to their social growth and maturity. If one looks around, he may conclude that freshmen have more social grace and appear a lot more "normal" than seniors. To take the attitude that it does not matter whether Caltech students mature or grow socially, as long as they can solve partial differential equations, is as myopic as it is commonplace.

The admission of women would help students learn how to deal with other people—a trait for which Caltech students are not renowned.

Not only would it be more equitable, not only would the happiness and social maturity of students be enhanced, but, if women were to become a part of Caltech undergraduate life, the Institute itself would very likely begin to reap benefits. At the present time qualified high school graduates sometimes elect to go to other schools because Caltech is not co-ed. Unquestionably the greatest cause of attrition during the undergraduate years at Caltech is the dissatisfaction with a monastic environment when other schools offer a good education and, in addition, a normal male *and* female environment. Caltech loses graduate students it might otherwise gain from its own undergraduate population because it is not co-ed. And, of course, Caltech completely ignores the pool of high school talent which happens to have been born female. All of these effects decrease the over-all quality of the students Caltech gets.

Women would add a new dimension to class discussion at Caltech. At the present time discussion is lopsided. Girls would bring a new viewpoint.

Finally, with improved student morale, the Institute could expect better academic performance—if not in terms of grade-point average, then certainly in terms of enthusiasm and interest.

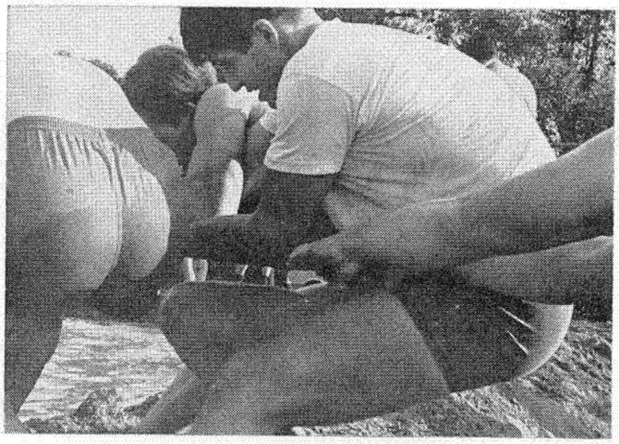
In fairness to everyone—the girls, the present undergraduates, and the Institute—women should at long last be admitted to Caltech.

—Richard Flammang '68

On November 27 the Institute moved one step closer to admitting women undergraduates when the faculty voted, by a large majority, to "recommend to the Administration and Board of Trustees that the Institute proceed with all deliberate speed to the admission of women to undergraduate work at Caltech."

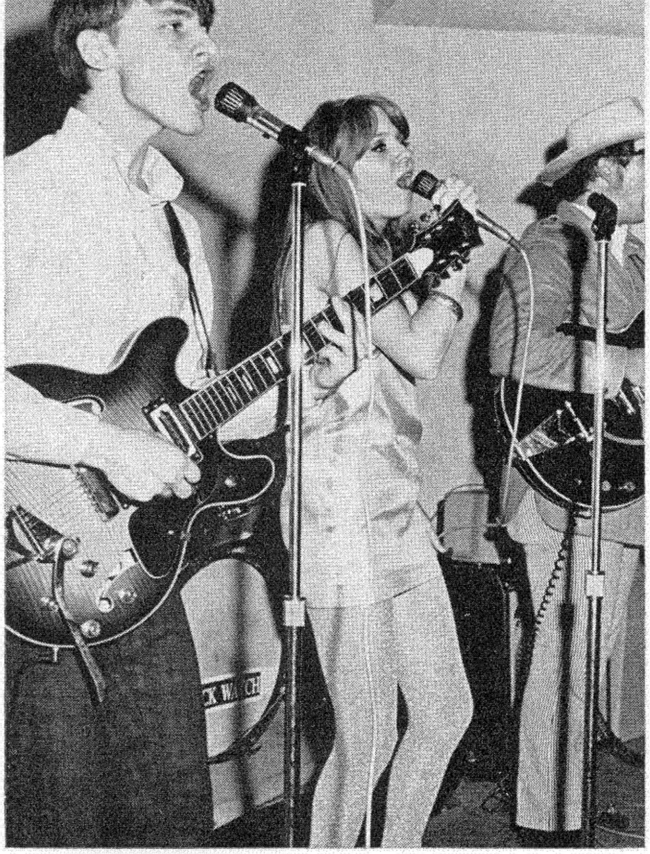
Though the faculty thereby indicated its approval, in principle, of women undergraduates, specific suggestions for the implementation of this proposal must now be worked out before the recommendation is sent to the Board of Trustees. —Ed.

