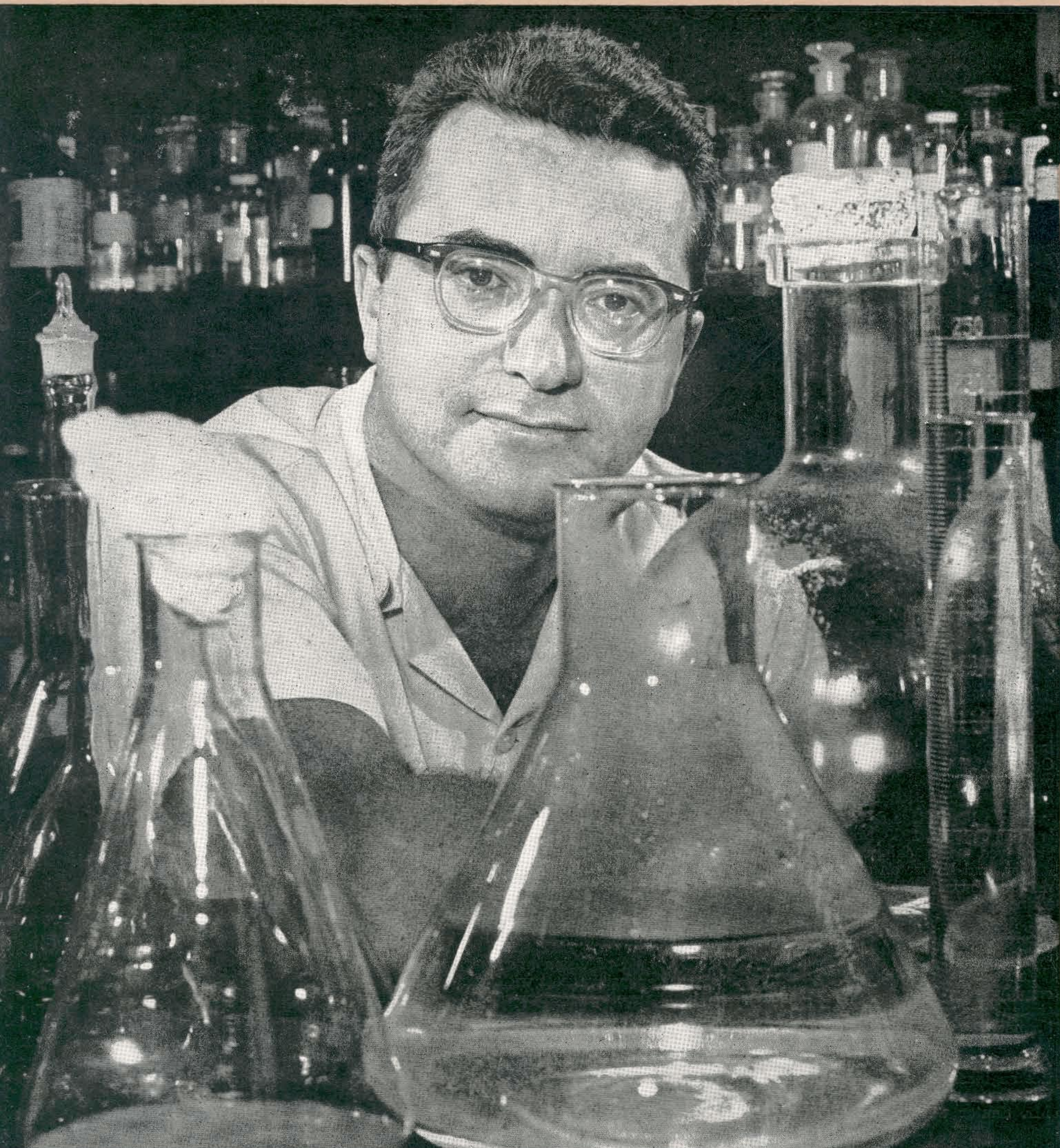
ENGINEERING | AND | SCIENCE

NOVEMBER/1956



The Origin of Life . . . page 21

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

ENGINEERING AND SCIENCE

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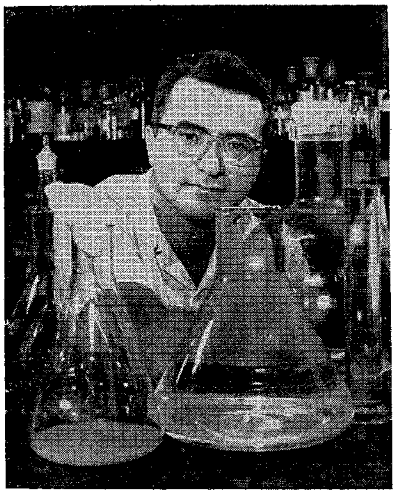

On our cover this month—Dr. Norman H. Horowitz, professor of biology at Caltech, and author of the article on page 21, "The Origin of Life." In this absorbing article, Dr. Horowitz, a geneticist, traces the history of man's attempts to discover the fundamental characteristics of living matter, from the earliest time down to the present.

"Volcanoes, Ice and Destructive Waves," the article on page 26, started life as a Friday Evening Demonstration Lecture at Caltech last spring. It was given, and written, by Dr. Frank Press, who came to Caltech last year as professor of geophysics. Dr. Press taught previously at Columbia University, where he received his PhD in 1949. He is well known for his geophysical investigations of the crustal structure of the continents and ocean basins, and for theoretical and experimental work on elastic wave propagation.

The letters are still coming in on Dr. Richard P. Feynman's article, "The Relation of Science and Religion," which ran in our June isue. You'll find some of the more provocative ones on page 6.

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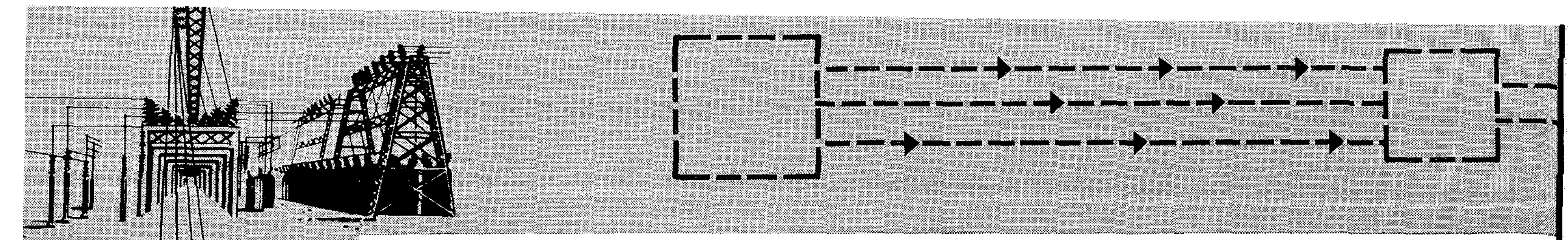
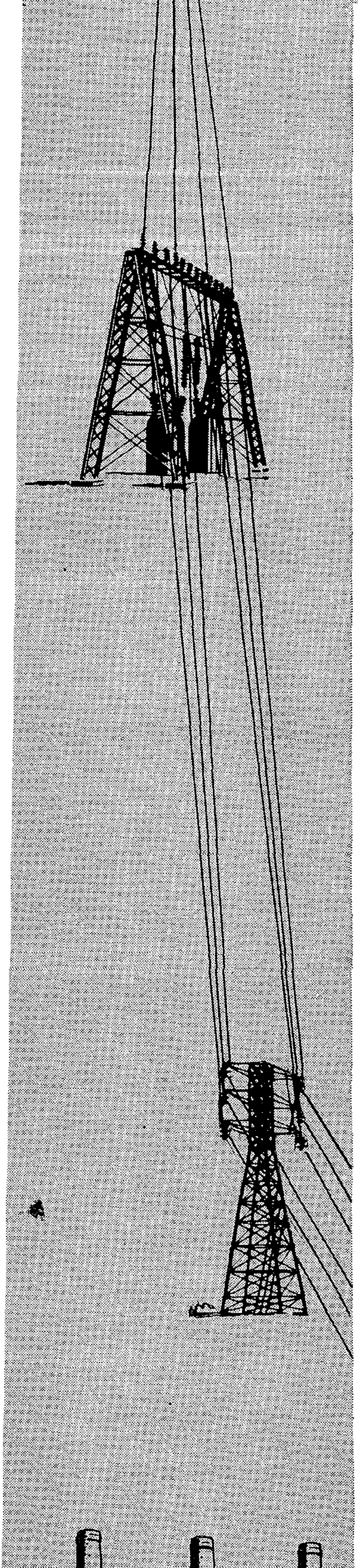




The Importance of

Coverings and Sheaths for

THE TERM "COVERINGS", as applied to insulated electrical wires and cables, refers to a relatively continuous homogeneous layer or layers of impervious and inert material, applied over an insulated conductor or conductor assembly for the purpose of protecting such conductors from moisture, chemical attack and mechanical damage. Coverings may be colored to indicate circuit identification. Chemical attack refers to damage to the insulation resulting from acids, alkalies and other chemicals in the atmosphere, the ducts or soil in which the cables may be installed. Mechanical damage may result from the abrading, compressing, cutting and tearing forces to which the insulation may be subjected during installation and service.

Coverings may be made of metallic or non-metallic materials. Metallic coverings may be, (1) a continuous metal tube over the insulated conductor, usually made of lead and known as a lead sheath, (2) metal tapes applied spirally about the insulated conductor and referred to as an armor or a shield, depending on the purpose for which it is used, or, (3) metal wires applied spirally either in one direction or in the form of a braid, and again known as an armor or a shield. Armor is a covering applied primarily for mechanical protection or to add strength while a shield is applied to protect the insulation from electrical stresses or for safety purposes. Non-metallic coverings may consist of, (1) a continuous layer of vulcanized rubber or rubber-like material, generally neoprene, or a thermoplastic material, called a jacket, (2) spirally applied, moisture-resistant fibrous yarn, usually cotton or jute, (3) moisture-resistant fibrous tapes, or, (4) moisture-resistant fibrous braids. Combinations of two or more of these may be used as explained later.

The kind and number of coverings used is determined largely by the size of the conductor or cable, the type of insulation on the conductor and the installation conditions. The following is a brief outline of the types of coverings required for the more important types of insulations and installation conditions.

INSTALLATION in DRY CONDUITS and DUCTS

Single-conductor rubber and varnished-cambric insulated cables require a covering over the insulation consisting of a moisture-resistant cotton braid on the small sizes and a double braid or tape and braid on the large sizes for protection against mechanical damage. On 600 volt cables for installation in buildings this covering must be flame-resistant, and is usually colored for circuit identification. A thin layer of neoprene may replace such fibrous coverings on rubber-insulated cables. Paper-insulated cables require a lead sheath for retention of the impregnant and for mechanical protection. Single-conductor polyvinyl chloride insulated cables usually require no coverings since they are generally considered resistant to flame and chemical and mechanical damage.

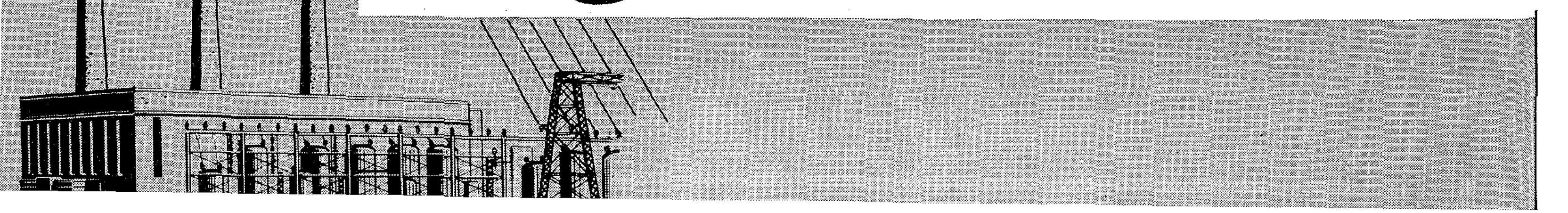
Multiple-conductor cables which consist of two or more single conductors assembled as a unit are protected by an outer covering. The individual conductors of multiple-conductor rubber insulated cables are generally protected by a single fibrous covering. The outer covering of multiple-conductor cables usually consists of a tape and moisture-resistant cotton braid on rubber and varnished-cambric insulated cables. A neoprene jacket may replace the outer braid on rubber-insulated cables. A polyvinyl chloride jacket is generally used on polyvinyl chloride insulated multiple-conductor cables. Multiple-conductor paper-insulated cables have a lead sheath over the assembled insulated conductors.

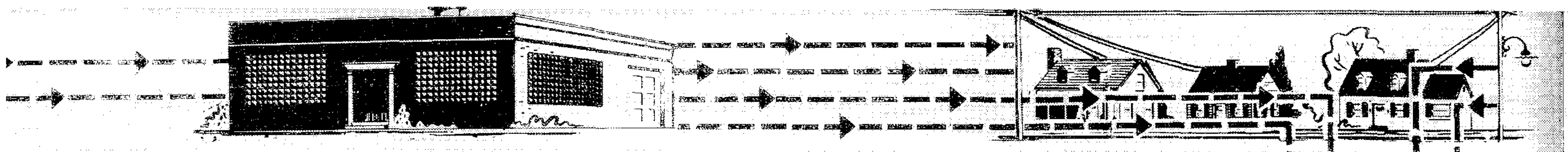
INSTALLATION in WET CONDUITS and DUCTS

The coverings described for use in dry locations on both single- and multiple-conductor cables are suitable for use in wet locations, except that a lead sheath is required over varnished cambric, paper and non-moisture-resistant rubber and polyvinyl chloride insulations.

Moisture-resistant rubber insulation requires mechanical protection in the form of a fibrous covering or coverings or a neoprene jacket. A neoprene jacket is preferred because of its greater resistance to deterioration in wet locations. Moisture - resistant polyvinyl chloride may be

US RUBBER **United States Rubber**





nsulated wires and cables

used without a covering on single-conductor cables.

AERIAL INSTALLATIONS

The types of coverings described for use in wet locations are generally suitable for aerial installations but greater thicknesses of non-metallic coverings, particularly for single-conductor cables, are required. Fibrous coverings for aerial use are usually made of moisture-resistant jute, sisal or loom-woven cotton of large size. Neoprene jackets on single-conductor cables for aerial installations are about 50 per cent greater in thickness than those used for duct installations. These thicker covers provide the additional mechanical protection required for aerial installations. Neoprene jackets are generally preferred over fibrous or rubber jackets because of their greater resistance to weathering. Lead-sheathed cables with the same sheath thickness as used for duct installations are suitable for aerial installations. A lead alloy containing small amounts of antimony or tin is used instead of pure lead to reduce failures due to crystallization.

DIRECT BURIAL

For direct-burial installations, rubber, rubber-like or thermoplastic jackets and lead sheaths are generally used. The jacket or sheath thicknesses are the same as those used for aerial installations. Lead sheaths require protection against mechanical damage. This usually consists of two servings of moisture-resistant jute yarn immediately over the lead, followed by two steel tapes over which are applied two servings of moisture-resistant jute.

SUBMARINE and VERTICAL CABLES

Submarine cables require protection against mechanical damage and additional strength over that provided by the conductors to prevent them from being broken by dragging anchors or other objects. Vertical cables frequently require greater strength for their support than that provided by the conductors. This additional strength and mechanical protection is usually provided by a serving of steel wires which completely covers the surface of the cable. This is known as a wire armor. A bedding consisting of two moisture-resistant jute servings is provided between the non-metallic jacket or lead sheath and the armor wires.

PORTABLE INSTALLATIONS

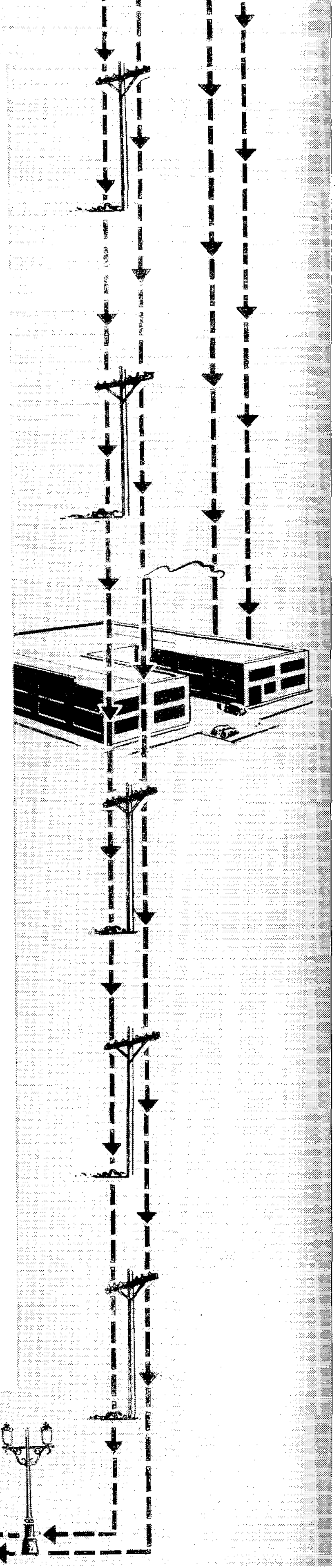
Cables for portable installations such as those used on dredges, shovels and mining equipment must be flexible and their sheaths must be resistant to abrasion, cutting and tearing. Tough wear-and-weather-resistant rubber or rubber-like jackets are therefore used. Such jackets are generally made in two layers with a reinforcing braid of high-strength cotton yarn between them. The jacket thicknesses for such cables are generally greater for a given size of cable than those of cables for non-portable installations.

SHIELDING

Shields consist of one or more conducting layers on insulated electric power cables, the purpose of which is to confine the dielectric field to the insulation on the individual conductors. The two most important functions of shields are, (1) to protect the insulation against harmful electrical stresses and discharges at its surfaces, and, (2) to reduce hazards of shock.

Since harmful electrical stresses can occur at both the internal and external surfaces of an insulation, particularly on stranded conductors, at high voltages, it is necessary to provide shields at both surfaces. Internal shielding in the form of a semi-conducting fibrous material is generally used immediately over the conductor for operating voltages above 2000. External shielding usually consists of a semi-conducting fibrous layer immediately over the insulation over which is applied a layer of metallic material. External shields are generally used at voltages above 3000 for non-metallic jacket cables and above 10,000 for lead-sheathed cables.

Metallic shields are made of non-magnetic materials such as aluminum or copper and are applied as tapes on cables for non-portable installations and as braids for portable cables. External shields must be grounded at all joints and terminals.



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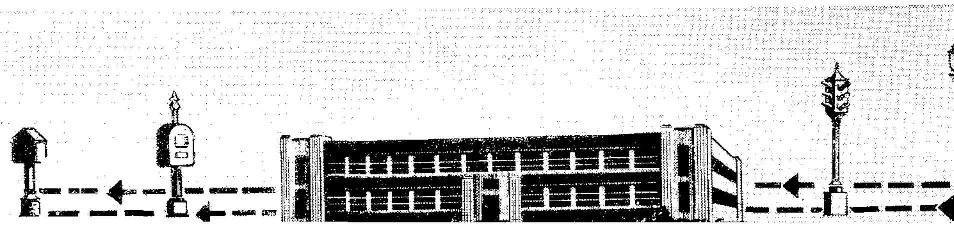
Electrical Wire and Cable Department

Rockefeller Center • New York 20, N. Y.



LETTERS

Sir:

PLEASE SEND *Engineering and Science* for one year. We are both engineering graduates from UCLA but our alumni magazine is all football. Thank you.

Mrs.——————

Pasadena, Calif.

Sir:

FROM THE ARTICLE, "Summer in the Alumni Pool" in the October issue of *E & S* it would appear that the operation of the summer program in the Alumni Pool returns a huge profit to the Institute.

We have been highly pleased by the enthusiastic response of the Institute personnel and their families the two years that this summer program has been in operation. However, to set the record straight, and to point out that this program isn't the big money-maker that the *E & S* article appears to make it, I must call to your attention some errors contained therein.

Instead of 1000 family permits at $30, there were 420 such permits, allowing 1316 persons to use the pool for a four-week or twelve-week period, at a fee from $6 to $30 per family. Instead of 22,000 single admissions paid, it should have read that the pool was used by various people approximately 22,000 times.

The program has been a decided success both years, and we are happy if we can come close to breaking even financially each year.

Hal Musselman,
Director of Athletics.

P.S. We are happy.

San Marino, Calif.

Sir:

THERE'S ONLY one thing I can think of to gripe about as far as Caltech is concerned. Why don't the alumni take a more active interest in football and get it on a more competitive basis at Caltech—or have it cut out forever? Watching Caltech football teams in action now is even too painful for me; we are so much purer than the purest of the PCC that we actually smell bad.

—Stuart L. Seymour '26.

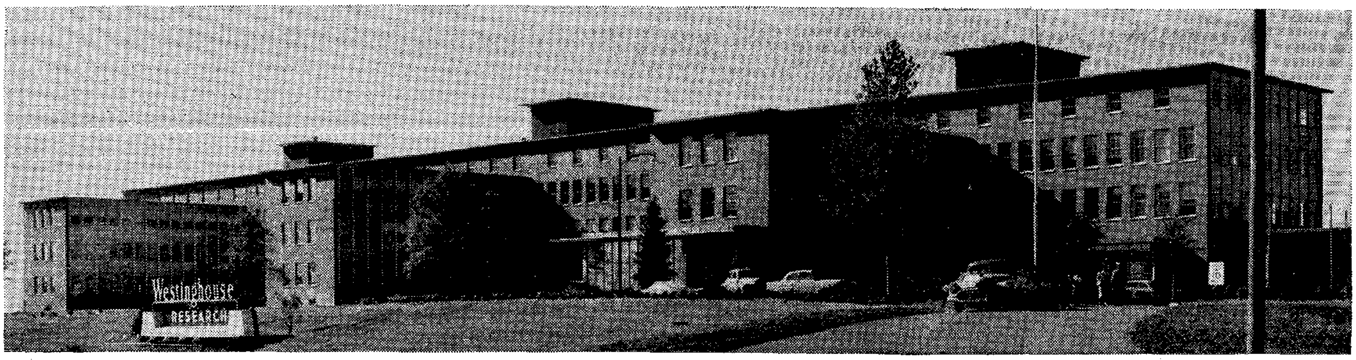
St. Louis, Mo.

