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ENGINEERING AND SCIENCE

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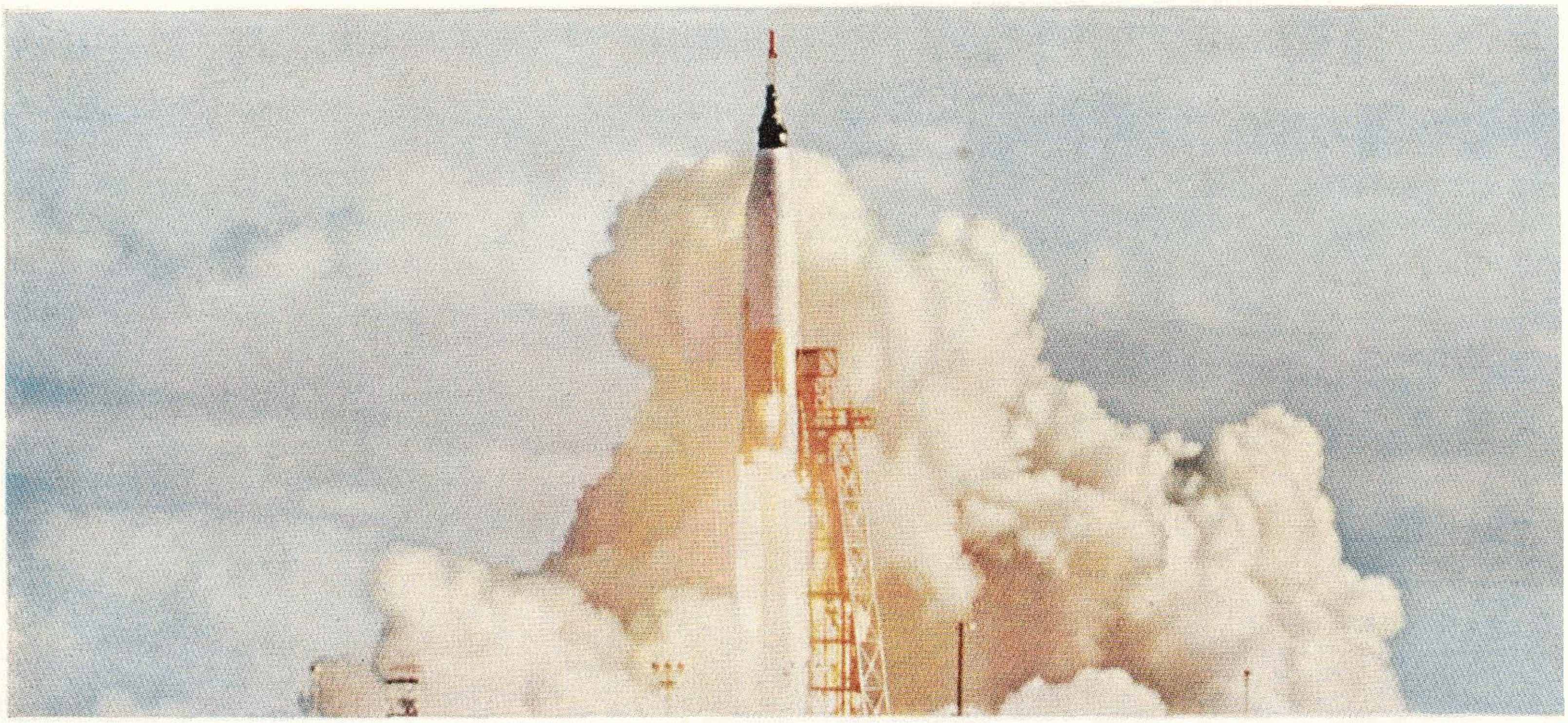

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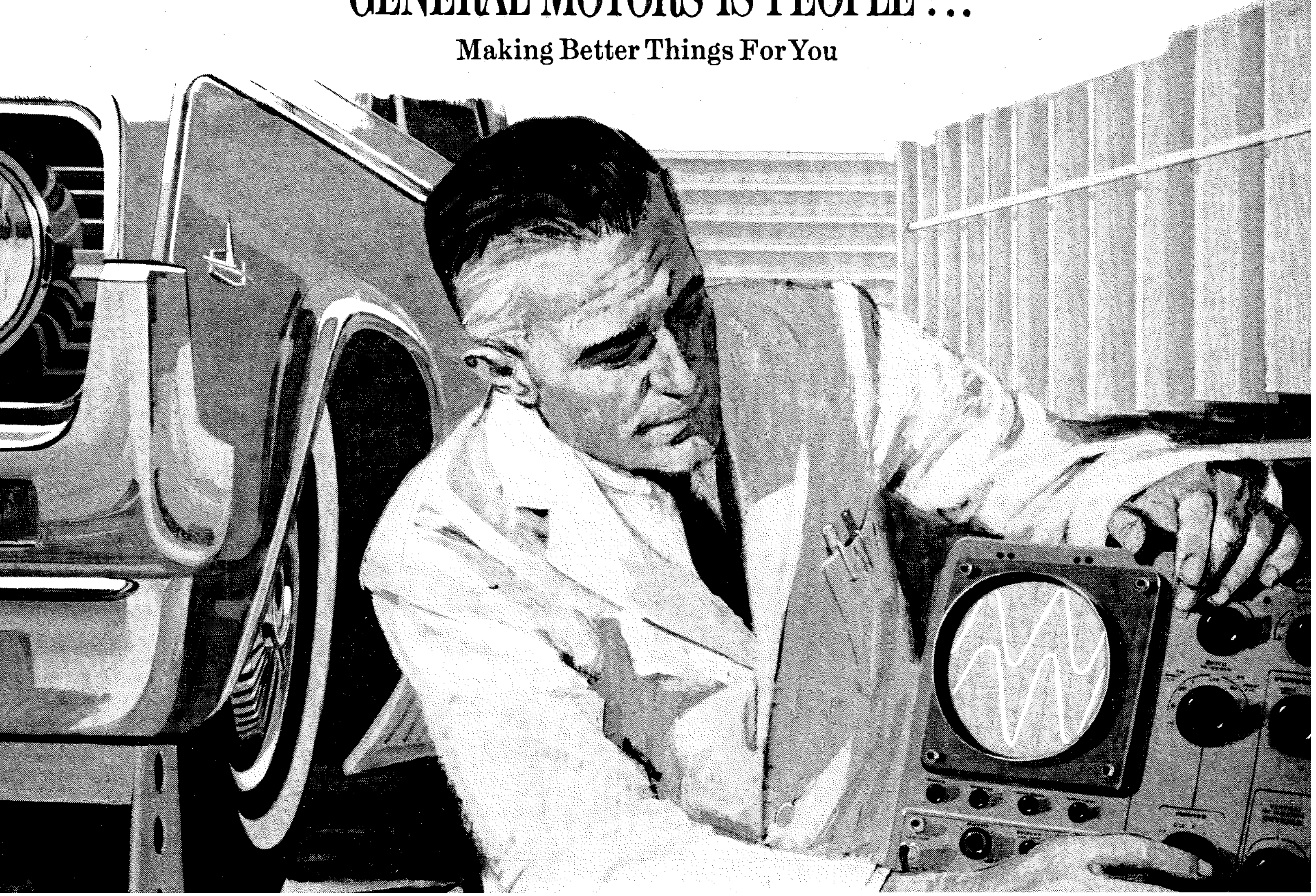

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On Our Cover
an aerial photograph of the Cucupa earthquake fault in Baja California, one of the many branches of California's notorious San Andreas fault, which is now the subject of a unique study by an eight-man team of geologists, seismologists, and geophysicists from Caltech. The story is on page 12.

"The Way of Life"

on page 7 is based on a talk given by Dr. James Bonner, Caltech professor of biology, at a joint meeting of biological societies, sponsored by the American Institute of Biological Sciences, at the University of Colorado in Boulder last summer. Dr. Bonner has been a member of the Caltech faculty since he received his PhD here in 1934.

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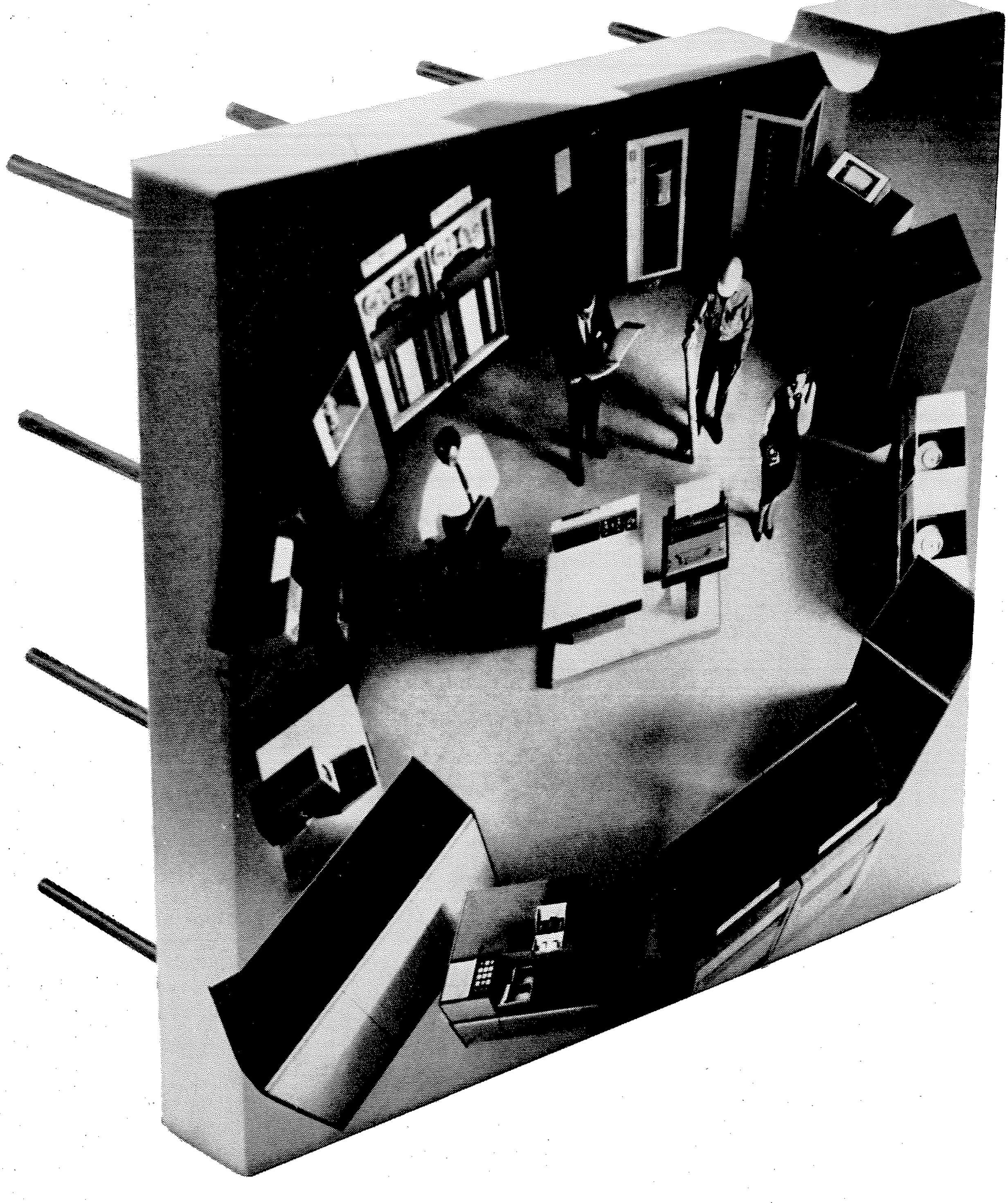

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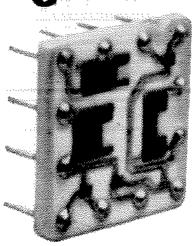

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The Way of Life

The process of development as seen through the window of modern biology

by James Bonner

The time has come for direct attack upon the central problem of biology, the problem of how it is that a single cell, the fertilized egg, gives rise to an adult creature made of many different kinds of cells. This process, which is known as development, has been described and thought about by biologists for as long as there has been a science of biology. Its nature has remained a mystery because we have not heretofore understood enough about the nature of life itself. Today we do. We know in detail what makes a cell be alive. We know that all cells contain the directions for cell life written in the DNA of their chromosomes and that these directions include specification of how to make the many kinds of protein enzyme molecules by means of which the cell converts available building blocks into substances suitable for making more cells.

We know that to make enzyme molecules, the DNA prints off RNA copies of itself, messenger RNA molecules, and that these messenger RNA molecules are decoded by ribosomes, also made by the DNA, and that the ribosome as it decodes a messenger RNA molecule uses the information to assemble a specific kind of enzyme molecule.