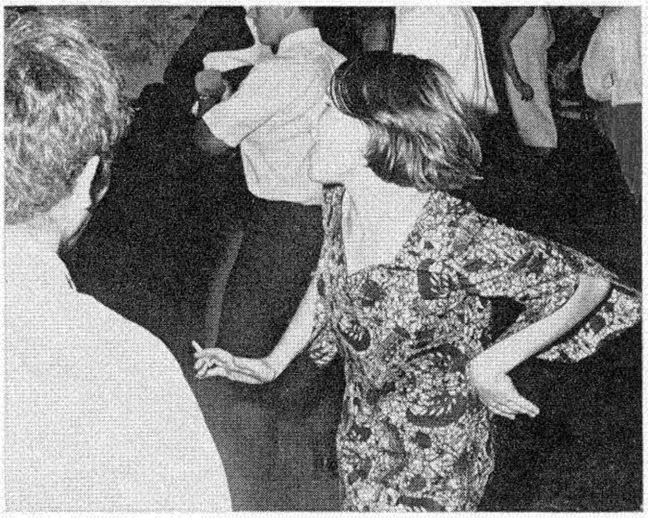
THE MONTH AT CALTECH

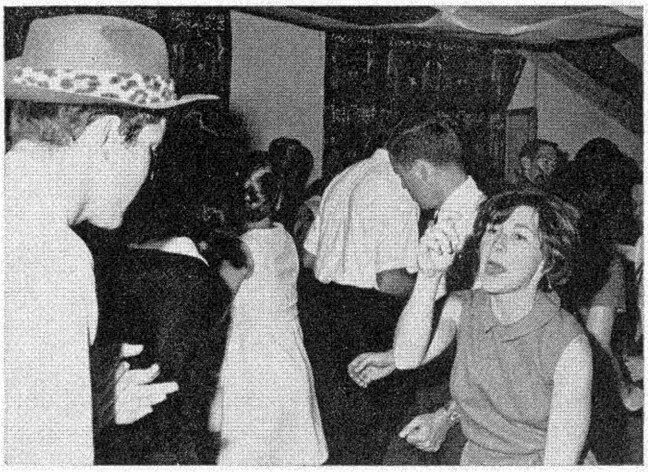


NEVER SAY DIE

Hallowed traditions disappear almost daily at Caltech, but one durable old tradition that refuses to lie down and die is the Mudeo. On November 14 teams of eager freshmen and sophomores slid once again into the big mud pit for the 53rd annual Mudeo. The freshmen won this one, so the sophomores threw the judges into the pit—to join the buried tennis shoes, T-shirts, and spectacles.