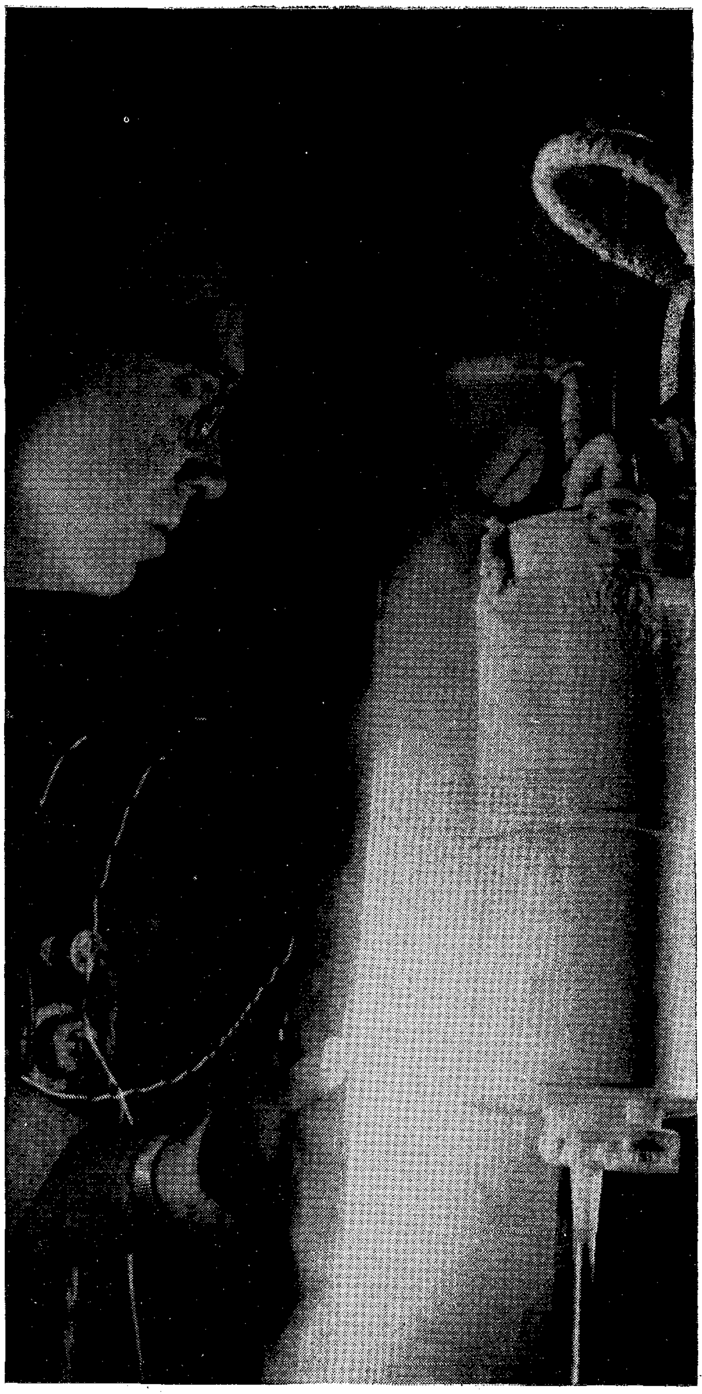
Sir:

DR. FEYNMAN'S article, "The Relation of Science and Religion," which ran in the June issue of *E & S*, sets up an urgent problem for which we appear to have no answer. The contemporary scientist, as well as intellectual leaders in many other fields, is unable to accept what may be called the metaphysical foundations of religion. He finds, however, that most of the moral teachings of the Western religions can survive the loss of their metaphysical underpinnings. As a disbeliever, the scientist may still make moral judgments that are basically the same as those of the religious man. He finds he lacks, however, that "strength and courage and inspiration" that helps the believer to do what he knows is right.

Here lies our problem. For the believer, these metaphysical, moral and inspirational aspects of religion are all interrelated. The metaphysical—for example, the existence of a personal God—supports the moral since the commandments are seen as the "word of God." The inspiration needed springs forth from the metaphysical assurance that God is with those who try to do His will. Once the reality of God, man's immortality, or Christ's divinity has become a myth, the ethical and inspirational aspects, which we still wish to retain, no longer have any justification or basis in the way things are.

"I don't know the answer to this central problem," says Dr. Feynman, "—the problem of maintaining the real value of religion as a source of strength and of courage to most men, while, at the same time, not requiring





an absolute faith in the metaphysical aspects."

I have no easy solution to offer either. However, since this article was presented as a starting point for discussion, I would like to present a few considerations that occurred to me as I read and reflected upon Dr. Feynman's "fresh observations on an old problem."

My present position as a Jesuit in training for the Catholic priesthood shouldn't invalidate me with regard to this problem of the disbelieving scientist. Frequently, during my own scientific training, both as a layman at Tech and at Notre Dame, and now as a Jesuit at St. Louis University, I have had to face conflicts between my scientific attitudes and my religious commitment. These personal experiences, coupled with a sincere appreciation of the reality of this problem in the lives of many other scientists, should allow me to at least suggest a few further questions and perhaps open up a few avenues of approach not touched upon in Dr. Feynman's talk.

Attitude of uncertainty

As the problem has been stated, it does seem impossible of solution; neither religion nor science would seem able to yield an inch without destroying themselves. If we grant that young scientists, as well as those in other fields affected by the scientific approach, do tend to develop this "attitude of uncertainty" that makes it impossible for them to accept religious teachings with that "absolute certainty that religious people have," it seems that the strength and courage that depend on "absolute faith in the metaphysical aspects" of religion is closed to them. . . . If we likewise grant that, in comparison with the picture of the universe that grows out of the sciences, a religious theory "that it is all arranged simply as a stage for God to watch man's struggle for good and evil seems to be inadequate," then I don't see how any inspirational motivation built around the religious

picture can be anything but dissatisfying to the scientist.

If the traditional religions have grounded their enthusiasm in a conviction about the way things are, about the metaphysical structure of the universe, it seems that their inspiration cannot be transplanted into other metaphysical soil and still survive. Certainly the scientist doesn't want enthusiasm with *no foundation* in reality, a groundless faith in faith itself. If he found this meaningless sort of encouragement sufficient, he *wouldn't* be asking our question.

In the face of this, I don't see how the modern church could be "a place to give comfort to a man who doubts God—more, to one who disbelieves in God." If the modern church retains any of its Jewish or Christian traits at all, it will be building its comfort on a religious view of the world, and that can give little consolation to the disbeliever. Of course, the churchmen must offer another and extra-ecclesial comfort; they must be willing to respect the sincerity of the disbeliever and the reality of his problem. Through mutual discussions some way to adjustment might open, although any reconciliation may at first seem impossible.

The modern predicament

There seem to be two directions we could take in at least starting towards some resolution of the problem. Both begin with what we have at hand — the modern predicament, as some call it. The fact is that we have come to think "scientifically," which involves a continual freedom to doubt and explore, joined with the acceptance of the world of "scientific things" as the *real* world, the only *objective* view of the universe.

It would be too simple to say that while pretending to doubt all, the modern thinker, in fact, accepts the new scientific picture as a dogma more certain than all those of the fading religions. There does, however, seem to be some touch of paradox here. The other fact is that we

continue to have moral convictions, which, as Dr. Feynman's analysis indicates, are not reducible to scientific statements.

The first approach involves a deeper investigation into the foundations of our moral judgments. Perhaps this further analysis would lead us to a source for our inspiration, as well as for our morality.

Two separate worlds

It may be that the scientific world-view, in terms of "a vast evolving drama" with "the atoms of which all appears to be constructed following immutable laws" and an "objective view" of man "as matter," seems logically consistent with our experiences of moral conviction. This can only mean that on the surface of it the logical formulations of one experience do not directly clash with those of the other. Going further, however, we see that neither is there any logical entailment here; we are living in two separate worlds. We can say, "All is really the result of the concourse of atoms" *and* "I judge that this is good for me," but we cannot insert a *therefore* between the two assertions. One cannot be understood in terms of the other; perhaps we may even go so far as to say that one is meaningless.

If the scientist were to probe more deeply into these convictions about the "good," he might be able to render them meaningful in such a way that he would find his needed inspiration. If he can't ground his convictions of conscience in his "scientific things," he may be forced to reconsider the unexamined presuppositions that uphold his whole scientific attitude.

This is the second approach to resolution, involving a critical self-reflection on the very climate of opinion which seems to be essential for the survival of the scientist and his work. A man who never felt the need of inspiration and who was at peace before the "mystery" of matter that somehow experiences moral compulsions, won't be facing our dilemma; he has, apparently, no need for religion, though we could not be sure of such a man's stability in a moral crisis. The scientist who does want to resolve this problem might take into consideration the difference between the simple statement of the *fact* of having these convictions as a scientist and the assertion that these are *justified* by a critical investigation of their foundations.

For example, it is one thing to claim that we scientists have to be free to doubt everything and another thing to carefully search into the basis of this claim and its possible limitations. If we want to retain our scientific humility and our intellectual honesty, we should try to pinpoint exactly for ourselves where this doubt is, why it comes in, and whether it is as extensive as we think.

More than one answer

Of course, we might look into the claim that *only* this scientific method, which never has absolute certitude under any aspect, is to be allowed to answer all of man's meaningful questions. Already we might suspect that there are other meaningful answers available to other methods of approach, since we have divided off the moral realm from the scientific. Certainly, even the scientist *lives* with firm assurance, though he may theoretically claim to dwell in a realm of "only highly probable."

Corresponding to this questioning of the basis and limits of his *method*, the scientist may want to turn a critical eye on that world of "scientific things" that he and his contemporaries so easily take for the true picture of what things really are. These "facts or partial facts"—what are they really? It would seem necessary to restrain our enthusiasm and draw a clear line between strictly scientific answers and that "philosophizing," poetic extrapolation and pure science-fiction that fills in the missing details.

It seems to be a very human failing to fill in the picture, even though

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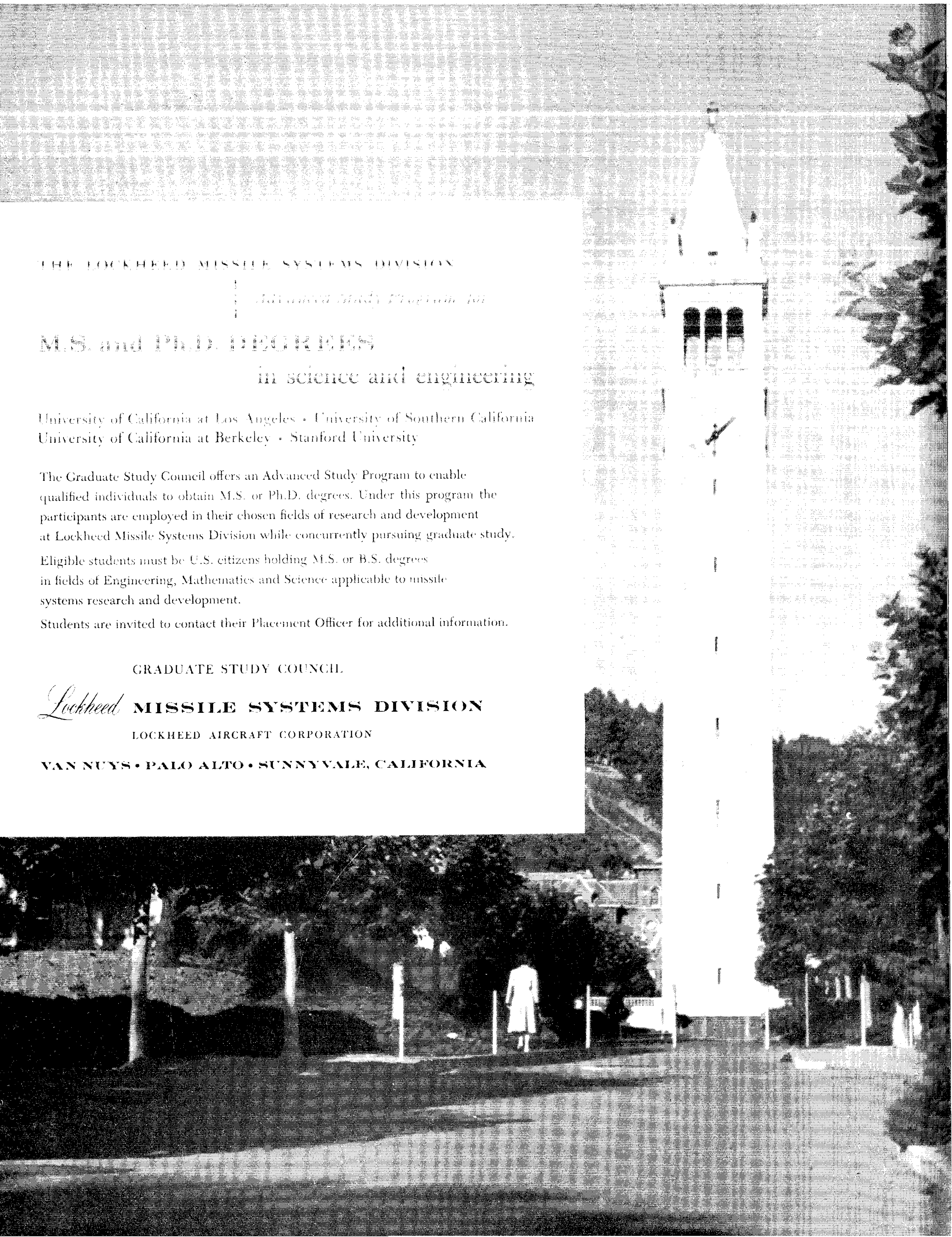
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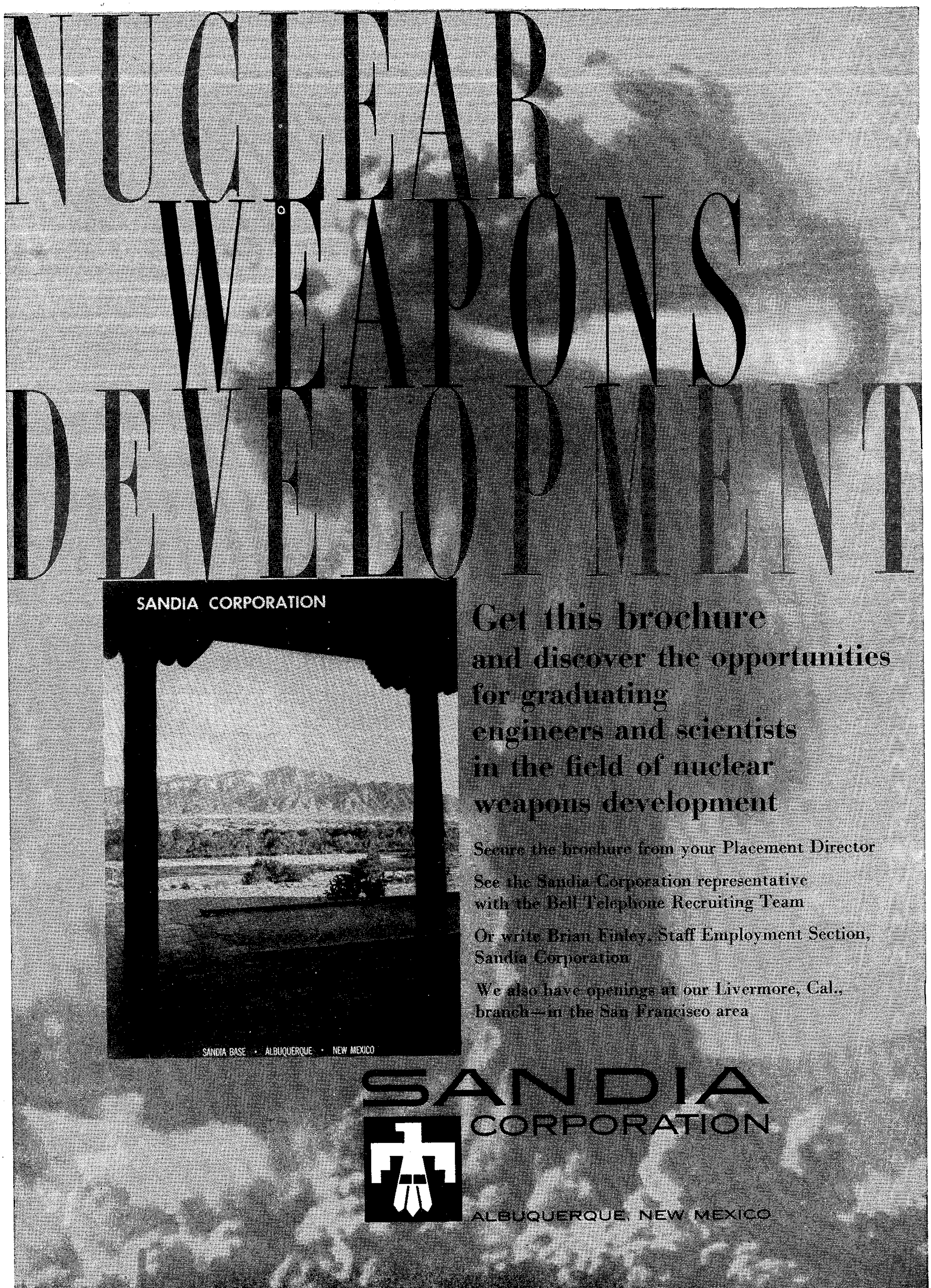
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THE PRESIDENT'S REPORT

Highlights from Dr. DuBridge's report on research and activities at the Institute in 1955-56

THE ROLE OF CALTECH in strengthening the scientific and technological resources of the nation is always under review. In order to understand it we must first clearly recognize that in any intellectual field—and especially in creative fields—shortages cannot be fully expressed in numbers. One could conceivably double the number of annual graduates bearing the label "engineer"—but if the new recruits were improperly selected and inadequately trained, they would change only the statistics of shortage without in the least speeding up the solution of the nation's engineering problems.

We are dealing, in other words, with a shortage of brains rather than only of bodies. Our problem is not to man an engineering production line in which there must be one drawing board every three feet. Our problem is to foster creative science and technology, to discover more about nature, to create new ideas and to develop them into practical form. One fertile and well-trained mind can do more of such creative work than a hundred mediocre ones.

An especially critical need at present is for more engineers and other applied scientists who have pursued their studies to the doctoral level. It is a paradox that physicists trained in pure science are in great demand in industrial laboratories where engineers would be preferred if men with the research experience represented by the PhD degree were available. Actually, industry may inadvertently profit by bringing in the point of view of the pure scientist; but industry should also help encourage more research training for engineers. It is, of course, tempting for the young BS in engineering to accept one of the dozen or so attractive jobs offered him. But he himself will be well rewarded in the long run if he takes more advanced work, provided he is qualified for it.

In this connection it should be stated that Caltech is not engaging in the so-called "cooperative" programs whereby a student has an industrial job for 30 or 40 hours a week and tries to pursue graduate studies on the side. Research is a *way of life*—not a series of lectures. Training for research means *living* the research life—all the time. We shall continue to accept, in both graduate and undergraduate divisions, only full-time students. We urge industry not to destroy the essential quality of graduate education by encouraging the notion that it can be done after hours while carrying on a full-time job.

The campus

The Institute was able to make three important moves in its program of "completing the campus" this year. In June 1956 ground was broken for the Eudora Hull Spalding Laboratory of Engineering. This large $1,500,000 structure will provide desperately needed additional space for chemical and electrical engineering. It enlarges but does not complete our engineering science plant. The financing has been made possible by the oil royalty income from the Sespe Ranch, a part of the estate left by Mrs. Spalding.

A second advance was the receipt of a gift from Mrs. Archibald B. Young to finance the building of a new Student Health Center, to be named in honor of her late husband. The Center will be located on the vacant lot at 1239 Arden Road and will provide expanded and permanent facilities for medical examination and treatment, and an infirmary of ten beds for light illness or emergency. The Caltech Service League is generously assisting in equipping and furnishing the Center. The location, though just across the street from the main campus, is in a residential area and the Center will conform architecturally to a residential style.

The sudden rise in the fraction of undergraduate students who live outside the commuting area has led to a crisis in dormitory accommodations. We welcome this broadened geographic base, even though it faces us with the sudden necessity of finding funds for at least one, preferably two, more Student Houses. They will cost nearly a half-million dollars each.

Unfortunately, if new Student Houses are constructed on the site now being reserved north of the present Houses, the temporary buildings in which are located certain engineering laboratories, the YMCA, the AFROTC offices and the maintenance shops will have to be removed, thereby necessitating the construction of other new buildings to house these activities. Thus a coherent plan of campus development is required. It is now being worked on. The needs for student housing thus add urgency to our whole program of campus completion, the funding of which will be one of the major tasks in Caltech's history.

Admissions and scholarships

The competition among colleges for the nation's top students is even more earnest, though more restrained, than the struggle for the best athletes.

Caltech is peculiarily fortunate in this respect. We could not ask for a better student body, for by every known test we have one of the very top ones in the country. There were dark days back in the 1930's when it must have been tempting to lower academic standards to increase enrollment. But the standards were maintained; and high standards are bound eventually to attract and challenge the best students. These students are applying in ever larger numbers for admission to Caltech; nearly 1400 applied in 1956 for a freshman class of 180. (Over 300 were actually granted admission to make up for expected withdrawals; other schools wanted them too!) Hence the quality of the Class of 1960 will be a notch higher than any other previous class.

A development of very great importance to the country—and one which had unexpectedly large repercussions on Caltech—was the establishment of the National Merit Scholarships. Some 550 of these scholarships, supported by private funds from foundations and corporations, were awarded on a competitive basis from among 60,000 contestants. The winners may go to any college of their choice with a monetary award based on actual need and costs. Caltech might have expected to be selected by ½ to 1 percent of the winners (we enroll 1/30th of 1 percent of the nation's 1956 freshmen). Actually, 20 Merit Scholars have registered here—which is 3½ percent of all the winners and 5 percent of the men.

By coincidence, the California State Scholarships were inaugurated also this year and 18 of our freshmen and 11 upper classmen have received those awards. We also welcome 5 of the new General Motors Scholars.

All of this has two important consequences. The first is the obvious one that our student body this year will be far better taken care of financially than ever before. Our own funds can be used for needy cases we could not otherwise assist.

A second unforeseen result is that more freshmen than ever before are coming from beyond the Los Angeles commuting area. These new scholarship funds have helped wipe out the economic barrier which previously prevented many residents of distant states from coming here. We are delighted that 40 percent of the members of the entering class in 1956 will be from east of the Rockies, 60 percent from outside California. But we apologize to the scores of students for whom we do not have space in the Student Houses. We shall remedy this defect as soon as funds are available, but even at best we can hardly hope to have new housing ready before early in 1958. By vote of the House residents themselves, 90 of the 370 spaces have been reserved for freshmen, even though many upperclassmen are thus left out.

