ENGINEERING | AND | SCIENCE

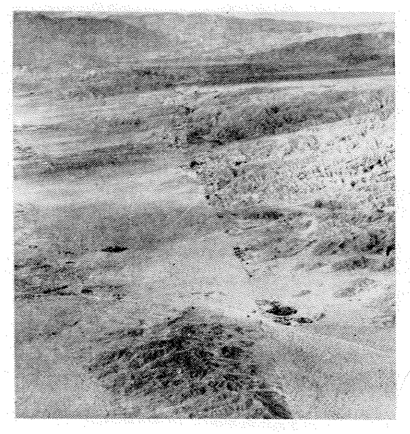
MAY/1957

The San Andreas Fault . . . page 17

PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY

ENGINEERING AND SCIENCE

IN THIS ISSUE



ON THE COVER is an aerial photograph of one of the many branches of California's famous San Andreas fault. This very noticeable earthquake line, located just north of Indio, was caused by earthquakes in prehistoric times. On page 17, Clarence Allen, assistant professor of geology at Caltech, tells what we can expect from the San Andreas fault in the future.

Allen's interest in earth surfaces began when he was an aerial navigator of a B-29 in World War II. After the war he entered Reed College in Portland, Oregon, but found that he couldn't take a geology course there, so he ended up with a BA in physics instead, in 1949. This led naturally to the study of geophysics when he came to Caltech to get his MS in 1951, and his PhD in 1954.

After a year of teaching at the University of Minnesota, he returned to Caltech in 1955 as assistant professor of geology. His background in geophysics, physics, and geology—plus a good working knowledge of seismology—comes in handy for his current research on the San Andreas fault.

PICTURE CREDITS

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CONTENTS

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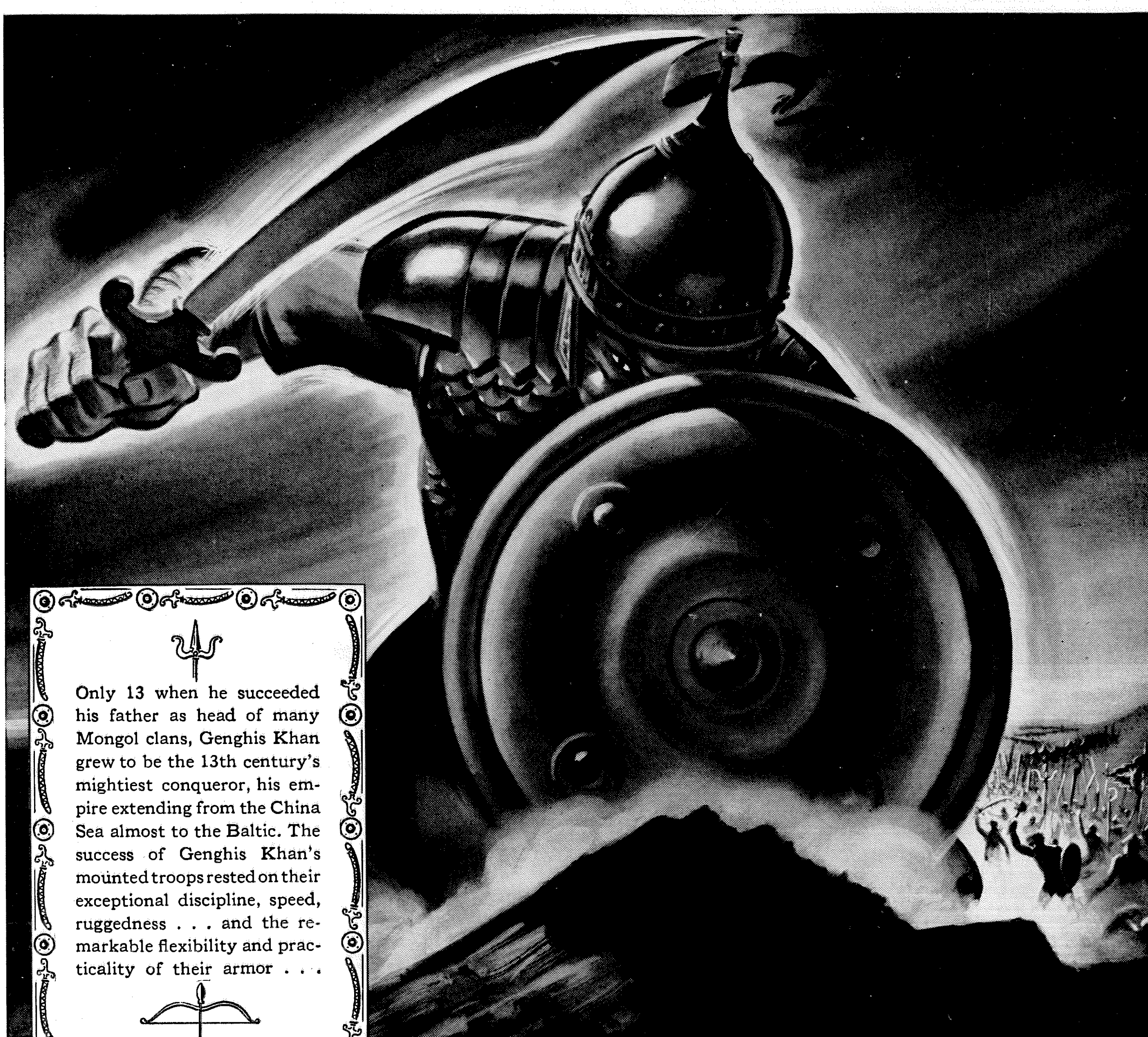


Questions students ask Du Pont

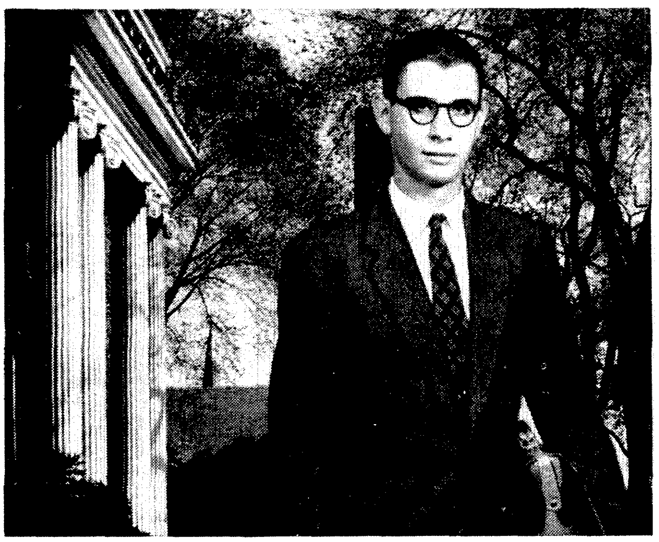
— and some of the answers in summary form

"Do you hire men who have definite military commitments?" asks Oran A. Ritter, Jr., of Louisiana State University.

Yes, because Du Pont has always been interested in men on a long-term basis. Du Pont has employed many graduates with military commitments even though they were due to report for duty a few weeks after joining the Company.

"Would a graduate degree help my chances for advancement at Du Pont?" asks John C. Nettleton, of Villanova University.

Many factors are involved. and an advanced degree would undoubtedly have a favorable effect in all technical work, but it would probably be of more direct benefit in research or development at Du Pont than in production, marketing or sales.



"Where would I work for Du Pont?" asks Gaylord E. Moss, of Tufts College.

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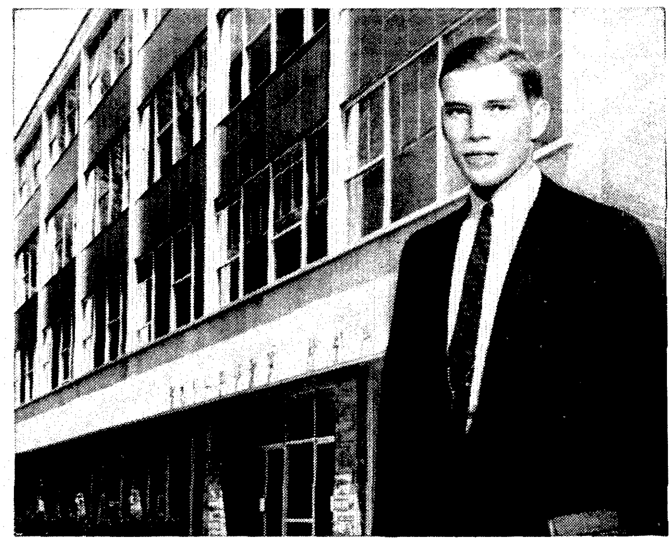

"How are chances for advancement in a large company like Du Pont?" asks Herschel H. Loomis, Jr., Cornell University.

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LETTERS

Fulbright scholars

Pasadena, Calif.

Sir:

I have learned that the number of Techmen applying for Fulbright Scholarships declined drastically this year over previous years. I was fortunate enough to have spent last year studying in Germany on such a scholarship, and I sincerely believe that, in failing to apply for these scholarships, Techmen are passing up a truly valuable opportunity.

I feel that the year of foreign study offered by the Fulbright program is particularly valuable to a Tech student who has just received his BS for it gives him a year to "recuperate" from the rather strenuous four years of undergraduate work behind him, and a chance to consider fully what sort of graduate work he wishes to undertake.

Of no less importance is the fact that spending a year studying in a foreign country is almost certain to give a reasonably intelligent and open-minded individual a much broader background, both intellectually and culturally. I feel that living among another people, and having the opportunity to compare their basic views and way of life with our own, gave me a better understanding not only of that nation but also of my own.

Since the university system of most European countries is very informal by Tech standards—required courses, problem sets, or tests being very infrequent—you have a great deal of free time to use as you see fit. I personally chose to devote a lot of this time to the cultural activities which I had been postponing for the last four years.

In closing I would like to point out one potential disadvantage in a year of foreign study — namely that, because of the great differences between the European and American university systems, there is very little

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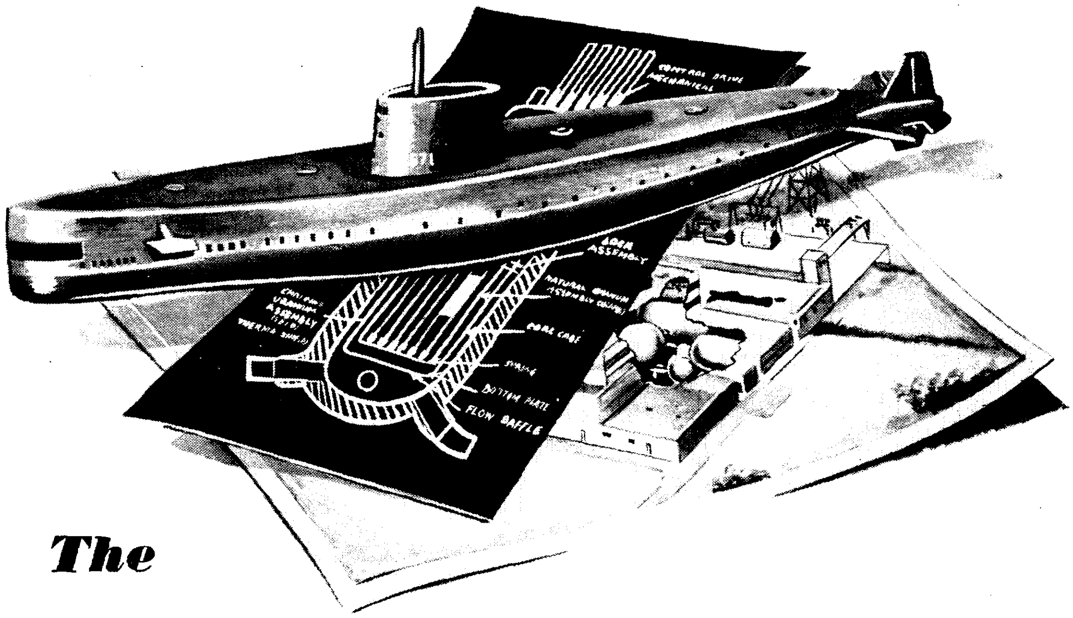

chance of obtaining formal credit for such a year of study. In many countries there is no clear distinction between graduate and undergraduate courses, so it may prove impossible to obtain credit toward an advanced degree for the work taken during this year. Thus, unless you are willing to delay your graduate program for a year you would be ill-advised to apply for a Fulbright. But if you are willing to postpone your formal graduate studies, I can certainly think of no better way to "waste a year" academically.

Since the applications must be submitted in November, I would like to urge all members of the class of '58 to seriously consider applying for one of these scholarships, and to decide on which country they would like to apply for. I would certainly be happy to talk to anyone interested in applying for Germany.

John Domingo '55

Calling all patent lawyers

New York City, N.Y.

Sir:

I have often wondered how many Caltech alumni are patent lawyers. I only know of about four, but there must be others, and I thought we might attempt a get-together during some future meeting of patent lawyers—as, for example, during the patent meetings of the Practicing Law Institute.

Dudley B. Smith '45
Cluett, Peabody & Co., Inc.
530 Fifth Avenue
New York 36, N.Y.

The Alumni Association has these additional names on file as patent lawyers. Anyone else who wants to be included in this list can get in touch with the Alumni Office.

William J. Elliott '45
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CONTINUED ON PAGE 14

FARAWAY PLACES

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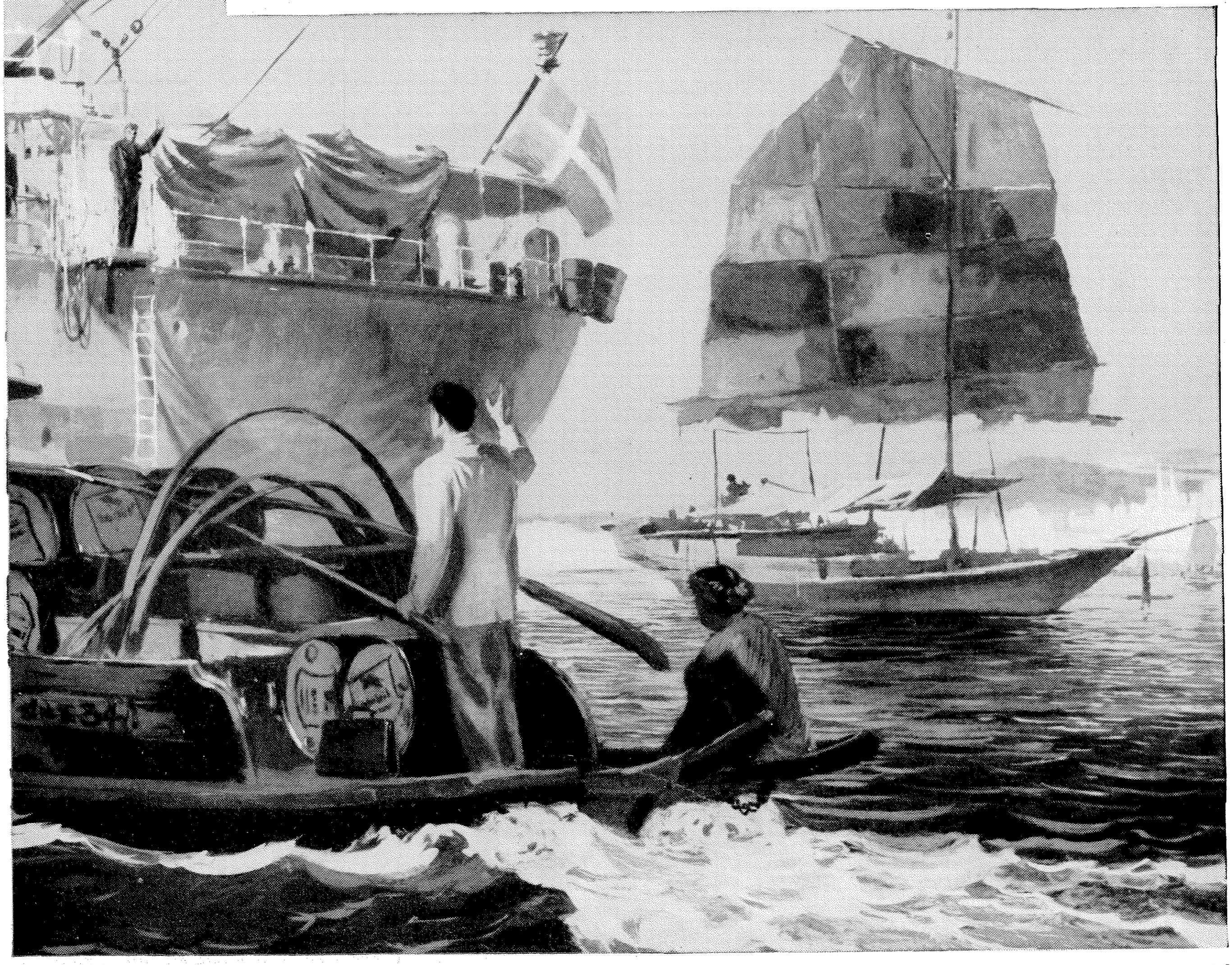

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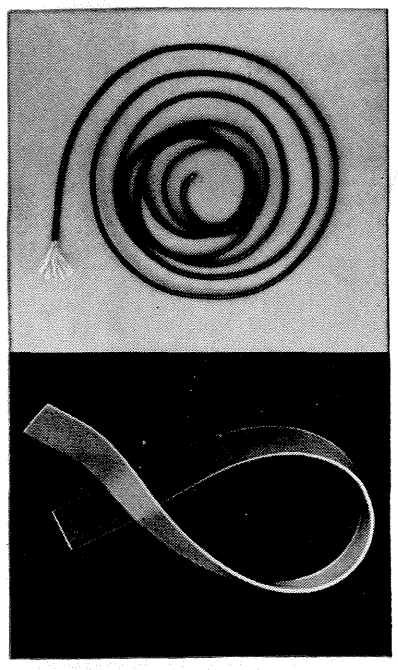

Nylon milk bottles

When you're looking to laboratory-stage plastics for new developments, it is somewhat startling to realize that a new raw material has come from one of the better established plastics, nylon.