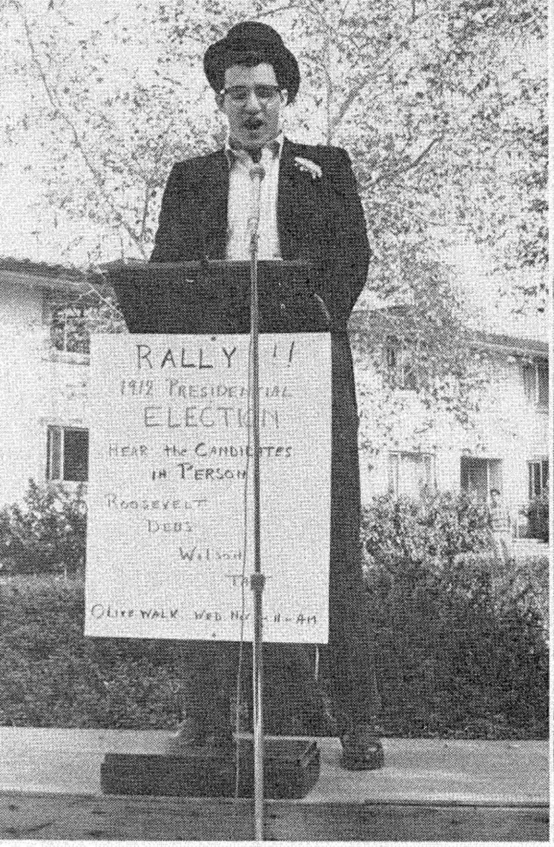


INTERHOUSE

Caltech's seven undergraduate student houses rolled up the rugs November 18 for the annual Interhouse Dance. The complex construction efforts ranged from Snow White's cottage to the Kingdom of Id, an Indonesian temple, and a prehistoric rain forest, but the BIG thing this year was sound (electronic) and light (psychedelic)—of which there was a surfeit.

SOME LIKE IT HOT

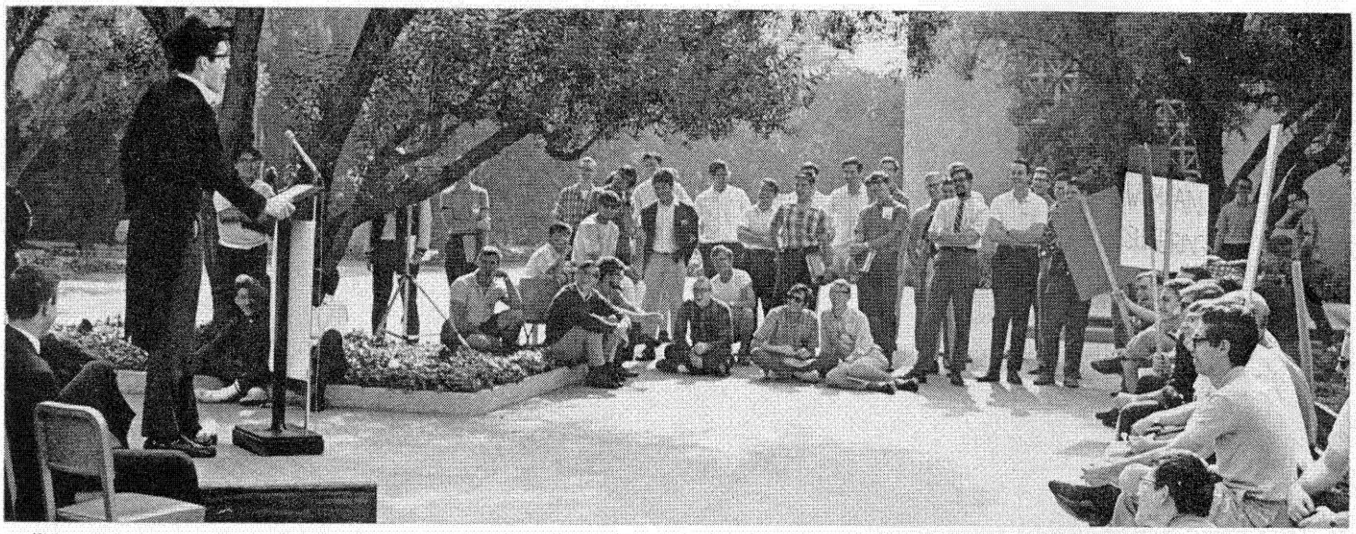
A Dixieland band strutted into Beckman Auditorium in New Orleans marching style for a November 12 concert sponsored by the Caltech YMCA. The Southern California Hot Jazz Society furnished the musicians, which included some of the great old Dixieland names, and the Caltech community, which included some students who, God forbid, had never heard Dixieland before, furnished the stomping feet.