This picture of life is that given to us by molecular biology and it is general: it applies to all cells of all creatures. It is a description of the manner in which all cells are similar. All cells possess DNA and this DNA makes messenger RNA, ribosomes, and hence enzymes. But higher creatures such as people or pea plants possess different kinds of cells. Some cells make hemoglobin, others do not. Some cells make pea seed globulin, others do not. The time has come for us to find out what molecular biology can tell us about why different cells in the same body are different from one another and how such differences arise.

The first thing we can say about the cells of the body of a higher organism is that they all have exactly the same amount and kind of DNA, the same genetic information. A single cell, the fertilized egg, divides into two cells and each of these receives a complete set of the genetic DNA. The daughter cells divide and divide, each cell continuing to receive a complete copy of the genetic book. But pretty soon in the course of embryonic development the cells of the embryo begin to become different from one another. Some produce hemoglobin, some produce muscle enzymes, some liver enzymes, and so on. The genetic information for making hemoglobin, for example, is in all cells but it is used only in a few cells, those which are to be red blood cells. In the other cells of the body the genetic information for making hemoglobin is turned off, repressed. To find out what causes development and differentiation, then, we must find out what it is in the cell that determines that particular units of the genetic information, particular genes, shall be active and make their characteristic messenger RNA, and what it is that determines that other genes shall be repressed, inactive in RNA-making.

Development is the orderly production by a single cell, the fertilized egg, of the several kinds of specialized cells which make up the adult creature. Specialized cells differ from one another in the kinds of enzymes which they contain. We are inexorably led by logic to the conclusion that the cause of development is a properly programmed expression and utilization of the genetic information. The genetic information is contained in the genes and these in turn are fastened together into the chromosomes which are housed in the cell nucleus. The new study of development must be occupied with the study of chromosomes since it is in the chromosome that the master plan for the architecture of the body resides.

My colleague, Dr. Ru-chih C. Huang, and myself have started such a study. During the past four years we have found out how to isolate chromosomes and how to cause them to make their messenger RNA in the test tube. We have found out how to couple this messenger RNA production to ribosomes so that enzyme molecules are made in the test tube. We have found that chromosomes from different kinds of specialized cells make different kinds of messenger RNA's and hence different kinds of enzymes, kinds characteristic of the cell from which the chromosome was isolated. In this way we have shown that the control of genetic activity characteristic of the chromosome in life is preserved in our isolated chromosomes in the test tube.

We have studied the control and programming of genetic activity on three levels, namely:

1. The hardware of genetic control – the nature of the material which represses gene activity.

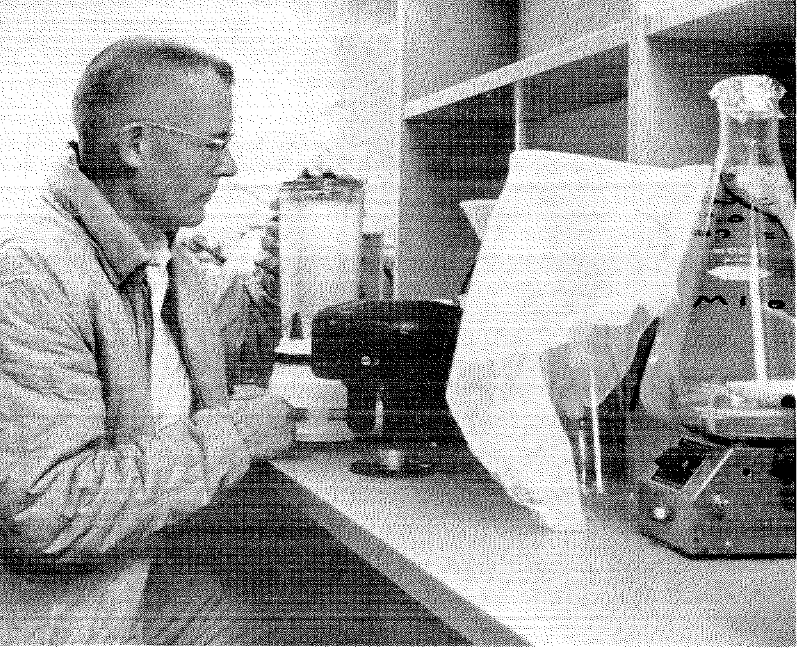
2. The nature of the genetic switching unit – the nature of the act by which genetic activity is turned on and off, and

3. The nature of the switching network by means of which the individual genetic switching units are linked and integrated into a developmental system.

We have studied the hardware of genetic control by focusing our attention on a particular gene of the pea plant. (We say, "If pea plants were good enough for Mendel to invent genetics with, they are good enough for us.") This gene is that which controls the manufacture of pea seed globulin, the reserve protein of the seed. It is made in growing pea seeds and is not made in any other part of the pea plant at any time during development. Its behavior is typical of development. Chromosomes isolated from growing pea seeds make messenger RNA in the test tube and this messenger RNA supports the synthesis of protein. This protein contains pea seed globulin, just as in life. Chromosomes from pea buds also make messenger RNA and this also supports protein synthesis. The protein includes no pea seed globulin. This also is as in life. But we know that the gene for pea seed globulin-making is in the pea bud chromosomes. It is merely repressed. How can we de-repress it? Simply. All that is required is to remove from the chromosome a characteristic chromosomal component, a particular kind of protein which is always associated with chromosomes, a class of protein called histone. A portion of the DNA in chromosomes is wrapped in histone. DNA that is thus wrapped cannot make messenger RNA. It is repressed. When we remove the histone from the chromosomes of pea buds, the gene for globulin-making is de-repressed, as are indeed all of the previously repressed genes of the pea bud chromosome.

We know, then, a little about the material nature of the repression of gene activity. The repressers include histones, although we do not know whether histones are the sole kind of repressers. The logic by which represser histones discover the proper

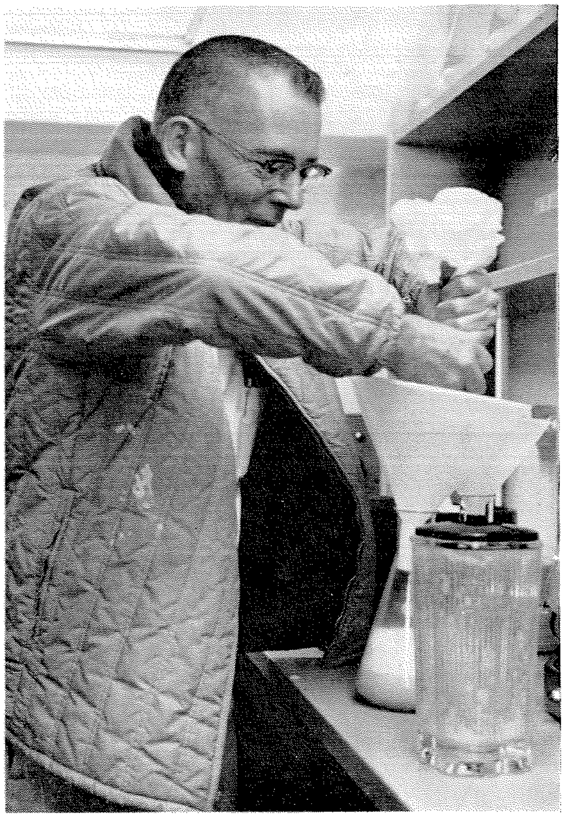
Dr. James Bonner, professor of biology, cuts buds from pea plants to obtain genetic material. The buds contain many small cells and are rich in chromosomes.



Left — Pea buds are ground in a blender, which ruptures the cells and releases the chromosomes. This and all subsequent operations are carried on in the cold room to minimize chemical changes which would otherwise occur after disruption of the cells.

Left, below — Ground tissue is filtered to remove membranes and other unwanted material.

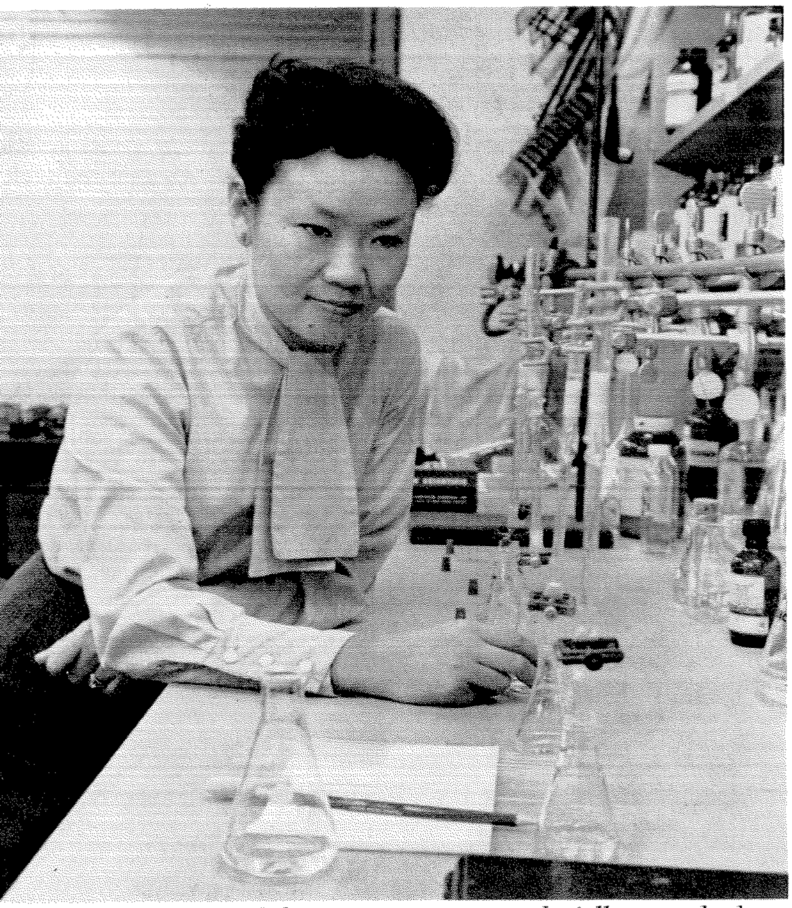
Below — Filtered extract is dispensed into centrifuge tubes. These will be centrifuged at 4000 times gravity — a field which sediments the large and heavy chromosomes but does not sediment other cell constituents.



genes to repress also remains to be found out. At least, however, the matter is now accessible to experimental study.

When we de-repress genes in the laboratory by removal of histone we do so by disassociating DNA from histone by the use of high concentrations of salt. It works nicely but not selectively; it de-represses all repressed genes. In the living cell de-repression is selective; one or a few genes may be turned on or off without influencing others. We are, however, beginning to know something about the nature of this genetic switching unit. Just as in bacteria, so also in high organisms it has been found that particular kinds of small molecules are able to turn off or on the activity of particular genes. In the bacteria these are small molecules and genes concerned with making everyday metabolites and the control serves the end of seeing to it that the bacterium does not make some particular kind of substance if that substance is available in the nutrient medium. In higher creatures this kind of regulation by small molecules serves the process of differentiation, and one important class of such molecules consists of the hormones.

A hormone on arrival at its target organ turns on individual or whole sets of genes, causing the pro-



Dr. Ru-chih C. Huang, research fellow in biology, studies isolated chromosomes in the laboratory. Such studies make use of the techniques of enzymology and biochemistry.

duction of characteristic enzyme molecules and setting a cell or cells on a new pathway of development. This is dramatically exemplified by the case of arousal from dormancy which has been studied by our colleague, Dorothy Tuan. The buds of freshly harvested potatoes do not grow. They are said to be dormant. The chromosomes of the cells of the dormant bud are almost completely repressed and cannot, therefore, make any messenger RNA. Dormancy can be ended at any time by supplying the bud with a particular hormone, gibberellic acid, or a synthetic substitute, ethylene chlorohydrin. Treatment with a minute amount of one of these materials causes the buds to grow — the chemical causing a substantial proportion of the genetic complement to be de-repressed and become active in RNA-making. Many hormones work in this way. Cortisone, when it arrives at the liver, causes the genes for making particular liver enzymes to be de-repressed. The flowering hormone, when it arrives at the bud, turns on the previously repressed genes for making flowers and fruit — turns on the flowering pathway.

There is much to find out about the unit genetic switch. We do not, for example, know in detail how a small molecule can bind to a larger represser molecule and change it so that it no longer represses. But again the matter is accessible to experimentation.

This leads us to the final aspect of the new biology of differentiation, the aspect which concerns how the individual genetic switches are linked together to bring about a sequential and orderly development. That the logic of development is based on such a developmental switching network there can be no doubt. The fact, for example, that the several hormones, each itself acting on a unit switch or switches, interact in their effects to bring about sequences of developmental processes shows at once that much interacting switching of genetic activity takes place in life.