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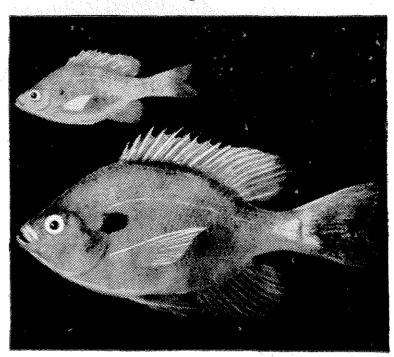

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Creative Research

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THE SAN ANDREAS FAULT

Its significance in California's past and future

by CLARENCE R. ALLEN

EVERY EARTHQUAKE on the San Andreas fault, no matter how small, seems to renew public interest in this intriguing geologic feature. The recent San Francisco earthquake of March 22nd was no exception, although the press reports might well have left readers in doubt as to the true significance of this earthquake in the over-all history of the fault. Is it true, as stated in one publication, that this earthquake represents the San Andreas's "periodic shrug"? What *is* the San Andreas fault, and what do geologists and seismologists expect in the way of future activity?

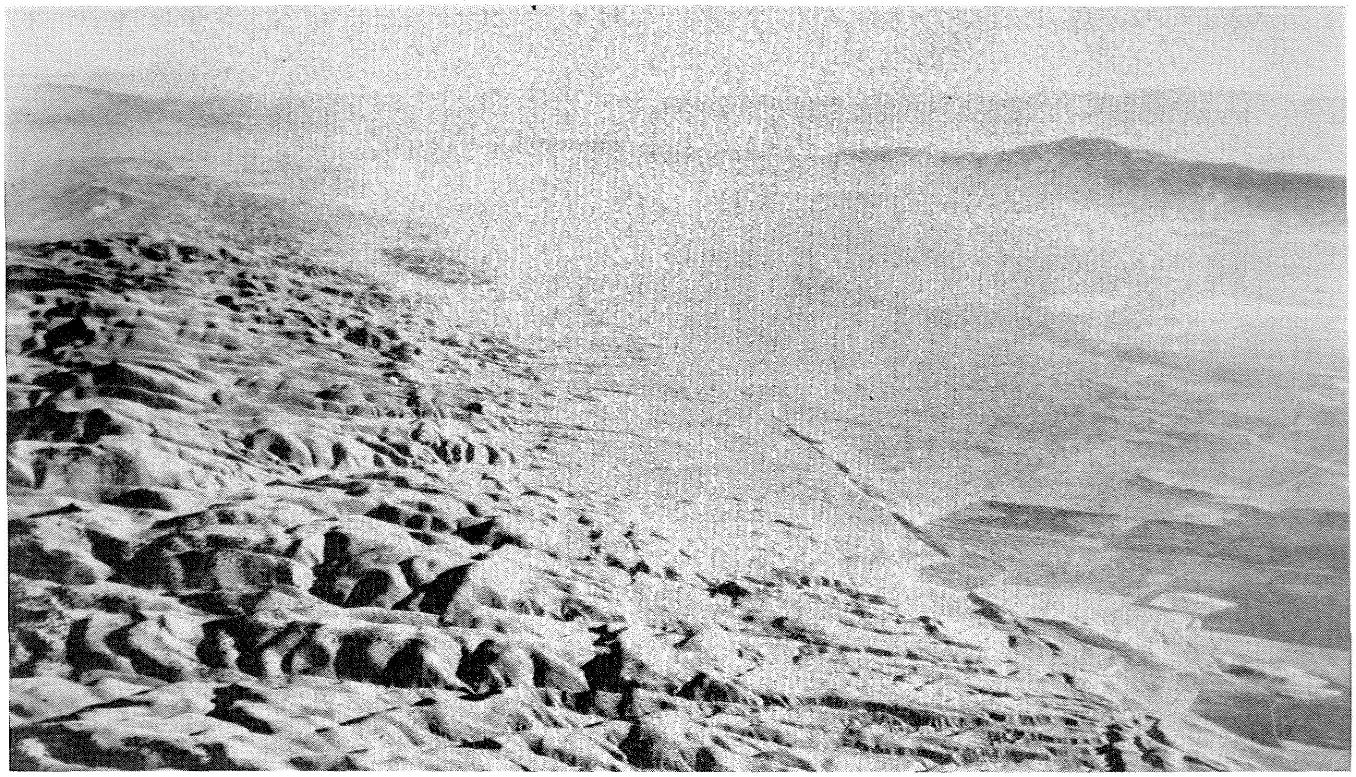
The San Andreas fault is literally a gigantic fracture in the earth's crust—the principal member of a great fracture system that cuts obliquely across the state of California from Point Arena to the Imperial Valley. Although other features of this type are known at scattered localities throughout the world, perhaps none is so long, so well exposed, and so thoroughly studied as the San Andreas. That the San Andreas is truly a fracture is indicated not only by geologic evidence of rock bodies that have been offset by it, but also by systematic ground fractures that develop along the fault during our largest earthquakes.

Seismologists believe that the fracturing that causes most California earthquakes commences at a depth of about 10 miles, but only during the large earthquakes does this fracturing actually reach and displace the surface of the ground. At such times the fracturing probably extends a comparable distance below the point of origin—perhaps to the base of the earth's crust at 20 to 30 miles. This is about as much as can be said in response to the often-asked question: "How deep is the San Andreas fault?"

It is, of course, the largest earthquakes that are of primary concern to the geologist, not only because they are the most disastrous, but also because the associated displacements of the ground surface tend to form much of the landscape around us. Most mountains in southern California owe their existence to repeated vertical displacements along bounding faults.

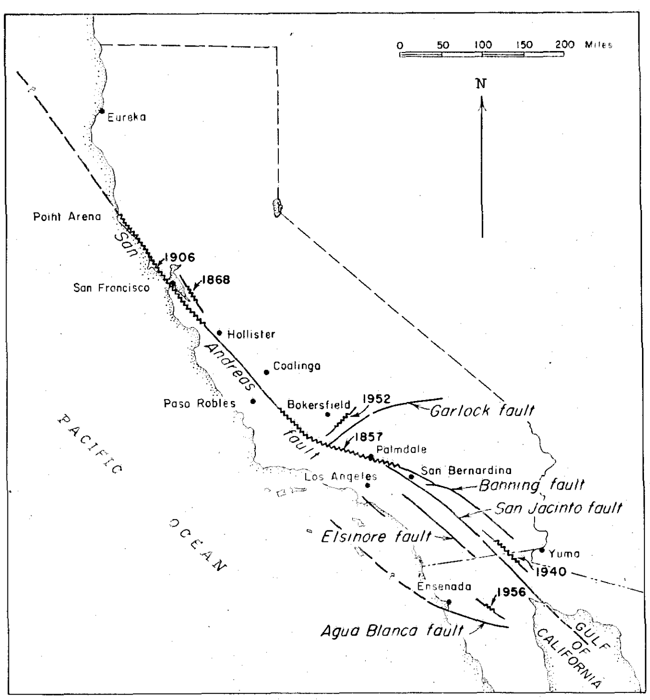
A significant difference between the San Andreas and many other active faults is that the displacements along it have been predominantly horizontal rather than vertical. During every large historical earthquake on the San Andreas fault that has been studied in detail, ground offsets indicate that the west or coastal part of California has moved northward relative to points across the fault to the east. Displacements of 15 to 16 feet were common along the part of the fault north of San Francisco during the 1906 earthquake. In the 1940 Imperial Valley earthquake the banks of the All-American Canal were horizontally offset nearly 15 feet, and the nearby International Border was presumably displaced a like amount. The sparse historical records of the 1857 "Fort Tejon earthquake" suggest similar displacements at that time along the segment of the San Andreas fault north of Los Angeles.

The geological evidence suggests that this same type



Oblique aerial view of the San Andreas fault in the Carrizo Plain area, 45 miles west of Bakersfield, California.

of movement has characterized the fault throughout its history, which probably goes back at least 100 million years. Indeed, Hill and Dibblee recently have suggested that the *total* displacement along the fault caused by repeated movements during this time may be as much as 350 miles! While difficult to imagine, such a total displacement would not be out of line with extrapolations based on the rate of displacement inferred from modern geodetic observations and the historic record.

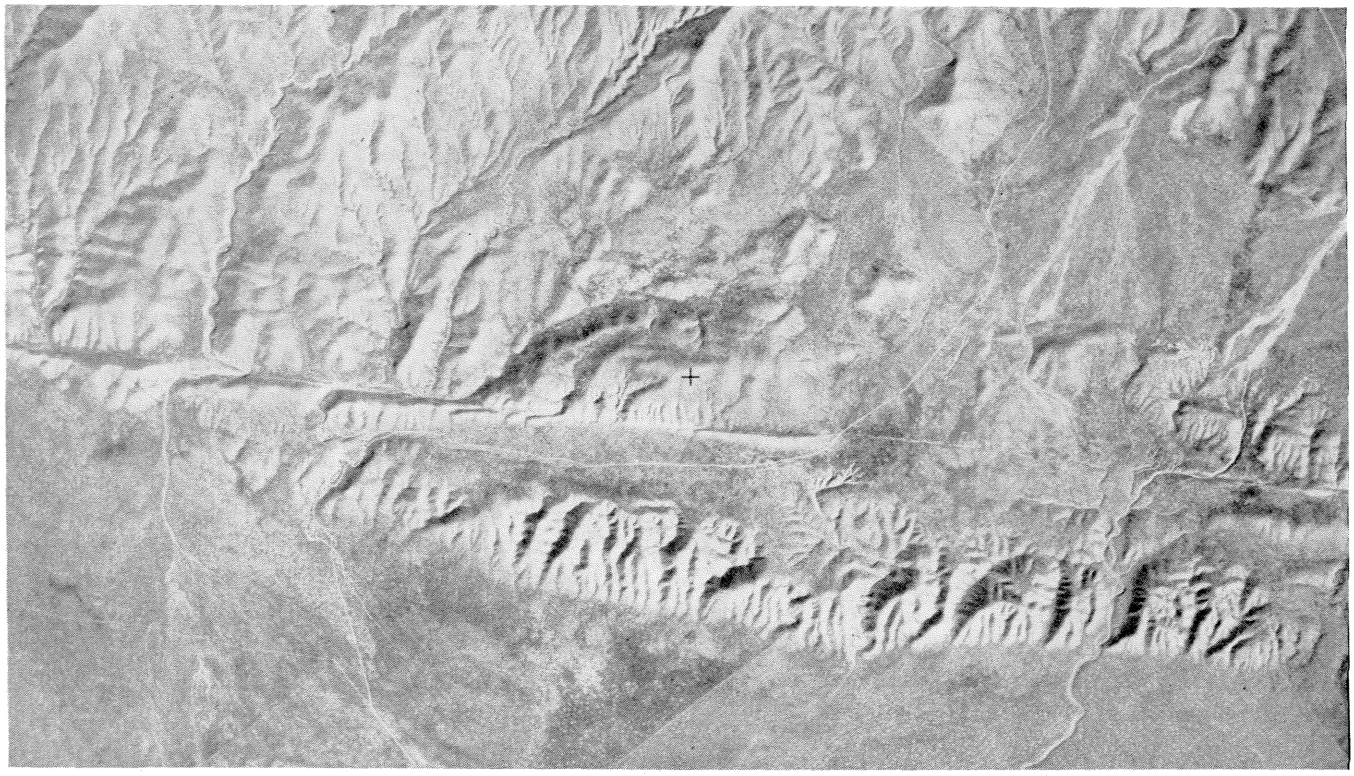


San Andreas and associated fault zones in California and northern Mexico. Zigzag lines show where surface of ground was broken during historic earthquakes.

Although isolated segments of the San Andreas fault had been recognized by geologists prior to the turn of the century, its continuity and geologic importance were not fully appreciated until after the San Francisco earthquake of 1906. As shown on the map at the left, the slippage that caused this earthquake broke the ground along the fault from Point Arena almost to Hollister—a distance of 190 miles. Investigations following the earthquake showed that the same physiographic and geologic features that characterized the fault in this segment also continued several hundred miles southeast, at least as far as San Bernardino, thus suggesting for the first time the continuity of the fault across most of the state.

What are some of these characteristic features? Most obvious is the tendency of the fault to occupy a broad trench and to be marked by exceptionally linear stream valleys. This pattern is caused not only by actual ground displacements, but perhaps even more by preferential stream erosion in the soft crushed rocks of the fault zone, which attains widths of several miles in places.

Such "rift topography," as it is called by geologists, is far more apparent from the air than on the ground. Thousands of people unknowingly cross the fault on highways every day, but few people escape noticing the anomalous topography when flying across the fault at high altitude. It is even more spectacular in oblique photographs taken from rockets over White Sands, New Mexico.



Vertical view of Carrizo Plain shows consistent horizontal offset of stream courses where they cross San Andreas fault.

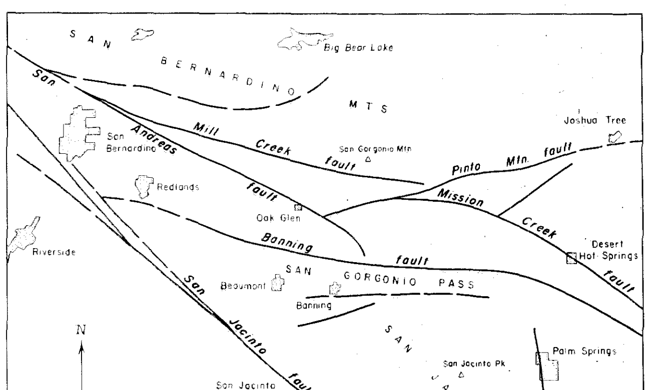
The problem of what happens at the ends of the San Andreas fault is a jackpot question that geologists wish they could answer—and the question is especially perplexing if horizontal displacements have amounted to hundreds of miles. About 100 miles north of Point Arena, the seaward prolongation of the fault intersects the great Gorda submarine escarpment, and some investigators have suggested that the fault veers sharply westward to follow this escarpment and its extension, the Mendocino escarpment. A broad zone of earthquake epicenters continues northwestward, however, and it seems more likely that the fault zone continues in this trend to a point off the Oregon coast where the epicenters finally die out.

On the southern end of the San Andreas fault, complications arise even before the fault trace disappears into the Gulf of California. Epicentral locations of earthquakes leave no doubt that the zone as a whole extends into the Gulf, but the fault frays out into a number of great branches southeast of San Bernardino, and it is not clear which, if any, of the branches truly deserves the parent name.

In southern California, the northwestward-trending San Andreas fault comes into conflict with a great system of east-west structures exemplified by the mountain ranges from Santa Barbara to San Bernardino—the so-called "Transverse Ranges." It is on the north side of this zone that the San Andreas fault makes its abrupt eastward bend, and even more severe complications take place within the Transverse Ranges themselves. It appears that faults associated with the Transverse Range and San Andreas systems have alternately offset one another, so that the modern breaks do not necessarily represent the trend or position of former breaks.

A good example of this literal "butchery" is given by the fault pattern in San Gorgonio Pass, 70 miles east of Los Angeles. As is shown on the map below, the San Andreas is not a continuous surface break through this area; many of the branches evidently represent former throughgoing lines of faulting that subsequently have been deformed and disrupted.

At the present time, the San Jacinto fault appears to be the most active member of the San Andreas system in southern California, and the southeastward prolongation of its trend is marked by features of recent displacement across the delta of the Colorado River and



The fault pattern in the San Andreas fault zone near San Gorgonio Pass, 70 miles east of Los Angeles.