Woodrow Wilson

William Howard Taft

Eugene Debs



*"I want to pay my tribute of respect to the President of the United States. I do not think any man who knows his facts can question the patriotism or the integrity or the public purpose of the man who now presides at the executive office in Washington, D. C."**

TAFT IS THE MAN TO BEAT!

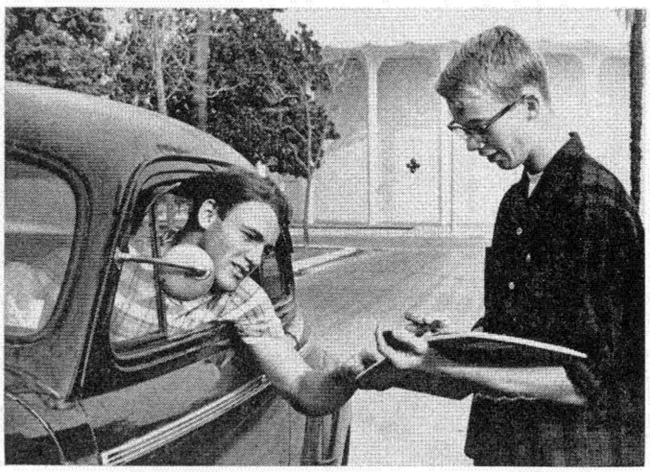
First came the candidates. Then their party supporters moved in with banners and posters. Up went the speakers' platform and the microphone, and the presidential campaign was under way on the Olive Walk, in the center of the campus, in the middle of the morning of November 8.

The campaign of 1912, that is.

Caltech students of History 151 ("Industrialization, Change, and an Age of Reform in America, 1865-1917") were concluding an assignment for Robert L. Woodbury, assistant professor of history. They had planned and charted a national presidential campaign strategy for the political party of their choice—the Socialist, Progressive "Bull Moose," Republican, or Democratic. Using only material that was public domain in 1912 (hindsight was considered out of bounds), and with the help of rolls and rolls of microfilm of *The New York Times* 1912 editions, members of the four parties delivered their 1912 campaign speeches to a gathering of slightly bewildered, but highly entertained 1967 passersby.

*Woodrow Wilson, of William Howard Taft—November 1967, Olive Walk

THE HONORABLE THOMAS H. KUCHEL *came to Caltech on November 30 at the invitation of the Caltech YMCA, not only to talk but to listen. The Senator gave a public lecture in Beckman Auditorium on the problem of the ghetto, the subject of the Y's year-long study program. But at a seminar of students, Senator Kuchel asked a few questions and did a lot of listening. Many of the answers he got came directly from the ghetto—from representatives from the Westside Study Center in Pasadena.*



Traffic timers Tom Burton and Ray Ellis.

ANOTHER ROSE BOWL INCIDENT

Drivers to the Rose Bowl game this New Year's Day may have two Caltech students to thank for saving them a $1 parking fee and the possibility of being late for the kickoff. Juniors Ray Ellis and Tom Burton were recently asked to do a time-delay study for the director of special projects of Pasadena in connection with the city's proposed Rose Bowl pay-parking program. The boys ran a series of timings on cars stopping, paying, and starting; accumulated some related statistics; and did a bit of calculating. They came up with the conclusion that 5,700 drivers would still be trying to get into the parking lot when the game began. Their report may have had something to do with the city's recent decision to shelve the project.

STUDENTS TACKLE SMOG

At an ASCIT board meeting in the spring of 1966, members talked over, for the first time, the need and desire among the student body for "something" that the undergraduates could do together that would involve them in science *and* the social sciences.