How can a genetic switching network be mapped out in molecular detail? The task will certainly be a vast one. For the present, however, we can at least think about it. Let us think of the vegetative bud of a plant at the moment of arrival of the flowering hormone. The hormone turns on some previously repressed genes. The control settings responsible for direction along the vegetative, leaf-producing pathway are reset to bring the developmental pathway on to a fresh course. Once set upon this course the bud inexorably develops step by step into a flower. Certainly, during the course of flower development further switching must take place; fresh genes must be turned on at appropriate places and times, and others appropriately turned off. But this whole latter sequence of genetic switching is called into play only as a result of the initial induction caused by the flowering hormone. Once induction has occurred, the further programming of flower development flows on automatically. It is as though induction by the flowering hormones calls into action a pre-programmed subroutine which contains all of the further directions about how to make a flower.

Let us then try for fit and attractiveness the concept of the life cycle of development as consisting of a master program constituted in turn of a set of subprograms or subroutines. What might be required by way of genetic subroutines to program a creature through its life cycle? A plant, for example, would certainly need a subroutine on cell life, directions for making the subcellular organelles and enzymes needed for cell growth, multiplication, and maintenance. It would also need a subroutine on embryonic development, together with one — a short one, perhaps — about a life as a seed. Then, too, our plant would require subroutines containing information about the making of each of the kinds of plant organs, stems, leaves, roots, and flowers.

Thus we might view the information needed for development as subdivided into categories, each category appropriate to a particular sub-task. How might these various subroutines be related to one another? How are they wired together so as to constitute the whole program?

Let us consider the problem by considering a simpler example which poses, however, the same questions. The individual subroutines provide the required example. Let us consider the subroutine for bud development. We cannot, of course, specify in detail all of the items which are contained in that part of the genetic book which tells how to make buds. We can, however, specify at least some of the kinds of things which must from the nature of bud development be contained in it.

The bud in some cases arises from a single apical cell which by continual division gives rise to the bud and thence the leaves and stem, always surmounted by the apical cell. Our apical cell must then have instructions about how to divide in appropriate planes and each daughter cell must have instructions about how to find out if it is now the apical one. Clearly, information must be provided about when and where to stop cell division. Such information might in some cases consist merely of a directive to divide so many times and then stop. This cannot be the case with the bud, however, since little pieces cut from the bud continue cell division until a complete bud is again produced.

The same is true of the development of embryos from isolated cells of the early animal embryo. We need a new principle and to this principle we assign the designation of test. In the case of the bud we imagine that the dividing and growing embryonic tissue continuously tests itself for size or for number of cells, each time comparing the value found to a value stated in the program as the desired one. When the correct value is ultimately reached, the cells of the bud can proceed to the next developmental step.

The concept of the test carries us, I believe, to the control core of the logic of differentiation. The growing bud tests itself against the required ultimate size. The same bud tests itself for the presence or absence of flowering hormone. A cell tests its neighbors for strangeness or similarity. In these and a myriad of further ways must we imagine that each cell in the developing organism keeps itself informed of where it is in the developmental path and what therefore is the appropriate next step. The test as one unit in the logic of differentiation is of course already known as an experimental fact, as in the case of the presence or absence of a hormone in its target organ. All that we do here is to extend the concept of the test to include other kinds of tests which, although not yet experimentally known, would seem to be essential to the machinery of development.

One of the clearest examples of the developmental test at work is provided by the example of the plant embryo. This normally develops as do all embryos from a single cell, the fertilized egg, and carries on its development inside an ovary full of the chemicals needed in embryonic growth. And these two conditions are all that are required to cause a cell to develop into an embryo: the cell must be single and be surrounded by the ovarian nutrients.

F. C. Steward at Cornell University has shown that fully differentiated cells of many different types start life anew and develop into embryos if these two conditions are fulfilled. We may imagine that the plant cell is continuously testing itself for the presence of neighbors. If it finds it has none, it then tests for the presence of the embryo nutrients. If the outcome of this test is positive, the cell must say to itself, "Well, it's strange, but I am all alone and here are the embryo nutrients, so I must be a fertilized egg and I will therefore develop into an embryo."

The developmental test as it is here conceived consists in the sensing by a particular gene of the concentration of a particular chemical substance. The concentration of this substance in the region of that gene determines whether the gene shall be active or repressed. In this way, through the use of a multitude of different sensor substances the cell keeps track of where it is in the developmental pathway.

We have found that, by using the concept of the developmental test, it is possible to write down model programs which, if carried out by a cell, would cause it to develop into an organ or organism. In such a model program, a successful outcome of one test leads to a directive to carry out a further and different test and so on. In format the developmental programs resemble those for computation by an electronic computor. For this reason our most lifelike program, one which causes a single apical cell to develop into a plant stem, is called "digital organ generator, model A," or, for short, DOGMA.

Such modeling of the developmental switching network is not done just for fun. Its usefulness lies in the fact that it not only helps to give us insight into the principles which underlie development but in that it also suggests which specific key control points in the developmental process will be most fruitful to investigate.

These are stirring times for the study of growth. The tools are at hand, the way is clear, and progress is being made at all levels in the deep probing of the processes of development and differentiation.

STUDYING THE SAN ANDREAS FAULT

An eight-man team of geophysicists, seismologists, and geologists from Caltech undertakes an intensive two-year investigation of the geological structure that is potentially the most dangerous on this continent

The San Andreas fault, a gigantic fracture zone some three to six miles wide which extends three-quarters the length of California, is the most potentially dangerous geological structure in North America. Caltech has now started an exhaustive study of this notorious fault by an eight-man team of geophysicists, seismologists, and geologists.

The ultimate objective of this study is to understand better the nature, mechanics, past history, and present condition of this fault, in order to evaluate its role in the geological evolution of the Pacific Borderland, to predict its future behavior, and to gain an insight into processes deep within the earth.

The San Andreas fault extends more than 650 miles southwest from California's Mendocino coast through the Coast Ranges and along the north edge of southern California's San Gabriel Mountains, eventually breaking into several branches that extend into the Gulf of California.

The land mass west of the San Andreas is continuously moving northward at a rate of two inches a year – more than 16 feet in a century – in relation to the mass east of it. This lateral movement may have totaled 350 miles over many millions of years.

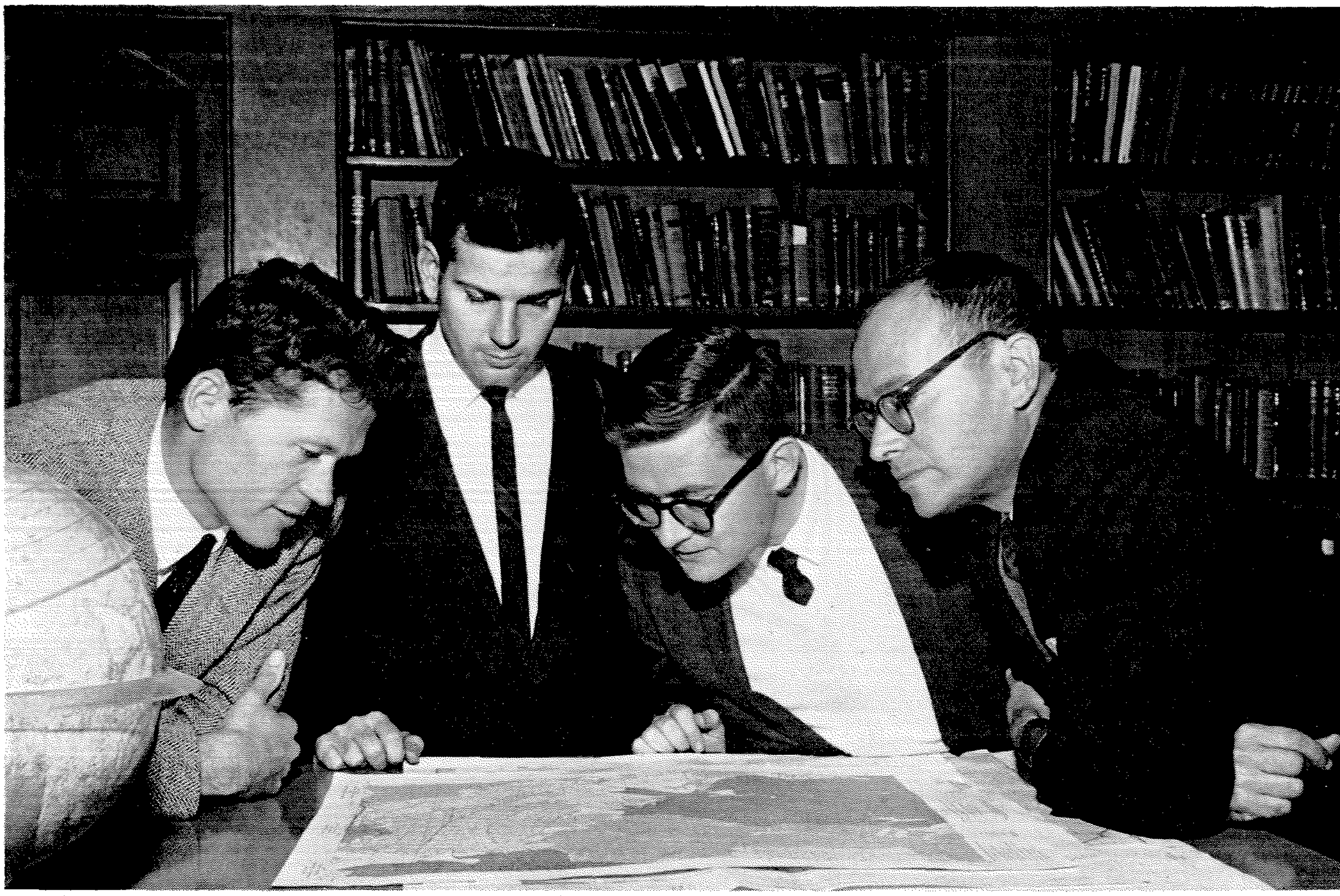
With two land masses moving in opposite directions, something has to give where they join. It does so along the San Andreas – not continuously, but infrequently, in sudden jerks. The distortion or strain builds up along the fault to a point where it exceeds the strength of the rocks and they break. The rocks suddenly slip many feet horizontally to relieve the strain and an earthquake results, releasing enormous amounts of energy.

"The San Andreas," says Robert P. Sharp, chairman of the Division of Geological Sciences, "can be thought of as a window through the earth's crust by means of which we can see far into the interior. True, it is a narrow, cracked, dirty, cobwebby window, but with skill, patience, and modern techniques and instruments we will be able to see more deeply and clearly into the earth than ever before."

Researchers comprising the team that is making this study are Clarence Allen, professor of geology and geophysics; Don L. Anderson, associate professor of geophysics; Barclay Kamb, professor of geology and geophysics; Leon Knopoff, research associate in geophysics at Caltech, and professor of geophysics at UCLA; Robert L. Kovach, assistant professor of planetary science; Frank Press, director of the Caltech Seismological Laboratory, and professor of geophysics; Stewart W. Smith, associate professor of geophysics; and Gerald J. Wasserburg, professor of geology and geophysics.

Drs. Kamb and Smith plan to measure the actual distortion of the rocks in and adjacent to the fault, with strain seismometers employing interferometry and capable of recording movements of one-millionth of an inch. Each of Dr. Smith's measuring stations will record strain over comparatively small areas, while each of Dr. Kamb's will cover more than half a mile.

Dr. Smith proposes the installation of an array of a dozen stations extending two to four miles across the fracture zone, possibly in the Lake Hughes area, some 45 miles north of Los Angeles. He has developed an automatic strain-measuring instrument. It consists essentially of three 10-foot quartz rods placed in a tripod shape below ground, the lower ends anchored to rock and their upper



Barclay Kamb, professor of geology and geophysics; Stewart W. Smith and Don L. Anderson, associate professors of geophysics; and Frank Press, professor of geophysics, and director of the Caltech Seismological Laboratory.

ends linked to an interferometer whose interference patterns are recorded by a camera. He plans to install the first station by the first of the year and expects that in a few months a strain pattern will appear.

Dr. Kamb will attempt to measure ground distortion with a triangle of mirrors anchored to rock and located some half a mile apart, the mirrors reflecting light into an interferometer. Any movement of one mirror in relation to the others will be recorded. If these measurements are possible, then detailed records can be made of progressive distortion. Several such installations could map the strain pattern for ten miles each side of the fault. Possible sites for the stations include Table Mountain near Wrightwood, Hollister, Anza, Carrizo Plain west of Taft, and Hughes Lake.