Industrial Associates

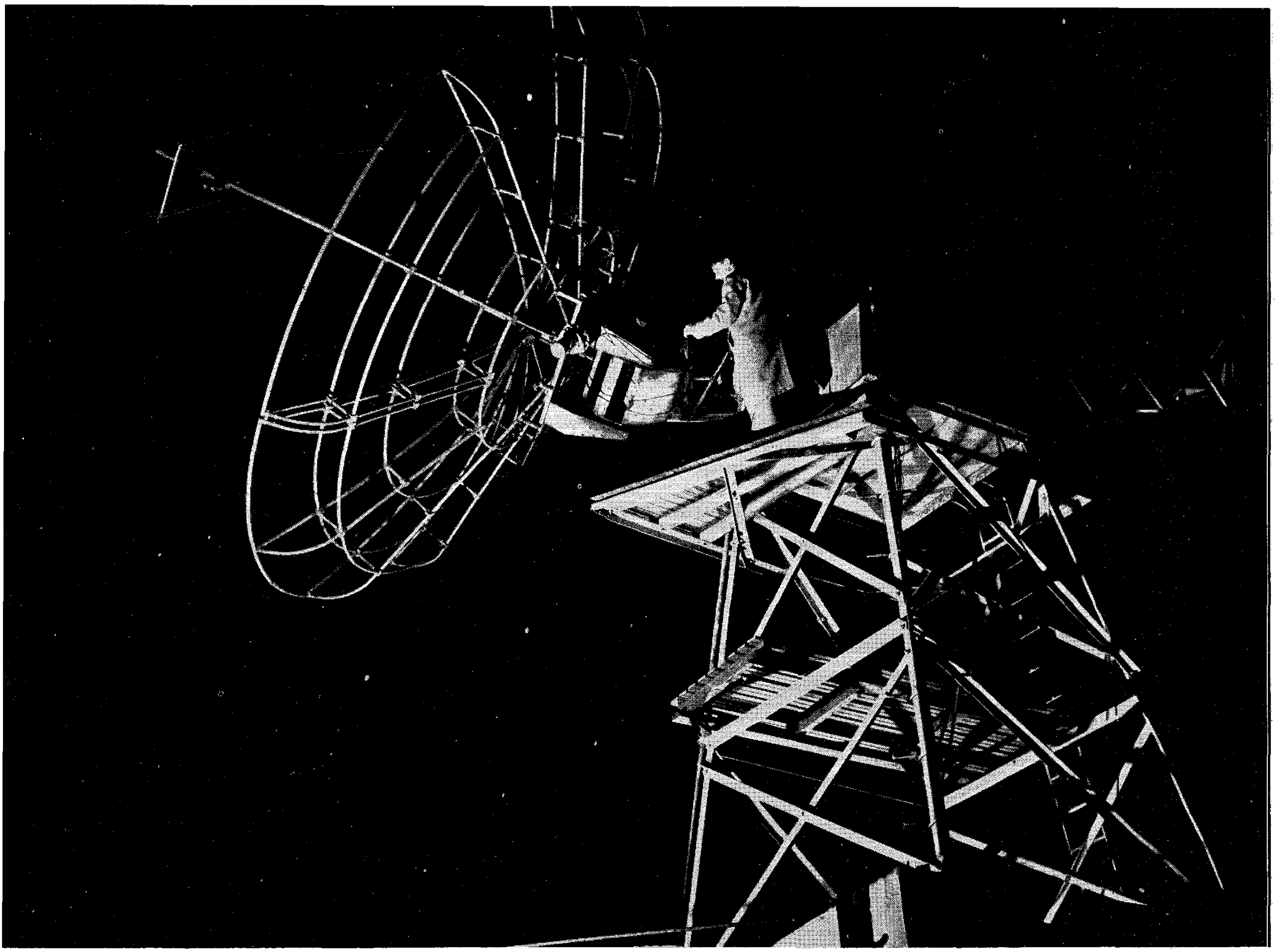
The rising tide of corporation support of higher education is one of the important phenomena of the past decade, and will be a decisive future influence in the financing of American colleges and universities.

Corporate support is not a new thing at Caltech. Ever since the Southern California Edison Company started financing high-voltage research here in 1924, the Institute has received continued support of its research activities from business and industry. The American Petroleum Institute has supported chemical engineering research for 27 years; the aircraft industry has supported aerodynamics research since 1928; the entire program of the Industrial Relations Section has always been supported by corporate contributions.

Industry has supported Caltech because the benefits of doing so have been obvious and relatively immediate.

The new development has been that corporate money no longer requires the direct benefit to the company to be either obvious or immediate. Rather, one might say that the long-run benefits of a program like ours have become so obvious that corporate support has greatly increased.

The chief instrument for encouraging general support of Caltech has been the Industrial Associates program. Thirty-eight companies now subscribe at least $10,000 a year each for membership in this group. They receive in return the opportunity to keep up to date on our research programs and to participate in important conferences on scientific and engineering subjects.



Dr. John G. Bolton works with a 16-ft. radio telescope in Australia; he'll have 90-ft. ones at Caltech's new site.

RESEARCH HIGHLIGHTS

THE PLANNING of a new radio-astronomy facility last year has resulted in a site for the large antennas, in a location which is level and free from radio interference, located near Big Pine, California, in the Owens Valley about 250 miles north of Pasadena. About 275 acres have been leased from the City of Los Angeles and construction of facilities has begun. Two 90-foot antennas — dish-shaped radio "telescopes" — have been ordered for installation next spring. They will be mounted on flatcars and will be movable on rails to give a variable interferometer. A smaller antenna is now in operation on Palomar Mountain. The rapid development of the field of radio astronomy and its relation to many problems under study at the Mount Wilson and Palomar Observatories add assurance that the new program will be an important one.

Of very great interest to physical science generally has been the recent work of Professor W. A. Fowler, and Dr. and Mrs. Geoffrey Burbidge (visiting from Cambridge, England), in clarifying the nuclear reactions which take place in the stars and which account for their energy, serving at the same time to build up all the chemical elements from primordial hydrogen. An interesting feature of the new theory is that the heavy elements of the periodic table (i.e. heavier than iron) are probably formed principally in gigantic explosions of stars known as supernovae — explosions similar in many ways to an H-bomb. The debris of these explosions is scattered into interstellar space, there to be picked up by other stars or possibly to be condensed into new stars. The existence on the earth of all of even the heaviest elements—up to uranium—means then that our sun and solar system must have picked up (or have been built from) such debris produced by a great explosion which took place more than five billion years ago.

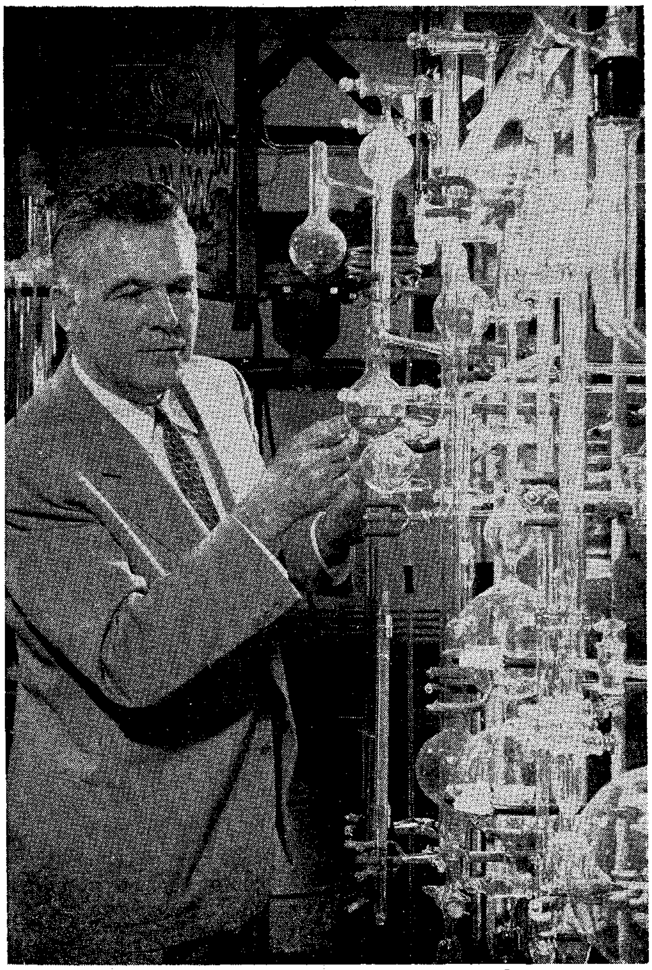
Astronomy, the oldest of sciences is undergoing a rebirth, caused partly by new advances in physics and electronics, partly by imaginative new ideas built on a growing basis of observations and theory. It is a satisfying example of the interactions between scientific groups that here at Caltech we see the coming together of astronomy, electronics and nuclear physics to contribute to the advance of understanding of the age-old questions.

Physics

LAST YEAR the electron synchrotron which had been operating for several years at an energy of about 500 million electron-volts was shut down for alterations designed to boost the energy to above a billion electron-volts. The alterations and delicate adjustments took longer than expected, but in August 1956 a beam was obtained of 1.2 billion electron-volts energy. Experimental work with this, the highest energy electron beam available in the world, is starting at once and much new information about nuclear phenomena will surely result. An eventual electron energy of about 1.5 billion electron-volts seems feasible. (The huge nuclear machines at Berkeley and Brookhaven accelerate protons, not electrons, to energies of several billion electron-volts.)

Professor J. R. Pellam's research at low temperatures has carried him down to .004° Absolute, and he can maintain his experimental chamber for several hours at temperatures around .07° to .14°. The properties of matter at temperatures so near the absolute zero are of great interest to physicists.

Another example of the way new discoveries of physics throw light on astronomical problems is the suggestion by Professor Fred Hoyle and others as to the source of energy of certain supernovae (exploded stars) which, after a bright initial flash, are growing dimmer with a half-life of 55 days. It is proposed that the great flood of neutrons released in the original explosion acted, as in the thermonuclear tests at Bikini, to produce great quantities of the element Californium —element number 98, which does not exist in nature, and whose isotope of mass 254 undergoes spontaneous fission with a half-life of 55 days. It appears quite possible that the radiant energy from these supernovae comes from the fission energy of this unstable element first discovered at Berkeley in 1950.

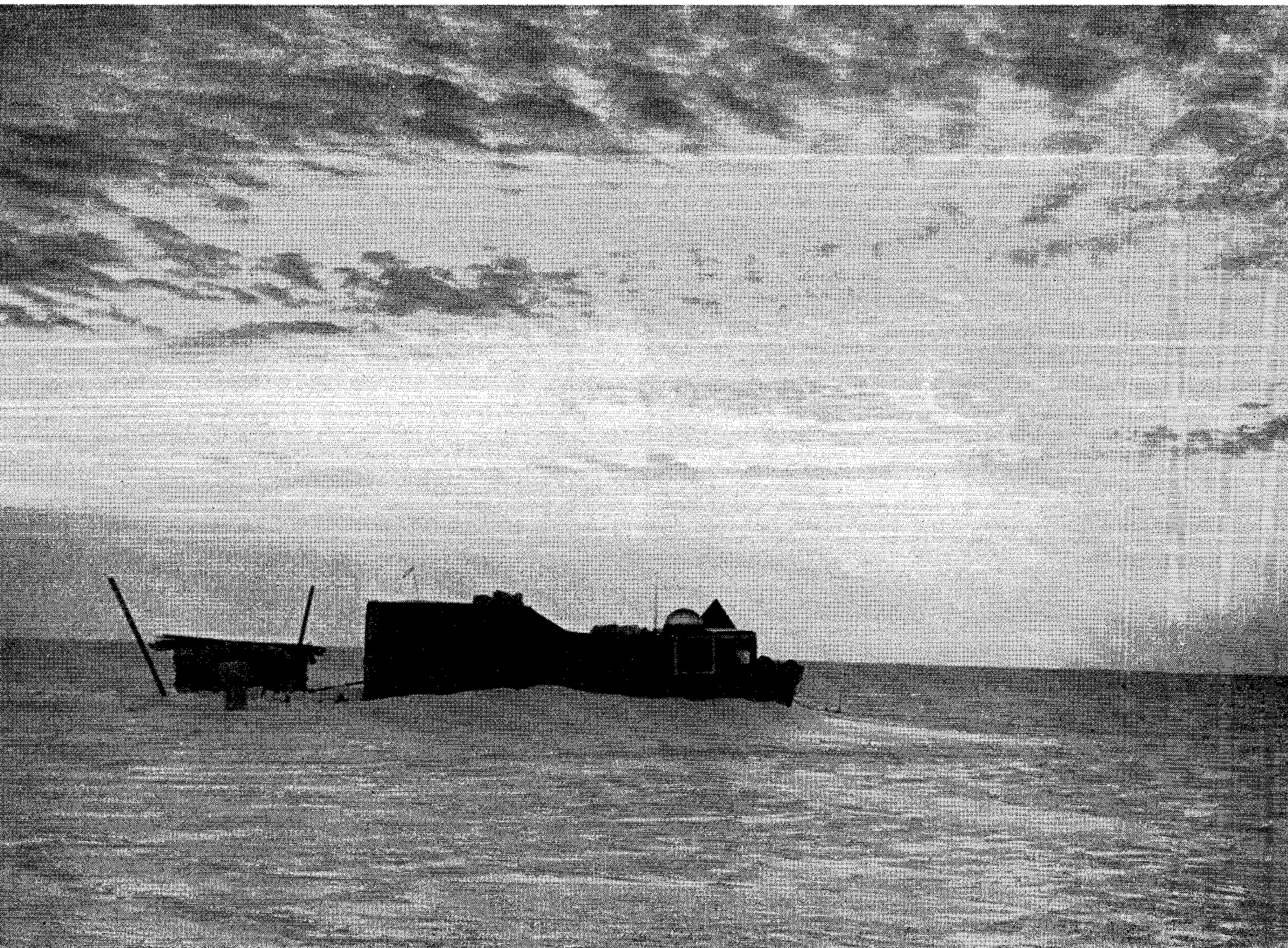


Physics Professor John R. Pellam studies the properties of matter at temperatures close to the absolute zero.

Geology

THE DISCOVERY of ore bodies bearing useful mineral deposits is a practical problem of great interest to geologists—and to everyone else too. Often the discovery of an ore body is a matter of pure luck, for there may be nothing in the surrounding region to indicate the presence of ore. The normal ore body has a sharp edge; the concentration of metal does not diminish gradually over a great distance, thus furnishing a handy clue. However, Caltech geochemists have found that since the original intrusion of a mineral-bearing body into the surrounding rock caused a heating of the rock for a considerable distance, the traces of this temperature gradient can be observed by measuring the ratio of abundance of the two isotopes of oxygen, O^{18} and O^{16}. Thus it is possible that a wholly new method of ore exploration may have been opened up, since detectable differences in this ratio are observed far outside the actual boundaries of the ore deposit itself. How an old-fashioned prospector would snort at the modern one—armed with a mass spectrometer!

Interestingly enough, the temperature sensitivity of the O^{18}/O^{16} isotope ratio has also yielded data on the cyclic variations through the years of the temperature at which snow fell on the Greenland ice cap, the O^{18} ratio varying with depth below the surface in such a way that it is possible to measure the relative depth of snowfall over each of many past years.



This is home to Caltech geophysicists making glaciological and seismic studies on a Greenland ice sheet.

Biology and Chemistry

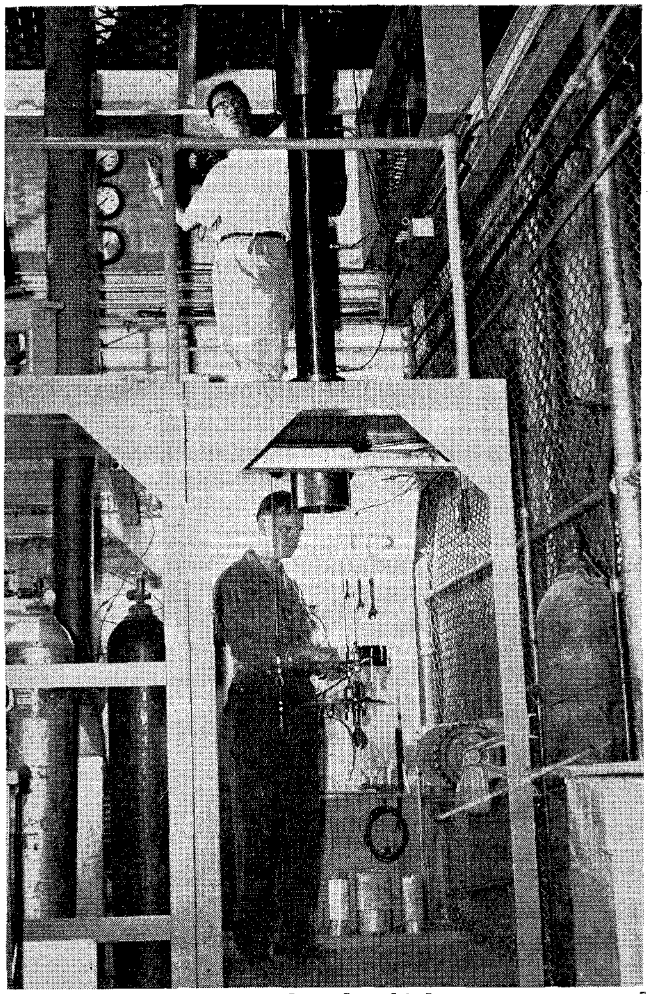
THESE TWO DIVISIONS are now jointly occupying the new Norman W. Church Laboratory for Chemical Biology and hence have more adequate facilities for their teaching and research programs. These programs continue to develop rapidly.

The success of Professors Linus Pauling, R. B. Corey and others in elucidating the structure of many protein molecules has led to encouraging progress in understanding the structure of viruses and genes which, though living, are yet very much like super molecules. A great mystery of "life" is the way these particles can reproduce their kind, and yet even this process is now becoming comprehensible, although still uncertain in detail.

There is evidence that abnormal molecules in the blood not only can cause specific types of blood disease, such as sickle-cell anemia, but also may result in impairment of certain brain processes. The announcement was made in August 1956 that a grant of $450,000 had been made to Caltech by the Ford Foundation to support a five-year study of this problem—whose great and fundamental importance is obvious. The project will be directed by Professor Pauling.

The techniques of studying animal and bacterial viruses which have been in use in the virology laboratory here now make possible accurate studies of the genetics of these bodies. Because of their relatively simple structures and the ease of growing them quickly in large numbers, they are good "experimental animals" for genetic research. Thus the "fine structure" of an individual gene has now been established and its molecular structure can be examined.

An important new instrument for studying structures of complex molecules is the nuclear magnetic resonance spectrometer, based on a discovery in physics made only ten years ago that molecules will undergo a transition from one magnetic state (or orientation of the magnetic axes of its various nuclei and electrons) to another, under the action of a radio-frequency field. The required frequency is sharply characteristic of each such transition and hence may be employed as an identifying mechanism. In other words, the series of fre-


Chemical engineers study ultra-high temperature and pressure reactions with the new ballistic pendulum.

quencies at which various transitions can be induced constitutes a unique "signature" for each type of molecule, often revealing subtle aspects of its structure not easily recognized in chemical or even in X-ray studies. Fortunately it was possible to purchase such an instrument last year, to be used by Professor J. D. Roberts in his research, and he has found it a versatile and powerful addition to the array of tools available for examining molecular structures.

Another new instrumental technique of growing interest in chemical research is the ballistic pendulum as developed by Professor B. H. Sage and his co-workers. A heavy, free-falling piston compresses a gas mixture, raising its temperature momentarily to possibly 15,000°F. Reactions taking place within from a hundred to a few thousand micro-seconds can be studied. Needless to say, ingenious electronic timing and measuring devices are employed.

Engineering

IN RESEARCH, in both pure and applied science, the occasional discoveries of exceptional interest are separated by long periods of laborious accumulation of information, the building and testing of equipment, the operation of calculating machines and the analysis and interpretation of data. It is not anticipated, for example, that a revolutionary discovery will come from the study of air flow around a flat plate, the analysis of the vibrations of a gasoline engine, or of the response of a building to earthquake waves. Yet more and better information on these and many other subjects is vital to the development of modern technology. Caltech does not manufacture airplanes, missiles, submarines, automobiles or vacuum tubes. But the design of all these things may be profoundly affected in the future, as it has been in the past, by the knowledge accumulated and the new ideas developed in the science and engineering laboratories on this campus.

The Guggenheim Laboratory of Aeronautics continues its difficult and important studies of air flow at speeds up to ten times the speed of sound. The mechanical engineering laboratory—before its old quarters were torn down to make room for the Spalding Engineering Laboratory—measured the vibrations of sonic frequency (noise) in a high-compression engine. In the hydraulics laboratory studies were made of sedimentation in stream beds, accumulating information necessary to the design of flood-control projects. The cause of water conservation in arid regions was advanced by the development of new methods for purifying and reclaiming sewage wastes, for a huge quantity of potentially usable water is frequently used in carrying away such wastes. The metallurgists obtained new data on the fracturing of steel and the corrosion of nickel-chromium alloys.

Almost every field of engineering is profiting from the development of electronic computing techniques, vastly speeding up the solution of analytical problems, and making possible the performance of design calculations never previously attempted. The Spalding Laboratory is to house a modern Computing Center which will be the focus of a campus-wide interest in new computational methods. Four major computing machines will be installed, including a new Datatron digital computer which has an exceptionally wide range of capabilities.

Jet Propulsion Laboratory

THE INSTITUTE'S largest single unit in terms of funds expended is the Jet Propulsion Laboratory. The Laboratory has now become one of the major research centers for the development of rocket and missile techniques for the United States Army Ordnance Department. The wind-tunnel work, the studies of fuels, motor design and guidance techniques are essential to the development of all types of missile systems—including the earth satellite project now being planned as a part of the scientific program of the International Geophysical Year.

THE ORIGIN OF LIFE

A colorful account of the studies man has made in his attempt to discover the fundamental characteristics of living matter

by NORMAN H. HOROWITZ

FROM THE EARLIEST times it has been believed that living things can originate spontaneously from non-living material. For centuries it was thought, for example, that worms, frogs, insects and scorpions could originate in mud, or from dew or decaying meat, without parents. Known as the doctrine of spontaneous generation, this was the view of the classical Greek authors — Aristotle, Lucretius and others who influenced Western thinking for 2,000 years. It was the generally accepted view all through the Middle Ages and well into the 17th century.

The following quotation from the works of a well-known physician and chemist named Van Helmont, who lived from 1577 to 1644, is typical:

> "Furthermore, if a dirty undergarment is squeezed into the mouth of a vessel containing wheat, within a few (say 21) days the ferment drained from the garments and transformed by the smell of the grain, encrusts the wheat itself with its own skin and turns it into mice. . . . And what is more remarkable, the mice are neither weanlings, nor sucklings, nor premature; but they jump out fully formed."

It is important to note that Van Helmont was not making this up; he actually carried out the experiment and this is the way he says it worked.