Out of that discussion has come a proposed two-year undergraduate research project which could involve more than 200 Caltech students, 50 or more participants from other campuses around the country, and up to 100 technician-trainees from ghetto areas around Los Angeles.

When Caltech classes began this fall, a special committee of students which had been meeting through the summer called an all-student meeting to choose a specific project from among a number of suggestions. The result is: A PROGRAM BY THE ASSOCIATED STUDENTS OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY FOR THE STUDY OF AIR POLLUTION.

In addition to a title, the project has some other concrete aspects: 100 students who have signed on to participate; a 12-man faculty advisory committee; a network of student, planning subcommittees; $2,000 from the Institute to set up project headquarters on the second floor of the converted residence that now functions as a student coffee house; an elaborate contextual map designed by Fred Thompson, professor of applied science and philosophy, to keep up-to-date information on current project developments available at a glance; and the draft of a proposal for $110,000 to finance a six-month pilot project, scheduled to begin in February 1968. In the next few weeks these funds are to be sought from an outside source.

Some of the specifics are still loosely defined on paper, but the project's purpose is firmly stated:

"The ASCIT research project is an experiment in redefining the American student into a vital member of society. By attacking a problem of national scope through areas of social, technical, economic, and psychological study and application, the project will call attention to the problem of the student and to the problems of Los Angeles County as well as the actual problem of air pollution.

"The research project is also an experiment in education. University students in the U.S. typically experience education as a sequence of vaguely related concepts. The research project offers an experience in problem-oriented education, that is, in tackling a real problem of sufficient complexity to encourage individual scholarship."

CALTECH'S NEXT PRESIDENT

A serious task faced by Caltech is currently being considered by a faculty committee headed by Robert P. Sharp, professor of geology. At the request of Arnold O. Beckman, chairman of the Caltech board of trustees, the former chairman of the faculty, Jesse Greenstein, acting with the advice and consent of the faculty board, appointed a faculty committee to consult with and advise the trustees upon candidates to succeed Lee A. DuBridge as president of Caltech.