"We also hope to measure the strain at depth," says Dr. Kamb, "and to compare this with strains computed from the surface measurements. We want to know if the strain build-up is continuous or jerky and how far it extends each side of the fault."

While it has generally been believed that the fault extends at least through the earth's crust to the mantle, some 20 to 30 miles deep, certain calculations suggest that it may extend down only as far as five miles. The rocks below that depth may be sufficiently plastic to flow.

The depth of the fracture will be measured by placing seismometers at strategic locations to record the passage of waves – generated by earthquakes arising from other faults (not necessarily the San Andreas), and by explosions – through and below the fault. Records of such waves passing through the fracture zone will be used by Drs. Press and Knopoff and others to "x-ray" the composition of the fault zone. Does it consist of ground-up rock or rock whose temperature was raised to or near the melting point during large fault movements in the past?

With an array of eight portable, sensitive seismological stations built into trailers, Dr. Press will gather information relating to these questions and also will attempt to determine whether very small earthquakes—too small to be detected with standard instruments—occur along the fault. If such temblors occur, they could relieve at least part of the accumulating strain. The site for the initial seismic recordings will be in the vicinity of Lake Hughes.

Drs. Wasserburg, Kovach, and Knopoff will make heat studies designed to show if the energy released

Clarence Allen (right), professor of geology and geophysics, and an authority on the San Andreas fault; and Gerald J. Wasserburg, professor of geology and geophysics, who will take heat measurements in the fault zone.

by the fault adds significantly to the heat flow from the earth's interior. Several holes will be bored in profiles across the San Andreas zone to depths of perhaps 1,500 feet.

Heat measurements will be made at various depths to learn if the fault zone is hotter than areas on each side. Fault ruptures may heat the underground rocks to higher temperatures than are characteristically found.

Dr. Anderson will measure changes in the elastic properties of rocks caused by strain increases. This information could be very useful in anticipating earthquakes. It seems likely that the compressing and stretching of rock formations adjacent to a fault would be accelerated before an earthquake is triggered.

Dr. Anderson will deploy six to nine seismometers in a grid perhaps a mile square on some active area of the San Andreas. Explosions touched off periodically at a fixed location on one side of the fault will generate waves that will radiate through the fracture region. The waves travel faster through compressed rock and slower through the same kind of rock when it is stretched. By periodically determining the velocities of the waves through these rocks it may be possible to measure changes in their elastic properties.

Other kinds of instruments will be used in the extensive study, including gravimeters to show the densities of subsurface areas in and near the fault. If rock is crushed its density may be changed.

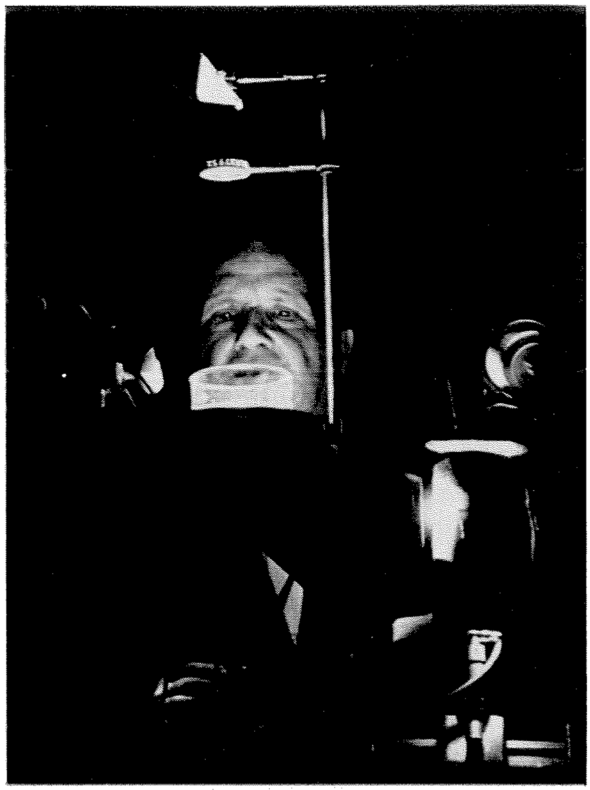
Dr. Allen, an authority on the fault, is working with the other investigators as a consultant on geological problems related to selecting locations for instruments. He will do detailed geological mapping of the selected sites. Dr. Allen will also continue his studies of the relation of earthquakes to fault systems.

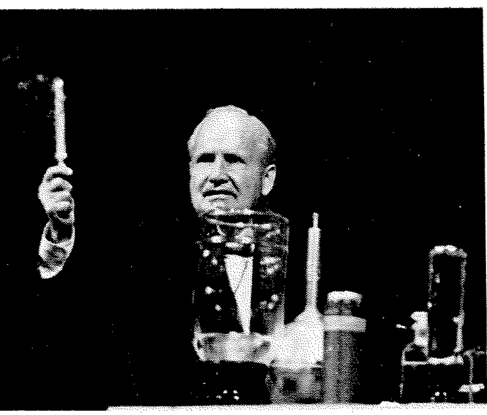
The over-all program calls for two years of investigation, with grants totaling more than $400,000 from the National Science Foundation.

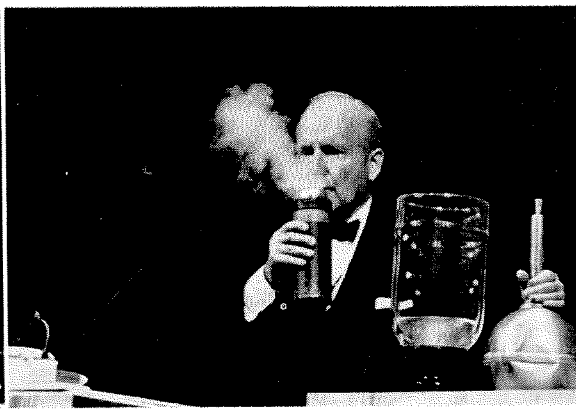
"We do not expect that at the end of two years we will be able to predict earthquakes," says Dr. Allen, "but we do hope that the results of our work will point toward promising fields of research that eventually will lead to this end."

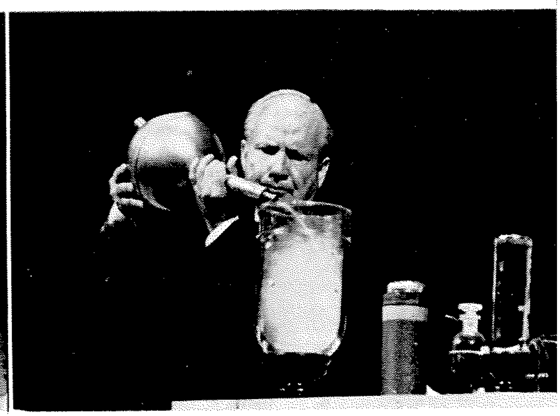
RETURN ENGAGEMENT

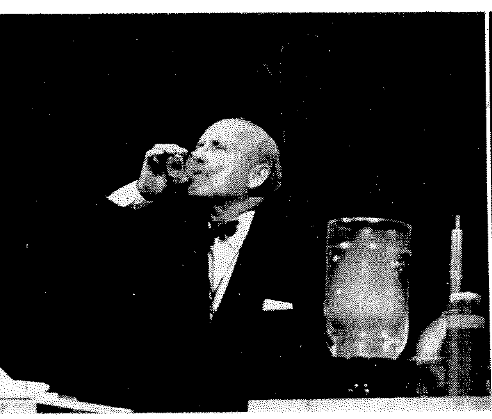
Earnest Watson, professor of physics emeritus, and former dean of the faculty, opens the Institute's new Caltech Lecture Series in Beckman Auditorium on October 12 with his famous lecture on "Liquid Air," which was the most popular of the Friday Evening Demonstration Lecture Series he launched in the 1920's.

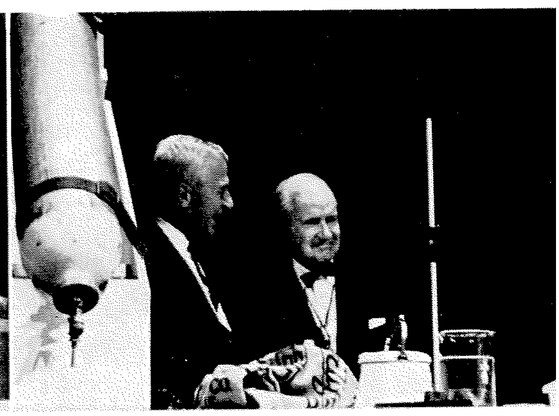












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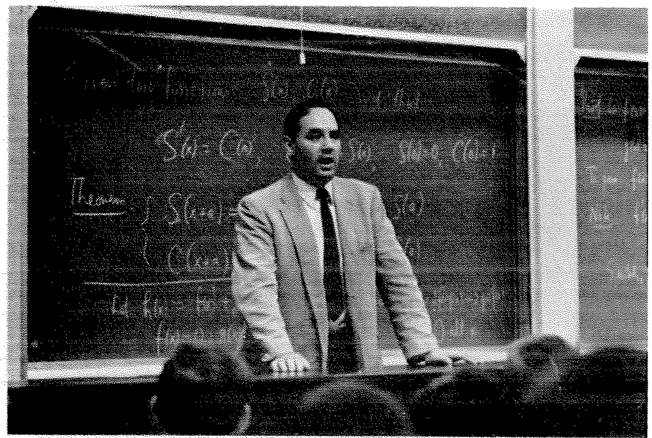
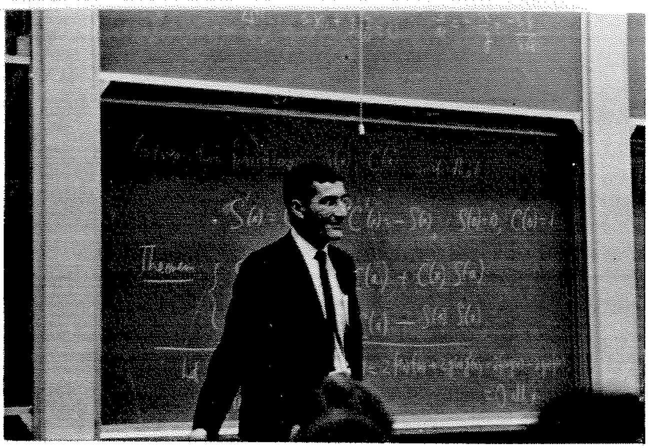
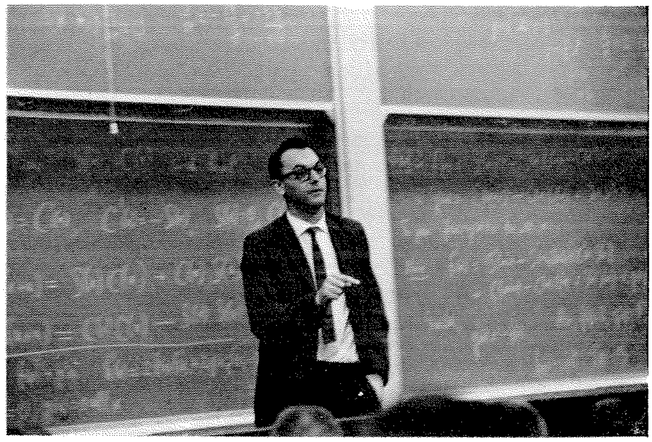


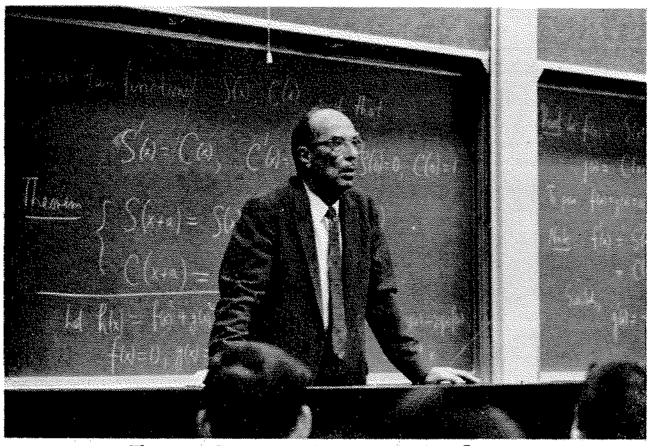
Robert Huttenback, Master of Student Houses