Displacement of this Imperial Valley orange grove occurred in the 1940 earthquakes. At the International Border, about 1 mile south, the horizontal slip was almost 15 feet.

into the Gulf of California. The fault pattern of this area, as well as that of the Gulf floor itself, suggests that the San Andreas fault dies out southeastward as a great series of parallel *en echelon* fractures.

What caused the 1906 earthquake? Following study of the 1906 displacements, H. F. Reid postulated that the fracturing had been the result of a slow build-up of regional shear-strain in the years prior to the earthquake. The coastal part of California west of the fault was envisaged as drifting uniformly northward with respect to the continental part of the state farther east, and the resulting distortion within the fault zone presumably had become so great in 1906 that the rocks broke and caused the earthquake. Thus the observed displacements at the time of the earthquake were thought to be the result of elastic rebound of rocks within the fault zone, caused by slowly accumulating regional strain.

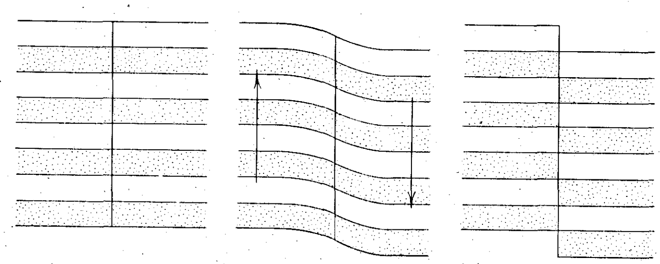
An obvious test of Reid's elastic rebound theory was to measure, at intervals of several years, the precise relative positions of survey stations located at some distance from the fault, and on both sides of it. Any continuous drift of the two blocks should show up as progressive displacements within the triangulation network.

A vigorous surveying program therefore was initiated by the U.S. Coast and Geodetic Survey following the 1906 earthquake, utilizing networks first surveyed as early as 1851. Despite some early difficulty in adjustment of the survey data—a real mathematical problem in itself—it has now been firmly established that a drift such as Reid postulated is indeed taking place. Across the northern part of the fault zone, for which the most complete data exist, the coastal part of California is drifting uniformly northward at about two inches per year relative to parts of the state farther east; the resulting strain must be accumulating in the fault zone.

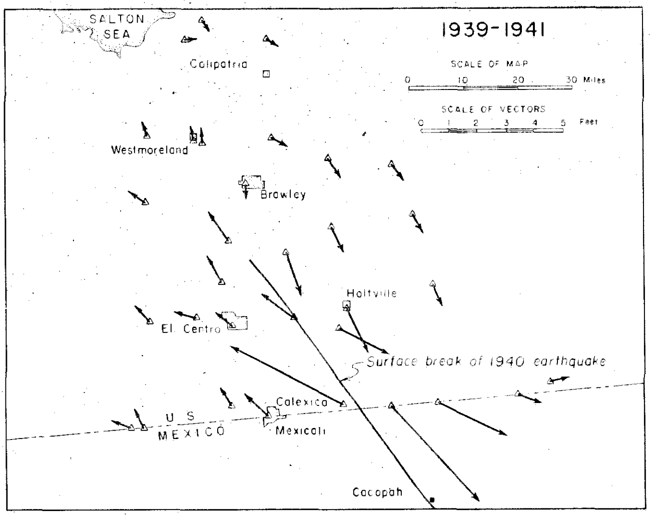
Although the basic principles of the elastic rebound theory have thus been pretty well demonstrated, the fundamental question of what *causes* the drift remains virtually as unanswered as it was in 1906. Certainly some sort of deep-seated rock flowage is necessary, but there is still spirited debate among geologists and geophysicists as to whether this is caused by crustal contraction, convection currents in the deeper layers, forces resulting from the earth's rotation, or still other causes.

A diagrammatic substantiation of the elastic rebound theory is given by U.S. Coast and Geodetic Survey measurements in the Imperial Valley, which is one of the most seismically active areas along the fault zone. The maps at the right show, by means of vectors, the relative displacements of triangulation stations in this area during two periods: the relatively short interval from 1939 to 1941, and the longer subsequent interval from 1941 to 1954. Note that the 1939-1941 period includes the 1940 earthquake, and the vectors shown on the map are largely the result of ground displacements at that time. These geodetic measurements support the field observations in showing maximum displacement near the International Border. As predicted by the theory, displacements decrease rapidly away from the fault trace, corresponding roughly to the limits of the zone that was most strained prior to the 1940 earthquake. the 1941-54 map shows the continued slow build-up of strain since that time, and it is interesting to note that the great width of the distorted area (at least as wide as the map) supports the geological evidence of a wide fault zone with many branching and parallel fractures. The relative rate of drift of the two sides of the Imperial Valley may be even slightly greater than the two inches per year measured over a longer period in the northern part of the state.

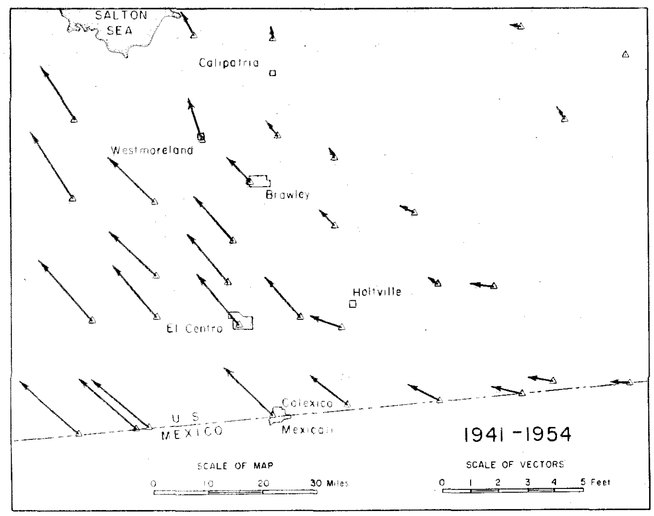
The recent San Francisco earthquake of March 22, 1957, has caused unwarranted assertions in the press that the accumulating strain along the San Andreas fault has thereby been relieved, as it assuredly must have been in 1906. But the contrast in size between this recent shock and the 1906 earthquake is far greater than might be supposed from the difference between the respective Magnitudes of 5.3 and 8¼. Owing to the logarithmic nature of the Magnitude scale, at least 50,000 earthquakes of Magnitude 5.3 would be required to equal the energy output of the 1906 shock. Thus it seems that the March 22nd earthquake—taken by itself—



A schematic representation of the elastic rebound theory. Unstrained rocks (A) are distorted by relative drift between the two blocks (B), causing strains within the fault zone that finally become so great that the rocks break along the fault and rebound to a new unstrained configuration (C).



Displacements of triangulation stations (note vector scale) in the Imperial Valley from 1939 to 1941. (1939 data includes surveys started in 1935). Displacements are caused primarily by elastic rebound during the 1940 earthquake.



Displacement of triangulation stations in the Imperial Valley from 1941 to 1954—assuming the stations on the east side of the valley to have remained stationary. Data for these displacement maps are from the U.S. Coast and Geodetic Survey.

can have no very significant effect in relieving the regional strain and delaying another much greater earthquake sometime in the future.

It is dangerously tempting to use the measured drift rate together with the 1906 field observations to extrapolate fault activity into the future. One might argue that, at the rate of two inches per year, it would have taken about 100 years to accumulate sufficient strain to cause the elastic rebound of 16 feet that was commonly observed along the fault in 1906; and inasmuch as the strains are still accumulating, the hasty conclusion might be reached that San Francisco would experience another great earthquake in 2006. This hypothetical 100-year period would be even more disconcerting to those of us living in the southern part of the state, where the last great earthquake on the main San Andreas fault occurred in 1857! Some of the factors that make such predictions unwarranted at the present time are:

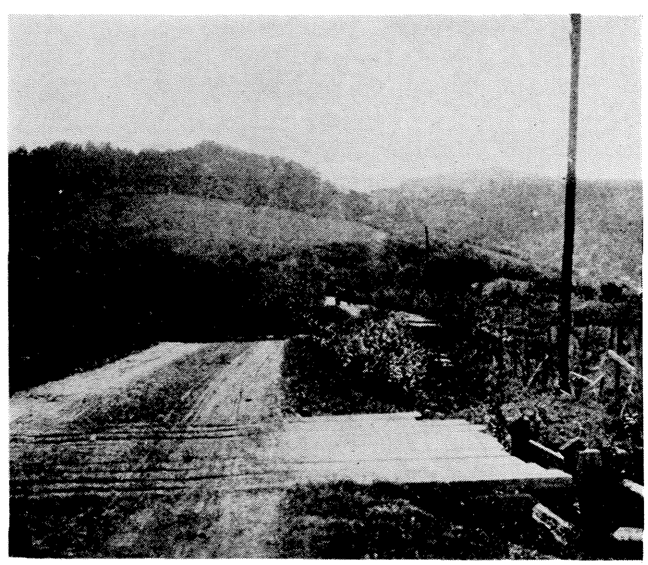
1. There is no assurance that ground displacements during the next great earthquake will be the same as those measured in 1906, although the historical evidence does suggest that most of the San Andreas fault is characterized by infrequent major shocks rather than by many small ones.

2. Some part of the accumulating strain presumably is non-elastic; that is, the drift must be causing some permanent deformation of the rocks that will not be recovered as elastic rebound.

3. Strain must be relieved to some extent by faults subsidiary to the San Andreas. For instance, the 1952 Kern County earthquake—though not on the San Andreas fault—must have relieved some of the regional strain.

4. The rate of strain has not been firmly established for the part of California near Los Angeles, although there is every geologic reason to expect the distortions here to be of the same order of magnitude as those measured farther north and south. Even in these better-studied areas, more needs to be known about the regional extent of distortion before firm quantitative conclusions can be drawn.

But in spite of our inability to make a firm prediction of the next major movement on the San Andreas fault, the general expectations based on knowledge of the accumulating strains and earthquake history seem valid. Most geologists would not be surprised at a great earthquake along the fault's central or southern portion within the next 25 years. Certainly the segment of the fault between Hollister and San Bernardino now appears far more dangerous than the segment of the fault near San Francisco which broke in 1906.



Road offset by the San Andreas fault during the 1906 earthquake. The far (west) side has moved relatively north about 20 feet. Photo taken near Point Reyes Station, 30 miles north of San Francisco.

ROBERT F. BACHER

Professor of physics, and chairman of the division of physics, mathematics and astronomy

As PROFESSOR OF PHYSICS; chairman of the division of physics, mathematics and astronomy; and director of the Norman Bridge Laboratory of Physics, Robert F. Bacher not only has one of the most important jobs on the Caltech faculty—he's got the longest string of titles on campus as well.

He has held these titles since 1949, when he came to Caltech from the United States Atomic Energy Commission. It wasn't his introduction to Caltech though; he'd spent a year here as a National Research Council fellow in 1930-31.

A graduate of the University of Michigan (1926), Bacher became interested in atomic spectra while working for his Ph.D. at Michigan. After he got his doctorate in 1930, he spent a year at Caltech, where he began collecting material on atomic spectra, then continued this work during the next year at MIT.

In 1932-33 Bacher had a fellowship at the University of Michigan, but by the fall of 1933 there were no fellowships—and no jobs—to be had anywhere. Bacher stayed on at Michigan, where he was at least given the use of the laboratories. Though he had no job, he had no obligations either, and the year turned out to be a profitable one scientifically.

In 1934 he went to Columbia University, where he taught a course in elementary physics, and one in atomic spectra—besides continuing his own studies of atomic energy relations.

When he went to Cornell University in 1935 he began an association that lasted for almost 14 years. Cornell, in 1935, was building the first small cyclotron in the East. Also, at that time, Cornell had some excellent spectroscopic equipment which was not being used much. All in all, it seemed an ideal place to work in the field of nuclear physics—and that was just what Bacher wanted to do. His interests in atomic spectra had led him to the study of hyperfine structure (which is due to the nuclear magnetic moment) and this work, in turn, led to an interest in nuclear physics.

At Cornell he began some neutron experiments, using radon-beryllium sources. In 1938, when he was put in charge of the University's cyclotron, he continued the neutron experiments on this machine. This proved to be a particularly fruitful field of research—and one which ultimately led Bacher to work both on radar and on the atomic bomb project. Some of his experiments, using the Cornell cyclotron, had to do with measuring neutron time of flight over a fixed distance. The times were small, and measured in millionths of seconds—and this work with small time led Bacher naturally into the field of radar. (The neutron work itself led, later, to his working on the atomic bomb project.)

In 1940 Bacher was invited to join the Radiation Laboratory, the radar project which had been set up at the Massachusetts Institute of Technology, headed by Lee DuBridge. Bacher took a leave of absence from Cornell and joined the Lab in 1941, where he was put in charge of radar receiver and indicator components and radar beacons.

In 1943 the Lab sent Bacher and his old Columbia colleague, I. I. Rabi, to serve as advisors to J. Robert Oppenheimer, who was then trying to set up the Manhattan District Laboratory in Los Alamos, New Mexico. In no time at all, Bacher graduated from the role of advisor and was put to work on the atomic bomb project—in 1943-44 as head of the experimental physics division; in 1944-45 as head of the bomb physics division.

At the end of the war Bacher went back to Cornell, where he became the first director of the University's new Laboratory of Nuclear Studies, and immediately set about building an electron synchrotron. Work was well under way on this in 1946 when Bacher was called to New York to serve as a scientific advisor to Bernard Ba-

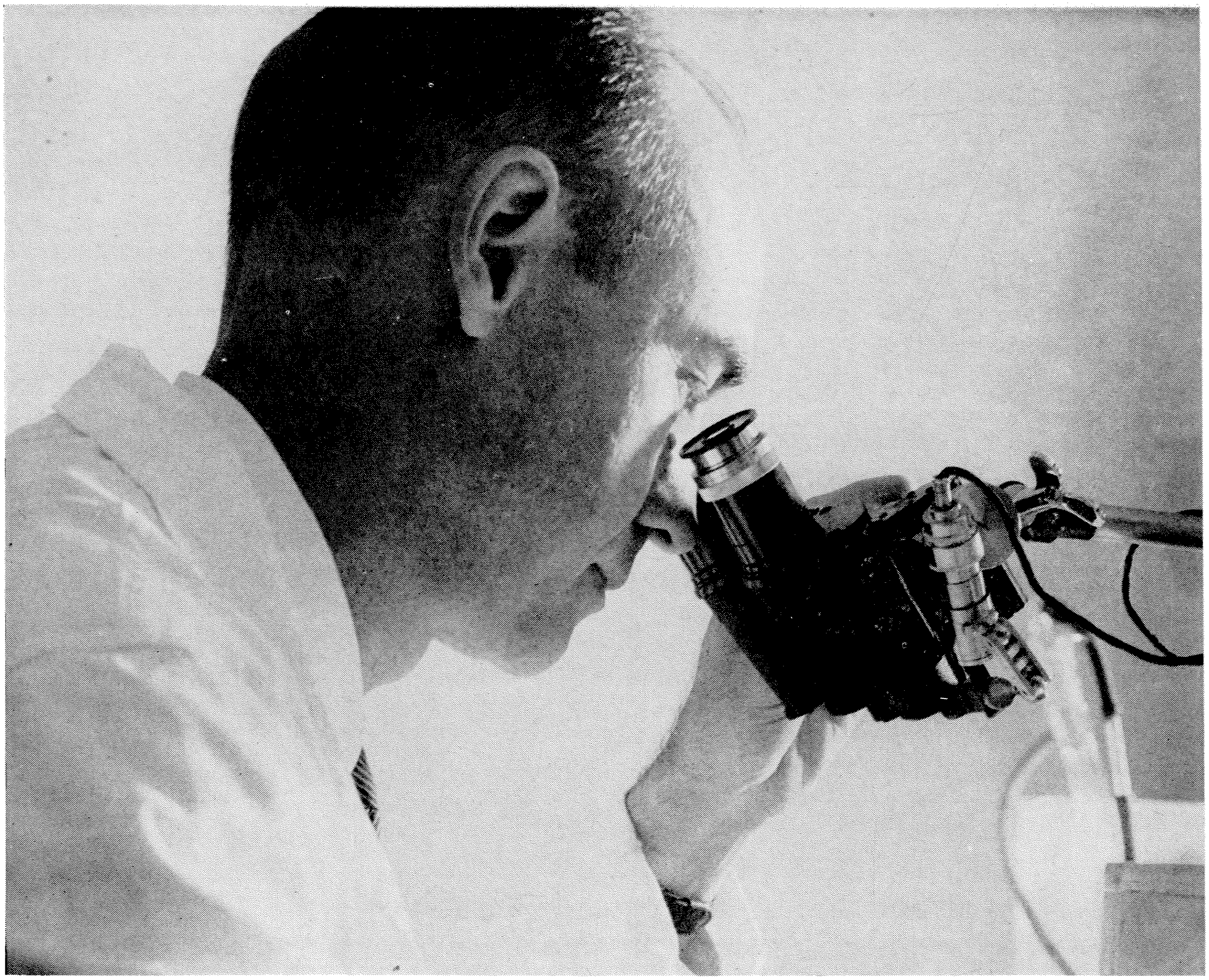
ruch, who was then head of the United Nations Atomic Energy Commission. The late Professor Richard Tolman was spending full time in New York as chief scientific advisor to Baruch, and through the summer of 1946 Bacher divided his time between the New York conferences and the Cornell laboratory. Then, that fall, when the United States Atomic Energy Commission was established, Bacher was appointed a member of it—the only scientist in the group.