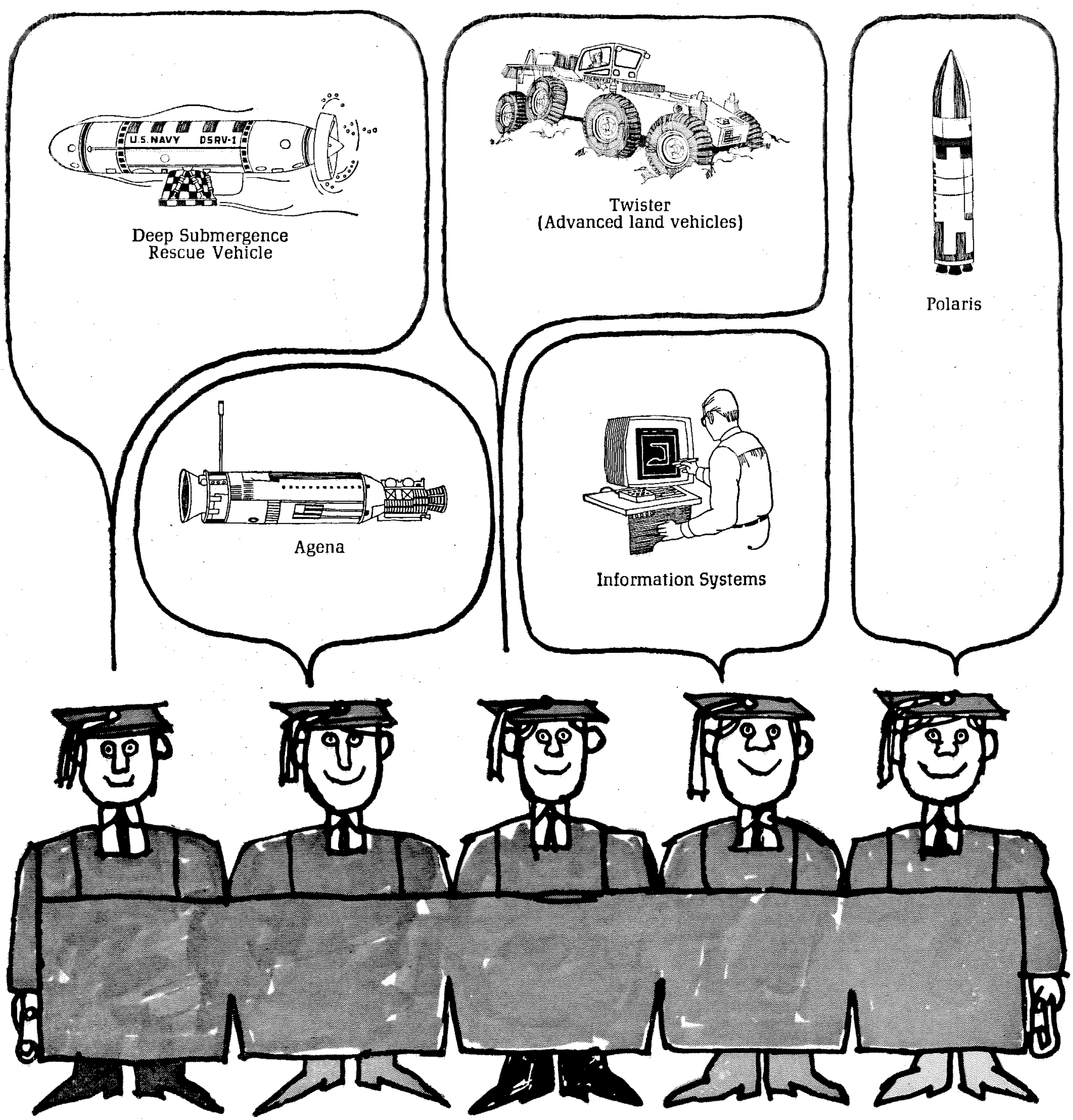
The faculty committee consists of 14 members: James Bonner, Norman Brooks, Robert Christy, Norman Davidson, Jesse Greenstein, Marshall Hall, George Hammond, Robert Huttenback, Lester Lees, Robert Leighton, Ned Munger, William Pickering, Hardy Martel, and Robert Sharp.

At its meeting of November 28, Dr. Sharp discussed the committee's plans and progress with the board of directors of the alumni association. He reported that a large list of names is being prepared from which the committee will ultimately choose a small number of especially attractive candidates for submission to the board of trustees, which is responsible for the final selection. Dr. Sharp stressed that the committee is eager to promote communication concerning potential candidates and would welcome comments and suggestions from alumni.

Why engineering students graduate to Lockheed.

Progress is a matter of degrees. But, that's only the beginning. At Lockheed Missiles and Space Company, we're working on wideworld... otherworld... upperworld... and subworld projects. ☐ We're pretty high on space... we've got Agena to prove it. And, when it comes to ballistic missiles, Polaris and Poseidon show an arc of triumph. We think deeply, too... consider our deep submergence vehicles, for example. And, just to show you our feet are solidly on the ground, we're working on advanced land vehicles. Information? Business, government and industry get it out of our systems. ☐ For more information write to: Mr. R. C. Birdsall, Professional Placement Manager, P.O. Box 504, Sunnyvale, California 94088. Lockheed is an equal opportunity employer.

LOCKHEED
MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION



ALUMNI DIRECTORY SUPPLEMENT

A supplement to the 1966 Alumni Directory will be ready for distribution some time after the first of January, 1968. This supplement will list the names and addresses of those who *received degrees in June 1966 and 1967.* Copies of this supplement will be sent automatically to Association members who received degrees in 1966 and 1967. Other Association members may secure a copy of this supplement by filling in the form below and sending it to the Alumni Office.