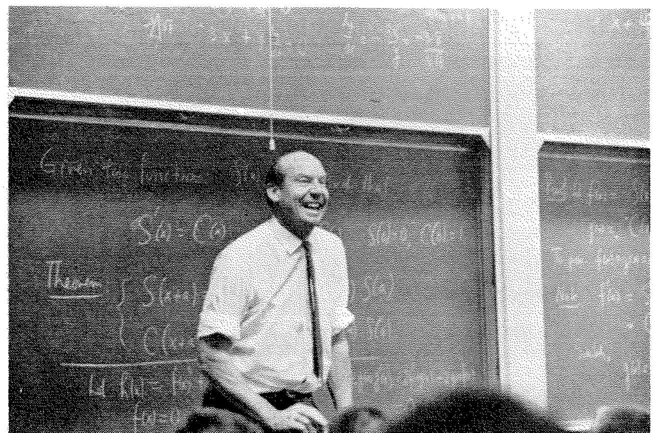
Tom Apostol, professor of mathematics



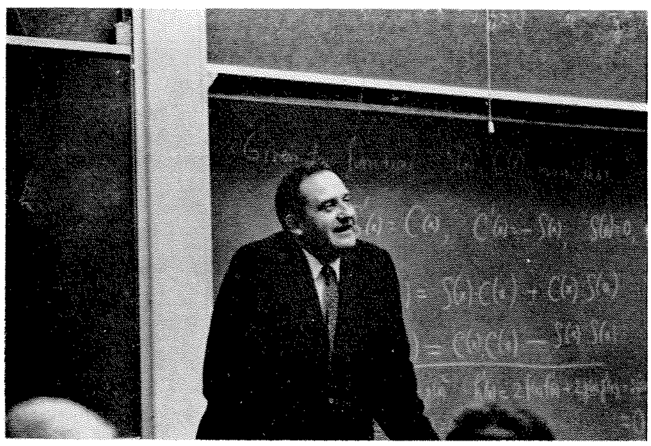
Rochus Vogt, assistant professor of physics



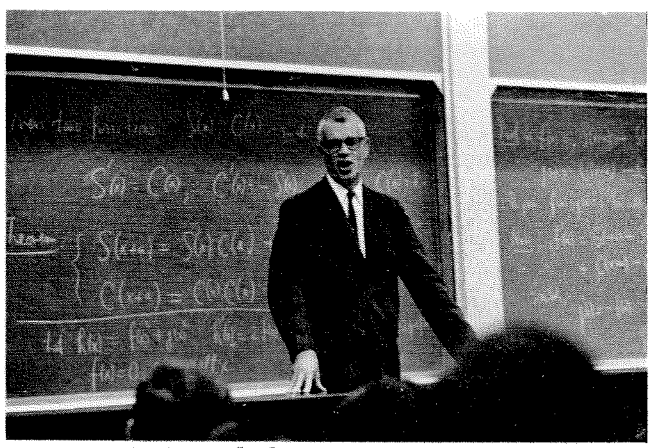
Foster Strong, Dean of Freshmen



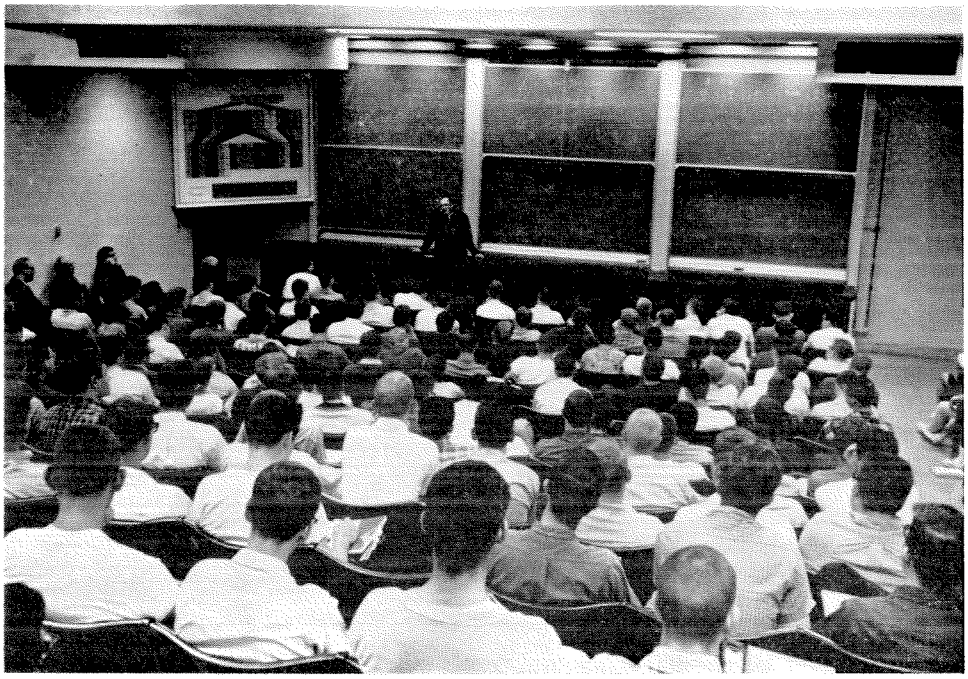
Jurg Waser, professor of chemistry



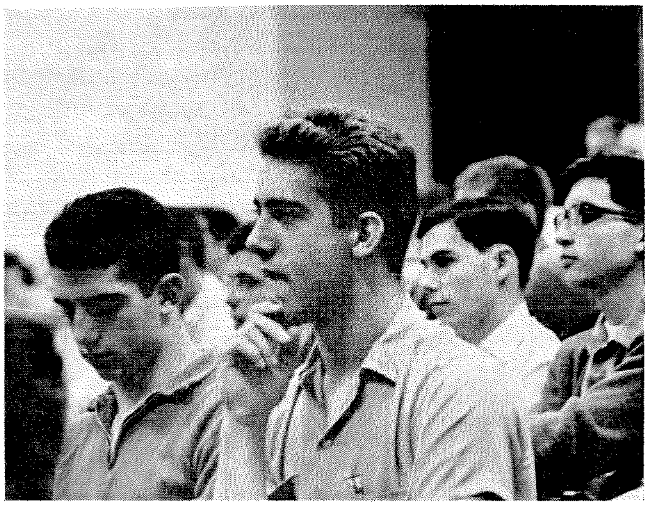
Ray Owen, chairman, Division of Biology



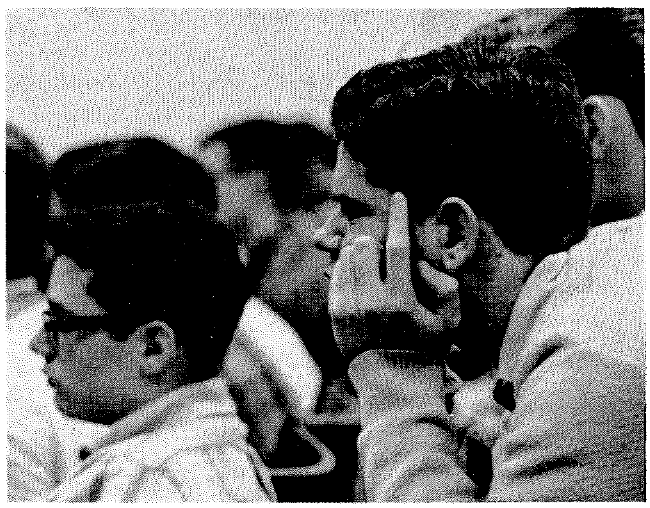
J. Kent Clark, professor of English



— No More Freshman Grades



At a special meeting of the freshman class on November 4, faculty representatives officially announced the decision to eliminate all freshman grades at Caltech for a trial period of two years. The move, which has been under consideration for some time, substitutes a pass-or-fail system for the usual letter grades. The faculty hopes that, under the new system, students will learn earlier to substitute more mature and substantial motives for work than the threat of a low GPA or the status of a high one.



Charles H. Townes (right, with JPL Director W. H. Pickering), at JPL for a NASA meeting on manned space flight, the day he got the news of his Nobel award.

NOBEL PRIZEWINNER

Charles H. Townes, provost of the Massachusetts Institute of Technology, who received his PhD from Caltech in 1939, is co-winner of the 1964 Nobel Prize in Physics. He will receive half of the $53,123 award, which he shares with two Russian scientists, Nikolai Basov and Aleksandr Prochorov, for development of the maser-laser principle of high intensity radio and light rays.

Dr. Townes and his colleagues developed the first maser (an acronym for microwave amplification by stimulated emission of radiation) in 1954, when he was professor of physics at Columbia University in New York. In the maser, radio microwaves are used to induce molecules and atoms to release stored energy, resulting in an amplified electronic wave — a concentrated radio beam with such power that it has become of major use to communications, astronomy, military science, and medicine.

Townes used his first maser to control an atomic clock of such extraordinary accuracy that it would vary no more than one second in 300 years.

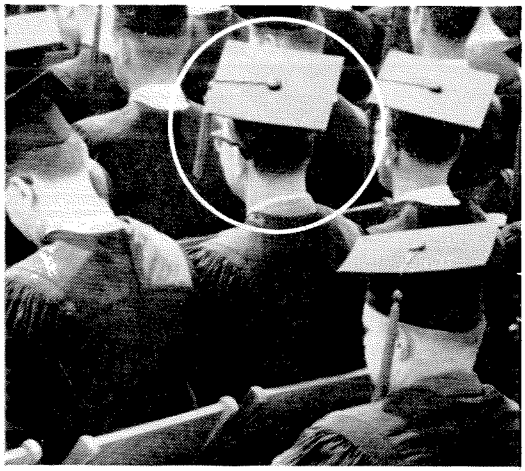
In 1958 Townes proposed the laser (light amplification by stimulated emission of radiation), a single color light beam whose intensity is so great and whose spread is so slight that it has been used to illuminate a small patch of the moon. Its wavelength is so uniform and coherent that it can be frequency- or phase-modulated. The laser is already being used in a variety of ways, in surgery, biological research, distance measurements, and signalling research. Future maser-laser techniques are expected to revolutionize communications by enabling transmission of as many as 10 million simultaneous television programs with a single beam.

Drs. Prochorov and Basov, who are both on the staff of the Lebedev Physics Institute in Moscow, conceived the idea of masers shortly after Dr. Townes began his work. Both are radio physicists. Townes and the two Russians are acquainted, having met at international conferences.

When Townes was at Caltech, he studied under Dr. William Smythe, professor of physics emeritus, and he is the fifth of Dr. Smythe's students to win the Nobel Prize in Physics. The others were Carl Anderson in 1936, Edwin McMillan in 1951, William Shockley in 1956, and Donald Glaser in 1960.

Townes received his BS in physics, summa cum laude, at Furman University in Greenville, S. C., at the same time as he received a BA in modern languages. He still retains a strong interest in languages, and has a working competence in French, German, Spanish, Greek, Russian, and Latin.

He got his MS from Duke University in 1937. After receiving his PhD from Caltech in 1939, Townes worked on the staff of the Bell Telephone Laboratories, where he developed wartime radar bombing systems and navigation devices. He joined the faculty of Columbia University in 1947, and was chairman of the physics department from 1952 to 1955. He was a Guggenheim Fellow in 1955-56 and a Fulbright lecturer, first at the University of Paris and then at the University of Tokyo. From 1958 to 1961 he served on the Air Force Scientific Advisory Board, and in 1959 was named a consultant to President Eisenhower's Scientific Advisory Committee. Prior to his appointment at MIT, he was on leave of absence from Columbia, serving as director of research for the Institute for Defense Analyses in Washington, D.C. He has been provost and professor of physics at MIT since 1961.