Bacher served on the AEC for three years, and left before the completion of his second appointment to come to Caltech and work once again with Lee DuBridge, who was now the new president of the Institute. Champing at the bit to get back into the field of high energy physics once more, Bacher got work started on an electron synchrotron at Caltech almost as soon as he arrived in Pasadena.

By the summer of 1952 the synchrotron was operating at 500 million volts, and in 1955 it was completely rebuilt to operate at a billion volts or more. In recent months the group of physicists working with the machine at Caltech has succeeded in the photo-production of heavy mesons and hyperons from hydrogen. These are unstable particles, produced in violent nuclear interaction—and a study of the production of these particles, scientists believe, will lead them to a better understanding of nuclear forces.

Bacher is a member of the National Academy of Sciences, the American Philosophical Society, the American Academy of Arts and Sciences, and the Physical Society—among others. He was given the President's Medal for Merit in 1946, for his war work. He is a trustee of the Rand Corporation, a director of the Consolidated Electrodynamics Corporation, and, in recent months, has been serving on a committee set up by the Edison Electric Institute to advise the power industry on what it should do to develop atomic power.

In 1932, Bacher, in collaboration with Samuel Goudsmit—with whom he had been working at the University of Michigan—produced a book which had a fairly spectacular publishing history. The book, which collected the known energy levels of atoms, was called *Atomic Energy States*. It had what may charitably be called a "modest" sale—until after World War II, when there was a surging demand for the book, and it quickly and completely sold out. It was almost 15 years old, and the subject matter was essentially obsolete—but the title, at this late date, couldn't have been timelier.



Roger W. Sperry, Hixon professor of psychobiology at Caltech.

BRAIN MECHANISMS IN BEHAVIOR

Some experimental observations on the workings of that baffling mechanism—the brain

by R. W. SPERRY

THE VERTEBRATE BRAIN, with an organizational complexity far surpassing that of any other natural or man-made system, and possessing in certain of its parts the puzzling property of conscious awareness, will probably continue to remain a challenge to man's understanding for many decades to come. At the present time, the cerebral events underlying even the simplest forms of mental activity remain quite obscure. Although it should someday be possible to start correlating subjective experience with the corresponding brain process—perhaps even to comprehend the basis and derivation of the "mental" properties—we have to be satisfied, for the present, to work at many removes from this ultimate goal.

How *far* removed can be judged from the following series of experimental observations that will serve to illustrate some of the things our psychobiology group has been doing, and will also serve to indicate the general status of some of the current problems in brain organization.

I will start with some early work dealing with nerve growth and regeneration, the results of which have been interpreted broadly to mean that brain function in the vertebrates generally is predetermined by inheritance to a much greater degree than formerly had been supposed. The findings also give us some ideas about how the inherent patterning of the brain circuits is achieved in embryonic development.

Our information on the developmental patterning of brain pathways has been obtained mainly from fishes and amphibians because the early developmental stages in these lower vertebrates are accessible to surgery, and because the central nervous system, in the larval and adult stages, retains a capacity for regrowth after surgical intervention that is almost entirely lacking in higher forms.

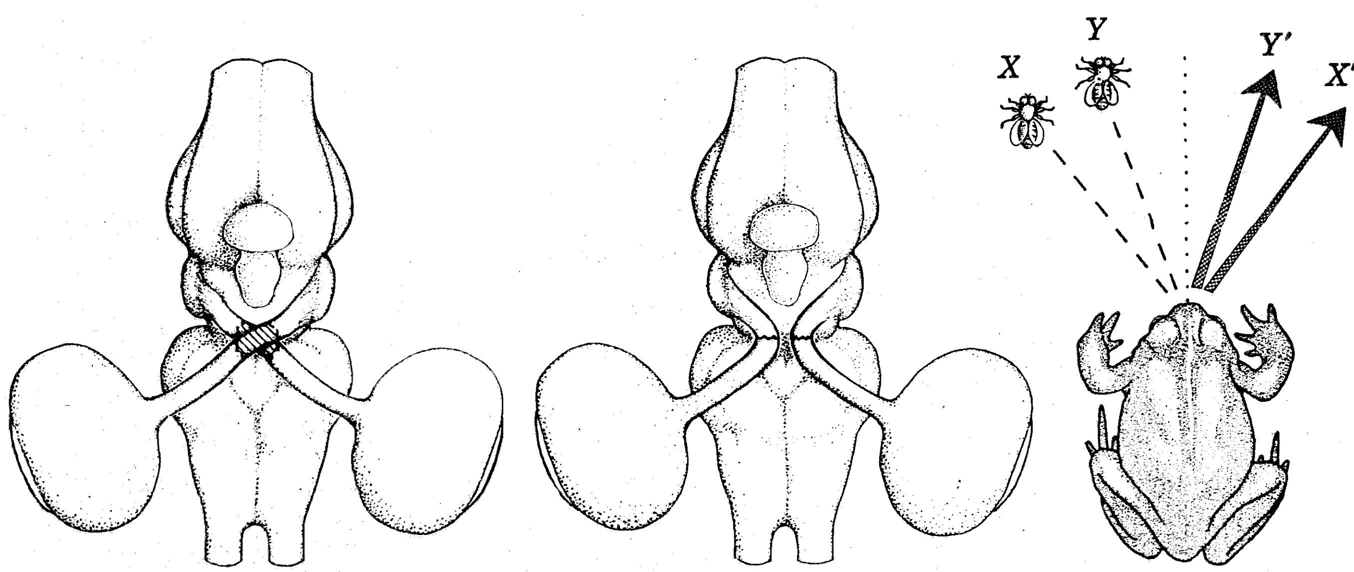
As shown in the diagram below, it is possible in these animals to cut the nerves of the eye where they cross, and to reunite them surgically in such manner that, when they regenerate, the eyes become connected to the wrong sides of the brain. Under these conditions, the animals respond thereafter as if everything seen through one eye were being viewed through the opposite eye. For example, when a fly moves within the field of view of a frog's left eye, the frog will strike out at a corresponding point in the right field of view. This right-left reversal of visual reactions persists indefinitely, with no evidence of correction by re-education.

The sensory surface or retina of the eye in all vertebrates is projected through the optic nerve fibers onto the brain in an orderly, topographic, or map-like fashion. In the foregoing experiment the behavioral tests (and other evidence) indicate that this orderly topographic projection is restored with systematic precision in the regeneration process—despite extensive intertangling of the regenerating fibers. In the diagram below, for instance, the relationships of X to Y, and of X to any and all other points within the same visual field are restored to their normal patterns. The fact that this occurs, despite the maladaptive functional effect produced by crossing the optic nerves, means that learning, or any other kind of functional readjustment, is not responsible for the orderly topographic patterning of the central hook-ups.

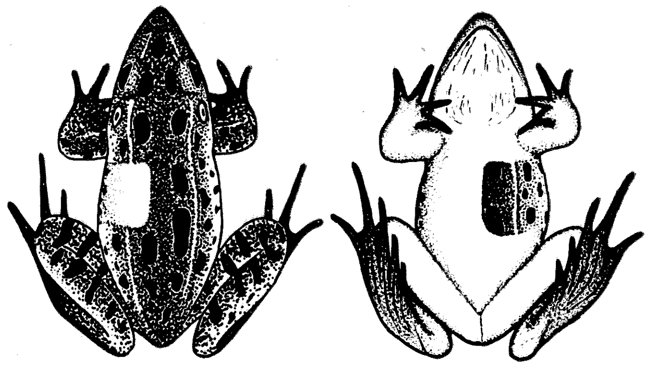
The fact, also, that this orderly restoration occurs in the face of random intermixing and intertangling of the regenerated fibers—particularly in the region of the nerve transection—has forced us to conclude that the optic fibers must differ from one another in quality.

In the lower vertebrates the optic fibers number around 25,000 (there are over a million in the optic nerve of man), and we have to infer that these individual fibers differ from one another in their biochemical constitution according to the particular points of the retinal field from which they arise. The further inference here is that the ingrowing fibers, on entering the brain, establish their central hook-ups in a selective, discriminative manner, governed by specific chemical affinities between the different types of ingrowing fibers and the central cells on which they terminate. This inference requires the corollary conclusion that a similar topical specificity exists among the nerve cells of the optic centers.

There is good reason to think that the qualitative specificity of the optic fibers is achieved in development through a polarized chemical differentiation of the retina. First, a naso-temporal, or front-back gradient of differentiation is laid down, and later—superimposed at right angles on top of this—an up-down gradient. This would mark each retinal locus with a latitude and longitude, so to speak, expressed as a unique ratio of chemical



Connecting of eyes to wrong side of brain results in an illusory right-left reversal of visual field. However, the relationships of X to Y, and of X to any and all other points within the same visual field are restored to normal patterns.



Skin grafts, rotated 180 degrees, result in a reversal of localizing reflexes. When back is stimulated in graft region, frog rubs belly—and vice versa.

properties. We don't know the exact chemical or physico-chemical nature of these neuronal specificities as yet any more than we know the chemical basis for most of the cellular differentiations that occur throughout the organism during development.

By rotating the eye surgically in the orbit, or by transplanting the eyeball from one orbit to the other, with different degrees of rotation, one may produce various other types of visual inversion and distortion. These inversions and distortions are always correlated directly with the orientation of the eyeball in the orbit; and, like the right-left reversal, they too persist without functional correction.

Leon Stone at Yale and George Szekely in Hungary have since carried these eye transplantations into pre-functional embryonic stages, and have found that inverted vision results in just the same way as it does in the later stages. It would appear that the perception of visual direction is built into the vertebrate brain and, contrary to earlier opinion, does not have to be learned.

In some related work on cutaneous sensibility it was found that if one crosses the major nerve trunks of the left hind foot in the rat into the opposite leg and reunites them with the corresponding nerves of the right hind foot, then, after regeneration of the fibers into the skin of the opposite foot, all sensations aroused in the right foot are falsely referred to the left foot, from which the nerves originally came. For instance, an electric shock applied to the sole of the right foot causes the animal to withdraw the left foot.

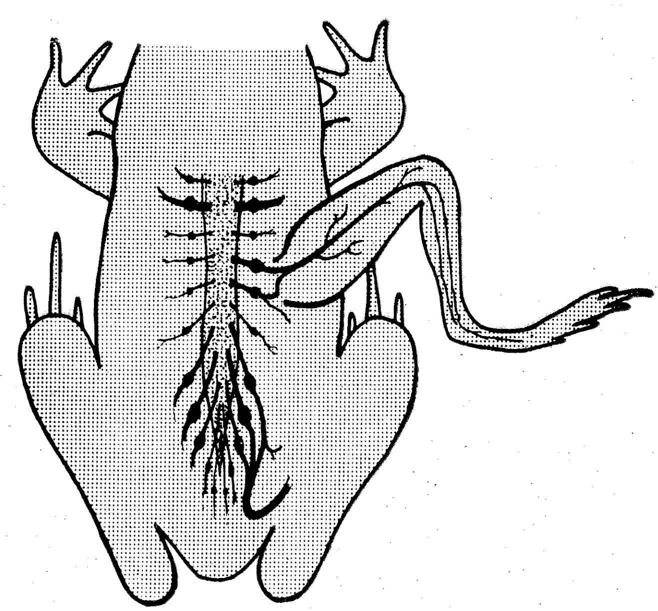
The surgery was done in these rats during the fourth week after birth—before the animals could have had much experience in localizing cutaneous stimuli. The resultant reversal of reflex-reaction with the false reference of cutaneous sensibility persisted indefinitely, despite prolonged efforts to re-train the reactions by conditioning techniques and other methods. The results suggest that the mechanism for locating points on the body surface, like that for sensing visual direction, is built into the nervous system, and, common assumption to the contrary, is not a product of experience and training.

This interpretation received further support in later experiments like the one carried out by Dr. Nancy Miner in which a flap of skin was peeled off the trunk region of a frog, lifted, and cut completely free of all nerve and other connections, rotated 180 degrees, and reimplanted (as shown at the left). The operation was done in early larval stages. When the tadpoles had grown up and undergone metamorphosis into the adult, we found that tickling these frogs on the back, within the graft region, caused them to scratch the belly with the foreleg. Conversely, stimulating them on the belly caused them to swipe at the back with the hind leg.

These, and related, experiments have confirmed the preceding inference that the mechanism for locating points on the body surface is organized in the growth process itself—ultimately, of course, under genetic control. This neural apparatus for locating points on the skin is not a simple thing: I am told that our engineering is not yet developed to the point where we could build a machine to do nearly so well—particularly one in which the points to be localized are on its own mobile parts.

The further interpretation of how the neural mechanism is put together and developed in the growth process—based on the foregoing, and similar, studies—goes something like this: The skin, like the retina of the eye, must undergo a refined local differentiation during development—probably also on a basic, biaxial plan. The local specificity of the skin is then stamped or imprinted upon the nerve fibers at their terminal contacts. This induced chemical specificity in the nerve fibers, after spreading centrally along the fibers into the spinal and cranial nerve centers, then determines the type of reflex hook-ups formed—again, presumably on the basis of specific affinities between the peripheral fibers and central cells with which they connect.

It was shown further by Dr. Miner that if an extra hind limb bud is transplanted into the trunk region of the frog (as shown below), the same trunk nerves that



Trunk nerves growing into transplanted limb form limb reflex connections instead of normal trunk reflexes.

X-ray picture showing tantalum wire inserts filling visual area of cortex. These are designed to short-circuit electric brain currents during visual pattern perception.

were involved in the preceding graft experiment—and which normally form belly, back, and side-wiping reflex patterns—now form entirely different patterns of central connections, suited in each case to the particular areas of the transplanted limb with which the fibers connect. By stimulating different points in the extra limb we get knee-wiping, thigh-wiping, and various types of kicking reactions. This means that cutaneous nerve fibers destined normally to form central hook-ups appropriate for the belly, flank, and back skin of the trunk, formed instead connections appropriate for the digits, heel, and knee of the limb.

All these responses, incidentally, are made by the normal limb on the same side as the transplant; the transplant itself has no motor function. The important point is that here again the local quality of the skin with which the fibers connect in the periphery, and not the functional effects for the organism, determines the patterns of synaptic hook-ups formed in the central nervous system.

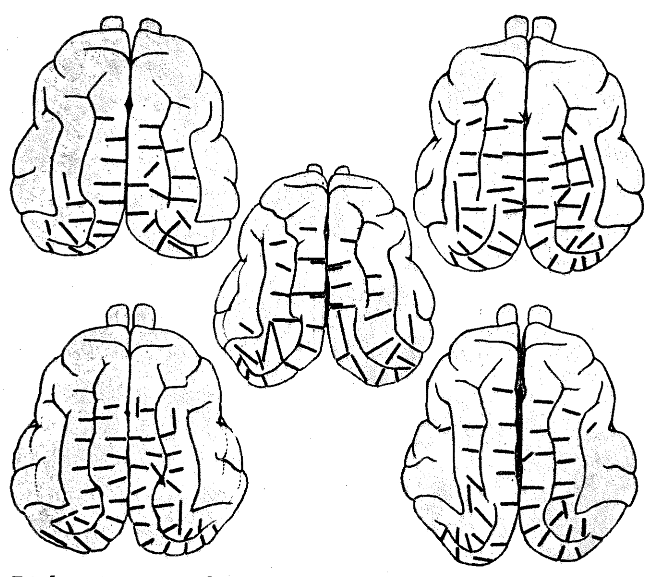
It used to be thought that the nervous system was first laid out in embryonic development pretty much as a random equipotential network that was gradually channelized through experience and training. The training effects were presumed to start way back in the early movements of the fetus in utero. Now our picture is quite different. We think that the great bulk of the neural circuits are laid down in precise, predetermined patterns in the growth mechanism itself. The effects of learning are presumably confined to the highest association centers, particularly the cerebral cortex, and are so minute a part of the total central nervous structure that they have thus far eluded any direct morphological demonstration.