Two hundred years later Pasteur commented on this quotation from Van Helmont. "What this proves," he said, "is that to do experiments is easy; but to do them well is not easy." One can see now how careless Van Helmont must have been when he set up this experiment. But the result came out just as he had expected; it was in keeping with the view of the times, and he didn't feel like being very critical about it. It is still true today, as it was then, that the easiest thing to do in a laboratory is to find the result you expect to find.

In 1668 an important discovery was made. An Italian physician named Redi decided to test the idea that worms were generated spontaneously in rotting meat. He put some rotting meat and fish in open jars, and he watched them. In time, he noticed that flies came and laid their eggs in the meat and that maggots hatched from the eggs. When he covered the jars with muslin he found that flies came and laid their eggs on the muslin, but as long as the eggs didn't get to the meat, no "worms" ever developed in it—and that was the beginning of the end of the theory of spontaneous generation of higher plants and animals. From this point on, this belief gradually died out among educated people.

A few years later, however, in 1675, another discovery was made which was to reopen the whole question at a different level. This discovery was made by Leeuwenhoek, a Dutch microscopist. Leeuwenhoek was the greatest microscopist of all time; he discovered a whole new world—the world of bacteria and protozoa. Nearly one hundred years later they were to form the subject of another controversy on the theory of spontaneous generation.

"The Origin of Life" has been adapted from a Friday Evening Demonstration Lecture given by Dr. Horowitz on March 16, 1956.

Leeuwenhoek is probably the most original figure in the history of biology. He was not an educated man; he was only an *amateur* scientist, and his true calling was the haberdashery business. Fortunately, he was able to spend a great deal of his time at his hobby, which was making microscopes. He made the best microscopes that were known up to that time. Actually, they weren't what we call microscopes; they were magnifying glasses of remarkably high power and resolution. One of them is known to have had a magnification of 270 diameters.

Leeuwenhoek learned how to blow glass and how to grind and polish lenses by going to the fair in Delft and watching professionals. Then he went home and practised by himself, and in this way he learned to make excellent lenses. But he never gave his secrets away; he never told anyone how he made the lenses. He never lent his best instruments, or sold any, or showed visitors his best glasses.

All of Leeuwenhoek's scientific discoveries were communicated in the form of letters to the Royal Society in London. The Royal Society had only recently been formed, and was in search of people doing interesting scientific work. Somebody from Holland told them that Leeuwenhoek was doing interesting things with microscopes, and he was invited to communicate his discoveries. So he wrote a long series of letters which were sent to London, translated and published. He was elected to membership in the Royal Society in 1680. In a way, this was the climax of his career. Elected to the company of people like Newton, Hooke, Robert Boyle, Halley and other great names of his day, Leeuwenhoek was deeply touched. On his death he left 26 of his best microscopes to the Royal Society. Unfortunately, these have all been lost.

Bacteria and decay

The next important date in the history of our subject was 1745, when a Scottish minister named Needham, also a microscopist, published observations and arguments which led him to believe that bacteria were generated spontaneously from decaying organic matter. People no longer believed that worms and mice were generated in this way, but bacteria were so small and primitive, so simple, that it seemed they were really on the threshold of non-living and living matter. It seemed quite reasonable to believe that bacteria were generated spontaneously, especially since it could be demonstrated that they were found wherever decay or putrefaction was going on.

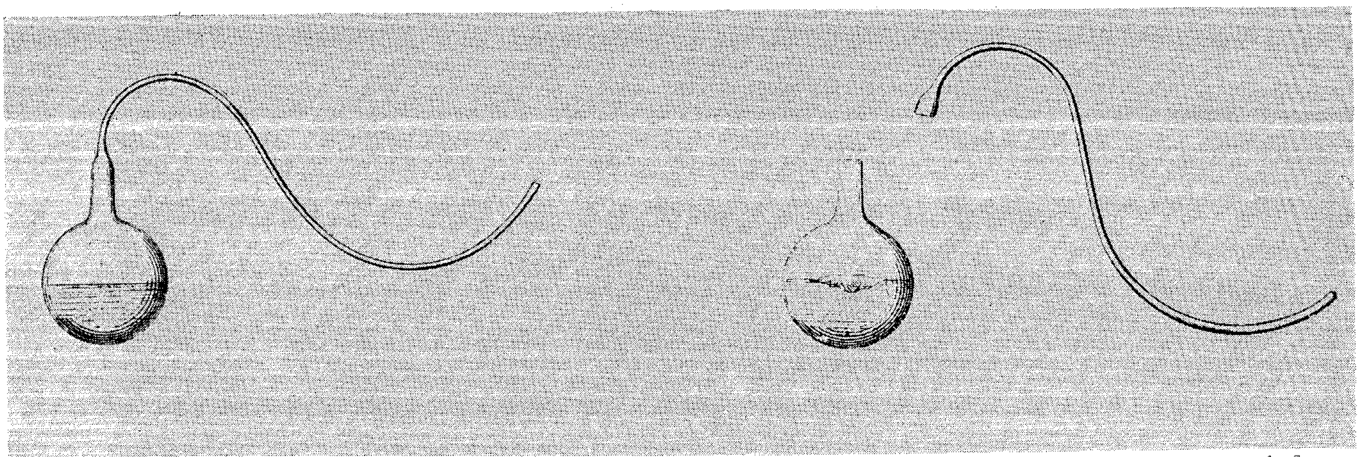
Needham's paper started a controversy. In 1765 an Italian by the name of Spallanzani published a report of an investigation which he thought disproved the claims of Needham. Spallanzani said that if he took mutton gravy, or any other medium suitable for the growth of bacteria, and heated it for a long enough time in a sealed vessel at the boiling point of water, it would no longer give rise to bacterial growth. Needham argued that what Spallanzani had done was to destroy some vital element of the air—some substance which was necessary for spontaneous generation—and that this experiment therefore did not disprove Needham's view.

Origin of canned food

This actually was to some extent true; years later, after oxygen had been discovered, it was shown by the French chemist, Gay-Lussac, that in Spallanzani's experiment the oxygen had, in fact, been used up. What Spallanzani had done was to fill the jar nearly to the top and heat it for 45 minutes; the oxygen was consumed by reacting with the organic material in the jar. So the controversy was not settled at that time. (One important thing did come out of it though. In one of Spallanzani's experiments he used garden peas as his growth medium, and he found that the peas kept indefinitely without spoiling. This was the first time that anything was canned, and it was directly from this observation that the canning industry started).

The argument was finally settled a hundred years later in a famous series of experiments by Pasteur. Pasteur proved, once and for all, that bacteria are not generated spontaneously—any more than Van Helmont's mice were. He showed that bacteria are not the product of decay, but the *cause* of decay. He communicated his results to the general public in a famous lecture which he gave at the University of Paris 92 years ago, and in which he demonstrated three important experiments.

Leeuwenhoek, a 17th century Dutch microscopist, first discovered the world of bacteria and protozoa.



Original illustration from Pasteur's paper on his famous experiments proving that bacteria are the cause of decay. Gooseneck flask at left kept broth sterile for months; open flask at right allowed entry of bacteria-laden dust.

In the first experiment, Pasteur showed that if you destroy the bacteria in a suitable medium by boiling, and allow only sterile air to enter the flask, you get no subsequent growth of bacteria.

In his next experiment he proved that growth of bacteria would start in the medium if it was inoculated with dust collected from the air.

Sterile solution

The third experiment (above)—and the one of which he was obviously most proud—was one in which he prepared his broth in an ordinary flask which he then pulled out in a flame so that it had a gooseneck. He boiled the medium in the flask for three or four minutes, allowing the steam to go up the gooseneck. Then he simply turned off the burner and let the flask sit there until it cooled. Then, without sealing it, and without any other precaution, he put the flask in an incubator and left it there. Nothing grew in it. The flask was completely open to the air, and there was no question of the oxygen being depleted because oxygen had free access to the flask. Yet the broth remained sterile. If you visit the Institut Pasteur in Paris today you will still see such flasks which, it is said, were put there by Pasteur. There is still nothing growing in them.

The explanation which Pasteur gave for this experiment is this: When the broth is boiled, the steam comes out the gooseneck and, of course, drives out the air. When the flame is turned off, air re-enters the flask, but it comes in contact with the liquid which is almost at its boiling point—hot enough to kill bacteria. As the broth cools down, the stream of air entering the flask slows down very much, to the point where dust particles in the air can no longer make the trip; they get caught in the moist gooseneck, so that they never reach the surface of the broth after it is cool.

This experiment, and the others that preceded it, settled once and for all the question of spontaneous generation of bacteria. Of course, many people repeated these experiments after Pasteur, and many failed; but it was a question of technique. Nowadays, it is commonplace to prepare a sterile solution that will remain bacteria-free indefinitely.

Researches that have been carried out since Pasteur's day have shown that bacteria are not nearly so simple as had been assumed up to that time. Although they are very small, they have a very delicate organization and very complicated chemical processes go on in them. They are just as complicated chemically as the individual cells that make up the bodies of higher plants and animals, and the idea of such complicated structures originating by chance in a medium containing nothing but organic chemicals is quite fantastic. As a recent writer has said: "Imagine a factory with smokestacks, machinery, railroad tracks, buildings, and so on springing into existence in a moment—following some natural event like a volcanic eruption. The same sort of event is assumed when one assumes that something as complex as a bacterial cell can originate in a pot of gravy."

Attributes of living matter

It was shown by Pasteur, and by others, that bacteria arise only from other bacteria. This property, which we call self-reproduction, is a very important and fundamental attribute of living matter, true of all cells. There is another attribute of living matter which we must consider: mutability. By mutability we mean the property of undergoing an hereditary change.

For example, if we take a culture of bacteria growing in broth and add some penicillin to the broth, we will destroy most of the bacteria, but there may be a few bacteria—a few mutants—which are resistant to the penicillin. They will continue to grow, and they and all their descendants will be penicillin-resistant. We say that these bacteria are mutated. This represents an elementary step of evolution. These bacteria have evolved to a certain extent; they have changed one of their fundamental properties, and they are a different kind of bacteria than their parents were. These two qualities—the ability to self-reproduce, and the ability to mutate—are probably the most fundamental characteristics of living matter, and the problem of the origin of life as we see it today is that of finding the simplest chemical structure which exhibits these two fundamental attributes.

We think that if we can find a molecule that exhibits these two qualities, we shall have found a simple form of life. Imagine, if you can, a chemical substance that is capable of reproducing itself and that is capable of blindly mutating in various directions. By mutating, our molecule will try out new ways of existence, and after a few generations it will be very different from the thing that it started from. In time, everything else that we associate with living matter will follow by logical necessity. For this reason we feel that these are the two qualities that we must look for when we examine the question of the origin of life.

What are the simplest systems which exhibit these qualities?

About thirty years after Pasteur's experiments — around 1900 — organisms were discovered which are even smaller than bacteria. These are the viruses, and they have played an important part in considerations of the origin of life.

The first virus to be discovered, the tobacco mosaic virus, has been very much studied, especially by Stanley and his collaborators at the University of California. This virus causes a disease of tobacco plants —a disease causing the mottling of the leaves—and in producing the disease the virus multiplies in the plant. If you inoculate the plant with a few particles of the virus, you will find, after a week or two, that the plant contains a great deal of the virus, and you can isolate from the plant juices many times as many virus particles as you put in. The interesting thing about these virus particles is that they are not only much smaller than bacteria—but they really seem to be simpler than bacteria. Viruses do not have a very complicated chemical structure; they don't carry on all the chemical activities of ordinary cells. It appears that the only activities viruses are capable of are reproduction and mutation. The viruses are very close to being particles which possess just the two elementary attributes of living matter.

The chemical composition of the tobacco mosaic virus has been studied, and it has been found to consist of only two parts—an outer jacket of protein and an inner core of nucleic acid. Recently two workers — Fraenkel-Conrat and Williams—at the Virus Laboratory of the University of California succeeded in separating the protein part from the nucleic acid part and then putting them back together again, reconstituting the infective virus.

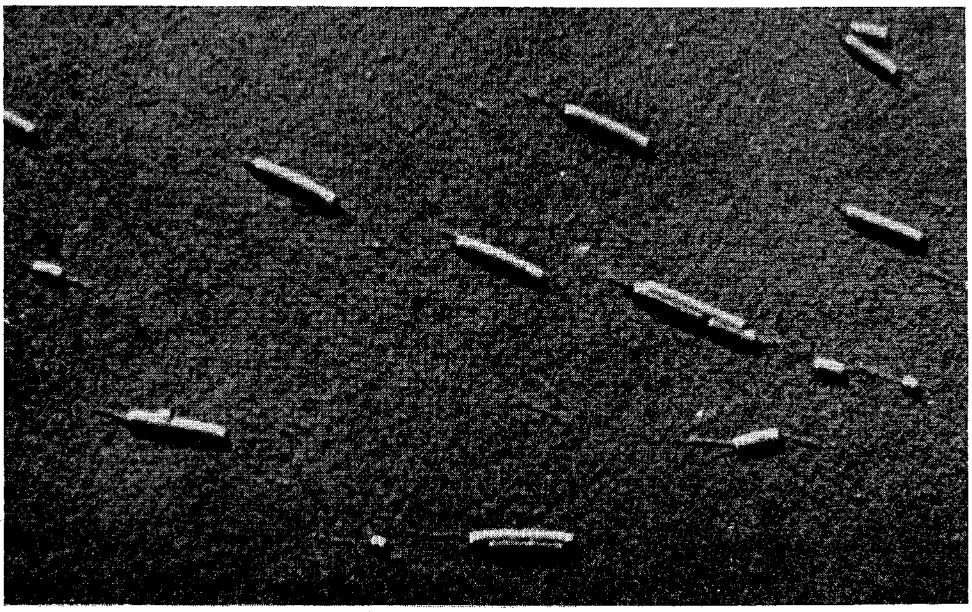
On looking at this experiment more closely a very interesting thing appears. Fraenkel-Conrat and Williams, of course, tested the solution of protein to find out if it had any virus activity by itself, and found that it does not. When they carried out the same test with the nucleic acid, they found a slight infectivity which, at first, they assumed was due to contamination by active virus particles that had not been disintegrated by the chemical treatment. On repeated tests, it appeared that they could not remove the small amount of infectivity from the solution of nucleic acid—and it has now been proven that the nucleic acid by itself has infective properties.

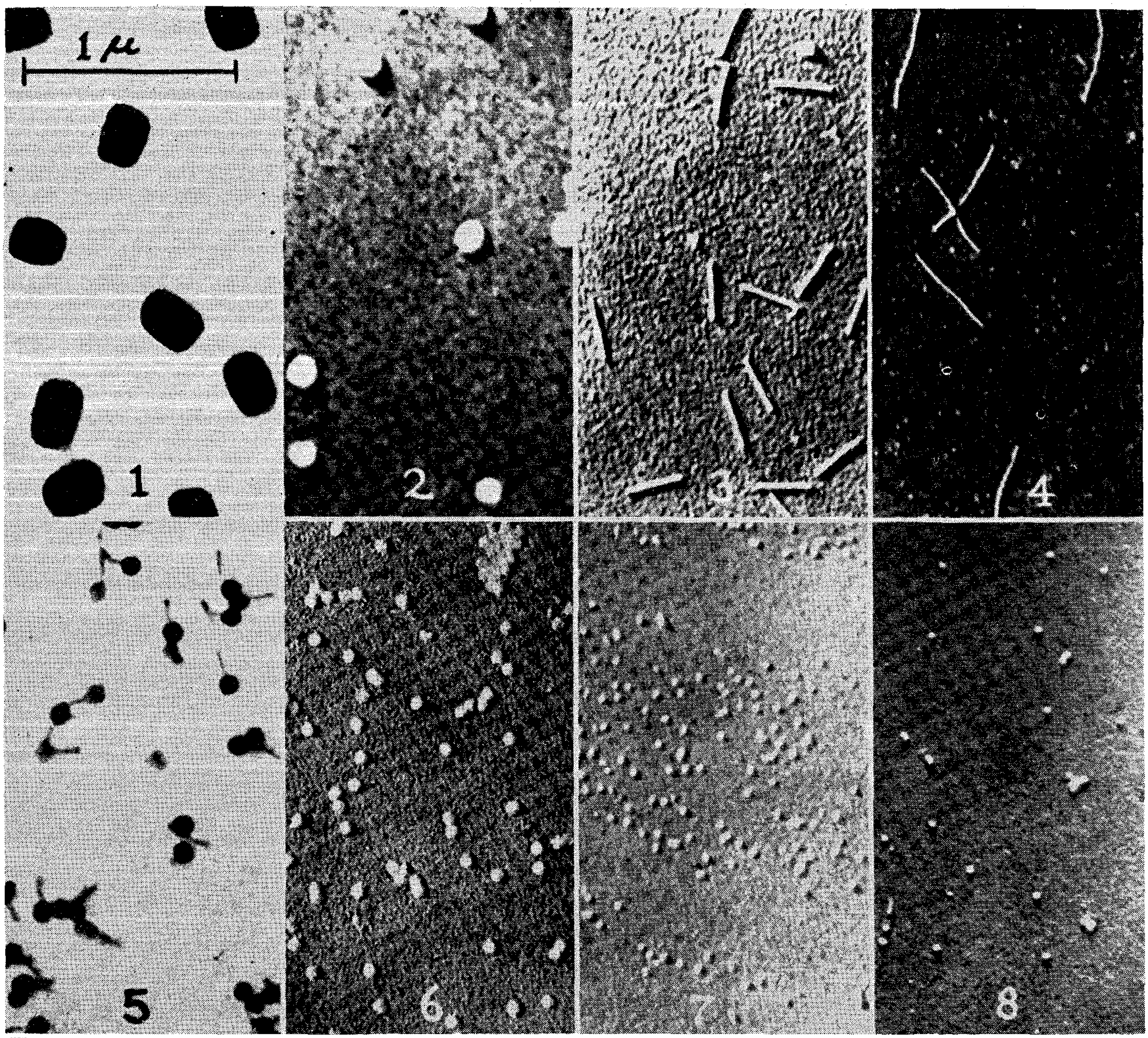
This means that the properties of self-duplication and mutability reside not in the whole virus particle but just in the nucleic acid part.

This finding is in accord with other experiments done on other organisms which indicate that nucleic acids have infective properties and are capable of reproducing themselves and of mutating.

Some biologists now think that the nucleic acids—perhaps combined with proteins — were the original

Electron micrograph of tobacco mosaic virus that has been treated with a hot detergent in such a way as to cause the decomposition of part of the virus—revealing that the virus consists of two parts, an outer jacket of protein and an inner core of nucleic acid.



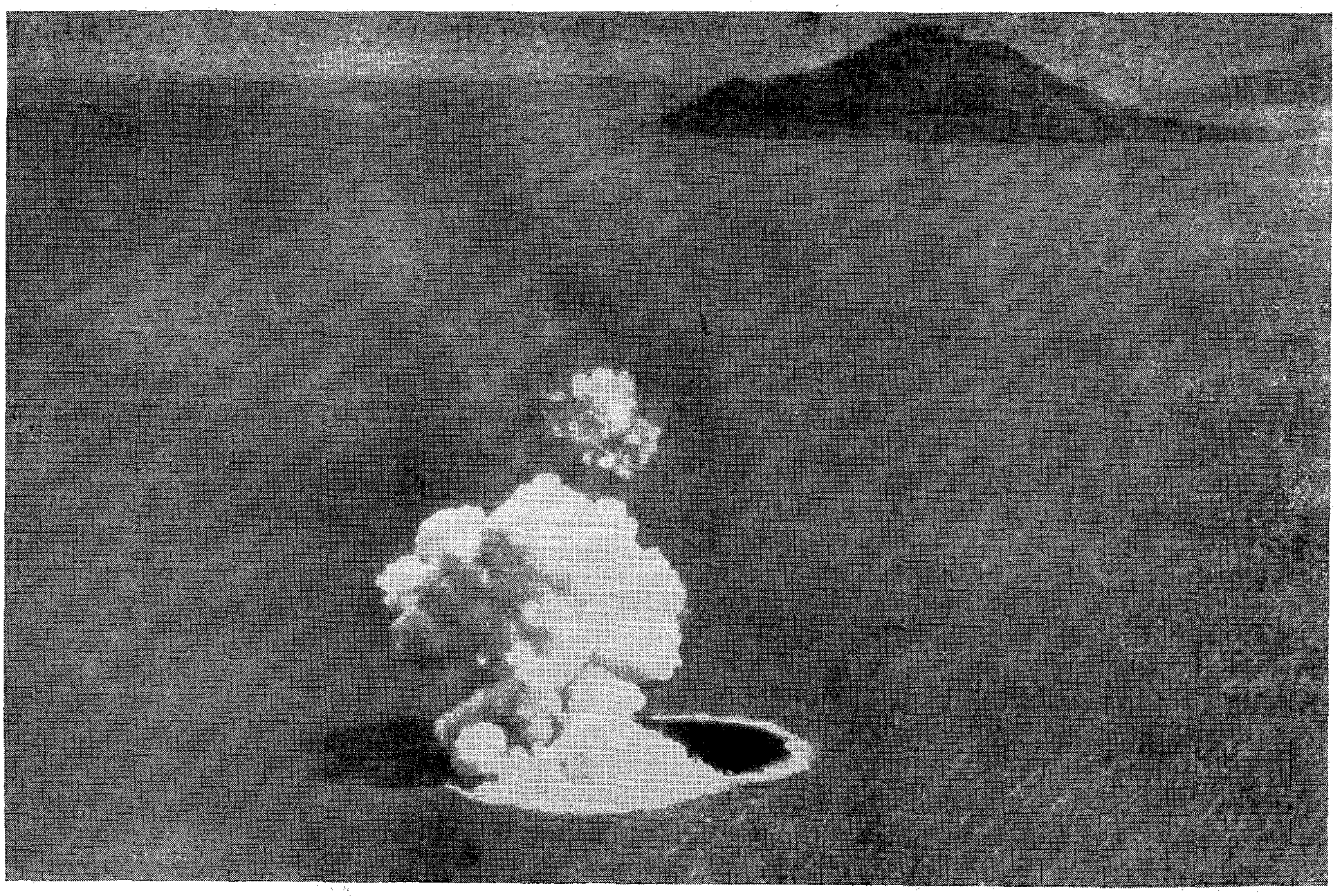


Electron micrographs of some highly purified viruses: (1) Vaccinia (2) Influenza (3) Tobacco mosaic (4) Potato-X (5) Bacteriophage (6) Shope papilloma (7) Southern bean (8) Tomato bushy stunt.

forms in which living matter first appeared on the earth. These molecules are very much simpler than bacteria, and Van Helmont's mice. There is a chance that, given enough time and given the right conditions, a nucleic acid molecule could be spontaneously generated in the proper chemical medium.