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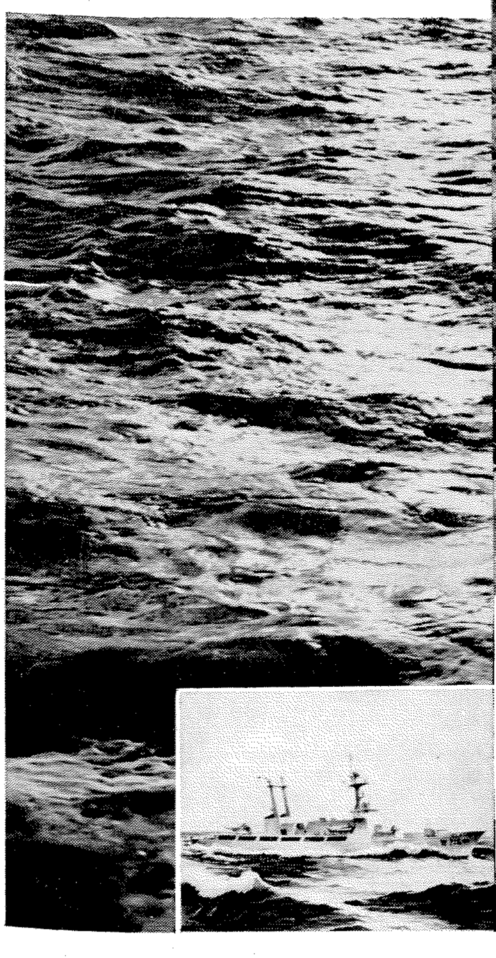

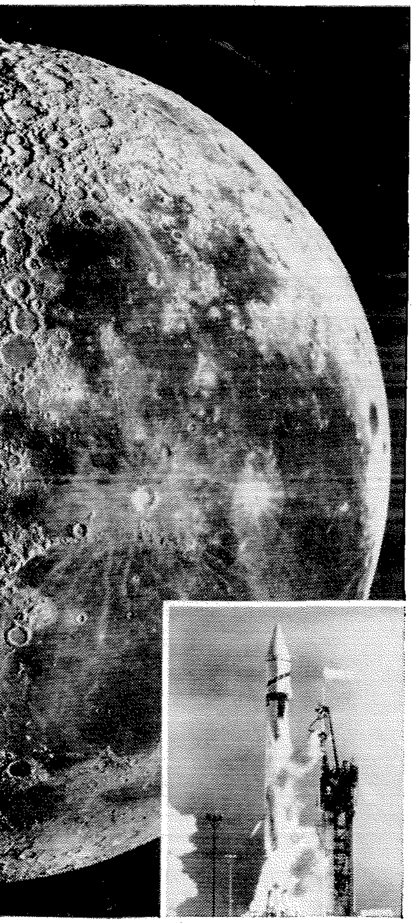

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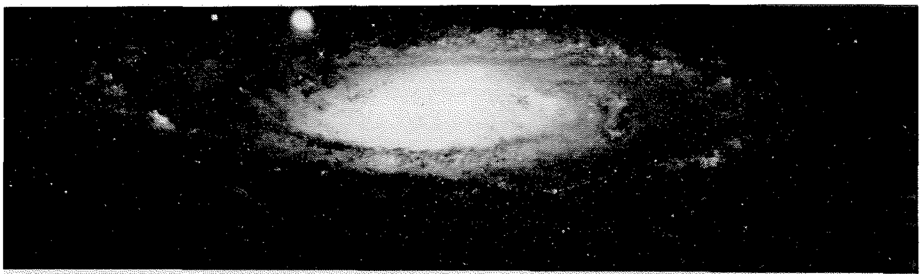
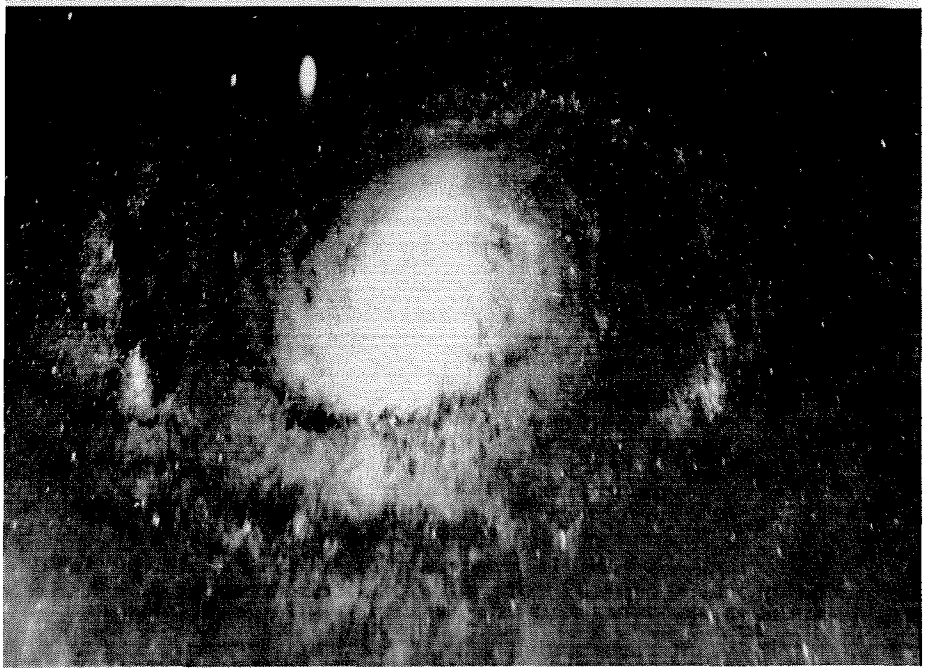




Andromeda Galaxy as seen from Palomar Observatory — and as it would look if it could be seen from above.

A NEW LOOK AT ANDROMEDA

The nearest big neighbor of our Milky Way Galaxy is the Andromeda Galaxy of 100 billion stars, thought to be very similar in shape and size to the Milky Way. The over-all appearance of the galaxy has been difficult to perceive and study, however, because it is seen from the earth almost edge-on. Now, using a unique combination of mathematical calculations and photography, Caltech astronomers have produced a picture of Andromeda from such an angle that we seem to be looking down on it. This new look has shown that the vast galaxy of stars, gas, and dust is much less similar to our galaxy than astronomers had supposed.

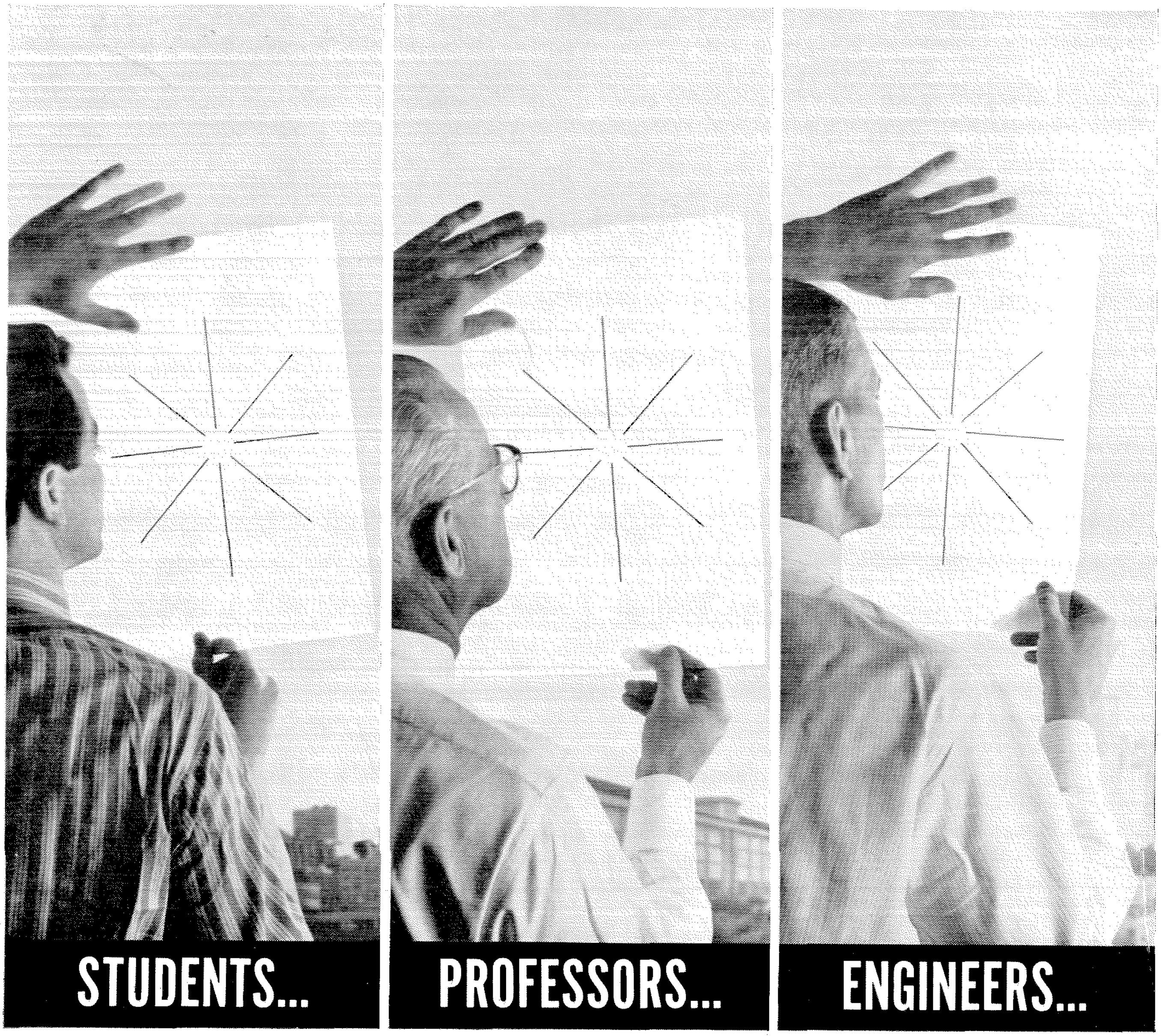
The work was done by Halton C. Arp, staff member of the Mount Wilson and Palomar Observatories; and William C. Miller, Observatory photographer. Dr. Arp made a lattice tracing of Andromeda's stars and mathematically lifted the lattice upright. Mr. Miller then photographed a picture of Andromeda at an angle, making it appear that he was looking down at the galaxy. The photograph and the mathematical lattice checked.

Studies of the photograph reveal that the galaxy's two major spiral arms are symmetrically coiled and spaced some 13,000 light years apart. In our Milky Way Galaxy, the arms are much closer together and probably are either multiple or branched, which suggests that the Milky Way has a higher percentage of gas than Andromeda, and therefore a higher percentage of young stars.

Attempts have been made in the past to project Andromeda upright so that its structure could be studied more satisfactorily. The late Dr. Walter Baade, of the Mount Wilson and Palomar Observatories, measured the positions of 688 emission nebulosities in the galaxy's arms; these are clouds of gas made fluorescent by hot, bright stars in their immediate neighborhood. Dr. Baade found that the emission clouds outlined segments of the spiral arm structure like "beads on a string."

Dr. Arp, a student of Dr. Baade's, found that the over-all spiral arm pattern of these fluorescent hydrogen clouds is difficult to interpret without also studying the effect of a small satellite galaxy of Andromeda's, known as M-32. It is a rich sphere of stars about 1,600 light years in diameter (Andromeda is 100,000 light years in diameter). M-32 is near one edge of the big galaxy and recent observations made with radio telescopes by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington have disclosed that M-32 has pulled the gas and stars, normally congregated together in the arms, away from each other on that side.

This observation opens the intriguing question of whether the effect is gravitational, magnetic, or both.



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CALTECH'S 1963 ALUMNI SURVEY

IV. *Occupation and Income*

by John R. Weir

Of the 4,615 alumni who completed the survey questionnaire, 52 are retired and 294 are still students, representing 7 percent of the total. All the rest are employed—61 percent of them in industry, 16 percent in education, 12 percent in government, and 6 percent in the military.

Industry

Almost half (46 percent) of the alumni employed by industry are doing research, design, or development work. One-third are in administration, and the remainder (15 percent) are mostly in operations, production, and marketing.

Electrical engineering was the most frequently mentioned field of specialization among those employed in industry. It accounted for 20 percent of the total. Business was next with 16 percent, followed by mechanical engineering (13 percent), aeronautics (10 percent), physics (7 percent), chemical engineering (5 percent), and civil engineering (5 percent). Each of the remaining 37 fields mentioned accounted for less than 5 percent.

Engineer was the most frequently reported position title (17 percent), followed by manager (15 percent), scientist (6 percent), and staff member (6 percent). The titles of president, vice president, and group supervisor each accounted for 5 percent. Director, project leader, and section head each had 4 percent, and chief, group leader, owner, and project supervisor each had 3 percent. There was less than 3 percent in each of the remaining 18 position titles used in the questionnaire.

The table of median income by job function for industry suggests high rewards for getting the product out the door and into the hands of the consumer. Alumni in research and design are at the bottom of the list.

Function	*Median annual earned income*
Administration	$20,000
Marketing	16,000
Production	15,000
Operations	15,000
Consulting	15,000
Development	15,000
Research	14,000
Design	13,000

Education

Caltech alumni employed in the educational sector of the economy are almost evenly distributed between teaching (45 percent) and research (47 percent). Many alumni indicated they are engaged in both, but for purposes of tabulation only their chief function was counted. An additional 7 percent are in administration.

"Education" was also listed as a field of specialization, along with the science, engineering, and other fields. This has led to a certain amount of redundancy, since 27 percent of those alumni employed in education and functioning as teachers checked their field of specialization as education as well. Others who are teaching in educational institutions listed their fields as physics (16 percent), mathematics (11 percent), chemistry (7 percent), and electrical engineering (6 percent). All other fields, such as aeronautics, astronomy, biology, chemical engineering, and mechanical engineering were less than 5 percent.

Twenty-four percent hold the title of professor, 18 percent assistant professor, 15 percent associate professor, 8 percent scientist, and 5 percent instructor.