Another part of our work deals with a brain theory of perception that developed out of the Gestalt school of psychology, and is perhaps most commonly referred to as the "electrical field theory of cerebral integration." Proponents of field theory have ascribed a primary role in brain function to gross electric currents that spread through the cortex *en masse;* that is, through the cortical tissue as a volume conductor. Most aspects of perception appear to be more readily correlated with these gross electric currents in the brain than with the more orthodox type of nerve impulses that travel in scattered discontinuous patterns along discrete fiber pathways.

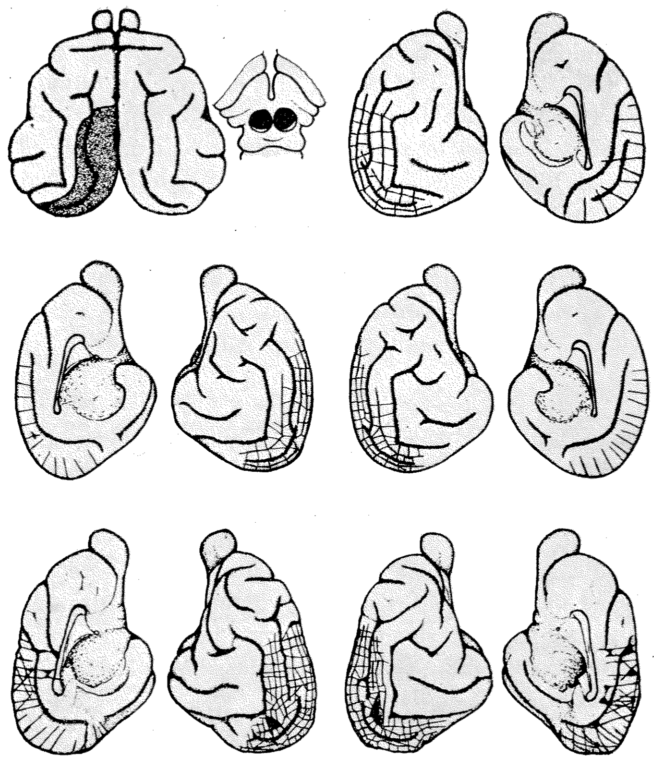
In an experiment aimed at testing this electrical field theory, the visual area of the cortex in the cat was filled with metallic inserts of tantalum wire (as shown at the left). The aim here was to short-circuit, and hence to distort, the normal patterning of DC current-flow in the cortex during visual form perception. These numerous metallic inserts, which are biologically inert and remained in the brain for months without any deleterious effects, proved to have no measurable effect on any visual reactions—including previously-trained high-level pattern discriminations.

In another experiment aimed at testing the electrical field theory the approach was just the opposite. Dielectric or insulating plates of mica were inserted vertically into the cortex, in the patterns shown below, in an attempt to distort—this time by blocking instead of by shorting—the postulated patterns of DC flow in the visual area during pattern perception. Although some functional impairment was found in this series, it was shown in controls to be correlated with the tissue damage produced by the inserts rather than with their dielectric effects, and the conclusion was the same as in the previous experiment.

The outcome of these two studies has rather discouraged any inclination, on our part at least, to forsake the traditional fiber conduction doctrine of brain function in favor of the newer electrical field hypothesis.



Dielectric mica plates inserted in visual cortex to distort the patterning of brain currents during perception.



Visual area of cortex, partitioned with numerous subpial cuts to test effect on pattern perception.

Any brain theory of perception, we believe, must square also with the following observation: The visual area of the cortex, in the cat again, was sliced with numerous subpial knife cuts in crisscross pattern, as shown above. When these cuts—in the top two cases—proved to have only negligible effects upon pattern perception, we decided—in the third case—to carry this slicing procedure to an extreme, making the cuts as numerous and as close together as possible. After four weeks, this third animal was performing again on our test scales at a level only one or two notches below its preoperative standard.

On the left (A), below, is shown the best discriminations that this animal was able to perform several months later. It could discriminate the central triangle when paired with any of those surrounding it. And it readily learned the size discrimination on the right (B). The lack of any marked functional disturbance after such slicing of the cerebral cortex seems to eliminate as an important factor in perceptual integration any tangential or horizontal spread of nervous conduction within the cortex itself—that is, on any scale large enough to mediate so-called relational or structuring effects in the perception of pattern.

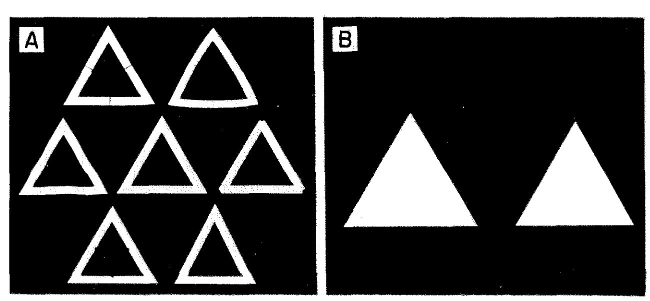
In another group of studies we have been concerned with the function in perception of long fiber connections in the mammalian cortex. The largest of the fiber bundles in the brain of higher mammals is the corpus callosum which unites the two cerebral hemispheres. It has been somewhat embarrassing to our concepts of brain organization that complete surgical section of this largest fiber tract has consistently failed in human patients to produce any clear-cut functional symptoms. In checking this observation in animal experiments, however, we have been able in recent years to demonstrate definite integrative functions for this structure.

In these experiments, carried out mainly in cats, we first section all crossed optic fibers at the chiasma, in order to restrict the input from each eye to the same side of the brain. The animal is then taught a few simple visual discriminations with a mask covering one eye. After the habit has been stabilized by overtraining, the mask is shifted to the other eye.

With this procedure it was shown originally by Dr. Ronald Myers that the trained performance transfers readily to the untrained eye, if the corpus callosum is intact; but if the corpus callosum has been sectioned prior to training, there is no transfer at all. Without the callosum, such animals apparently have no recollection with one eye of what they have been doing with the other eye. In fact, it is possible to train opposing incompatible discriminations to the separate eyes concurrently without getting any interference. Work in progress shows the same to be true in the monkey.

In collaboration with Dr. John Stamm, we have obtained similar results for the contralateral transfer from one forepaw to the other of tactile discriminations. Cats are trained to push the correct one of two pedals which they can reach with only one forepaw and which they are unable to see and must distinguish entirely on the basis of touch. One gets 70 to 80 percent transfer of learning upon shifting to the untrained paw in unoperated animals. When the callosum is sectioned, the transfer is zero.

Perceptual learning and memory thus seem to proceed independently in the two hemispheres of the brain in the absence of the corpus callosum. It is interesting that, in spite of this independence, the learning curves for the two separated hemispheres are remarkably similar in character, suggesting that the individual variability in perceptual learning is predetermined to an unexpected degree by the intrinsic structural, and functional organization of the cerebral hemisphere. This was found to be true in cats for both tactile and visual discriminations, but seems to be much less characteristic of the monkey, the difference here reflecting perhaps an important species difference in learning.

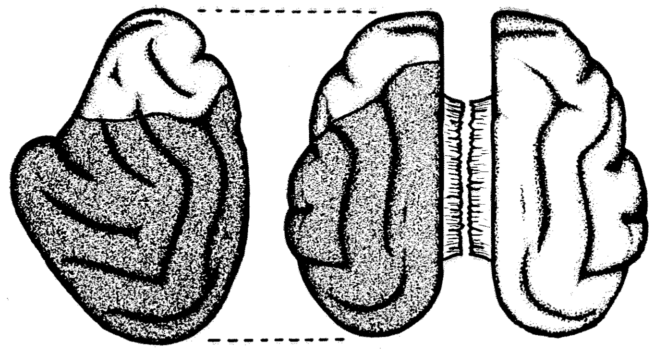


With its visual cortex subdivided by multiple crisscross cuts, test animal could discriminate central triangle in A, above, when it was paired with any of those surrounding it—and also learned size discrimination in B.

Attempts to localize in the brain the memory traces for particular habits have generally failed. The memory traces, or engrams, appear to be extremely elusive and diffuse and so far have not been specifically localized or demonstrated. In the case of the memory traces ingrained for the visual discriminations in the foregoing experiments, it was possible to show that they are not confined to the directly trained hemisphere. One can remove the visual and the neighboring association cortex on the trained side in these animals before switching the mask, and still get the transfer to the untrained eye through the callosum. Further, one can still get this transfer even if the entire callosum is sectioned after the completion of training, but before testing for the transfer. Some kind of mnemonic carryover into the opposite hemisphere is evidently effected via the corpus callosum.

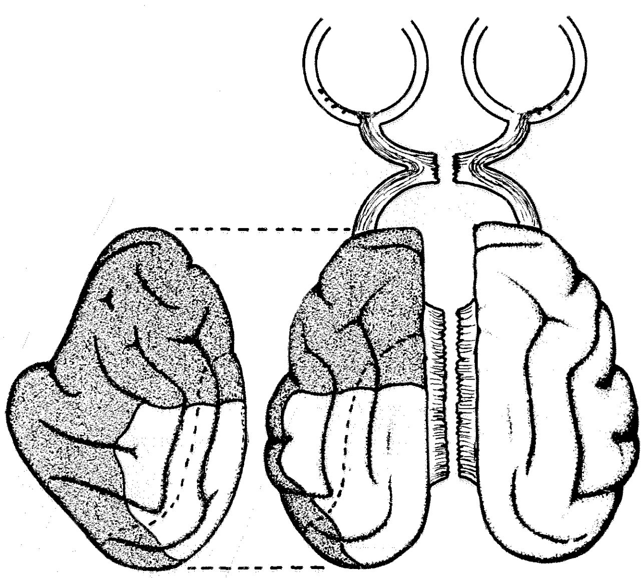
At the present time we are investigating the functional capacities of small islands of cerebral cortex. In these studies we put to use the above-mentioned functional independence of the two hemispheres in what we have come to call the "split-brain preparation." This is an animal in which the brain has been split down the middle by sectioning the corpus callosum, hippocampal commissure and the optic chiasma and, frequently also, some of the lower-level connecting systems. To casual examination, these split-brain animals after recovery are indistinguishable from normal in their general cage behavior.

In such animals the brain-lesion analyses can be carried out in one hemisphere alone; the other hemisphere being kept intact to maintain generalized background functions. In the test hemisphere, instead of the customary small lesions in the critical area, it becomes possible in such preparations to use the opposite approach—that is, to remove the greater part of the cortex and to leave intact only the small critical area, the functions of which one wishes to investigate.



Small island of intact cortex retains capacity to remember and to learn new tactile discriminations almost as well as the whole hemisphere.

To what extent would visual perception be possible, for example, if all parts of the cerebral cortex were removed excepting just the visual area itself? We have found that vision is practically absent on the test side when the visual area is isolated in cats to the degree shown in the drawing below.



Removal of non-visual cortex with preservation of visual area abolishes visual functions for reasons still undetermined.

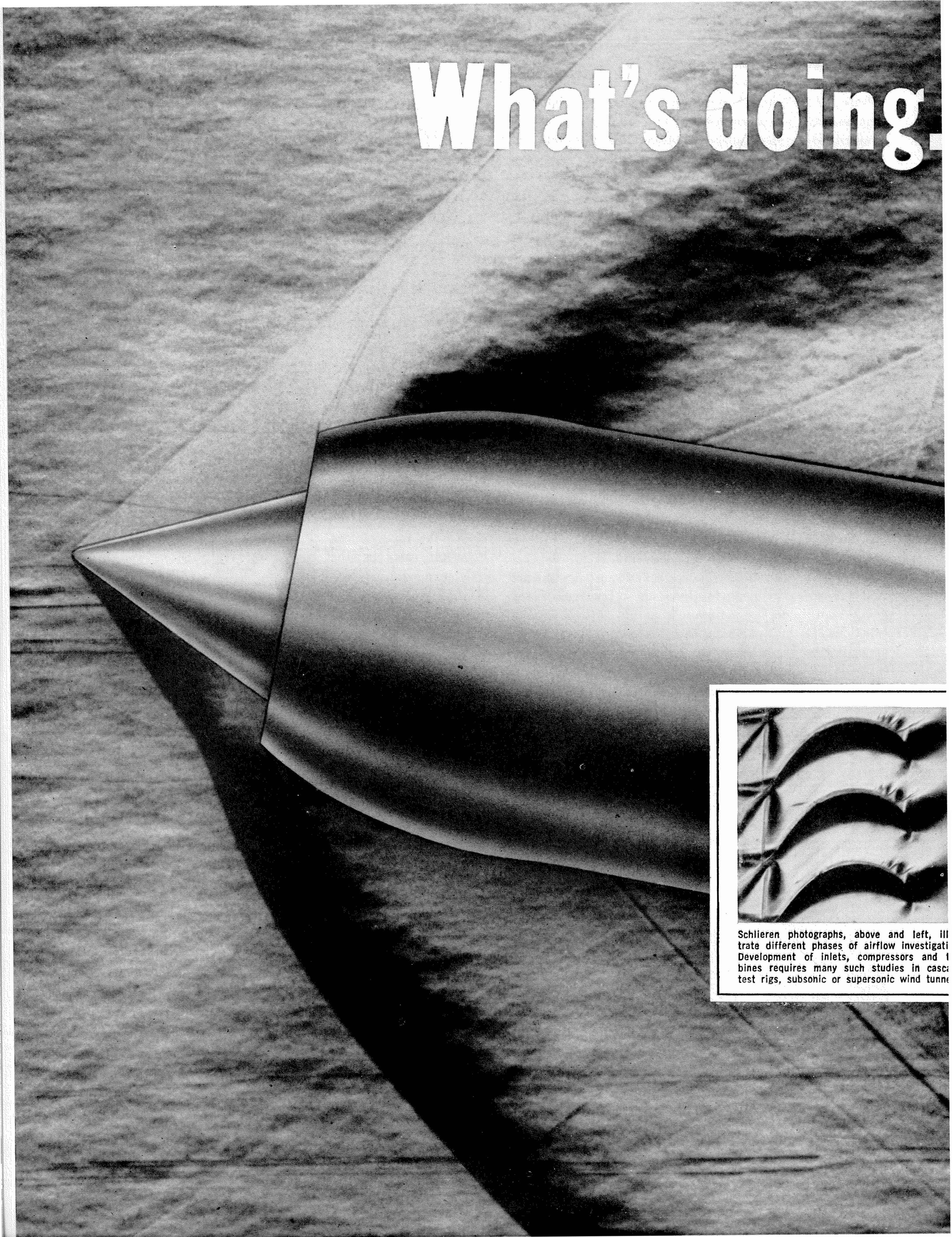
If the non-visual parts are removed in two or three separate operations, starting with the cortex immediately surrounding the sector to be preserved, it is not until the final removal of frontal or temporal lobes, as the case may be, that we get the really severe visual impairment.

Similar isolation of the cortical area for touch perception, as shown above, has yielded quite different results. In this case the cats, after operation, are still able to perform, at a high level, previously-trained tactile discriminations. They also are able to learn new discriminations with the isolated area almost as well as with the whole hemisphere. If circumscribed lesions are subsequently placed in the forepaw tactile area in the opposite, intact hemisphere, it is possible to abolish all discrimination with the affected paw without significantly impairing the performance of the paw that is controlled through the isolated remnant of cortex.

It would appear that the processes of cortical integration and reintegration involved in the learning and memory of these tactile discriminations are localized within the intact cortical island. Under normal conditions it is entirely possible that the integrative processes are much more wide-spread through the cerebral hemisphere, but it is important to know at least that these unknown cerebral mechanisms are of such a nature that they *can* be handled with a rather small, isolated sector of the cortex.

This is about where we stand on these projects at the moment. As can be seen, we are still a very long way from being able to blueprint the circuit diagrams for perpetual integration, learning or memory. Nor have we the vaguest notion of the general type of circuits needed, for example, to build into a machine so simple a thing as pain sensation. We don't know enough to say in theory even that it can—or ever could—be done.

What's doing.



Schlieren photographs, above and left, ill
trate different phases of airflow investigati
Development of inlets, compressors and t
bines requires many such studies in casc
test rigs, subsonic or supersonic wind tunn

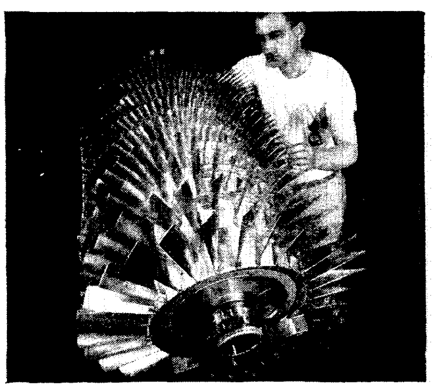
. . at Pratt & Whitney Aircraft in the field of Aerodynamics

Although each successive chapter in the history of aircraft engines has assigned new and greater importance to the problems of aerodynamics, perhaps the most significant developments came with the dawn of the jet age. Today, aerodynamics is one of the primary factors influencing design and performance of an aircraft powerplant. It follows, then, that Pratt & Whitney Aircraft — world's foremost designer and builder of aircraft engines — is as active in the broad field of aerodynamics as any such company *could* be.