Please send the 1968 Supplement of the 1966 Alumni Directory to:

Name..

Address..

City....................State................Zip Code..............

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION (Act of October 23, 1962; Section 4369, Title 39, United States Code). 1. DATE OF FILING: September 25, 1967. 2. TITLE OF PUBLICATION: *Engineering and Science.* 3. FREQUENCY OF ISSUE: Monthly, October through June. 4. LOCATION OF KNOWN OFFICE OF PUBLICATION: California Institute of Technology, 1201 E. California Blvd., Pasadena, Los Angeles County, California 91109. 5. LOCATION OF THE HEADQUARTERS OR GENERAL BUSINESS OFFICES OF THE PUBLISHERS: California Institute of Technology, 1201 E. California Blvd., Pasadena, Los Angeles County, California 91109. 6. NAMES AND ADDRESSES OF PUBLISHER AND EDITOR: PUBLISHER—Alumni Association, California Institute of Technology, Pasadena, California. EDITOR—Edward Hutchings Jr., California Institute of Technology, Pasadena, California. 7. OWNER: Alumni Association, California Institute of Technology, 1201 E. California Blvd., Pasadena, California. 8. KNOWN BONDHOLDERS, MORTGAGEES, AND OTHER SECURITY HOLDERS OWNING OR HOLDING 1 PERCENT OR MORE OF TOTAL AMOUNT OF BONDS, MORTGAGES, OR OTHER SECURITIES: None. 10. EXTENT AND NATURE OF CIRCULATION: A. Total no. copies printed—Average no. copies each issue during preceding 12 months, 6855; single issue nearest to filing date, 6800. B. Paid circulation—1. Sales through dealers and carriers, street vendors and counter sales: Average no. copies each issue during preceding 12 months, 135; single issue nearest to filing date, 110. 2. Mail subscriptions: Average no. copies each issue during preceding 12 months, 5575; single issue nearest to filing date, 5330. C. Total paid circulation—Average no. copies each issue during preceding 12 months, 5710; single issue nearest to filing date, 5440. D. Free distribution by mail, carrier or other means—Average no. copies each issue during preceding 12 months, 850; single issue nearest to filing date, 930. E. Total distribution—Average no. copies each issue during preceding 12 months, 6560; single issue nearest to filing date, 6370. F. Office use, left-over, unaccounted, spoiled after printing—Average no. copies each issue during preceding 12 months, 295; single issue nearest to filing date, 430. G. Total—Average no. copies each issue during preceding 12 months, 6855; single issue nearest to filing date, 6800. I certify that the statements made by me above are correct and complete.

Edward Hutchings Jr., Editor and Business Manager.

GIFT IDEA

The **Caltech Glee Club** has a limited supply of recordings from its home concerts:

1960, 1961*, 1962, 1963, 1964, 1965* @ $3.00 each; 1967** @ $4.50 each.

Please send orders to: Caltech Glee Club
Dabney Hall, Caltech
Pasadena, Calif. 91109

* available in mono or stereo (please specify)
** compatible stereo (play on mono or stereo)

Price includes postage and handling

ALUMNI ASSOCIATION OFFICERS AND DIRECTORS

PRESIDENT
Frederic T. Selleck '49

SECRETARY
Donald S. Clark, '29

VICE PRESIDENT
Donald D. Davidson '38

TREASURER
John R. Fee, '51

Fred C. Anson, '54
Horace W. Baker, '35
William F. Chapin, '41
Manfred Eimer, '47
Craig T. Elliott, '58
Sidney K. Gally, '41
Robert C. Perpall, '52
Martin H. Webster, '37