The median annual income for those in administration is $18,000. It is $11,000 for those in research and $10,500 for those in teaching.

The median annual income is $20,000 for chairmen. For professors it is $18,000, for associate professors $13,000, for assistant professors $10,000, and for instructors $9,500.

Among those in education who list their primary function as research, 25 percent are in physics, 15 percent in chemistry, and 7 percent each are in biochemistry, electrical engineering, and mathematics. Six percent are in geology.

Government

About half (45 percent) of the 12 percent of Caltech alumni who are employed by government are in research. Another quarter are in administration, with 10 percent each in design and development, and 5 percent each in operations and consulting.

The fields of specialization within government employment that contain significant numbers are:

Field	*% of those in gov't employment*
Civil engineering	18
Electrical engineering	15
Physics	14
Aeronautics	8
Mechanical engineering	7
Geology	7
Meteorology	5
Chemistry	4
Mathematics	3

Somewhat over a third (36 percent) have the title of engineer or scientist, while 37 percent have a management title such as head, supervisor, director, manager, or chief.

Incomes do not have as wide a range as they do in education and industry—nor do they go as high.

Function	*Median annual earned income*
Administration	$15,000
Consulting	14,000
Research	13,500
Development	12,850
Design	12,000
Operations	11,500

Military

The six percent of alumni in the military are in development (24 percent), research (20 percent), administration (20 percent), design (14 percent), and operations (14 percent).

Almost half (42 percent) are in meteorology, 18 percent in electrical engineering, 13 percent in aeronautics, 10 percent in mechanical engineering, and 5 percent each in petroleum and civil engineering.

Those in development report the highest median annual incomes—which is contrary to the situation in industry, education, and the government.

Function	*Median annual earned income*
Development	$14,000
Design	12,750
Administration	12,500
Research	12,000
Operations	11,000

Leadership

Until fairly recently it was customary to think of scientists and engineers as working in relative isolation, and therefore needing no special managerial, administrative, or human relations skills. But complex research and development projects now involve large numbers of technically trained people, and managerial, supervisory, and leadership skills have great importance in determining job success. Our survey data indicate that this is particularly true for Caltech alumni.

Of the 4,269 working alumni, 881 have positions that indicate they possess outstanding management skills. These are the alumni who list their job titles as "owner," "partner," "president," "vice president," or "manager." They represent 20 percent of the total.

A second group of 415 have positions that would seem to require almost equal management abilities. They have such titles as "director," "chief," "superintendent," "chairman," "dean," or "head."

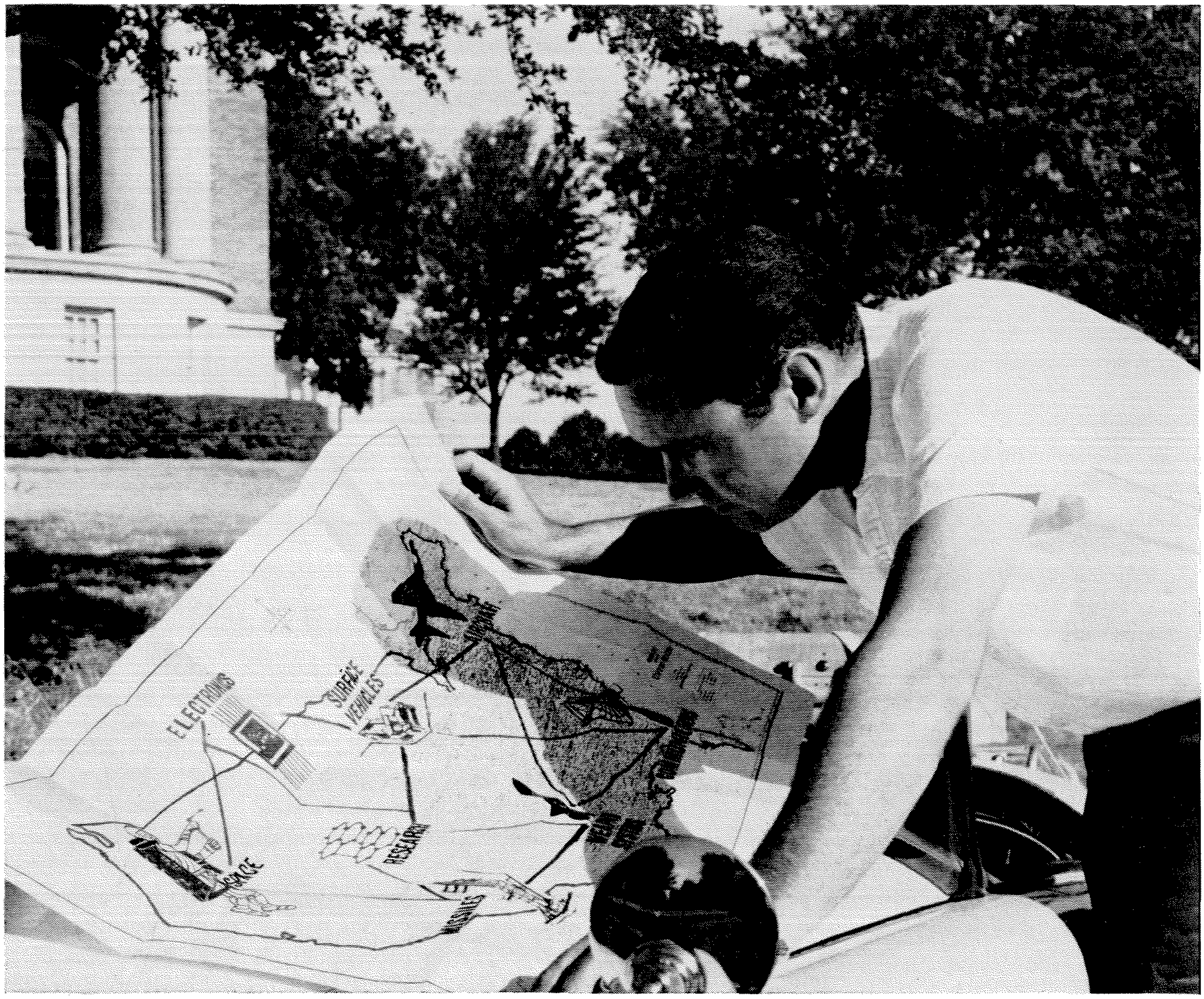
An additional 679 have job titles of "section head," "group supervisor," "group leader," "project supervisor," or "project leader." While working at a somewhat lower level of responsibility than the two preceding groups, alumni with these positions must certainly need managerial as well as technical skills.

These three groups, made up of the alumni with positions of top management responsibility, total 1,975. They represent 46 percent of all working alumni—which means that almost half of the alumni are now in positions that require skill in management, leadership, and human relations.

But even these figures do not provide the complete picture. Among those remaining there were 530 who reported that ten or more people were directly or indirectly responsible to them. Supervision of this number of subordinates certainly requires more than average leadership ability.

The same can probably be said for an additional 303 alumni who check administration as their job function. Administration almost always involves coordinating, or at least influencing, the efforts of others, often without recourse to any authority.

We have now included everyone we can identify directly as having important management positions or responsibility. They total 2,808 alumni and represent 66 percent of all those holding jobs. It is somewhat surprising to discover that two-thirds of our alumni, all highly trained in engineering, science, or mathematics, are actually devoting a large portion of their working hours to problems of human and organizational relationships.



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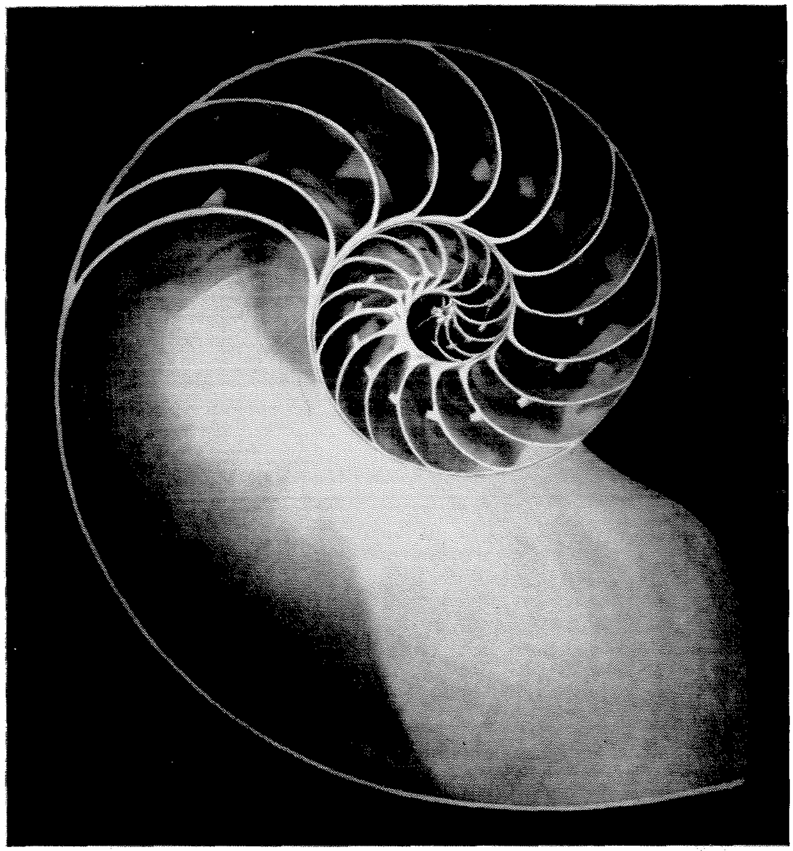

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Even among the 1,461 alumni remaining, many are in positions that require leadership and human relations skills. For example, there is a total of 276 "full," "associate," and "assistant" professors and instructors. There are 24 "advisors" and 22 "representatives." There are 169 who checked "other" rather than one of the titles provided — two-thirds of whom can be assumed to be in positions of management, since this was the proportion we found for the rest of the alumni. And there are also 187 "engineers" and 106 "scientists" who indicated they have between two and nine people responsible to them.

If we add these alumni to those whose occupations are more obviously managerial or administrative in nature, we have a grand total of 3,535.

This number represents 83 percent of all alumni. The pattern of modern research and development is becoming increasingly a matter of group activity dependent upon the collaborative efforts of many people. Caltech alumni are deeply involved in directing and coordinating these efforts.

Income

Alumni were asked to report their incomes from "occupation," "consulting," and "other" sources. Almost everyone supplied such data, permitting us to make several detailed comparisons:

Source of income	*Lower quarter*	*Median or midpoint*	*Upper quarter*	*Number reporting*
Occupation	$11,000	$13,500	$19,700	4,321
Consulting	1,200	2,600	6,000	542
Other	1,200	2,600	5,200	2,063
Total	11,700	16,000	23,300	4,454

At one extreme, 6 percent have total annual incomes under $5,000. They are mostly students. At the other extreme, 3 percent have total incomes over $50,000. (Ten report annual incomes over $100,000, three over $200,000.)

Only about 12 percent have income from consulting activities, and the highest proportion of these are among the PhD's in teaching positions.

It is interesting to make a direct comparison of the distribution of occupational incomes today, with those in the Caltech survey of 11 years ago. Inflation, the space age, and higher gross national product have combined to make some dramatic changes in these figures:

Income from occupation	*% in 1952*	*% in 1963*
Less than $1,000	4	1
$1,000-$5,000	14	6
$5,000-$7,000	28	2
$7,000-$9,000	25	5
$9,000-$19,000	26	59
$19,000 and over	3	27

Occupation

Earned income varies with field of specialization. The table below groups fields that have similar median incomes. The figures in the parentheses are the number of alumni checking that specialty as their main activity.

Median annual earned income	*Occupations in this income interval*
$10,000	Service occupations (12)
$11,000	Education (147), writing (11)
$12,000	Architecture (13), astronomy (30), biochemistry (50), biology (45), geology (175), mathematics & information processing (124), meteorology (36), military (133), sanitary engineering (17)
$13,000	Chemistry (208)
$14,000	Civil engineering (282), industrial design (14), physics (385)
$15,000	Chemical engineering (159), food (12), electrical engineering (698), economics (16), insurance (19), mechanical engineering (427), metallurgy (36), transportation (12)
$16,000	Merchandising, sales, advertising (44)
$17,000	Aeronautics (378), films (19), petroleum (91)
$18,000	Farming (10), medicine or dentistry (44)
$19,000	None
$20,000	Business and manufacture (445), finance (36), law (41)

The occupations in this list fall into three distinct groups on the basis of median incomes. In the first group ($10,000 to $13,000) are education, military, and science and mathematics. The second group has the engineering occupations, and the medians are $14,000 and $15,000. The third has business and the professions, with medians of $16,000 to $20,000.