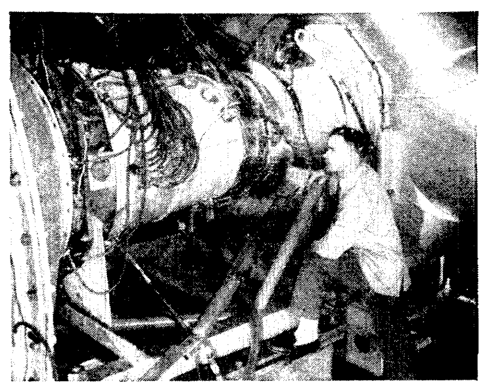
Although the work is demanding, by its very nature it offers virtually unlimited opportunity for the aerodynamicist at P & W A. He deals with airflow conditions in the engine inlet, compressor, burner, turbine and afterburner. From both the theoretical and applied viewpoints, he is engrossed in the problems of perfect, viscous and compressible flow. Problems concerning boundary layers, diffusion, transonic flow, shock waves, jet and wake phenomena, airfoil theory, flutter and stall propagation — all must be attacked through profound theoretical and detailed experimental processes. Adding further to the challenge and complexity of these assignments at P & W A is this fact: the engines developed must ultimately perform in varieties of aircraft ranging from supersonic fighters to intercontinental bombers and transports, functioning throughout a wide range of operational conditions for each type. Moreover, since every aircraft is literally designed around a powerplant, the aerodynamicist must continually project his thinking in such a way as to anticipate the timely application of tomorrow's engines to tomorrow's airframes. At his service are one of industry's foremost computing laboratories and the finest experimental facilities.

Aerodynamics, of course, is only one part of a broadly diversified engineering program at Pratt & Whitney Aircraft. That program — with other far-reaching activities in the fields of instrumentation, combustion, materials problems and mechanical design — spells out a gratifying future for many of today's engineering students.

dern electronic computers accelerate both the analy- and the solution of aerodynamic problems. Some of se problems include studies of airplane performance ich permit evaluation of engine-to-airframe applications.



Design of a multi-stage, axial-flow compressor involves some of the most complex problems in the entire field of aerodynamics. The work of aerodynamicists ultimately determines those aspects of blade and total rotor design that are crucial.



Mounting a compressor in a special high-altitude test chamber in P & W A's Willgoos Turbine Laboratory permits study of a variety of performance problems that may be encountered during later development stages.

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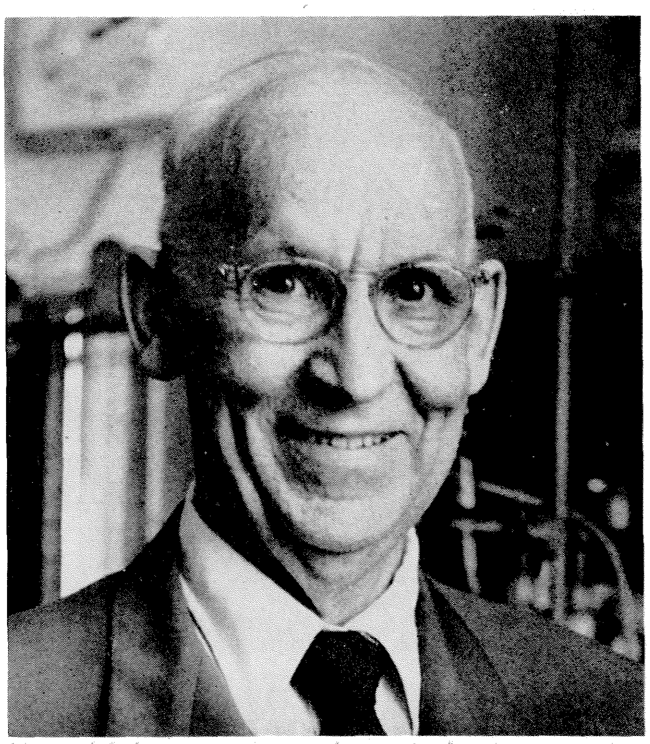
THE MONTH AT CALTECH

Jesse L. Greenstein, professor of astrophysics

National Academy of Sciences

JESSE L. GREENSTEIN, professor of astrophysics and staff member of the Mount Wilson and Palomar Observatories; and Howard J. Lucas, professor of organic chemistry, emeritus, were elected to the National Academy of Sciences last month—bringing Caltech staff membership in the Academy to 30. The Academy offers membership to only 500 American citizens and 50 foreign associates who have made valuable contributions in scientific research.

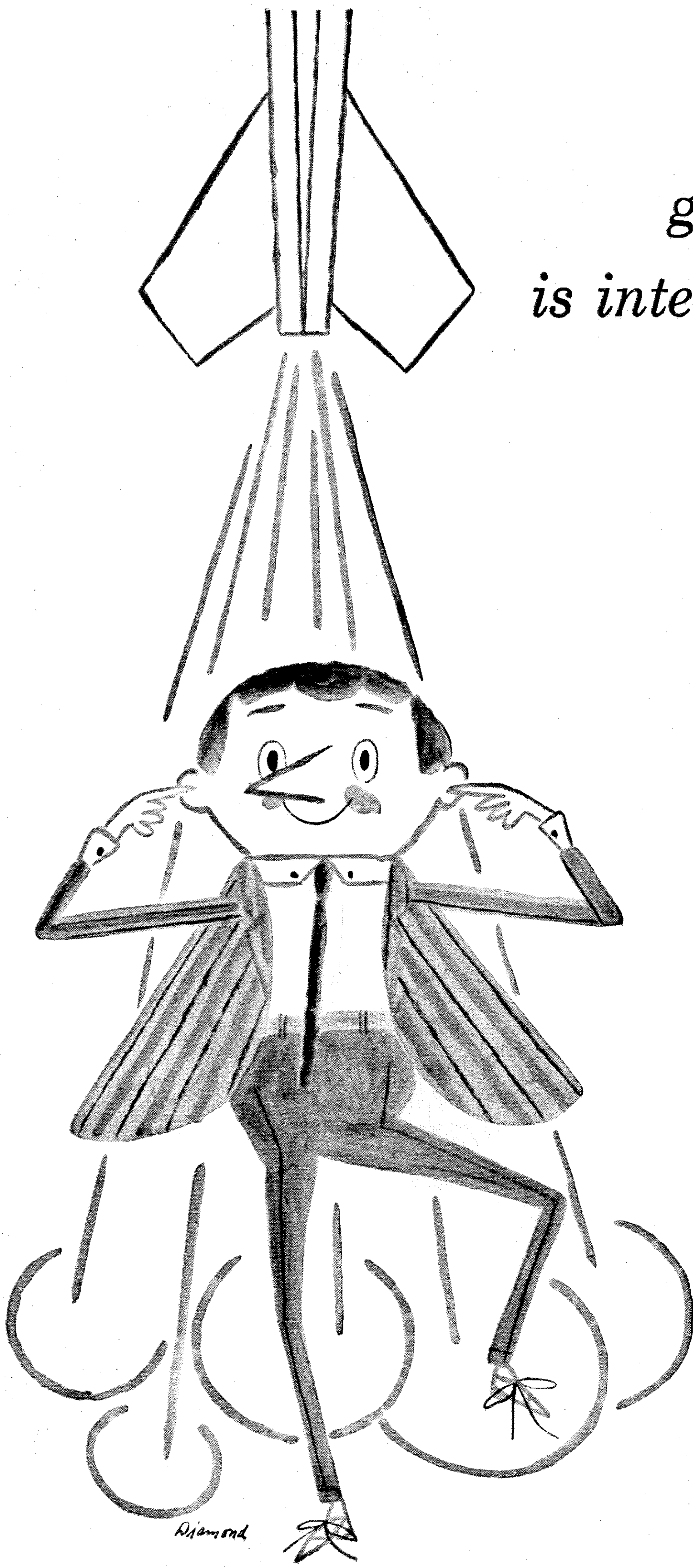
Dr. Greenstein has made a number of important investigations of stellar atmospheres and of the material in interstellar space. His spectrographic studies are now yielding fundamental data on cosmic chemistry, especially on the questions of relative abundances of various atoms and whether all stars have the same composition. Of special interest is his investigation of the abundances of certain elements that are subject to thermonuclear disintegration. This particular branch of his research has led to important conclusions regarding the evolutionary processes in the interiors of stars and the formation of elements.


Howard J. Lucas, professor of organic chemistry, emeritus

Dr. Greenstein was graduated from Harvard University in 1929 and received his MA there in 1930. After several years in business in New York, he returned to Harvard where he received his PhD in 1937. He came to Caltech in 1948, after eight years as a member of the staff of Yerkes Observatory.

Dr. Lucas, a member of the Caltech faculty for 40 years prior to his retirement in 1955, helped to modernize the field of organic chemistry. He was one of the first chemists to recognize the value of electronic interpretations of chemical data, and he made numerous contributions to the understanding of the electronic structure of organic molecules. In 1935 he established the pattern for all modern elementary organic chemistry textbooks with his *Organic Chemistry*.

A graduate of Ohio State University, Howard Lucas received his MA there in 1908. In 1909-10 he served as a teaching fellow in chemistry at the University of Chicago, then went to work as an assistant chemist for the United States Department of Agriculture. He came to Caltech in 1913. He received the Scientific Apparatus Makers Award of $1,000 as "the outstanding chemistry teacher in the United States in 1952." And, in 1953, he was awarded the honorary degree of Doctor of Science by his alma mater, Ohio State.



THE NEXT HUNDRED YEARS . . . II

As population increases, the need to obtain more food becomes more pressing. A noted plant physiologist considers some of the ways we might increase our food supply.

by HARRISON BROWN, JAMES BONNER AND JOHN WEIR

This article has been extracted from the book, The Next Hundred Years: Man's Natural and Technological Resources, *by Harrison Brown, James Bonner and John Weir, copyright 1957 by The Viking Press, Inc., to be published in June. Dr. Brown is professor of geochemistry at Caltech; Dr. Bonner, professor of biology; Dr. Weir, professor of psychology.*

This extract, the second in a series of three, has been drawn largely from Dr. Bonner's evaluation of our agricultural resources. Next month, Dr. Weir discusses technical manpower sources.

THE POPULATION of the world has climbed with extraordinary rapidity during the course of the last century and has now reached a level of about 2.6 billion persons. Between 1850 and 1900 the world society grew by about 0.7 percent per year; this rate would produce a doubling of population every century. Between 1900 and 1950 the average annual rate of increase was 0.9 percent, shortening the doubling time to about 75 years . . . If we were to assume that the increase of population during the next century would average 1 percent per year, we would foresee a world of nearly 7 billion persons by the middle of the next century.

Such rapid rates of population growth can, in the long run, be maintained only if the production of food can keep pace with this growth . . . Thus, in our forecasts concerning the future, we must examine the problem of feeding this number of persons adequately.

Increases in food supply are attainable by wider application of present technology. Agricultural productivity can be increased by the use of more irrigation, more fertilizer, more insecticides; by the application of more plant-improvement technique; and by practicing more intensive agriculture. The rate at which such increase can be achieved is between 2 and 4 percent per year and should thus suffice to take care of our increasing world population.

True, to spread this technology will be a long, hard task, since it must diffuse to so many people, but theoretically it can be done. And, meanwhile, new technological developments may increase the rate of growth of our food supplies, or raise the maximum amount of food which can ultimately be produced, by the introduction of new methods of management of crops and of human diets.

A most effective method of increasing the amount of food available to people would be to decrease that fed to animals. Animal protein forms an important part of the human diet today, particularly in the Western countries. The American, for example, consumes about one-third of his diet calories in the form of such things as meat, milk, and eggs; the Western European about 20 percent; the Asian only about 5 percent. We consume animal protein not only because it tastes good to us, but also because it provides a plentiful supply of the amino acids essential to human nutrition, in the most favorable proportions. Yet these same amino acids are

CONTINUED ON PAGE 36

present in the protein of plants, from which the animal product has derived them, and with proper preparation can be effectively used.

The animal is a relatively inefficient converter of plant material to food for human beings, as is shown in the following table.

Production of Protein per Acre by Different Methods of Land Management (All values for cultivated crops on arable land)

METHOD OF LAND MANAGEMENT	METHOD OF RECOVERING PROTEIN	EDIBLE PROTEIN (pounds, per acre per year)
Planted to forage, grain, fed to steers	as beef	43
Planted to forage, grain, fed to cows	as milk	77
Planted to soybeans	as soybeans	450
Planted to alfalfa, U. S. average crop	as extracted protein	600
Planted to alfalfa, Western U. S. irrigated	as extracted protein	1500

The production of protein by conversion of plant substance to beef, which supplies about one-half of the world's meat, has an efficiency of only 5 to 10 percent, both in terms of food calories and in terms of protein. The production of milk protein is considerably more efficient than is the production of beef. Both of these procedures are, however, much less efficient than it would be to use our crop area for the production of soybeans, which produce seeds rich in protein, and to eat the soybeans ourselves. And the plant which produces seeds rich in protein is, again, less efficient as a protein producer than is a plant such as alfalfa, which is rich in protein in all its vegetative structure.

Alfalfa is, of course, grown to supply protein for animal diets, and there is no reason in principle why it cannot be used to supply protein directly in the human diet. If we are to use plant protein on a large scale as food for people, however, it will be necessary to devise methods by which the plant may be ground and the protein extracted. We will also have to find ways of fabricating the protein thus extracted into materials resembling such things as meat, eggs, and milk. But these are merely technological problems and are certainly soluble. This modification of our food technology would permit us to supplement human diets with the needed amino acids at a fraction of the cost in acres that characterizes our present system.

A second modification of our agriculture which could provide an important increase in the world's food supply is the replacement of crops which are less efficient in food production by crops which are more efficient. This raises the question of the efficiencies of different crop plants. Wheat yields less food per acre than do rice, potatoes, or sugar beets, but this is in part because the land sown to wheat is often less favored by rain or temperature than are the lands chosen for the other crops. Similarly, yields are often low in the underdeveloped areas because of limited supplies of fertilizer.

Let us, then, compare the efficiencies of crop plants as producers of food when each crop is grown under conditions as nearly ideal as possible.

Efficiency of Various Crops in Production of Food in Varied Regions

REGION	CROPS	FOOD PRODUCED (millions of calories per acre per year)
United Kingdom, moderately intensive farming	cereals (wheat)	2.9
	potatoes	6.7
	sugar beets	7.3
Northern Europe (Denmark, Holland), intensive farming	wheat	4.5
	potatoes	8.0
	sugar beets	13.0
Japan, intensive farming	rice	6.5

It is clear that the cereals compare unfavorably with potatoes or sugar beets, since high-yielding crops of the latter produce up to twice as many or more edible calories per acre as do the cereals. This is due to two principal factors. For one thing, the potato or sugar-beet crop takes longer to develop than does the cereal. Leaves that are exposed longer to the sun's energy have more opportunity to gather and store that energy. And in the second place, 50 to 60 percent of the potato or sugar beet plant is edible and digestible by man, as contrasted to 30 percent or so of the cereal.

To look at it in another way, the energy which is stored in plant material is energy the plant has captured from the sun's rays. Plants as we know them appear to be very similar in the efficiency with which they store solar energy in chemical form. Given favorable temperature, plenty of water, and abundant fertilizer, our crop plants uniformly capture about 2 percent of the incident energy.

High yields of food material per acre are attainable if we use a crop which remains active in the field for a long time. Thus the tropical sugar cane, which captures the sun's energy the year round, readily produces twice as much sugar per acre as does the sugar beet, which grows for but five months or so. And, in addition, the chemical equivalent of 2 percent of the sun's energy must be divided among the varied portions of the plant. The grain is a smaller portion of the cereal than is the sugar of a sugar beet.