Geophysicists think there were about two billion years between the origin of the earth and the first signs of living matter. That is a long time, of course, and many improbable things can be accomplished in that long a stretch. The conditions of the earth at that time, we are told, were quite different from now. The atmosphere consisted not of oxygen, nitrogen and carbon dioxide, but of hydrogen, ammonia, methane and water. Quite recently Dr. Stanley Miller of the University of Chicago (a post-doctoral fellow at Caltech last year) tried the experiment of passing an electric discharge through an atmosphere consisting of these four gases to see what would happen. He was simulating on a small scale the conditions that the geophysicists say existed on the earth some two billion years ago. He found a large number of organic compounds at the end of the experiment, including a number of amino acids. He found no nucleic acid, or nucleic acid building blocks, but he did find amino acids, which are the building blocks of protein.

There are about 20 different amino acids in an ordinary protein. In Miller's experiment, he found glycine, alanine, aspartic acid, glutamic acid and about 20 others which do not occur in protein. These four amino acids are very far, of course, from a protein, and they are even much farther from a living cell, but that is where this problem stands today—and I guess that is where I had better leave it.



Krakatoa, the volcano that shook the world in 1883, still rumbles deep in its submarine crater.

VOLCANOES, ICE AND DESTRUCTIVE WAVES

by FRANK PRESS

THE NEWSPAPERS in recent months carried dispatches about the detonation of a hydrogen bomb in the megaton range. This was the largest man-made, or artificial, explosion ever achieved. Impressive as this was, however, one of nature's explosions still transcends all of man's attempts in this field to date—the explosion of the volcano Krakatoa which took place in the Sunda Strait on August 27, 1883. Not all of the phenomena associated with this explosion are understood even today, nearly 75 years later. Fortunately for modern students of Krakatoa phenomena, the data are readily available in the form of a detailed report prepared by a committee of the Royal Society appointed soon after the explosion.

Krakatoa lies almost in the middle of the Sunda Strait, a narrow, shallow body of water, with an average depth of about 200 feet, which ties the Indian Ocean to the China Sea. The volcano was in a period of relative inactivity prior to May, 1883. Gas and steam issued from a few scattered vents, but in May a new series of violent eruptions began. Typical of these eruptions, as the old books describe them, was a flaming region where the boiling lava poured down the sides, and a tremendous cloud of steam and volcanic ash that went high into the atmosphere, producing rain and severe electric storms in the vicinity of the volcano. Pumice and ash filled the Sunda Strait, and ships had difficulty cruising there. As the eruptions became more and more severe the strait was cloaked in darkness even in midday as clouds formed by a combination of steam, mud and water blotted out the sun. There was a rainfall of hot mud and soot which fell on the decks of nearby ships, until the crews had to use their sea pumps to play water on sails and decks to remove the hot sulphurous materials that came down from the sky.

It is only a matter of conjecture at this time as to why Krakatoa exploded the way it did. Volcanoes erupt in different ways. They erupt through fissures that occur in the earth, through which lava flows freely and forms plateaus such as we have in the Pacific Northwest. At the opposite extreme are the eruptions which result in cones with very steep sides, formed by falling cinders. Severe explosions are rarely associated with a volcano; in fact, Krakatoa represents the only known occurrence of a cataclysmic explosion in which a tremendous amount of energy was released almost instantaneously.

The reason why

Why this occurred at Krakatoa is not known. Conjecture has it that the ready access of sea water surrounding the island was responsible—not so much in forming superheated steam as it floated into vents and tissues, but in entering the crater and forming a cap by chilling and solidifying the lava. This did not stop the volcanic activity below, of course, which continued with the generation of steam and gas. Pressure was gradually built up, while the cap prevented its release. Then, at one stroke, the cap was impulsively blown out. The explosion was so tremendous that it almost entirely eviscerated the volcano, and it profoundly altered the surface and submarine topography in the surrounding region. A vast quantity of solid material was blown into the atmosphere, the coarse components falling locally, creating new banks and shoals in the Sunda Strait. The lighter material went into the atmosphere and formed clouds. These clouds were so extensive that at Batavia, more than 100 miles away, there was almost complete darkness at noon. The rain which fell was essentially a rain of mud—the drops consisting of 90 percent mud and 10 percent water. Associated with the mud-fall were severe electric storms. It was quite a frightening spectacle.

The fine dust went high into the atmosphere—so high as to reach air currents which disseminated the particles throughout the world. Unusual atmospheric optical effects appeared. Brilliant sunsets with unexpected hues, blue-colored moons, and rings and halos around the sun and moon were observed throughout the world.

The main loss of life which was connected with the eruption of Krakatoa resulted from destructive sea waves which were excited by the final explosion. Some 36,000 inhabitants of the adjacent coastal areas lost their lives in 100-foot waves that came without warning. (But, strangely enough, ships in the Sunda Strait close to the volcano were not harmed.)

As is the case with most tidal disturbances, it was the local effect of the coast line which funneled the destructive waves into certain areas. The Krakatoa tidal wave was not unlike the earthquake-generated sea waves which occasionally visit the coasts of South America and Japan. One theory has it that the earthquake initiates a submarine avalanche which runs down the continental slopes into the deep ocean, providing enough push to set the big tidal wave into motion.

California tidal wave

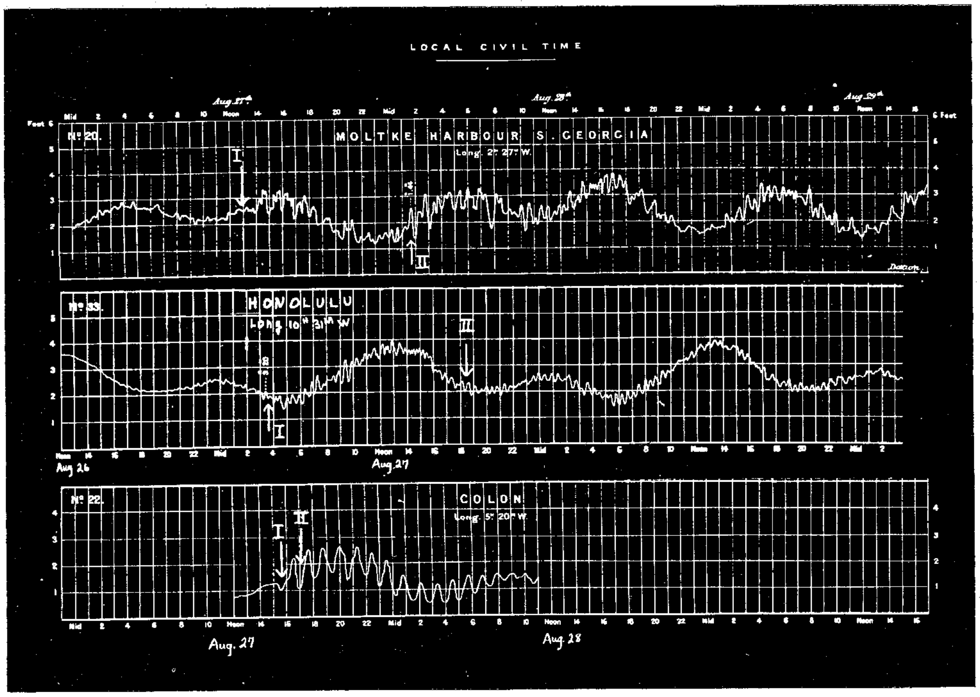
California is fortunate in not having tidal waves associated with its earthquakes—though this is not entirely true because, in 1812, one of our big earthquakes was accompanied by a tidal wave that may have reached a height of 50 feet at Ventura and at Gaviota, and about 30 to 35 feet at Santa Barbara. There was not much habitation in that area then, and the reports that we have are quite meager, but if it happened today, of course, tremendous destruction would occur.

Once excited, a tidal wave crosses the ocean at a very definite speed (given by the square root of gh, where g is the acceleration of gravity and h is the depth of the water). Tidal waves sometimes traverse the ocean many times. Earthquakes have been known to send them across the Pacific to another continent, where they are reflected and returned to the continent from which they started. These are by far the most destructive tidal waves.

Another variety is that associated with a storm. This is the kind of wave that did such damage on the East Coast last year, along with the Edna and Hazel hurricanes. This wave is associated with the low pressure area and the winds of the hurricane moving on the shore. When these arrive at a time of normal high tide, the excess above high tide produces an inundation on the coast line. This is not so much a wave coming in and going out as it is a general rise of the sea level that lasts from 6 to 24 hours.

The Krakatoa tidal wave was different. The explosion, the debris coming down, and its impact on the water—all of these together produced the tidal wave.

One of the most important features, scientifically, of the Krakatoa explosion was the sea wave which reached remote places throughout the world. These waves were only one or two feet high—too small to cause any damage—but of great significance because of their mechanism of propagation. Our knowledge of these comes from records made by tide gauges which were operating in important harbors. It is very important for shipping to measure the tides precisely so that ships can know the best time to come into harbor, the best

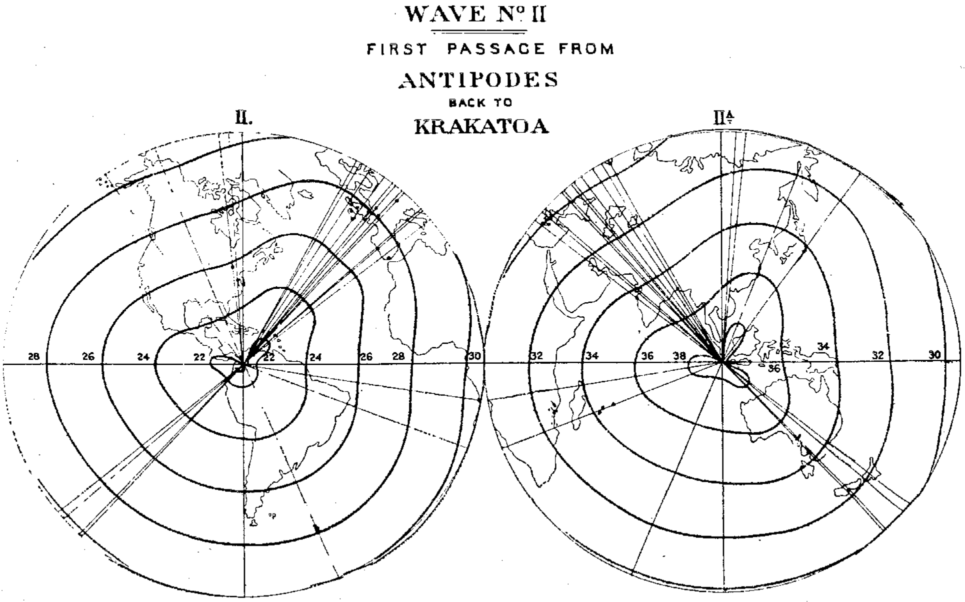


Tide gauge records from South Georgia, Honolulu and Colon showing Krakatoa sea waves superimposed on the normal tides. Arrows indicate arrival of first and second atmospheric waves.

time to tie up, and to sail. It was especially important, of course, in those days when so much depended on wind. Fortunately, the tide gauges of 1883 were sufficiently well designed to provide fairly good records of the Krakatoa waves. Thus we have instrumental data for the Krakatoa sea waves from such widely separated places as Honolulu, San Francisco, Colon, South Georgia and English Channel ports.

Another significant phenomenon associated with the explosion of Krakatoa was the atmospheric waves. We would expect an explosion of this sort to make a big sound—and it did; in fact, it was probably the biggest sound that was ever created, that we know of. It was as if there was an explosion in New York and the sound was heard in Los Angeles. Audible sounds, not unlike distant cannonading, were reported from as far as central Australia and India. The sub-audible atmospheric pressure pulse was detected by barographs on each of four passages around the earth. The fact that these early instruments were able to detect the wave after it had travelled some 75,000 miles testifies to the strength of the explosion.

One feature of the Krakatoa sea wave remained unexplained until very recently. The wave that reached the English Channel had to go around Africa and travel up the Atlantic Ocean. The wave that reached Colon had, further, to cross an effective barrier formed by the Antilles. The wave that came to San Francisco could not have gone by a direct route because of the barrier formed by the East Indies; in order to explain its arrival it was necessary to postulate a path involving a detour below Australia.



Atmospheric waves sent out by Krakatoa explosion made at least four passages around the earth. Diagram shows wave front of aerial disturbance after first passage through Antipodes. Times noted are in hours after zero hours, GCT, August 27, 1883.

Even if these unlikely paths are accepted, the observed travel times of the waves correspond to velocities that are inconsistent with the known depths of the ocean. Thus, the Krakatoa sea waves that reached widely separated parts of the world presented such a problem that most investigators came to doubt their connection with the explosion. The only explanation that could be offered was the unlikely one that local earthquakes, occurring coincidentally, produced the local sea waves. This basically untenable explanation of the Krakatoa sea waves remained with us until very recently.

Ice provides a clue

Oddly enough, it was work on ice that finally gave us a clue to the mechanism of propagation of the Krakatoa sea waves. Several years ago, together with colleagues at Columbia University and the Air Force Cambridge Research Center, I worked on ice—in the form of floating sheets, as it occurs in northern lakes or in the Arctic Ocean. Our interest in floating ice was stimulated by an Air Force problem—that of finding a method by which planes can determine the ice thickness in order to know whether it is safe to land or not. We thought of all sorts of fancy electronic schemes to use in the solution of the ice-landing problem, and in the very early days of this project we had some weirdly complicated contraptions—all of which were in sharp contrast to the simple solution found by a few Arctic pilots. They just bounce their planes off the ice without losing flying speed, then circle around and examine it. If the ice has a hole or a crack in it, they know it isn't thick enough. With the modern trend towards electronic methods, however, such a simple scheme never had a chance for wide adoption.

Our first serious approach to this problem involved the use of elastic waves transmitted through the ice. We conceived the idea of parachuting a small telemetering seismograph to the ice so that elastic waves excited by a small bomb could be detected in the airplane. We started experimenting directly on floating ice by exploding small charges and detecting the resultant elastic waves with small microphones—geophones—placed on the ice surface at distances of several thousand feet from the explosion. Explosions in the ice, or below it, gave the expected results of flexural vibrations which are characterized by a gradual variation of frequency and phase velocity with travel time.

To avoid the trouble of digging shot-holes in the ice, several tests were made in which the charges were detonated on the surface. Much to our surprise, the character of the resultant vibrations was profoundly altered. The geophones detected a train of constant frequency vibrations in which the phase velocity was equal to the speed of sound in air. In other words, we inadvertently demonstrated in this experiment that an explosion in the air can produce significant elastic waves in the ground of a special kind—in that the phase velocity of these waves in the ground is the speed of sound in the air.

Air wave and sea wave

So the tidal waves from the Krakatoa explosion were not tidal waves in the usual sense, but were excited by the great air wave as it swept across the ocean adjacent to the tide gauge stations. Indeed, a check on the arrival time of the Krakatoa air and sea waves at a number of widely separated locations shows that this is the only plausible mechanism.

Thus the ice work, completely unrelated, and performed for an entirely different purpose, provided the key to the unexplained sea wave from Krakatoa. Another clue was provided by an equally unrelated research project.

This part of our work began when the New York *Times* published a news dispatch concerning a disturbance which occurred on Lake Michigan on the morning of June 26, 1954. About a dozen people were fishing from docks in the vicinity of Chicago. The weather was clear at the time. Suddenly a wave appeared out of nowhere and swept seven people to their death.

This unique event was all the more peculiar since Lake Michigan is located in a non-seismic area and the weather was clear. Why should a destructive sea wave, with an amplitude of 10 feet, suddenly appear and wash all of these people into the lake?

A coupling mechanism

It occurred to us that this might be another example of the coupling mechanism we found in our ice studies, which so well explained the Krakatoa wave. We surmised that an atmospheric pressure disturbance swept across the lake with just the right velocity to excite a destructive sea wave, and an examination of the meteorological records showed this to be the case. A pressure pulse did indeed occur an hour before the accident, and its velocity was the critical one for this part of Lake Michigan—65 miles an hour. Fortunately, though atmospheric pressure disturbances occur frequently, very few travel with this high velocity.

We have seen how three apparently unrelated phenomena are tied together by a common mechanism. In one sense we have here an argument for broadness in science, for had we not known about the Krakatoa problem, our ice work could have been simply an interesting experiment, performed for a very special purpose. As it turned out—not only could the special purpose be satisfied, but a fundamental geophysical mechanism could be demonstrated.

THE MONTH AT CALTECH

Chemical Biology

THE NORMAN W. CHURCH LABORATORY of Chemical Biology, a major addition to the research facilities at Caltech, will be officially opened on November 15. The new laboratory accommodates the Institute's rapidly expanding research in areas where chemistry and biology overlap, in relation to medicine.

The building, which cost more than $1,500,000, is equipped for the newest advanced techniques in chemistry and biology. Located at the northwest corner of the campus, at the intersection of Wilson Avenue and San Pasqual Street, it is 305 feet long and 52 feet wide, with five floors over half its area and four floors over the other half. A wing connects it with the Crellin Laboratory of Chemistry on the east, and another wing connecting it with Kerckhoff Biological Laboratories on the south is planned for the future, when funds are available.

The building was constructed from August 1954 to August 1955—financed by a gift of the late Norman W. Church and a sum of $510,000 advanced by the Caltech Board of Trustees. The total cost of the laboratory, when fully completed and equipped will probably run to more than $2,000,000.

There will be no formal ceremony at the dedication of the laboratory on November 15, but an Open House will be held for Associates and Trustees, chemical biology faculty members and special guests. In the evening, at a dinner in the Athenaeum on campus, guests will hear a talk by Warren Weaver, vice president for the Natural and Medical Sciences of the Rockefeller Foundation.

The Rockefeller Foundation is supporting the work in chemical biology at Caltech with a $700,000 seven-year grant. Additional supporting funds for the new building and equipment have been given by the National Foundation for Infantile Paralysis, the Carl F. Braun Estate, the Ford Foundation and anonymous donors.

Nobel Prize

WILLIAM SHOCKLEY, who received his BS at Caltech in 1932, and spent a term here in 1954 as visiting professor of physics, is one of three American scientists to share in the 1956 Nobel Prize in physics. The $38,634 award will be divided equally between Dr. Shockley, Dr. Walter Brattain of Murray Hill, New Jersey, and Dr. John Bardeen of Champaign, Illinois, for their work in inventing and developing the transistor.

The development of this small, inexpensive device which performs practically every function of a vacuum tube in electronics and communications, was first announced in 1948, when the three men were all at the Bell Telephone Laboratories in Murray Hill, New Jersey —Shockley and Brattain working together, as members of the research staff, and Bardeen working independently.

Dr. Brattain is still with Bell Labs, as a member of the technical staff; Dr. Bardeen is a professor of physics at the University of Illinois; and Dr. Shockley is now director of the Shockley Semiconductor Laboratory in Mountain View, California. A division of the Beckman Instruments Company of Fullerton, the laboratory was set up under Shockley's direction in December, 1955, to further development of the semiconductors of which transistors are made.

Plant Research

FRITS W. WENT, Caltech professor of plant physiology, received a doctorate from The Sorbonne in Paris early this month, in recognition of his outstanding research on plant life. This honorary degree is given only once every six years in the field of botany. While in Paris, Dr. Went will give several lectures at the University of Paris and at The Sorbonne, speaking in particular on

CONTINUED ON PAGE 36

smog in Paris and the resulting damage to plants. In his studies of air pollution in Paris in 1950 and 1952, he found no smog, but in 1954 Dr. Went found that a gradual development of smog was causing serious damage to certain plants in the French capital.

Dr. Went is in charge of Caltech's Earhart Plant Research Laboratory and is also president of the California Arboretum Foundation, Inc., in Arcadia.

Russian Astronomy

DR. JESSE L. GREENSTEIN, professor of astrophysics at Caltech and staff member of the Mount Wilson and Palomar Observatories, returned last month from a one-month trip to Russia, where he was a guest of the Soviet Academy of Sciences at the opening of the new Bjurakan Observatory, near Erevan in Soviet Armenia. Only seven other non-Russian scientists attended the conference—two from the United States, two from Red China, and one each from France, Jugoslavia and Mexico.

By American standards Bjurakan is not a particularly remarkable observatory, according to Dr. Greenstein; it is equipped with 20-inch telescopes. The largest telescope in Russia today is a 50-inch reflector. But the Russians are placing a good deal of emphasis on astronomy, and their effort is at least as great as ours, Dr. Greenstein says; they are certainly spending as much money on it as we do, and they have twice—maybe three times—as many astronomy students as we have in this country. It seems certain that the Russians will eventually overcome the deficit in equipment, and they are already planning construction of 80-inch and 100-inch telescopes.

President Clark

DONALD S. CLARK, professor of mechanical engineering, director of placements, and secretary of the alumni association at Caltech, was installed as president of the American Society for Metals on October 10, at the society's annual meeting in Cleveland, Ohio.

Dr. Clark was National Trustee of the American Society for Metals in 1939-40, served as Edward DeMille Campbell Lecturer of the society in 1953, and has been national vice-president for the past year.

Ford Aid to AUFS

THROUGH ITS MEMBERSHIP in the American Universities Field Staff, Inc., Caltech will share in the benefits of a new Ford Foundation grant of $1,800,000.

Caltech is one of 10 educational institutions that control and help to support the activities of the AUFS, a nonprofit corporation that was established in 1951 by a group of college presidents who wanted to breathe a little life into the study of foreign nations and cultures. The new Ford grant assures continuation of the AUFS program.

The AUFS selects and trains qualified young men, and sends them into the foreign field for two-year periods. These correspondents send back a total of more than 100 reports a year to the institutions sponsoring the AUFS program. After each two-year stint, correspondents return to the United States to visit the member campuses and report personally on current conditions, problems and personalities in the areas they are covering.

Each year four AUFS men visit the Caltech campus to give a series of lectures and informal talks. First to arrive this year will be Lawrence Olson, home from Japan, who will be on campus from January 7 to 16. On January 21 Edwin S. Munger will be here to talk about events in Africa south of the Sahara; this will be Mr. Munger's third visit to Caltech. Albert Ravenholt will also be here for the third time, reporting on the Philippines and the Far East, from February 4 to 13. Finally, Charles Gallagher will check in on February 25 to discuss Northwest Africa.

To finance the AUFS program, each of the 10 sponsoring institutions contributes the equivalent of the average salary paid to an associate professor on its faculty. Additional income to support the program comes from the use of correspondents' reports by business firms, other institutions and publications, and endowments. The new Ford Foundation grant may make it possible to add more correspondents to the AUFS staff.

Campus Poll

IT'S PAST HISTORY now, but students in Dr. James Davies' course in political parties and pressure groups—in cooperation with the Caltech YMCA—took a pre-election poll last month of campus opinion on candidates, parties and campaign issues. The results, though they could not be said to have forecast the election with the accuracy of Gallup or Roper, should at least provide Dr. Davies' students with enough baffling information to analyze for the rest of the year.