ALUMNI CHAPTER OFFICERS

NEW YORK CHAPTER

President Willis A. Bussard, '44
Appleby Drive, RFD 1, Box 78B, Bedford, N.Y. 10506
Vice-President Frederick E. Wood, Jr., '51
c/o IBM 1000 Westchester Ave., White Plains, N.Y. 10604
Secretary-Treasurer Harry J. Moore, Jr., '48
c/o IBM, Old Orchard Rd., Armonk, New York 10504

BOSTON CHAPTER

President Francis Morse, '40
16 Reservoir Rd., Wayland, Mass. 01778
Vice-President Theodore G. Johnson, '57
Annursnac Hill Rd., Concord, Mass. 01742
Secretary-Treasurer Thomas C. Stockebrand, '53
Depot Rd., Boxborough, Mass. 01720

WASHINGTON, D.C. CHAPTER

President Willard M. Hanger, '43
4720 Sedgwick St.,N.W., Washington, D.C. 20016
Vice-President Bernard B. Watson, '35
Research Analysis Corporation, McLean, Va. 22101
Secretary-Treasurer John T. Cookson, Jr., '66
1225 Noyes Drive, Silver Springs, Md. 20910

CHICAGO CHAPTER

President Laurence H. Nobles, '49
Dept. of Geology, Northwestern Univ., Evanston, Ill. 60201
Vice-President Philip E. Smith, '39
714 Forest Ave., Wilmette, Ill. 60091

SAN FRANCISCO CHAPTER

President G. Neal Huntley, '54
3136 Padre St., Lafayette, Calif. 94549
Vice-President William N. Harris, '49
5 Pembroke Pl., Menlo Park, Calif. 94025
Secretary-Treasurer Harrison W. Sigworth, '44
10 Casa Vieja, Orinda, Calif. 94563

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

SACRAMENTO CHAPTER

President Kenneth M. Fenwick, '28
6161 Riverton Way, Sacramento, Calif. 95831
Vice-President Wayne MacRostie, '42
3840 San Ysidro Way, Sacramento, Calif. 95825
Secretary-Treasurer Herbert H. Deardorff, '30
3849 Annadale Lane, Apt. 4, Sacramento, Calif. 95821

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

General Motors is people making better products for people.

Ben Bouier makes his mark of excellence with a brush.

Ben Bouier came to General Motors 13 years ago. As a janitor. He was soon a machine operator. He went to night school. Took electronics, engineering and drafting courses.

Today, he's a Graphic Illustrator at GM. His job: Helping set up the quality control standards of excellence followed by GM car divisions everywhere.

Ben Bouier is only one of many highly-skilled, self-made men who have made their mark at GM by making the pursuit of perfection a way of life.

It's one of many good reasons why you will always find the Mark of Excellence on every Chevrolet, Pontiac, Oldsmobile, Buick and Cadillac car.

Benjamin H. Bouier, Jr., GM Manufacturing Development Staff, Warren, Michigan.

"Traffic is terrible today!"

". . . Accident in the left hand lane of the Queens-Midtown access ramp. Right lanes moving slowly. Fifteen minute delay at the Brooklyn Battery Tunnel. Lincoln Tunnel backed up to the Jersey Turnpike. Extensive delays on Route 46 in the Ft. Lee area. That's the traffic picture for now, Bob."

However, technical people at GE are doing something about it. Development and design engineers are creating and improving electronic controls and propulsion systems to guide and power transit trains at 160 mph. Application engineers are developing computerized traffic control systems. Manufacturing engineers are developing production equipment and new methods to build better transportation products. And technical marketing specialists are bringing these products and systems to the marketplace by working with municipal and government agencies.

Young engineers at GE are also working on the solutions to thousands of other challenging problems—products for the home; for industry; systems for space exploration and defense. When you begin considering a career starting point, think about General Electric. For more information write for brochure ENS-P-65H, Technical Career Opportunities at General Electric. Our address is General Electric Co., Section 699-22, Schenectady, New York 12305.

GENERAL ELECTRIC