These considerations are clear enough and provide us with a clear-cut goal in plant improvement. We want a plant which grows over a long season and of which as high a proportion as possible is edible. The commer-

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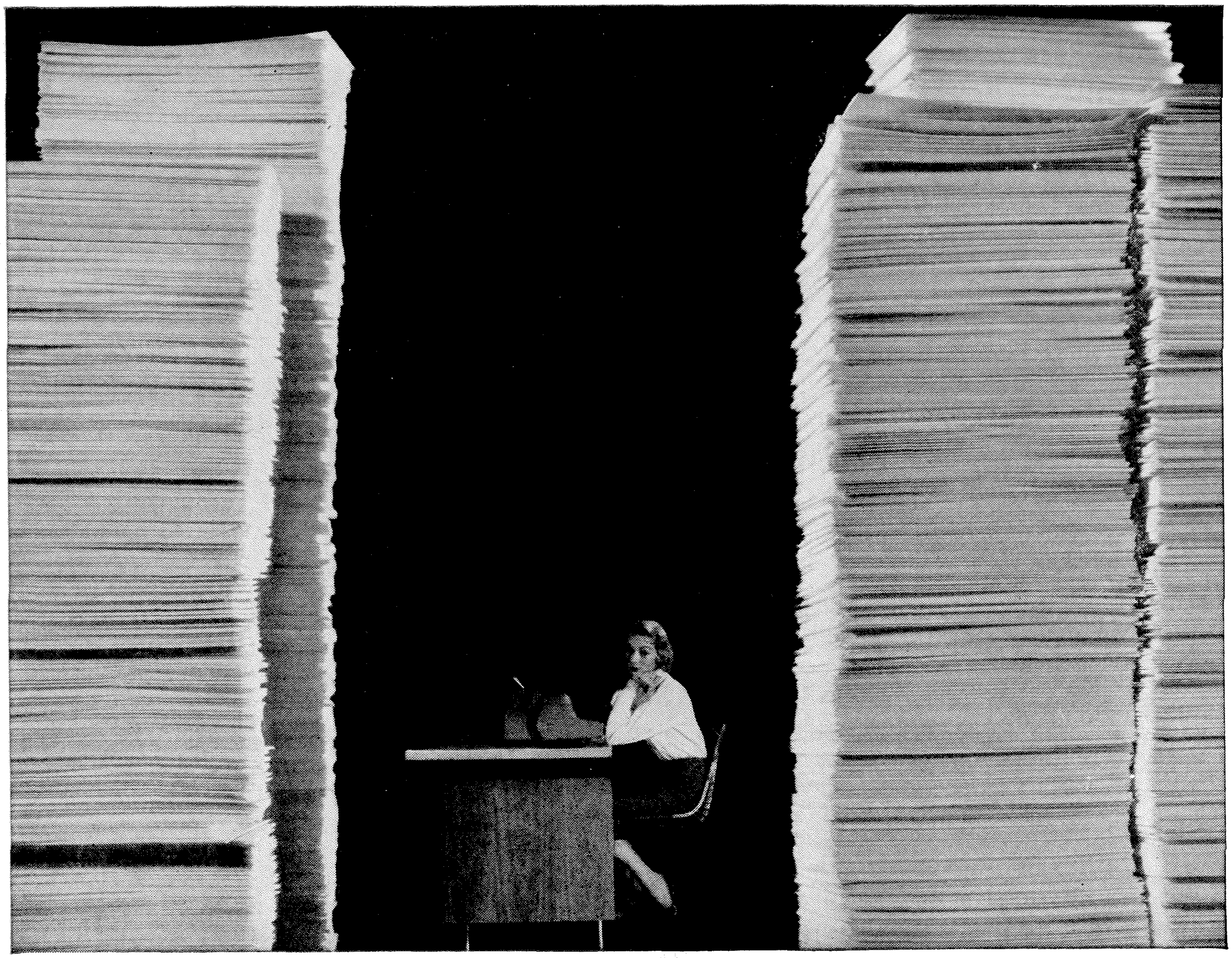

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ELECTRONICS FOR LIVING

cial sugar beet is in fact a product of genetic improvement by which the original low-sugar plant has been bred for high sugar content and high per-acre yields. We know how to breed crop plants high in other constituents, such as fat and protein. It is not at all impossible that we might be able to alter our sugar-producing plants by genetic means to cause them to accumulate fat, protein, or other dietary necessities in higher yield. Thus, we might breed a meat beet or a fat plant.

Inedible residues

There is still another approach to the problem presented by the fact that only a relatively small portion of the cultivated plant is edible to the human being. We can convert the inedible residues to food. Such residues are abundant. In the United States, for example, in which the human being yearly eats about 0.37 ton of food, we produce each year about 1.75 tons per capita of the inedible residues of corn and wheat—stalks, stems, corn cobs.

The technology of the conversion of these woody materials to material digestible by man is well worked out. It is possible to treat the woody plant material with hot acid and produce a molasses-like syrup of roughly 50 percent of the weight of the original material. The present estimated cost of molasses from this source is roughly ten times that of molasses from sugar beet or sugar cane. It is further possible to convert the molasses by yeast fermentation to a protein-rich material. The yeast obtainable from the molasses in 50-percent yield is also potential food for man.

If the need for food in the world were great enough we could theoretically convert the bulk of our woody residues to sugar or protein by this method, a measure which by itself would increase our food supply by perhaps 50 to 100 percent. The food increment would be costly, since it would require the expenditure of a great deal of energy and investment in much new technology, but it could be done, should it become necessary.

The step which appears, however, to be most practical for the ultimate augmentation of our world's food supply has to do with the management of water. Water availability is today a major limiting factor in crop production and in determining crop areas. There are in addition vast areas of steppe and desert which would be suitable for agriculture if water were available.

At the present time about 11 percent of the world's cultivated acres are supplied with water by conventional irrigation schemes. This amount is rapidly increasing, particularly in Asia and Latin America. It has been estimated that if the waters of the rivers of the world are appropriately conserved and distributed it should ultimately be possible to irrigate 14 percent of the world's cultivated acres at current prices of water and of farm products. This amount could undoubtedly be increased still further, perhaps to as high as 20 percent of the world's cultivated acres, by the building of expensive conventional irrigation projects. There is nonetheless just not enough water in the streams to irrigate any substantially greater portion of the earth's surface than this, by conventional methods.

We cannot hope, therefore, to water the steppes and deserts, which together constitute over twice as large an area as the land now under cultivation, by conventional irrigation projects. If we are to irrigate this area we must acquire water from other sources, and this means in the long run the reclamation of sea water. What are the economic prospects for the reclamation of sea water and for the irrigation of the deserts of the earth in this way?

It is now economical to carry on agriculture in the United States in regions in which irrigation water from conventional projects costs as much as $10 per acre-foot and in which from 2 to 5 feet are applied per acre per year. It is proposed to intensify this practice within the next 20 years with irrigation water that costs up to $40 per acre-foot. Supplementary irrigation in the southeastern United States, the application of relatively small amounts of water to enable plants to survive through drought periods, is already being carried out with water which costs as much as $75 per acre-foot.

Reclamation of sea water

The cost of reclamation of ocean water has been investigated by various groups. These forecasts agree in suggesting a probable cost for fresh water from the sea of from $100 to $200 per acre-foot. To this we must add the cost of building canals and pipelines to carry and distribute the water. And so, if we are to irrigate the arid areas of the earth with reclaimed sea water, we will do so at great expense. To supply irrigation water alone will cost more per acre per year than the average value at present prices of the crop produced on such an acre.

But as our world becomes more populous, and as the need to obtain more food becomes more pressing, we have available to us this straightforward means of extending an otherwise conventional agriculture to a very large area indeed. It would probably be possible to double or quadruple the world's ultimate food production by supplemental irrigation of the less favored portions of our present crop land and by extending irrigation to the areas which are now arid.

It has been shown that although nine-tenths of the photosynthesis of the earth's surface occurs in the oceans, still, only a small portion of the resulting material finds its way into the human diet. We harvest sea produce primarily in the form of fish, which contribute a negligible fraction of the diet calories that today support the world's human population. We know too that we cannot greatly extend the fish harvest without bringing

CONTINUED ON PAGE 40

about the depletion of the ocean's fish populations.

Why is it that the ocean's potential contribution of fish is so small, even though the ocean's yearly crop of algae is so large? The answer to this question seems to be that it takes a lot of algae to make even a little bit of fish. It has been estimated that about 100,000 pounds of algae will produce only 1 pound of codfish. The algae is first consumed by some microscopic animal, which retains about 10 percent of the calories. This small animal is next eaten by a larger one with another energy recovery of 10 percent, and so on and on. The food chain from algae to fish involves three, four, or five steps. Only a food contribution of from 0.001 to 0.1 percent of the original plant material is eventually available as fish for the diet of human beings.

By and large, then, the fish is an inefficient converter of plant to human food. If we wish to use the ocean efficiently as a source of food, we must apparently make unconventional approaches to the harvesting of plant material from it. We could of course strain the algae from ocean water directly by some mechanical means, but we would have a lot of straining to do, since 1 cubic meter of sea water contains on the average about 1 cubic centimeter of plant material. We might, however, contemplate the possibility of using the ocean as we do grazing land. We might domesticate an ocean-going vegetarian beast—a sea pig.

Algae as a food crop

The cultivation of algae as a food crop has been widely discussed in recent years. In principle it should be possible to cover an area with large tanks, fill these tanks with an appropriate nutrient solution, inoculate them with a suitable type of alga, and harvest the algae periodically.

If the tanks were covered with transparent plastic or glass, the carbon-dioxide content of the atmosphere could be enriched, thus leading to a production of larger crops for a given area than would be obtainable in the open. At the same time, however, such closed tanks must be cooled in some way, since they act as heat traps when the sun shines upon them. Conventional crop plants as well as algae respond to increased carbon-dioxide concentrations by increased yields. The advantage of algae lies principally in the fact that it is technically rather simple to supply them with extra carbon dioxide.

The investment in preparation of land for the culture of algae is, however, ten to one hundred times greater than that for conventional agriculture. Yield of plant material per unit area of surface exposed to sunlight and under equivalent carbon dioxide concentration is the same for algae and for conventional crop plants. And when the algae have been finally grown and harvested, we have merely a nasty little green vegetable, the consumption of which presents the same sorts of technological and psychological problems as are associated with the utilization of, for example, alfalfa as food for man. It seems logical to conclude that expansion of our food supplies by the more familiar agricultural techniques will precede expansion of our food supplies by the cultivation of algae.

Chemical synthesis of food

The chemical synthesis of food would also appear to be an exceedingly remote possibility, at least so far as provision of general diet calories is concerned. The human being requires in his nutrition chemical compounds which are complex and exceedingly various. Although we do know how to use simple compounds as the starting materials for the chemical synthesis of the sugars, fats, amino acids, and vitamins required in the human diet, it is still a complicated chemical job.

Perhaps the most elaborate large-scale efforts to produce human-diet calories by synthetic means was undertaken by the German government during the Second World War. In order to cope with a severe shortage of edible fats, factories were made to synthesize fats, starting with the hydrogenation of coal. The process was extended with major effort until it supplied about 2,000 tons of fat per year, about one-thousandth of the amount yearly consumed in Germany.

Chemical synthesis of food is a big job. We should bear in mind, too, that it cannot be based permanently on the use of petrochemicals (chemicals obtained from coal and petroleum) as starting materials but must ultimately be based on the reduction of carbon dioxide, as is agriculture itself.

Although the chemical synthesis of bulk dietary calories appears to be impractical for the foreseeable future, that of dietary supplements is a practical matter even today. It is possible to supply a human being with his required rations of vitamins, all synthetically produced, at a cost of between 25 cents and a dollar a year. The vitamins, although complex to manufacture, are required by human beings only in minute amounts.

It is also possible to supplement diets with synthetically produced amino acids, although this is still of questionable practicality from an economic standpoint. Populations in underdeveloped areas who live primarily on cereal diets sometimes suffer from amino-acid deficiencies, probably through lack of the amino acids methionine, lysine, and trytophane. A year's supply of these three amino acids, synthetically produced, costs approximately $40 per person today, so that it is hardly feasible economically for most of the world's population to supplement diets with them.

It may well be, however, that in the future we can enrich our diets with an increasing variety of synthetically produced materials, devoting our agriculture to the business of supplying the bulk of the calories we need.

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Mid-morning coffee break on Alumni Seminar Day

ALUMNI NEWS

20th Annual Seminar

THE 20TH ANNUAL Alumni Seminar brought 657 alumni, wives and guests to the Caltech campus on April 6. Featured on the daytime program were a series of six lectures and a symposium on the future of the earth's natural resources in relation to man and his technology. In the afternoon alumni toured the Southern California Cooperative Wind Tunnel in Pasadena. And in the evening, after dinner at the Pasadena Elks Club, Dr. Ray Untereiner, who is on leave from the Caltech faculty to serve as a commissioner of the State of California Public Utilities Commission, spoke on "California Utilities and the Commission."

25th Reunion

THE CLASS OF 1932 has a whole series of special events lined up for its 25th reunion celebration in Pasadena next month. On the evening of June 4 the class will gather at the Huntington-Sheraton Hotel, where the out-of-town members of the class will be staying with their wives. The tentative program calls for dinner at the Huntington-Sheraton at 7 p.m., followed by a general bull-session.

On Wednesday morning, June 5, members of the class, and wives, breakfast at the hotel at 8 a.m. From 10 to 12 a.m. the group will make a guided tour of the campus and check over the developments that have occurred since '32. Luncheon will be served for the group at noon in the Athenaeum, where President DuBridge will give a short talk. In the afternoon, members of the class and their wives are on their own. The Alumni Swimming Pool and dressing rooms will be available to the group from 2 to 4 p.m.

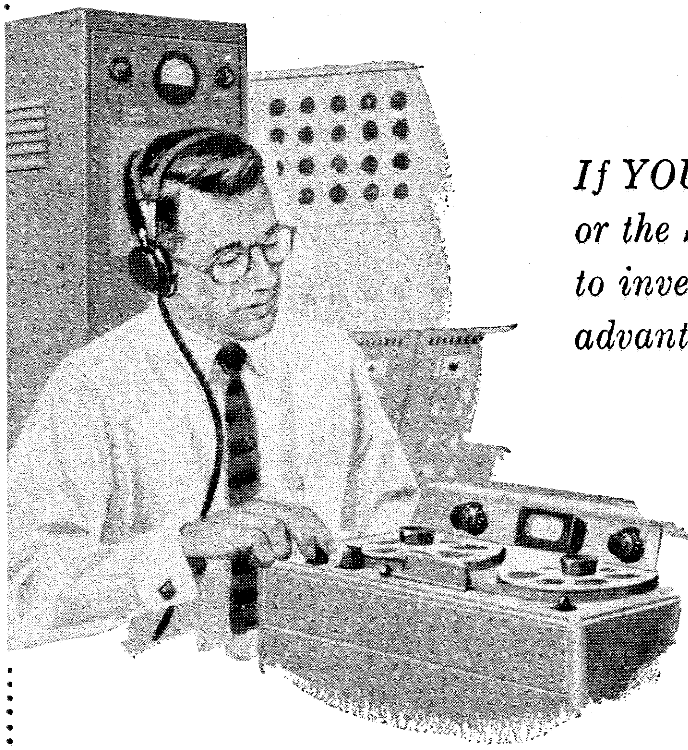
At 5 p.m. members of the class will meet for cocktails at the Rodger Young Auditorium. This is for men only—as is the Annual Alumni Dinner which follows, at 6:30 p.m. A special program will be arranged for wives at this time, including dinner at the Athenaeum and a theater party afterwards.

A good percentage of the class has replied to the correspondence that has been sent out to every member of the class of '32. If anyone still wants to join the group, get in touch with Mills Hodge, 3626 Gaviota, Long Beach 7, California.

Alumni Fund

THE BOARD OF Directors of the Alumni Association, at its meeting of April 23, 1957, agreed to officially close the solicitation for funds for the Alumni Scholarships on June 30, 1957. All funds in the Alumni Fund, as of the end of June 30, 1957 will be transferred to the Institute Alumni Scholarship Fund. Any contributions received by the Alumni Fund after June 30, 1957 will be held in that Fund by the Institute for assignment to whatever new project may be mutually agreed upon by the Association and the Board of Trustees of the Institute.

—*Donald S. Clark, Secretary*



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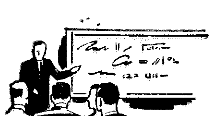

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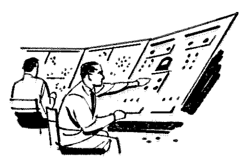

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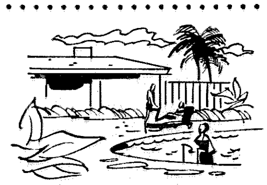

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PERSONALS

1902

Royal W. Lescher, a graduate of Throop Academy (CIT's official name in 1902) died at the age of 73 in Phoenix, Arizona on January 30. A native of Carpinteria, California, he had lived in Phoenix since 1908 and designed many of the city's leading public (as well as private) buildings. From 1912 to 1923 he was in business for himself as an architect, and since then had been in partnership with Leslie P. Mahoney.

1920

Harvey W. House, former laboratory director for the National Clay Pipe Manufacturers, is now on the research staff of Gladding McBean & Co., in Los Angeles.

1932

E. Bryant Fitch is now director of the Westport laboratories of Dorr-Oliver, Inc., in Connecticut.

1933

Merrill Berkley, owner of the Berkley Engineering and Equipment Company in Los Angeles, has opened a new office in Honolulu to extend the sales work, engineering and services of his industrial instrument company throughout the Hawaiian Islands.