A random sample consisting of half the faculty, one-quarter of the graduate students, and one-quarter of the undergraduates was used for the poll. Returns came in from 70 percent of the undergraduates, 57 percent of the graduate students and 59 percent of the faculty. With a total of 63 percent returns, the Caltech community went 52 percent for Eisenhower, 43 percent for Stevenson and 5 percent Undecided.

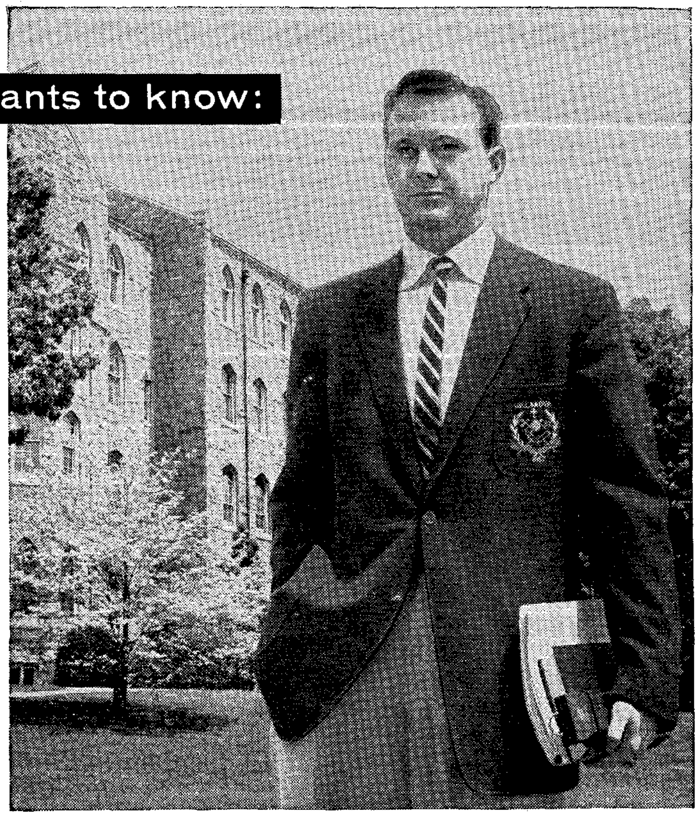
The breakdown by "class" was more interesting:

	Eisenhower	*Stevenson*	*Undecided*
Undergraduate	63%	32%	3%
Graduate	55%	36%	9%
Faculty	22%	76%	2%

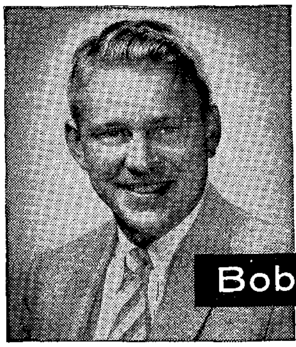
History 25 students are already at work trying to find out what it all means.

John Nettleton wants to know:

How would a graduate degree affect my chances for advancement at Du Pont?



John C. Nettleton expects to receive his B.S. in chemical engineering from Villanova University in June 1957. He has served as president of the student chapter of A.I.Ch.E., and as secretary of Phi Kappa Phi fraternity. John is now wondering about the pros and cons of advanced study in his field.



Bob Buch answers:

Robert J. Buch, M.S., Ch.E., came to the Engineering Development Section of Du Pont's Grasselli Research Division from the University of Louisville four years ago. Since then, he has engaged in many kinds of chemical engineering work, from pilot-plant operation to evaluation of the potential of proposed research programs. Within the last year, Bob has taken the responsibility of procuring B.S., M.S., and Ph.D. technical graduates in all phases of chemistry and chemical engineering for the Grasselli Research Division.

An advanced degree would undoubtedly have a *favorable* effect in technical work, John, but let me enlarge on that just a little. In your own field (and mine, too) a higher degree is considered to be evidence of ability in carrying out original research. It is therefore helpful in obtaining work in research and development, where that skill is definitely important. You might say that it gives a man a head start in proving his ability in those areas.

It's less important in some other areas, though. For example, in production or sales work ability for handling human relationships is just as important for advancement as technical competence. If an engineer is sold on production work or sales, a graduate degree in marketing or business administration might be more helpful to him than advanced technical training in getting started.

But I've noticed this at Du Pont. Once a man lands a job in his chosen field and actually begins to work, his subsequent advancement depends more on demonstrated ability than on college degrees. That's true throughout the entire company—in scientific work, administration, or what not.

So an advanced degree is not a royal road to anything at Du Pont, John. But when coupled with proven abilities, it is unquestionably helpful to a man in research and development work. It often gets him off to a faster start.

Are you interested in research work?

About 2,000 Du Pont scientists are currently engaged in research, aided by some 3,500 other employees. Laboratory facilities of the highest quality are available at the Du Pont Experimental Station near Wilmington, and elsewhere throughout the country. Information about research at Du Pont is given in "Du Pont Research." Write for your copy of this free 28-page booklet to the Du Pont Company, 2521 Nemours Building, Wilmington, Delaware.

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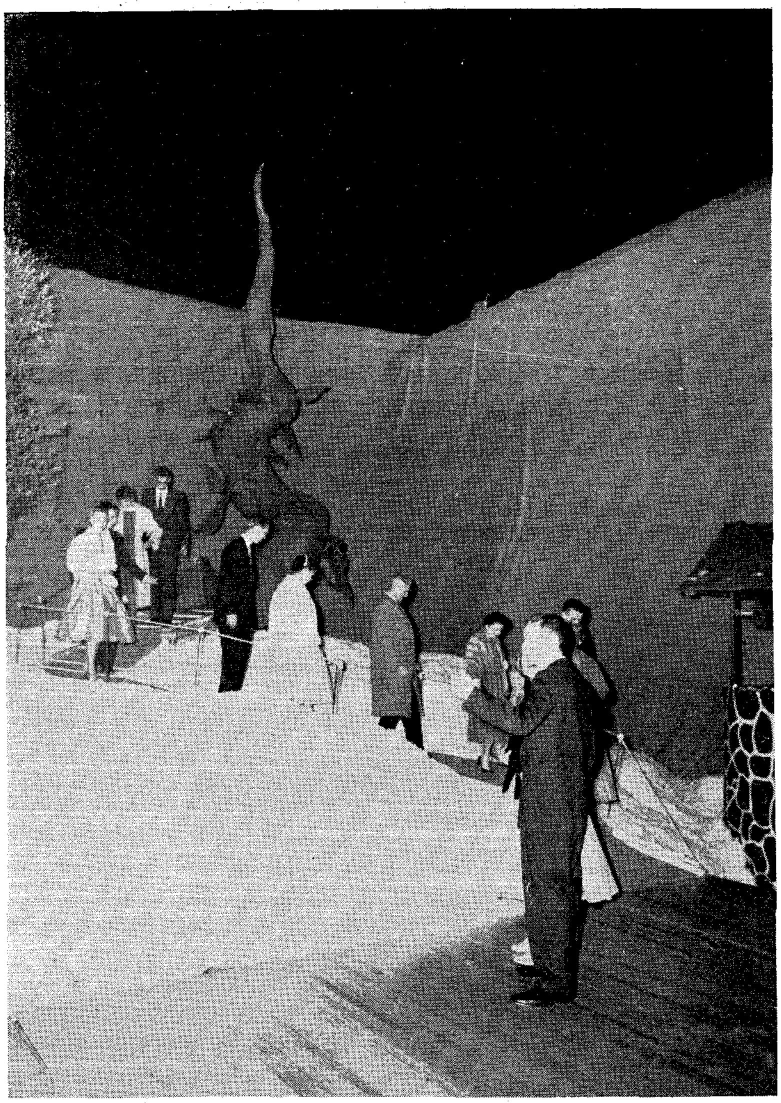


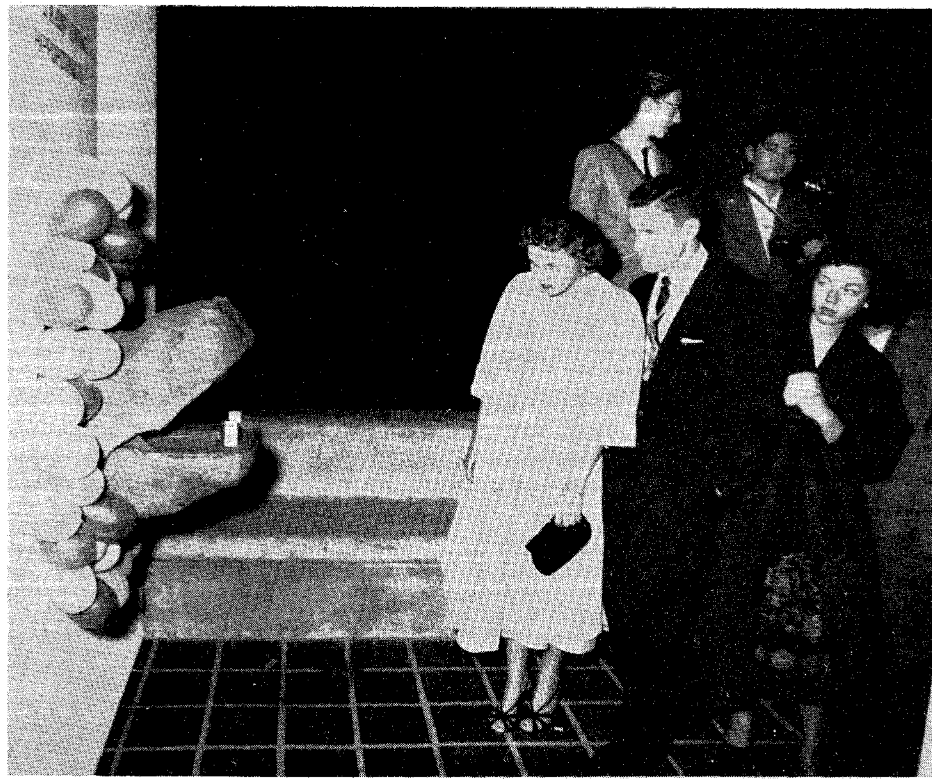
Guests descend on Blacker House by way of a 40-foot beanstalk

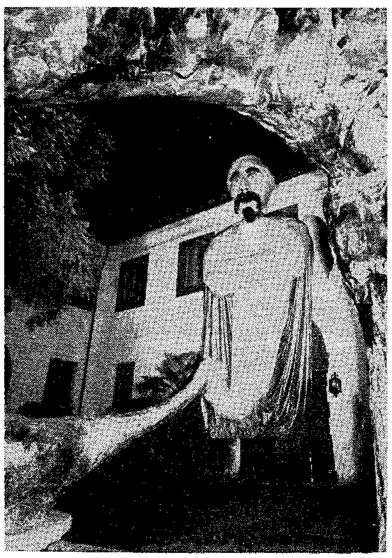
ONE-NIGHT STAND

At CALTECH'S 1956 Interhouse Dance on November 3, guests were able to visit Venice (Fleming), Interstellar Space (Throop), Toyland (Dabney), an Arabian Night (Ricketts), or Jack and the Beanstalk (Blacker). Though the pictures on these pages can only give a pale approximation of the glittering event, they at least indicate why this annual undergraduate Spectacular has become—not only famous, but even notorious.

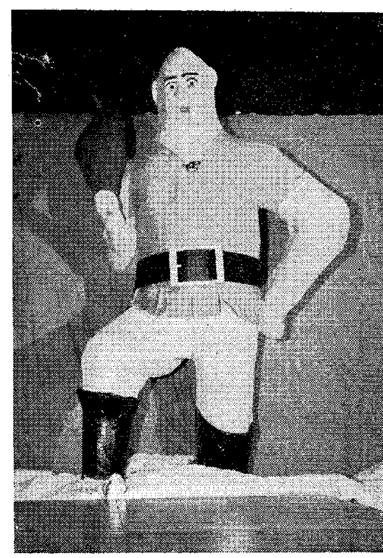
Dabney's dance floor, covered over with a budget-busting blanket of balloons

Awed guests warily approach Dabney's versatile hippopotamus, which rolled its eyes, wiggled its ears and swallowed paper cups throughout the evening.





Biggest men at the dance were the genie (left) issuing from a magic lamp in Ricketts' Arabian Nights courtyard, and the wide-eyed giant in Blacker's Jack and the Beanstalk layout.



In Toyland, a lemonade spring bubbles brightly at the foot of a hyperactive volcano, shooting popcorn from its crater.

brains regulating processes better than could be done by human hands or judgement. Honeywell instruments, for instance, are presently in use on every U. S. atomic reactor. Instrumentation holds sweeping potentialities as industry becomes increasingly complex and as automation is applied to more and more of its processes. Typical industrial products include indicating, recording and control types of potentiometers, pyrometers, pressure gauges, industrial thermometers and flow meters, electronic control panels, and thousands of other devices.

3. Aeronautical controls: In addition to extensive research, engineering and manufacturing facilities in Minneapolis, another complete plant is being built in St. Petersburg, Florida, expressly for the development and manufacture of inertial guidance systems. There is also a complete Engineering Development Center for aircraft and missile controls in West Los Angeles. Some challenging engineering interests include automatic flight control systems; hydraulic and pneumatic jet, ram jet, and rocket engine controls; instrumentation; and airborne digital and analog computers. Honeywell is a major supplier of automatic pilots, bombing systems, gyroscopes, and integrated weapons systems for aircraft and guided missiles. The Honeywell electronic fuel-measuring system is the standard of the industry, and Honeywell leads in developing transistorized instruments for aircraft.

4. Precision switches: Engineering and manufacturing in Freeport, Illinois; with additional plants in Warren, Illinois and Independence, Iowa; plus research facilities in Denver. Honeywell's 5000 variations of electrical MICRO SWITCH snap-action and mercury switches are used in countless ways. They permit a slight motion or a small physical force to control an electric motor or current. They are particularly useful where space or weight limitations are important—as in aircraft, missiles and rockets, automatic machine tools, dictating machines, and automatic transmissions for automobiles.

5. Ordnance: Engineering and manufacturing in Minneapolis; a complete new Engineering Development Center for missiles in Monrovia, California; and engineering laboratory facilities in Seattle, Washington. In this Division a great many vital defense products and systems—such as complete missiles and components, fire-control systems, and proximity fuzes are produced.

6. Servo components: Honeywell engineering and manufacturing plants in Boston produce precision synchro motors, gyroscopic instruments, and electro-mechanical servo components for standard use in jet fighters, guided missiles, and bombers. The newest development is a vital control device for the automation of manufacturing processes.

7. Oscillographic and Photographic equipment: The Honeywell plant in Denver produces high speed recording oscillographs, scientific laboratory equipment, and a complete line of Heiland photographic flash equipment.

8. Transistors: The Boston plant develops and manufactures high-output power-type transistors.

9. Research: In a complete Research Center in Hopkins, a suburb of Minneapolis, emphasis placed on fundamentals has led to comprehensive basic research programs in the fields of: solid state physics, metallurgy, ceramics, magnetic and dielectric materials, physical chemistry, electronics, heat transfer, and mechanics. Honeywell is continuing its steadily increasing expenditure for fundamental research.

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MINNEAPOLIS
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IT'S ABOUT THAT TIME

SENIOR YEAR—It didn't seem much different from any other year, the Senior thought to himself.

When he had been a freshman, the Seniors had been a class apart. They'd been older, wiser, worldlier, even a little bit *bigger* somehow. Just as it had been in high school, they were a world removed from the lower classmen. Every time a Senior—with an imaginary capital letter attached to him—had stopped to talk and joke with him, it had been a lift, a reassurance that he was really a *college* man now.

Now he was there, and somehow the perspective was all different. It was the Seniors who were the regular guys, his buddies, his classmates. He saw the freshmen moving around the campus, groping for a place, and he didn't think he had ever been a freshman—just as, three years ago, he didn't think that he was ever going to be a Senior.

It was the same old *him*, wasn't it? The same interests, the same buddies, the same classes.

The book in his lap was an unnatural weight and he set it aside and stared out the window at the autumn day, drumming his fingers on the chair arm. Outside, the air was cool and clean, and the sky was spotted with little cotton-candy clouds, and the mountains were flecked with the season's first snow.

No, it wasn't the same, nothing was the same, the Senior decided, and he felt that he'd known it all along.

Tomorrow he would be sixty years old. Tomorrow he would be a smiling, wrinkled old grandfather, and the laughing girl who shared his secrets now would be white-haired and quiet.

And he'd watch the kids playing across the street, and he'd think to himself, Pop, you were never like that. And the kids would play in the sun and the autumn, and never believe that they would ever ever be sixty years old.

It was starting already, he thought with a little amusement and a little fear. Now he was "Mister" to the kids, just as much a grown-up as his father had been a dozen years ago. Now nobody ever called him "young man" or "sonny" any more.

I still have until June, he thought mischievously. I can still be a kid for eight months longer.

His mood shifted as he daydreamed about the mad, foolish, childish things he would still do before that frighteningly imminent June came crashing through to the front of the calendar. He thought of the mountains and the beaches, of parties and pranks, of laughter and love.

Twenty-first year.

Year of Commencement, he thought, sobering again. Year of Decision, Year of Orientation. Year of the death of childhood, the year when the preliminaries were completed and the real test began.

It's about that time, the Senior thought with a new seriousness. If I'm not ready to pull up roots, it's about that time. If I'm not willing to say good-byes, to stand in my cap and gown and shake hands with guys that I've loved as brothers and know that I'll never see again, then I've got eight months to make ready.

Outside the sky was dusky now, and the approaching sunset spoke with throaty blues and whispering pinks. Warming at the lovely colors of the autumn sky, the Senior stood and gazed thoughtfully at the quiet lawn.

The Senior had a fatal weakness for pretty sunsets. Throwing on his jacket, he deserted the room and walked eagerly through the hallways. Here and there yellow lights were on now, shading gracefully into the somber twilight.

I have eight months to go, and then I shall be a man, the Senior said to himself matter-of-factly. Soon there would be responsibilities, commitments, and necessities. Soon I will have common sense, soon I will be mature and responsible.

In eight months and a little more I shall be a voter, a professional man, a family man, a prominent citizen, a grandfather.

Meanwhile, the Senior thought warmly, I am twenty years old, strong, self-reliant, and quite free to do what I please. With a heavy inclination to do so.

And nobody's going to stop me if I want to go chasing sunsets.

Bright-eyed, the Senior walked out into the autumn air.

—*Marty Tangora '57*

ALUMNI SCHOLAR

David Bailey '60 is the third winner of an Alumni Association grant

DAVID BAILEY, a freshman from Philadelphia, Pa., is the third Caltech student to receive an Alumni Scholarship—a four-year, full-tuition grant made by the Caltech Alumni Association, through contributions to the Alumni Fund. In 1954, the first scholarship went to Timothy Harrington '58, of Santa Rosa, California. Last year the Caltech Committee on Undergraduate Scholarships gave the second one to Kendall Dinwiddie '59, of Larkspur, Calif.

David Bailey, the Alumni Scholar in the class of 1960, is 17 years old. He seems to have been interested in physics most of his life, and even in grade school used to build crystal radio sets and amuse himself by performing home experiments in electronics and optics. It's his present intention to work for his PhD in either theoretical physics or mathematical physics. Then—and the day seems pretty far off now—he'll decide whether he wants to teach or to work in industry.

Oddly enough, David's father is also a physicist. (A Caltech alumnus, class of 1925, Emerson Bailey is now working for the Budd Co. in Philadelphia.) Even more oddly, David's twin brother, Thomas—now a freshman at Amherst College in Massachusetts—intends to study physics too. David has two older sisters, however—Elsa, 20 and Andrea, 24—who are *not* interested in physics.

David went to Central High School in Philadelphia, which is a pilot school for one of the Ford Foundation's educational experiments, whereby certain college-level courses are given to high school seniors. In David's case, at least, the experiment was successful; he was given credit for Math 1 when he entered Caltech and is taking Math 2 during his freshman year.

In his senior year in high school David also distinguished himself by winning a Philadelphia Science Council Award. The Council gives a battery of aptitude and science tests each year to students selected by science department heads in the Philadelphia high schools. David not only took first prize ($350) but got a summer job out of the competition to boot—working in the Merck, Sharp and Dohme Research Laboratories.

He worked with an experimental psychologist at the laboratories who was investigating the effects of tranquilizing drugs. Animals were used in these experiments—not Bailey. He was usually so busy checking on the animals and repairing the experimental apparatus that he rarely had time to take any tranquilizers himself. As a matter of fact he has never tried them out yet—not even in the first furious weeks of his life at Caltech and the rigors of indoctrination, rotation and initiation. Gives you an idea of the kind of stable character Mr. Bailey is.

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we have at hand only the barest hints. It would not be so destructive if we did not also take our myth as the whole and only explanation of how things really are. The Greeks built for themselves a beautiful heaven of concentric, crystalline spheres, in terms of which everything here below was meaningful. It may have been a good scientific hypothesis for those times, capable of "saving the appearances," but they took it for reality, instead of a partial shadow. Our great simple picture of a universe of *nothing but* evolving matter may be likewise deceiving us. It seems to be quite a logical leap from the strictly scientific question, "If I do this, what will happen?" to a complete picture of the universe.