"This venture will be managed by A. R. (Rex) Dalby who has had a long and varied career in mechanical engineering with the Santa Fe system, Ralph M. Parsons Company and The Fluor Corporation," Merrill writes. "Rex attended Caltech when it was known as Throop Institute, but did not complete work for his degree in engineering due to wartime circumstances. He will move his family over to the Islands in June, shortly after his youngest daughter graduates from USC.

"On a routine visit to the Ewa Plantation Company on the island of Oahu recently, I ran into *Walter Lyde McCleery, Jr.*, shop superintendent of this large sugar mill, and we remembered each other as classmates of the vintage year of 1933."

1935

Clyde C. Chivens and *Harry B. Boller*, '38 are in their 12th year as partners in business as Boller and Chivens Inc., designing and manufacturing custom scientific instruments. They recently moved their machinery and 35 employees into a larger building in South Pasadena, and early next year will be assembling the 12 telescope cameras they now have under construction for the Smithsonian Institution, which will be used to track the IGY earth satellite.

1939

Charles F. Carstarphen, MS '40, has been appointed division superintendent of Food Products for the Procter & Gamble factories at Portsmouth, Lexington and Omaha. He's been with the company since 1940.

1940

Robert B. Young was appointed vice president of Aerojet-General's Liquid Rocket Plant in Sacramento last month. He joined the company in 1943, and since then has been associated with all of the liquid-propellant rocket-engine development and production programs of the company.

Robert L. Wells, MS, former executive assistant to the vice president in charge of the Westinghouse Electric Corporation's aviation gas turbine division in Kansas City, Missouri, has been named manager of the company's atomic power department in Pittsburgh, Pennsylvania. Bob has been with Westinghouse since 1940.

1941

Emil J. Burcik, PhD, associate professor of petroleum and natural gas engineering at Pennsylvania State University, is the author of *Properties of Petroleum Reservoir Fluids*, a college textbook published this spring by John Wiley & Sons.

Fred W. Billmeyer, research chemist at the Du Pont Company in Wilmington, Delaware, has also had a textbook published this spring (by Interscience Publishers), covering the field of high polymers. Fred has been with Du Pont for 12 years and also teaches courses in high polymers at the University of Delaware.

1943

Melvin L. Merritt, PhD '50, manager of the weapons effects department of the Sandia Corporation in Albuquerque, New Mexico, was reported as "scientific advisor to the supervisor of Operation Plumbbob at the Nevada Test Site" in the April *E&S*. He's sent along a note which modifies his position to "scientific advisor for the Sandia efforts in Operation Plumbbob —but not for the whole show. This is still a fairly large effort. What the title means is that the department which I head is designing a number of experiments for that operation, and is advising our field test organization on a number of service functions which they undertake in connection with the tests."

Doyle F. Mattson writes that he's transferring from Lockheed Aircraft in Burbank to the Lockheed Missile Systems Division at Santa Cruz, California. The

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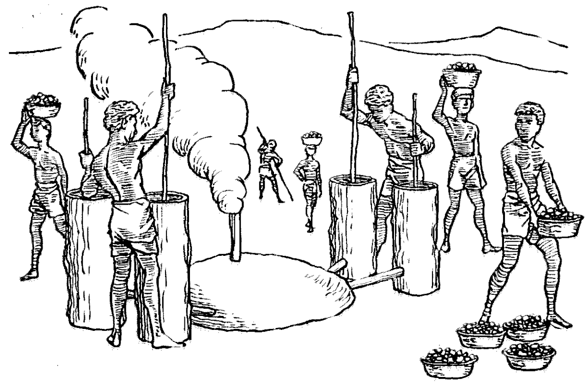

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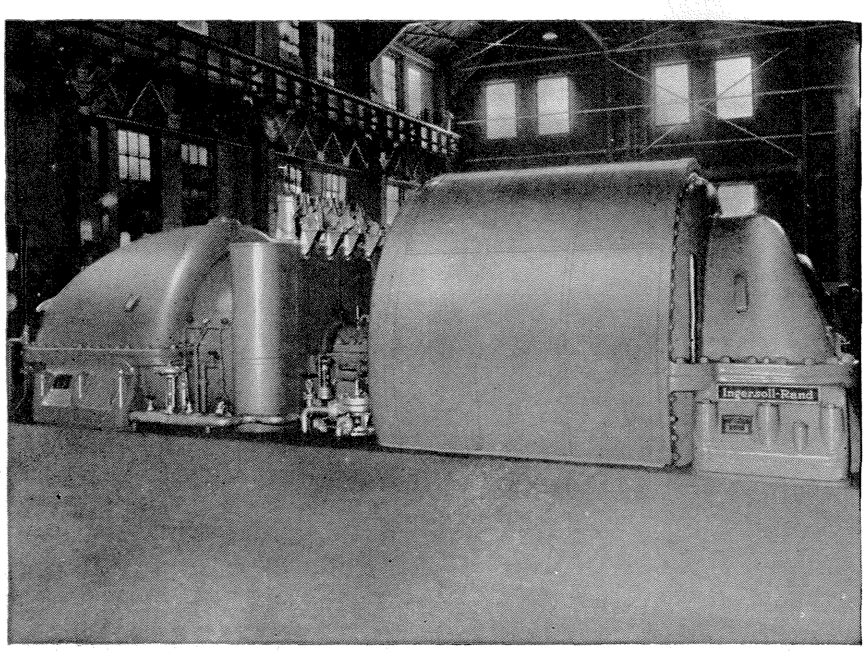

THE HUGE blast furnaces of today gulp air at 130,000 cubic feet per minute. For it takes *three tons of air* to produce a single ton of pig iron.

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Mattsons have three children now—two boys and a girl.

1946

Fern Wood Mitchell, MS, PhD '48, is now manager of the research services group of the research and development division of W. R. Grace & Co. in New York. Before joining the Grace organization in 1955, he was chief analytical chemist at the American Cyanamid Company's Fortier Plant in New Orleans.

John J. Burke, MS '48, is vice president in charge of engineering of the Hallamore Electronics Company in Anaheim, California. The company is a division of the Siegler Corporation, and produces electronic control and test systems. John was formerly head of the guidance and electronics division at JPL.

1947

C. Burton Crumley, MS '49, writes that "since 1949 I've been at Stanford University; since 1951 as a research associate in the electronics research laboratory, lately specializing in traveling-wave tube and beam focusing work. I have two sons—one four years old, the other four months old. I finally got my PhD from Stanford in 1955. Many fellow CIT alumni in this area are enjoying relatively smog-free atmosphere—albeit an occasional earthquake."

1949

Rolf M. Sinclair writes that he's "now at the Physikalisches Staatsinstitut of the University of Hamburg in Germany, on a year's leave of absence from the Westinghouse Research Laboratories. I'm still doing research in nuclear physics, now under Professor Willi Jentschke (formerly of the University of Illinois), who is director here. I left the States last September, and have been dividing my time since then between physics and traveling."

1951

Carroll R. Lindholm is now at Caltech's Jet Propulsion Laboratory as a resident engineer of the Motorola Research Laboratory in Riverside, California. He's working on the analysis of missile computer systems.

William W. Wood, PhD, is now group leader of a newly formed group in the GMX division of the University of California's Los Alamos Scientific Laboratory. Bill is married and has two sons.

Peter V. Mason, MS '52, writes that "after four years at JPL, I decided I didn't know enough, so I'm back at Caltech working on a PhD in EE." The Masons now have three children—2 girls and a boy—the latest addition being Margaret, 4 months old.

Robert F. Connelly, sales manager of the aircraft and chemistry division of the Bray Oil Company in Los Angeles, has been elected chairman of the Los Angeles section of the American Society of Lubrication Engineers for 1957-58.

1952

Waheed Khan Khauri, exploitation engineer for the Shell Oil Company, was transferred in February from Bakersfield to Los Angeles. He and his wife announced the arrival of a son, John, on March 18.

1953

Perry Vartanian is working as a senior project leader at the Sylvania Electric Company's microwave physics laboratory in Mountain View, Calif.

CONTINUED ON PAGE 26

Richard W. Flygare, MS, ME '55, is now supervisory mechanical engineer in the Underwater Ordnance Department at NOTS in China Lake, California. He started his career at NOTS while continuing his graduate studies at Caltech in 1953.

1954

George L. Johnston, who is studying at Harvard Law School, has received a Harvard Law School National Scholarship for the current year. This award is given to "students of outstanding quality whose homes are far from New England," and is renewable from year to year.

James N. Pinkerton, a graduate student at Harvard, sends along the following: "Mr. and Mrs. James Pinkerton of Cambridge, Massachusetts, wish to announce the arrival of an addition to their family —Geoffrey, a dog."

Private Robin Neal Huntley, MS '55, was high man in the proficiency test at the end of his eight-week basic training course at Fort Ord recently. His score of 103 out of 116 not only led his company of 270 men but is second only to the Fort Ord record of 104 which was set last year. Robin was a production foreman for Procter & Gamble in Long Beach before he joined the US Army Reserve last year. He is stationed in a USAR control group which meets at Fort MacArthur.

Pehr H. Schalin, AE '55, writes from Linkoping, Sweden, that he's still head of the guided missiles project and development group at the Saab Aircraft Company. "We've had a busy time since our return in August, 1955. We are just planning to build a house this summer. We've had one addition to the family—Eva-Stina in September, 1956. Among her godparents is *Dr. Vaino Hoover*, '27, MS '28, PhD '31, in Los Angeles. Our other two children—Pra, 7, and Peter, 5—just don't speak English any more. I have applied for the professor's chair in Finland in the aeronautics division, although nobody yet knows the result."

1955

E. Vern Nogle is now a research scientist for the Lockheed Missile Systems Division in Sunnyvale, California.

Frank C. Michel writes that he graduated from basic jet training last February and is currently assigned to all-weather interceptor advanced training in the F-86D at Perrin AFB, Texas.

1956

Richard Van de Houten was married to Michelle Auldridge in Pasadena in March. Dick is studying for his MS in electrical engineering at Stanford.

J. McKim Malville, one of the IGY scientists in Antarctica, is stationed on the Filchner Ice Shelf in Widdell Sea, his mother writes. He will be there, with nine other scientists, for the next twelve months. He cannot get mail in this isolated spot. Kim has charge of research on aurora austrolis, geomagnetism and meteors. His party left Punta Arenes, on the Straits of Magellan, on December 8 and for 43 days fought the ice. The freighter, Wyandot, and its icebreaker, the Staten Island, were both damaged and the proposed site was never reached. The alternate site, not very far from the English station from which Sir Edmund Hillary is to land a party across the continent, had to be built in two-weeks time instead of the six that had been planned on, as the ship had to leave on February 10 to avoid getting icebound.

ANNUAL ALUMNI BANQUET

The Caltech Alumni Association at its annual dinner to be held June 5, 1957, at the Rodger Young Auditorium will feature as its principal speaker our own Dr. Lee DuBridge who will speak to the association on the subject "Around the World in 100 Days."

This Verne-ian title has obvious reference to Dr. DuBridge's recently completed trip around the world during which he visited universities, engineering schools and scientific research centers.

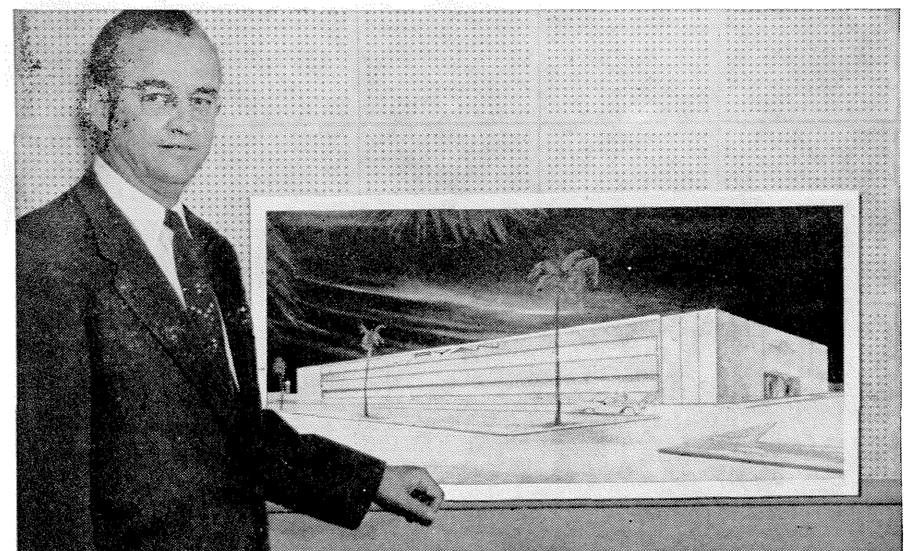
The customary annual report on Institute affairs will be given to the association this year by Dean Watson on the subject of academic affairs and by Mr. Albert Ruddock on financial and trustees' affairs.

All alumni are cordially invited to attend. Reservations should be in the Alumni Office by May 31.

Martin H. Webster, '37
Chairman, Banquet Committee

REPORT FROM RYAN

New Engineering Opportunities Created as Ryan Projects Mushroom



FRANK W. FINK, RYAN VICE PRESIDENT AND CHIEF ENGINEER inspects architect's drawing of new Engineering and Research Center.

New Engineering and Research Center To Meet Ryan's Expansion

Construction of a modern two-story, engineering and laboratories building has begun at Ryan, to meet the company's expanding work in Jet VTOL—Automatic Navigation—Jet Drones—Missile Guidance—Jet Metallurgy—Rockets.

The new facility will provide additional quarters for many of the 1000 employees in Ryan's fast-growing engineering division. It will also house complex, new chemical, metallurgical, instrumentation, environmental and autopilot equipment.

With one in six Ryan employees in engineering, this division has tripled in three years. Its mushrooming growth reflects Ryan's increased importance as a research facility in aerodynamics, propulsion and electronics.

RYAN ENGINEER "zooms" straight up in unique rotatable cockpit.

Vertical Flight Probed with New VTOL Cockpit

Shortest way into the sky is straight up—in the Ryan Vertijet. To probe this new realm of flight without becoming airborne is a trick performed daily by Ryan engineers. Their secret? A rotatable cockpit connected with electronic computers.

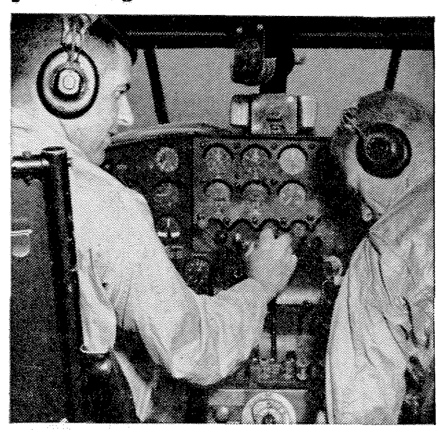
Ryan's flight simulation laboratory is a prime tool in the test of new aircraft designs. Both the Vertijet and the subsonic, turboprop-driven Vertiplane are put through their paces via earthbound flight test. Ryan leadership in this revolutionary new concept of flight is based upon $2\frac{1}{4}$ million manhours of VTOL research and development. It is another example of how Ryan builds better.

Ryan Automatic Navigator Guides Global Flight

An advanced system of aerial navigation, designed for high speed, long range flight, has been developed by Ryan electronics engineers, working under sponsorship of the Navy's Bureau of Aeronautics.

Designated AN/APN-67, the new navigator is the lightest, most compact, *self-contained electronic navigator in* production. Developed to meet military needs, it will also meet commercial jet flight requirements.

The system provides pilots and navigators with continuous information on longitude, ground speed, ground mileage, drift angle and ground track. It is accurate and instantaneous. Requires no computations, ground facilities or wind data.



AUTOMATIC NAVIGATOR guides pilots with single instrument (above).

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CALTECH CALENDAR

ALUMNI EVENTS

June 5 — Annual Meeting
Rodger Young Auditorium

June 29 — Annual Picnic
Disneyland

ATHLETIC SCHEDULE

VARSITY TRACK

May 17
Redlands Invitational at Redlands

VARSITY GOLF

May 17
Conference Tournament at Pomona-Claremont

VARSITY BASEBALL

May 18
Whittier at Whittier

May 21
El Toro Marines at Caltech

May 22
Redlands at Caltech

VARSITY TENNIS

May 17
Conference Tournament at Redlands

May 18
Conference Tournament at Redlands

FRIDAY EVENING DEMONSTRATION LECTURES

Lecture Hall, 201 Bridge, 7:30 p.m.

May 17
Brain Mechanisms in Behavior
—by Dr. Roger Sperry

May 24
Geologic Exploration of Alaska
—by Dr. James Noble

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