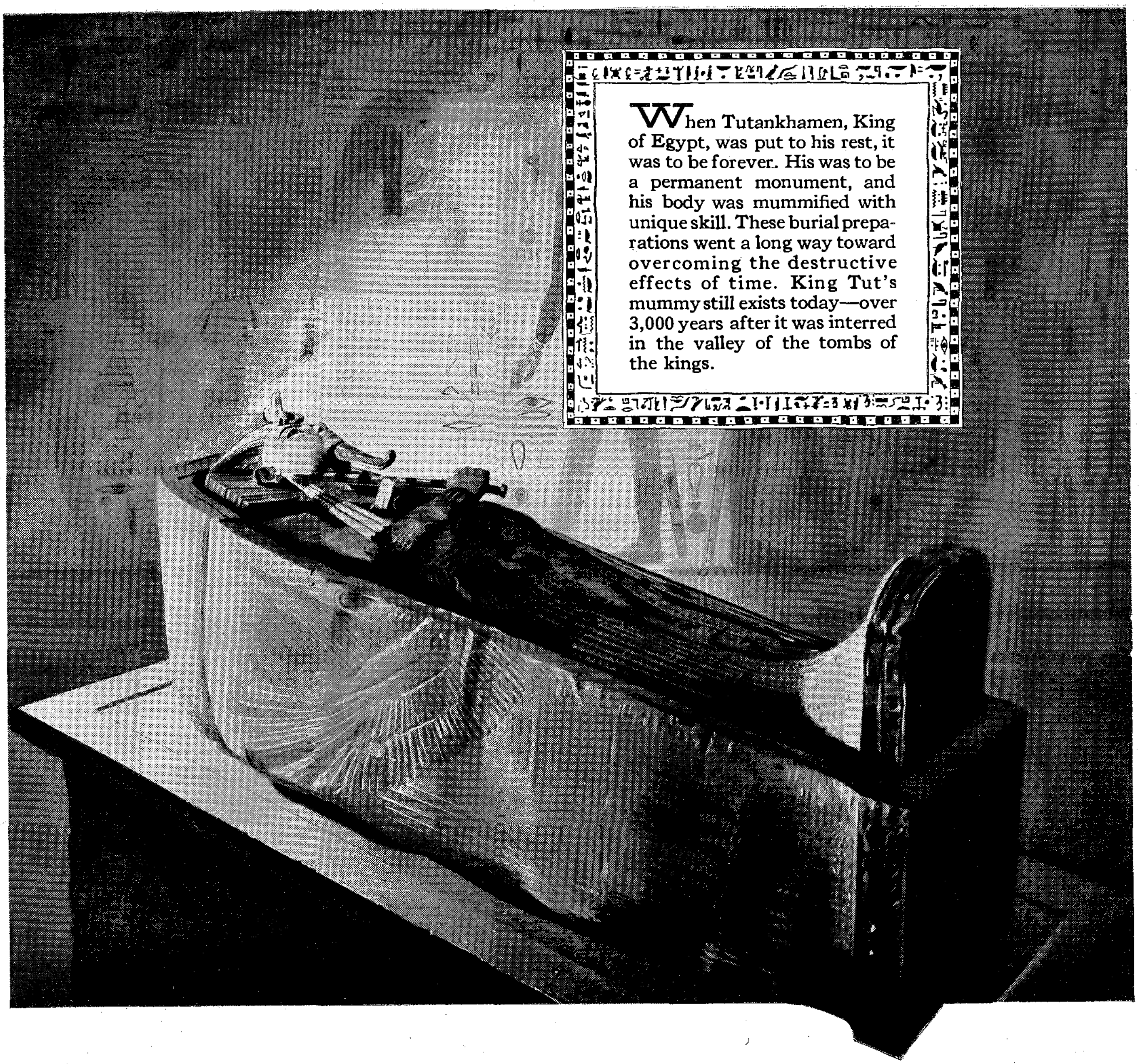
Our discussions and re-examinations should not be confined to the area of scientific method and content alone. If we want to salvage part of religion, we should have a deeper understanding of its inner structure and its attempts at self-justification. I fear that most of us come to our scientific studies with a rather primitive understanding of the content and method of discovery that are involved in our home religions. If we never consider a treatment of a religious question at a level of sophistication somewhat comparable to that at which we do our scientific thinking, we are bound to find religious explanations dissatisfying. If we take a kindergarten expression of a religious view and confront it with a highly evolved scientific statement, we are forced to turn away in wonderment at the religious story's naive simplicity.

A professional viewpoint

If, however, religion can present itself on a theological level similar to that of a specialized science in its professional attitude (though it does not use the same type of starting point or the same method of procedure), then it would seem only sensible to examine its claims in terms of this more fully-developed statement of their grounds.

It may be that religion, when it has made careful self-reflections, can justify itself as a complementary approach to reality which in no way conflicts with that of science. As long as scientists do not use their science to answer questions beyond its powers, and religionists likewise do not force their religion to give them answers that it has no ability to provide, they might be able to avoid the apparent clash which comes from "trying to answer the same questions in the same realm."

. . . The major block in the way of any reconciliation of science and religion today seems to be the lack of an adequate metaphysical method. Any development of religion or of


When Tutankhamen, King of Egypt, was put to his rest, it was to be forever. His was to be a permanent monument, and his body was mummified with unique skill. These burial preparations went a long way toward overcoming the destructive effects of time. King Tut's mummy still exists today—over 3,000 years after it was interred in the valley of the tombs of the kings.

science, and any attempt to relate the two must involve certain metaphysical presuppositions, but we rarely have taken the trouble to justify these or even to become aware of their existence. Religion, in the absence of any really philosophical methods, tends to become anti-intellectual and to take flight into the realm of an emotional faith in faith itself. Science suffers too; not having a sound philosophical approach to supplement its partial considerations of reality, it tries to fill in and "philosophize" without the proper tools. Thus, while Dr. Feynman says that he does "not believe that science can disprove the existence of God," and I suggest that science proper can't answer many other questions that perplex us, still it is used by many to try to answer the "metaphysical" questions, and the result must be myths and uncriticized half-pictures.

Some few attempts are being made today to present the case for a really metaphysical knowledge of the world. This must involve not just statements or grand assertions of the way things are, but also careful and critical presentations of the source of this knowledge and the way in which it is elaborated. The methods of procedure must be open to discussion and criticism, if this is to be a way of knowledge available for common use.

A philosophical approach

Among those working for the establishment of a valid metaphysics are the American Metaphysical Society and the Association for Realistic Philosophy. This latter group has published *The Return to Reason,* an anthology of articles on various facets of philosophy, and is producing a series of textbooks in realistic philosophy. The *Review of Metaphysics,* published at Yale, presents a cross-section of various contemporary attempts at a respectable metaphysics—a philosophy which is neither merely analysis of language nor a collection of the findings of the special sciences elevated to the status of a *Weltanschauung.* American Catholic philosophers are rediscovering the metaphysics of their past and stating it again in the light of modern science and modern philosophy. Even among the Naturalists and the modern Materialists there are beginnings of a strictly philosophical method of approaching reality.

It seems that if a scientist can't find the time to investigate these claims of the metaphysicians of our day, he should at least hesitate to say that they are meaningless. Even the scientist is dabbling in metaphysics if he says that all things *are* material. The difference between his metaphysics and that of the full-time

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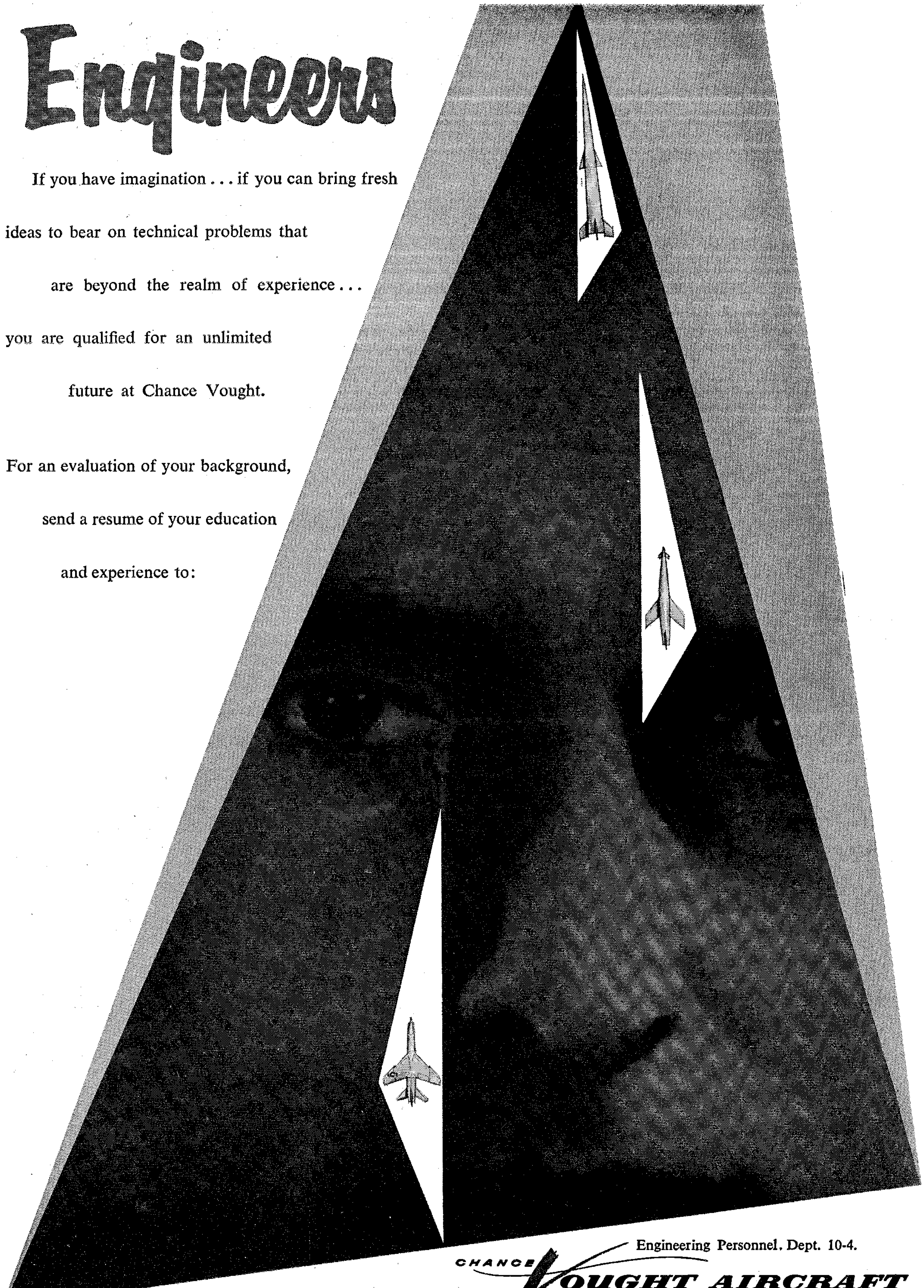

Engineering Personnel. Dept. 10-4.

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Letters . . . CONTINUED

metaphysician lies in the fact that the scientist merely asserts, or feels convinced, of a position, while the professional metaphysician has at least made an effort to establish the justification for his position.

But a scientist should not despair of understanding these metaphysical methods; it is not impossible for a scientist to penetrate a little into the work and sympathize with the spirit of this foreign field. For example, E. F. Caldin, the British chemist, has been able to write *The Power and Limits of Science*, which shows a keen appreciation of the methods of both science and philosophy.

Critical reflection

. . . If there is any basis to my suggestions that maybe moral judgments can be made meaningful in terms of the metaphysical structure of man, and that maybe there are limits to the scope of the scientific approach and its uncertainties, then it seems that the scientist who is sincerely looking for a foundation for his morality that will give him the strength and encouragement to follow his conscience, should want to do some critical reflection.

It is perhaps here that contacts between men of science and those of religion, with the aid of mediating philosophers, would prove very fruitful. All efforts to really appreciate another point of view seem to be fore-doomed if there is no living contact or opportunity for prolonged discussion. Perhaps underlying the central problem of the conflict of science and religion is the departmentalism which segregates thinkers in one field from those in another and leaves little room for real appreciation of the work the other man is doing. I feel that the first step to any reconciliation of religion and science depends on the religionists and the scientists getting to know each other as human beings. From this common ground we can begin our discussions.

Donald P. Merrifield, '50, S.J.
Los Angeles, Calif.

PERSONALS

1920

Virgil H. Best has been retired from his duties as a science teacher for the public schools for the past two years. He now has his own business at home designing and constructing machines.

1923

Harold A. Barnett, owner of Barnett, Hopen and Smith, Civil Engineers and Land Surveyors, in Pasadena, was appointed city engineer of the city of Vernon last February. Hal has been city engineer for Gardena and San Marino since 1930 and 1935, respectively.

Laurance G. South, who has been in business for himself as a general contractor since 1933, reports that he is now on the board of directors of the Building Contractors Association. His offices are in Pasadena and he is currently doing some work for Caltech's Cooperative Wind Tunnel. Larry has three daughters (two married and one at the University of California at Santa Barbara) and "almost" six grandchildren.

1926

Stuart L. Seymour, who is a general building contractor in San Marino, writes that his daughter has just entered Redlands University. At the parents' afternoon tea there last month, says Stu, it looked like old home week for Caltech grads because he met *Felix Fricker* '26, *Robert Grossman* '33, *John Gates* '36 and *Merrill Berkley* '33 — all of whom had children just starting at Redlands, too. Stu's son entered Stanford Medical School this fall.

Harry L. Remington was killed in an auto accident in Colorado on September 19, on his way home from a vacation in California. Harry had been a patent examiner at the U. S. Patent Office in Washington and lived in Silver Spring, Md.

1928

George T. Harness Jr., PhD '33, was appointed associate dean of the School of Engineering at the University of Southern California this fall. George has been at SC since 1946 as professor and (in recent years) head of the department of electrical engineering.

1930

Thomas T. Hiyama writes from Tokyo, Japan, that he has been with the Nippon Columbia Company ever since he left the United States in 1932. Tom is chief of the engineering department in the record manufacturing division. He has two daughters in college, two sons in high school.

1932

Edward C. Keachie, associate professor of industrial engineering at the University of California in Berkeley, writes that he and his family have just returned from a year at the Technische Hochschule in Darmstadt, Germany, on a Fulbright grant. Ed also reports that; "Once again the great value of Tech's broad education, including humanities, is pointed up; the Cal engineering college at Berkeley is now broadening our humanities program."

1935

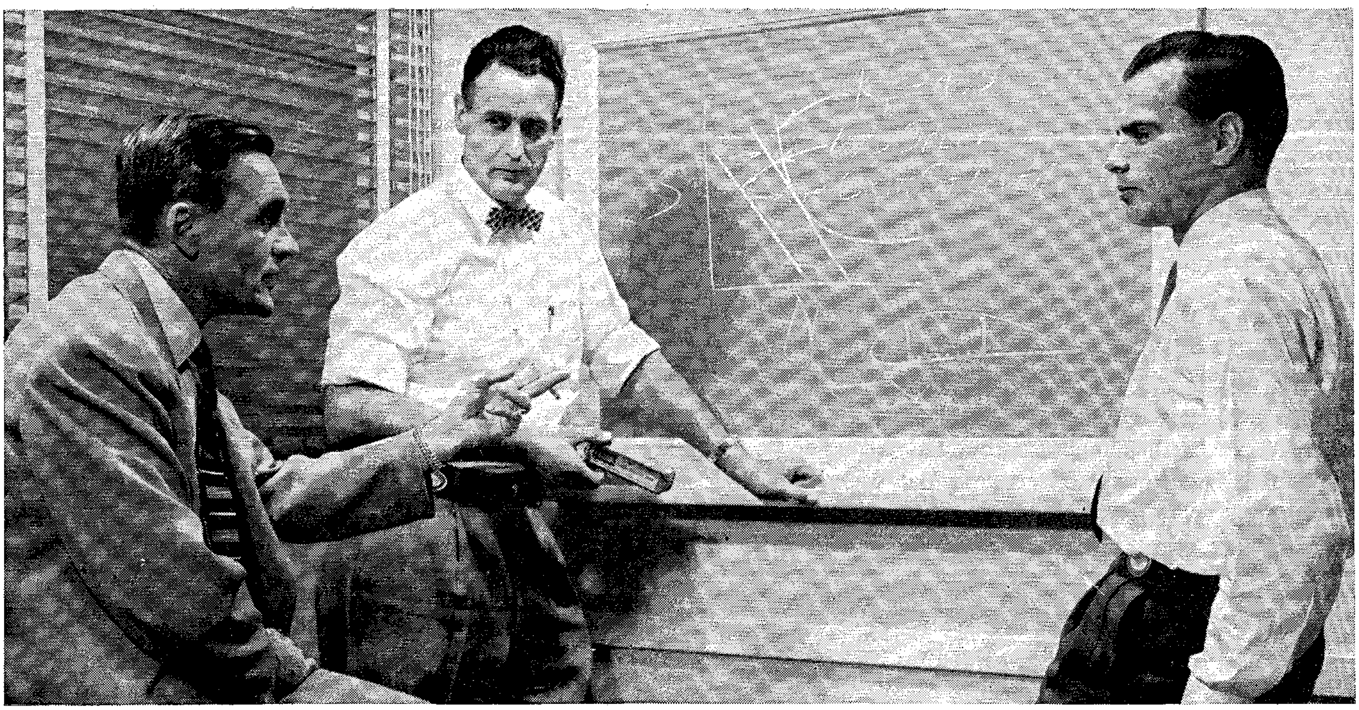
William V. Medlin, PhD, has been appointed a supervisor in the Shell Development Company's Emeryville research center. Bill has been with the company since 1935.

Horace W. Baker writes that he's still vice-president of J. T. Thorpe, Inc., a Los Angeles contracting firm. He reports "no additions or deductions and no changes" in the Baker family set-up.

Adrian H. Gordon, MS '36, writes from England that he's still chief of the Meteorological Office Training School at Stanmore, a small town 10 miles north of London. "In addition to training newly-recruited staff of all grades," says Adrian, "we give refresher courses to men at outstations and also take foreign students from a number of countries. On the personal side, Marty is nearly 9 and Susie was 5 last summer. I spent a two-month holiday (which I had saved up) with my mother and sister in Johannesburg, South Africa, this year. The last time I saw my mother was 20 years ago, at the Los Angeles bus station, when I was returning to England at the end of the Tech year.

"One more item—I am chairman of a world meteorological organization committee on something called 'Dynamic Climatology,' which is holding an international meeting in Washington, D.C., in January. Hope I can make it."

Robert O. LaRue completed 20 years with the Shell Oil Company this summer.



J. F. McBrearty, *chief structures engineer (left), discusses fatigue test program of integrally-stiffened wing lower surface structure of a new transport with E. H. Spaulding, structures division engineer, and J.G. Lewolt, stress engineer. Lockheed's 500,000 lb. Force Fatigue Machine was used in test program.*

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60

Bob is a geophysicist in the company's Denver area exploration department. Before this, Bob had a 14-year period of seismic review assignments in various West Coast offices. The LaRues have a son, Buddy.

1936

Willard L. McRary, MS '38, PhD '40, professor of chemistry at the University of California's Santa Barbara College, has now been appointed acting dean of letters and science there. A member of the Santa Barbara faculty since 1940, he also holds the post of assistant director of relations with schools. One of his recent research projects was the investigation of Chagas' disease, or Brazilian sleeping sickness, on an Office of Naval Research contract.

Apollo M. O. Smith, MS '37, '38, writes that his third child, Kathleen Roberts, was born on August 21. Supervisor of design research at the Douglas Aircraft Company, he just returned in September from the Ninth International Congress of Applied Mechanics. The Smiths are living in El Segundo.

1939

John C. Evvard, MS '40, chief of the Supersonic Propulsion Division of the National Advisory Committee for Aeronautics' Lewis Flight Propulsion Laboratory at Cleveland, Ohio, attended the Ninth International Congress of Applied Mechanics this September in Brussels. From there, John and his wife toured France, Switzerland, Italy and other parts of Europe.

1940

Lt. Col. William W. Stone, Jr., was graduated in June from the Command and General Staff College, the Army's senior tactical school, at Port Leavenworth, Kansas.

Willis G. Worcester, MS, writes that he has been appointed executive director of the engineering experiment station and professor of electrical engineering at the University of Colorado in Boulder.

1942

John Rubel, director of the Hughes Fire Control Systems Laboratories in Culver City, was featured in the first of a series of Hughes ads last month which ran in several leading publications. John's job includes the development of airborne weapon and control systems for the U. S. Air Force and Navy.

Jean C. Schwarzenback, MS, AE '42, welcomed his fourth child, John Gerald, last December. He is president of U. S. Propellers, Inc. and lives in Pasadena.

1943

Loren W. Crow, MS, now has his own office as a consulting meteorologist in Denver. Most of his work deals with technical reports relating the influence of weather and climate to planning problems of various industrial firms.

1944

Ralph S. Riffenburgh, MD, has been awarded a research grant by the National Institute of Metabolic Diseases for work on diabetes as related to the eye. He'll be working at Huntington Memorial Hospital Research Institute in Pasadena.

Robert G. Thomas, MS '47, PhD '51, died—apparently by his own hand—on October 12 in Los Alamos, New Mexico. Bob had been working as a physicist at the Los Alamos Scientific Laboratory. He leaves his wife and two sons, James and Laurence.

Joseph H. Chadwick, Jr., is a senior research engineer in the marine division of the Sperry Gyroscope Company at Garden City, N.Y.

1946

E. Richard Cohen, MS, PhD '49, group leader of theoretical neutron physics for Atomics International, a division of North American Aviation in Canoga Park, attended the International Congress on Fundamental Constants of Physics in Turin, Italy, in September.

1947

Langdon C. Hedrick reports that, with the arrival of a second son last November, he now has four children. Langdon is chief engineer of the Wiley Electronics Company in Phoenix, Arizona. The new company is a subsidiary of Savage Industries, Inc., and specializes in coherent radar systems research and development. Langdon is also secretary-treasurer of Wiley Electronics, and a board member of both companies.

Roger D. Stuck, electrical engineer at the Warren H. Wilson Junior College in Swannanoa, North Carolina, received his MS in electrical engineering at North Carolina State College in Raleigh in June. Roger, who has been at Wilson since 1947, has two children, Roger Dean II, and Phyllis Jean.

Arthur T. Biehl, MS, PhD '49, is now a vice-president and director of Aerojet-General Nucleonics, a new subsidiary of the Aerojet-General Corporation, with offices in Walnut Creek, California. The new corporation is engaged in the development and

and in the production of nuclear reactors.

Col. Charles M. Duke, a missiles project officer in the U. S. Army, is now serving in the office of the Chief of Engineers in Washington, D.C.

1948

Robert E. Bond, ID, is now a partner with Melvin Best Associates, an industrial design firm in Pasadena. The Bonds have a son, Russell Elston, born last February.

Harry J. Moore, Jr., is now director of purchasing for the International Business Machines Corporation. He has been assistant director of purchasing since last March and has been with the company since 1948, when he started as an assistant sales representative in Los Angeles. The Moores live in Larchmont, New York, and have seven-year-old twins, Craig and John.

Wayne E. Sefton writes that he not only has a new job title (Engineering Scheduling Coordinator) at Lockheed Aircraft Corporation in Burbank but he will also pay off the mortgage on the family homestead next year, and he caught a 28-pound salmon during his vacation in Santa Cruz this summer.

1949

Charles H. Knight, Jr., is now a field engineer for the Portland Cement Association in Los Angeles. Chuck joined the company after five years as an engineer in the bridge department of the California Division of Highways and two years as chief engineer at the Nigg Engineering Corporation in Covina. The Knights live in Monterey Park and have three children —two boys and a girl.

1950

Jack K. Willis writes from San Francisco that he is working for the Ampex Corporation in Redwood City, after a couple of years with Douglas Aircraft in Santa Monica, two-and-a-half years as senior designer with the General Motors engineering staff at the new Technical Center in Detroit, and a year in the auto repair business in San Francisco, as service manager in his father's garage. His duties with Ampex consist of research and development leading to pilot models of new magnetic-tape instrumentation. "Those who remember my audio amplifier bug at Caltech," Jack says, "will note that I have finally found an outlet for all that noise-making — happily coupled with an opportunity to use my ME education."

Jack also reports that he was married on October 27 to Jacqueline Keevil of Royal Oak, Michigan, in Carmel.

Robert H. Blaker, PhD, is now assistant director of DuPont's Petroleum Laboratory in Wilmington, Del.

Commander John T. Shepherd, U. S. Navy, received his promotion from Lt. Cdr. in September and is still at the Naval Air Test Center in Patuxent River, Maryland.

Donald A. Dooley, MS, has been appointed assistant professor of aeronautical engineering for a two-year period, on a half time basis, at the University of Michigan. Don had formerly been a research engineer at the Jet Propulsion Laboratory and a research specialist in the missile development division of North American Aviation.

1951

Harold F. Martin is a technical and project engineer for International Business Machines at San Jose. Hal started with IBM in 1951, at Endicott, N.Y., as a design engineer and transferred to San Jose in 1953.

Marc Kampé de Fériet, MS, ME '53, research engineer for Electricité de France, announced the birth of a daughter, Annick, on August 10 in Paris.

Dr. Thorne J. Butler writes from Chicago that in medicine it seems difficult to end your formal educational career. For the next four years he will be at the Northwestern Medical University Medical Center while taking a residency in pathology.

Cornelius J. Pings, Jr., MS '52, has been promoted to assistant professor of chemical engineering at Stanford University.

James A. Ibers, PhD '54, chemist at the Shell Development Company in Emeryville, Calif., is the author of "The Crystal Structure of Ceric Iodate Monohydrate," published recently in ACTA Crystallographica. The paper represents work done at the Gates and Crellin Laboratories of Chemistry at Caltech before he joined Shell last year.

1952

Donald K. Tautz, MS '53, writes that he's in the Army, stationed at the Armed Forces Institute of Pathology at Walter Reed Army Medical Center in Washington, D.C. He says, "I've recently seen *Phil Orville*, '52, *Ed Pyatt*, '51, *Morgan Ogilvie*, '53, *Stan Wilkes*, '53, and several other nearby Tech-mates, and would like to hear from others living or visiting in this area."

Deane K. Smith Jr. received his PhD from the University of Minnesota in Minneapolis last June.

1953

Bruce Holloway, PhD, writes from Australia that "Canberra seems to be one part of Australia that is very Caltech-minded because there are no fewer than three PhD graduates in this town. *Peter Goldacre,* PhD '53, is a research officer of the Division of Plant Industry in the Commonwealth Scientific and Industrial Organization; and *John Lovering,* PhD '56, is a research fellow in the department of geophysics of the School of Physical Sciences at the Australian National University here. I am also a research fellow in the same department. The number of Caltech PhDs in Canberra was temporarily increased to four during the winter months (your summer months) when *James Bonner,* PhD '34, paid a three months visit to advise the Plant Industry division of CSIRO. In addition, a research officer of the Plant Industry division is, at present, doing his PhD at Caltech in the Biology Division, Ric Davern by name. Over the last few years we have had visits from Professor Frits Went, and President DuBridge. Also while in Sydney last month I met Dr. Paul Whitfield who spent a post-doctoral year recently in the Biology Division. All this adds up to very strong Australian-Caltech bonds."

The Holloways have one son, 2½, and are expecting another child in January.

1954

George Allen Baker Jr. received his PhD from the University of California at Berkeley in September and a week later was married to Elizabeth Ann Coles of Albany, Calif. George is now doing post-doctoral work in physics at Columbia University on a National Science Foundation Fellowship.

LaVerne G. Eklund, MS, is now an instructor for the Seventh Army's Aviation Training Center in Germany, where he is teaching aircraft maintenance to non-commissioned officers. LaVerne entered the Army in November, 1954, and has been overseas since July, 1955.

Ralph D. Handen is in his final year at the Fuller Theological Seminary in Pasadena, and is also teaching physics and math in an L.A. high school. Don was married last year to Joene Hey of Oakland.

James C. Crosby, MS '55, was married in June to Hester Gooding. Jim is an associate development engineer for the Consolidated Engineering Corporation in Pasadena.

1955

Gunnar E. Broman, MS, has been appointed a Guggenheim Jet Propulsion Fellow at Caltech this year. A native of Stockholm, Sweden, Gunnar is on leave of absence from the Royal Swedish Air Board.

Allen E. Fuhs, MS, is also a Guggenheim Jet Propulsion Fellow at Caltech this year.

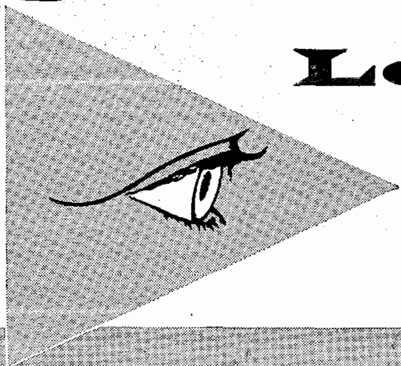
Bruce O. Nolf, MS, is now acting instructor in geology at the University of California's Santa Barbara College.

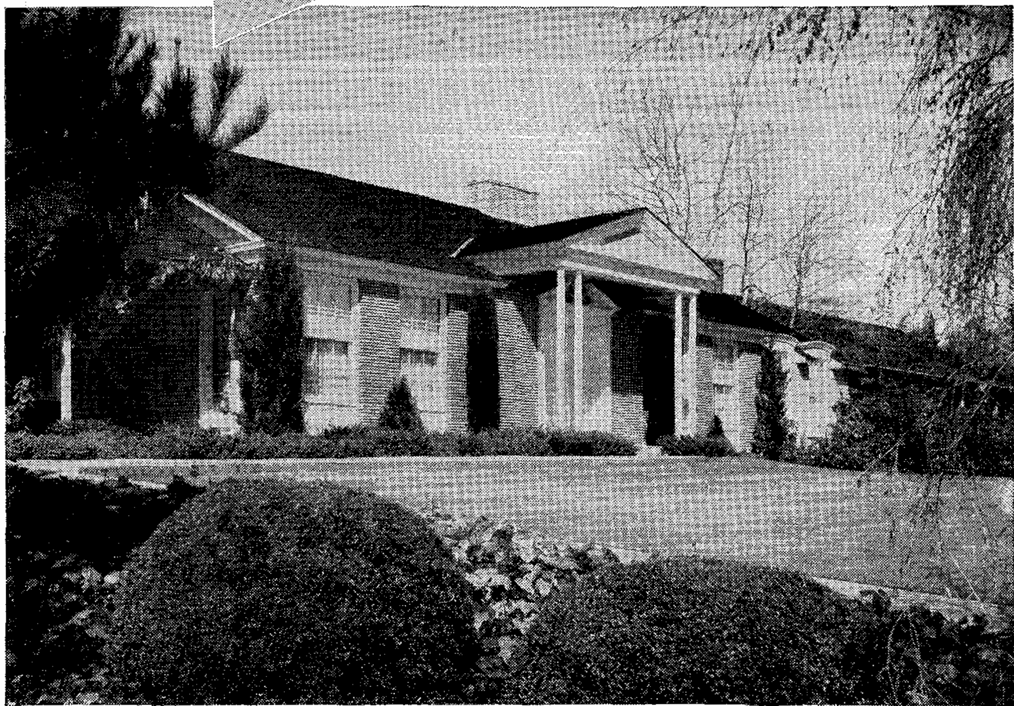
1956

Abe Sklar, PhD, is serving as an instructor in mathematics at the Illinois Institute of Technology.

Robert R. Johnson, PhD, is now manager of digital-computer-engineering for the General Electric Company's industrial computer section in Syracuse, N.Y. Bob has been with General Electric since 1950, when he began as a test engineer.

Engineers... Look ten years ahead!





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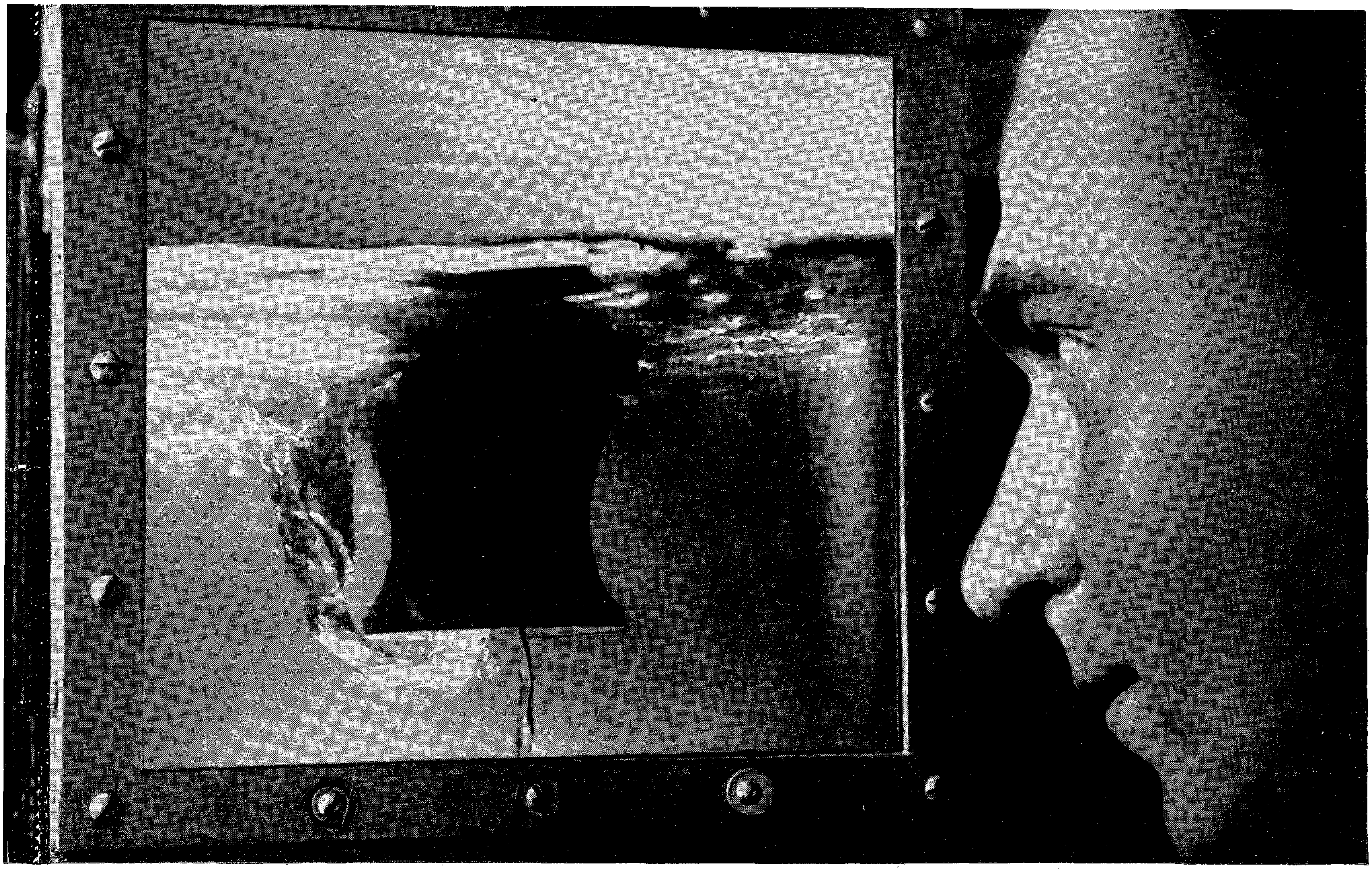

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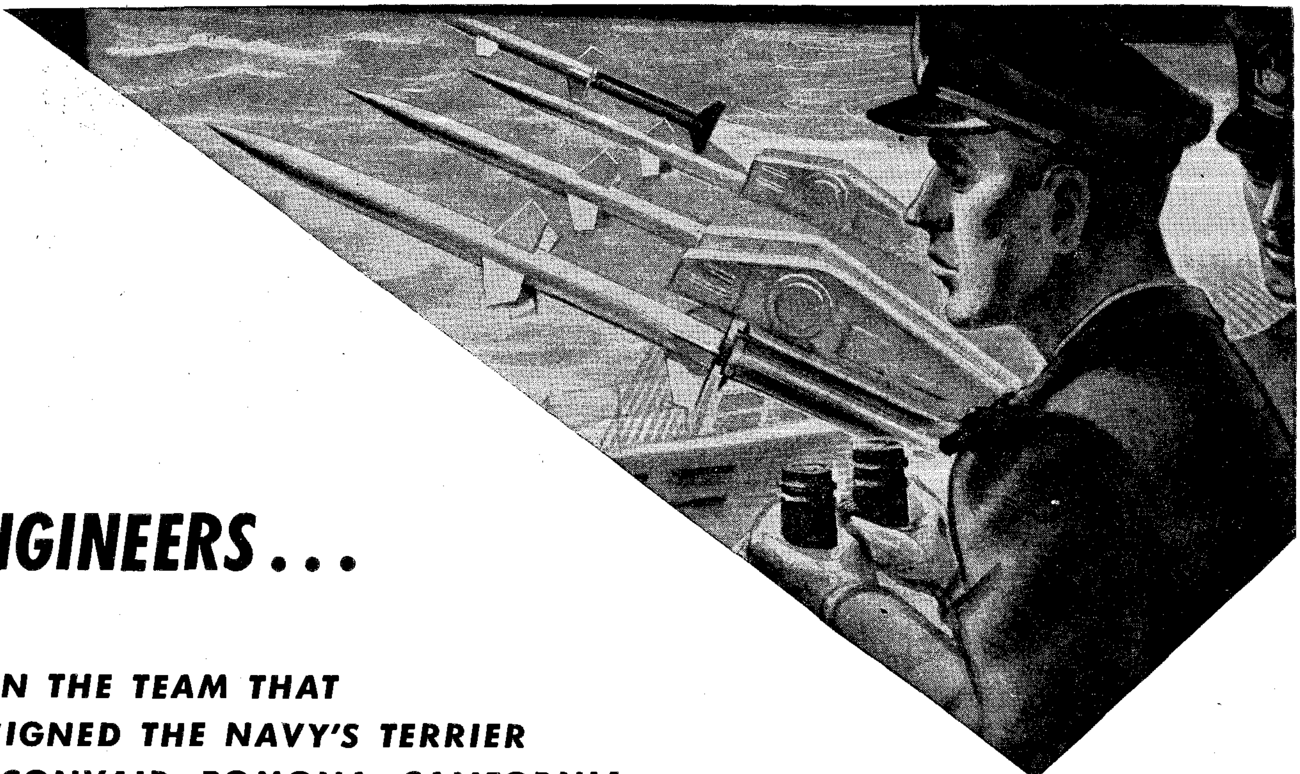
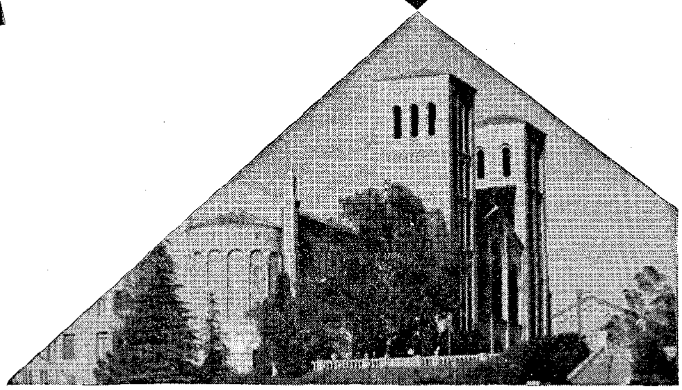


ENGINEERS...

JOIN THE TEAM THAT DESIGNED THE NAVY'S TERRIER AT CONVAIR, POMONA, CALIFORNIA



CONVAIR... for over two decades has been a respected name in the aeronautical field and is today the leader in the Guided Missile Field for the design and production of the famous TERRIER an Operational Weapon for the United States Navy.

ENGINEERS... vastly accelerated projects in all phases of Engineering including research, design, test and production are now under way at Convair Pomona.

POMONA... just thirty minutes from downtown Los Angeles, lies in the heart of Pomona Valley out of the heavy traffic conditions where California outdoor living is at its best. **Excellent housing is available located within close proximity of Convair's new air-conditioned plant to eliminate unnecessary time of traveling to and from work.**

Write Employment Dept. **4-C**

Complete resume desirable
for evaluation.
Information confidential.

EDUCATIONAL . . . opportunities offered by Convair include a formal program with U.C.L.A. leading to a M.S. degree while you are employed at the plant. Also many in-plant courses are taught by top engineers with whom you are working, including transistor electronics, stress analysis, magnetic amplifiers, computers, servo-mechanisms, probability theory, differential equations, engineering mathematics, hydraulics and aerodynamics. These courses are so designed to give you every opportunity to further your career in the engineering field.

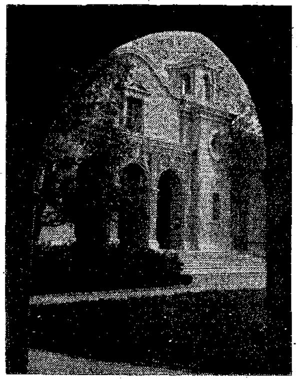
EXCELLENT OPPORTUNITIES IN:
- **ELECTRONICS**
- **AERODYNAMICS**
- **MECHANICS**
- **THERMODYNAMICS**
- **PHYSICS**

C-V CONVAIR

CONVAIR
A DIVISION OF
GENERAL DYNAMICS CORPORATION
(POMONA)
POMONA, CALIFORNIA

GD GENERAL DYNAMICS

CALTECH CALENDAR



ALUMNI EVENTS

January 17	Winter Dinner Meeting
February 9	Dinner-Dance
April 6	Alumni Seminar
June 5	Annual Meeting
June 29	Annual Picnic

CALTECH ATHLETIC SCHEDULE

VARSITY FOOTBALL

November 17
Caltech at LaVerne

WATER POLO

November 13
Caltech at L.A. City College

November 16
Occidental at Caltech

November 28
J.C. and College Playoffs

November 29
J.C. and College Playoffs

VARSITY SOCCER

November 17
Caltech at Cal Poly

November 21
UCLA at Caltech

CROSS COUNTRY

November 16—4:15 p.m.
Caltech at Pomona

November 20—10 a.m.
Nazarenes at Caltech

December 1—4:15 p.m.
Conference Meet
at Mt. San Antonio JC

FRIDAY EVENING DEMONSTRATION LECTURES

Lecture Hall, 201 Bridge, 7:30 P.M.

November 16
How We Inherit
Dr. George W. Beadle

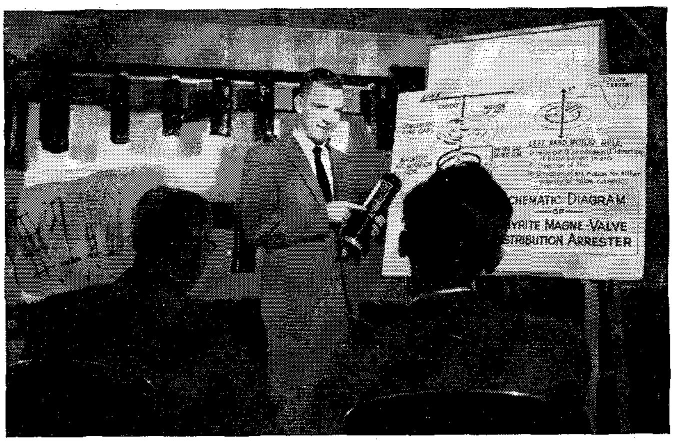
November 30
Sediments Transportation in Streams
Dr. Vito A. Vanoni

December 7
Desert Plants
Dr. Frits Went

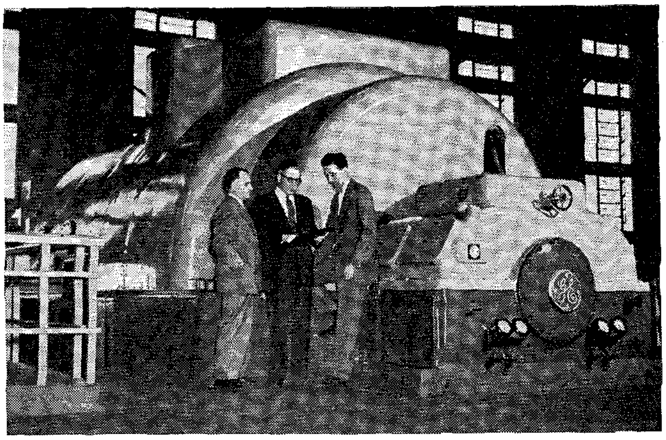
December 14
Coral Reefs: Present and Ancient
Dr. Heinz A. Lowenstam

At General Electric . . .

Here's how your engineering background fits you for the broad field of Technical Marketing



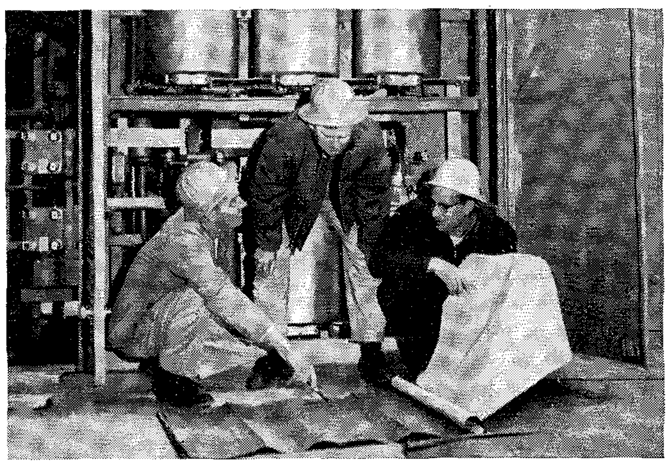
IN PRODUCT SPECIALIZATION complete knowledge of certain product lines assures their proper application to best serve the customer's requirements.



IN SALES ENGINEERING lies the prime responsibility for the integration of all sales and engineering activities between General Electric and the customer.

IN HEADQUARTERS MARKETING product planning, marketing research, and sales direction all contribute to successful marketing of General Electric products.

IN APPLICATION ENGINEERING electrical and mechanical components are engineered into the customer's product, power system, or manufacturing process.



IN INSTALLATION AND SERVICE ENGINEERING customer satisfaction is assured by proper installation and service of equipment supplied by General Electric.

MAIL COUPON FOR FULL INFORMATION ON THESE TECHNICAL MARKETING CAREERS

Mr. George E. Mullin, Jr.
Technical Marketing Program
Building 2 *Section 956-8*
General Electric Company, Schenectady 5, New York

Please send me your descriptive bulletin on the Technical Marketing Program, GEZ-515B.

Name______________________________

College______________Degree & Year________

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