Similar results appear when we compare earned incomes for alumni whose undergraduate major was in science ($13,000) with those who majored in engineering ($15,000). This differential, which is greatest in the decade immediately after the BS is earned, disappears in later years.

	Median annual earned income	
Years after BS	*Science majors*	*Engineering majors*
1 to 5	$ 4,300	$ 9,300
6 to 10	10,000	12,000
11 to 15	13,000	15,000
16 to 20	16,500	16,500
21 to 25	16,000	18,000
26 to 30	17,500	17,000
31 to 35	17,000	17,500
36 to 40	17,000	16,000
41 to 45	12,000	15,000
All ages combined	13,000	15,000

The median earned income of business and the professions ($20,000) is a high one. Only 23 percent of alumni have earnings equal to or greater than this. Another 23 percent earn less than $11,000 annually.

continued on page 32

Is it possible that a builder of space simulation equipment has a hand in Becky Hull's ballet lesson?

You'd expect that the leading maker of arc carbons that produce the brilliant light for projecting motion pictures would be called upon to duplicate the sun's rays in space simulation chambers. These chambers are used to test space devices, such as the communications satellites and space vehicles... and even the astronauts themselves.

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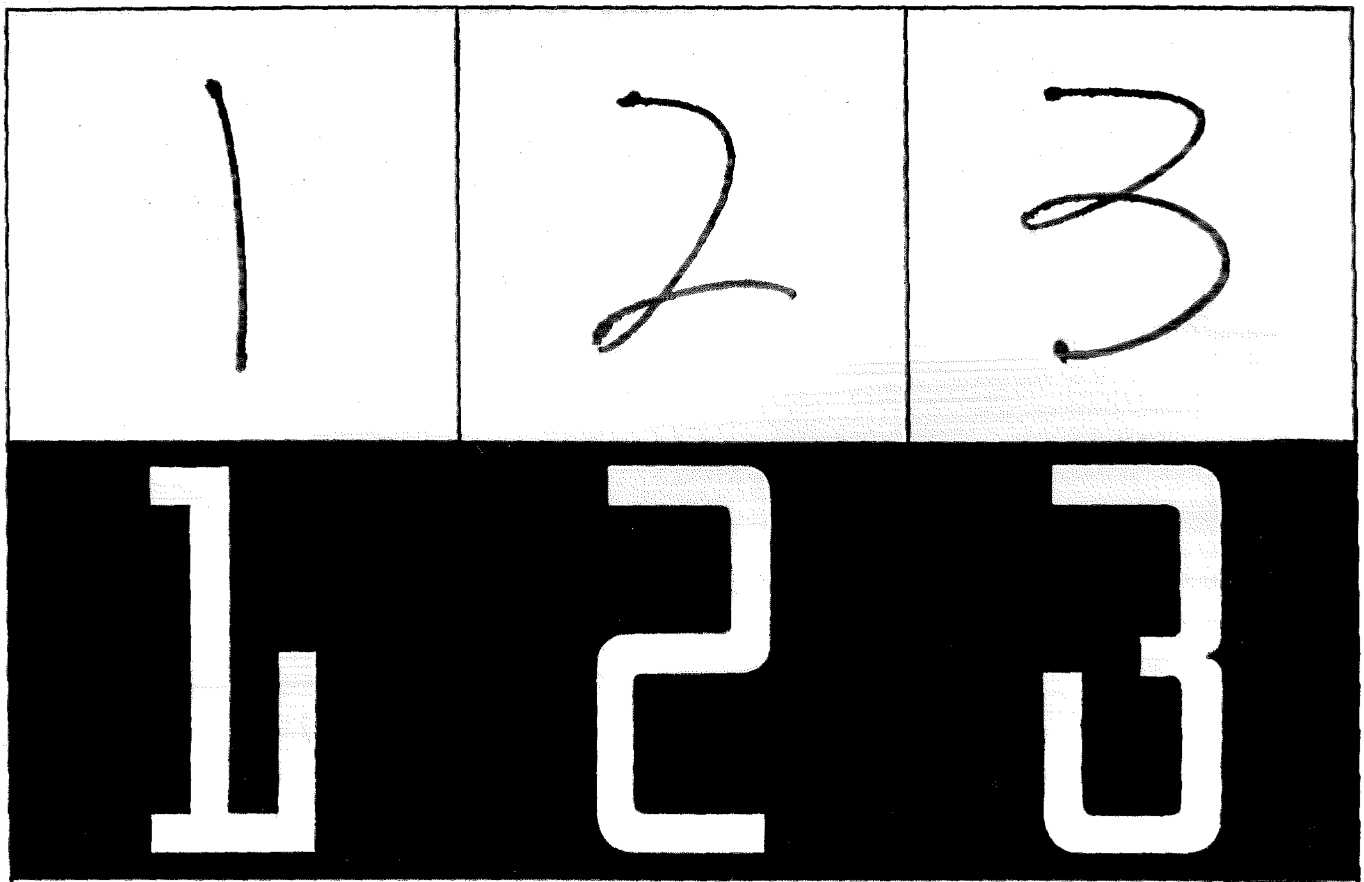

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Graduate Degrees

The median earned income for all alumni with the BS as the highest degree is $14,500. It is $13,000 for those with the MS, and $15,000 for those with the PhD.

The relatively low MS and PhD medians are due to the fact that many BS's are in industry, where the pay is high, while many MS's and PhD's are in education and government, where the pay is low.

Employed in	*% BS*	*% MS*	*% PhD*
Industry	70	60	40
Education	8	15	38
Government	9	11	12

Employed in	*Median earned income* BS	MS	PhD
Industry	$15,000	$15,000	$18,000
Government	13,200	12,500	15,000
Education	8,000	10,000	12,000
Military	12,000	12,400	13,000
Other	8,400	9,000	16,900

The differential tends to remain the same for all years out of college.

Years after BS	*Median earned income* BS	MS	PhD
1 to 5	$ 7,000	$ 8,900	$ 8,700
6 to 10	12,000	11,000	11,000
11 to 15	14,000	15,000	14,400
16 to 20	16,000	15,000	17,000
21 to 25	18,000	17,000	17,000
26 to 30	17,000	16,000	18,000
31 to 35	17,000	17,000	18,000
36 to 40	16,500	15,000	17,000
41 to 45	16,000	12,000	15,000

College

Study at Caltech pays off in dollars and cents for those earning advanced degrees.

Median annual earned income	*Degree combination*	*Median estim. undergrad GPA*
$13,500	BS CIT, MS other	2.8
$14,000	BS other, MS CIT	3.4
$14,500	BS CIT, MS CIT	3.0
$13,800	BS CIT, PhD other	3.0
$15,000	BS other, PhD CIT	3.6
$16,000	BS CIT, PhD CIT	3.2

The advanced degree holder earns least if he took his graduate work elsewhere, most if he did all of his work—both undergraduate and graduate—at Caltech. The pattern of median undergraduate GPA's for the different degree combinations suggests that those with BS's from other institutions are in the middle of the income ranges as a result of more stringent standards of admission to graduate study than is required of Caltech BS's.

It is usually taken for granted that students with high grades will be more successful than their classmates who get lower grades. Our data confirm this opinion, at least as far as earnings are concerned, although the difference is not great.

Grades	*Median total income*
As	$15,000
Bs	15,500
Cs	14,000

Our data also support the statement that outstanding achievement in extracurricular activities in college is predictive of later success. In fact, the income differential between *no* and *many* activities is the same as it is between A grades and C grades—$1,000.

Extracurricular activities	*Median total income*
None	$15,000
1 to 3 kinds	15,000
4 or more kinds	16,000

If high grades and participation in extracurricular activities are each accompanied by higher incomes, then the combination of both should increase the differences. This is true of Caltech alumni when we cross-compare the extremes:

Grades	*Median total income — Extracurricular activities* None	*4 or more kinds*
A's	$15,000	$17,000
C's	13,000	13,200

The difference of $4,000 between the total income medians for C students with no extracurricular activities is four times the size of the difference for either grades or activities taken singly. We found similar differences in our 1952 survey, although at that time grades were not as influential as they are in this study.

Civic Activities

When we made a comparison of the total incomes of alumni who were very active in civic affairs with those who were inactive, we found very large differences. A further division into those with BS's in science and BS's in engineering revealed similar differences for both groups.

Number of civic activities	*Median total income* BS in Science	*BS in Engineering*
None or 1	$ 9,000	$12,000
2 to 6	14,200	16,000
7 or more	17,000	19,000

These higher incomes should not be ascribed wholly to participation in civic affairs. An alumnus must be well established—and therefore often in a high income bracket—to have the time and opportunity to be active in civic affairs. There is undoubtedly a large proportion of young alumni in the low civic activities group. However, these figures, considered along with the higher earnings for alumni who were active in extracurricular activities, do

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Occupational Success

Earned income is an important indicator of occupational success, and by this standard Caltech alumni are certainly successful. But income is not an entirely satisfactory basis for judging the success of a group with members who often hold academic values higher than monetary rewards. In an attempt to overcome this difficulty, we asked alumni to report their fellowships, academic honors, publications, organizational offices, and directory listings.

A total of 350 have held important post-doctoral fellowships such as Fulbright, Guggenheim, NSF, and Sloan; 364 have received honorary degrees or other academic or professional honors; half (2,201) have published articles or papers, and 639 have each published ten or more; 561 have published a book or monograph, and 164 have published two or more; 649 are officers, directors, or trustees in a firm, institution, or organization that is not necessarily that of their occupation, while 247 hold two or more such offices; and 1,121 are listed in special directories such as *Who's Who* and *American Men of Science.*

These figures represent significant achievement for any alumni group.

There is some evidence that many of our alumni have a feeling of such accomplishment. In response to the question, "In your present job, do you consider yourself more, as, or less successful than the average?" over half (55 percent) thought they were "more successful." Only 4 percent thought they were "less successful."

We selected a group of alumni who had outstanding records in these activities for further study. They consisted of those who met any three of the following six requirements: 1) received a fellowship, 2) held an honor or award, 3) published two papers, 4) published a book, 5) was an officer or director in a firm or institution, and 6) was listed in a special directory.

There were 619 alumni, representing 14 percent of the total, who met this criterion. Forty percent were in industry, 40 percent in education, 13 percent in government, 2 percent in the military, and 5 percent in "other."

The kinds of accomplishment we used to select this group are more likely to be achieved by alumni with advanced degrees, particularly the doctorate. Sixteen percent of those who got a BS from another institution and a PhD from Caltech qualified for this achievement group. But 33 percent of those who received a BS from Caltech and a PhD from another institution, and 34 percent of those who received both their BS and PhD from Caltech are in this high achievement category. The relatively high proportion of PhD's with BS's from Caltech suggests either a highly selective undergraduate admissions program, or a very effective educational program.

Success, whether measured in terms of income or leadership positions, notable non-monetary achievement or self-evaluation, is implicit in the earning of a degree from Caltech. The relative extent of the success varies somewhat with the kind of degree, whether obtained entirely at Caltech or by some combination of Caltech and another institution, and the undergraduate major in which a degree was obtained. Yet, the over-all success of Caltech alumni when compared with other U.S. college alumni is undeniable.

This was also the conclusion arrived at from the 1952 alumni survey. At that time the median total income of Caltech alumni was $7,900—considerably higher than the $6,140 median income of all U.S. college graduates.

Dollar incomes have increased enormously in the United States in the 11 years between surveys. The U.S. Department of Commerce Current Population Report of September 29, 1964, gives the median U.S. family income in 1952 as $3,890, and in 1963 as $6,249—a 61 percent increase. The median family income for all white U.S. college graduates in 1963 was $9,900—again a 61 percent increase over $6,140 in 1952.

The median earnings of Caltech alumni, however, have increased 93 percent—from $7,000 in 1952 to $13,500 in 1963. And the median total income of Caltech graduates has increased 103 percent—from $7,900 to $16,000!

The median total income of Caltech alumni in 1963 was at the 88th percentile of the income for all U.S. college graduates. Current undergraduates and graduate students, dwell on this thought when you are dismayed, discouraged, and disenchanted with your labors. They *are* worth the time, effort, and money you are putting into them.

Fourth in a series of articles on the survey conducted last year by Dr. Weir, associate professor of psychology. In our next issue, Dr. Weir will discuss alumni opinions of life at Caltech and their suggestions for change or improvement.

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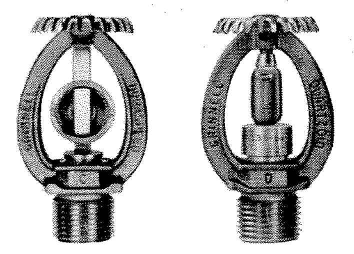

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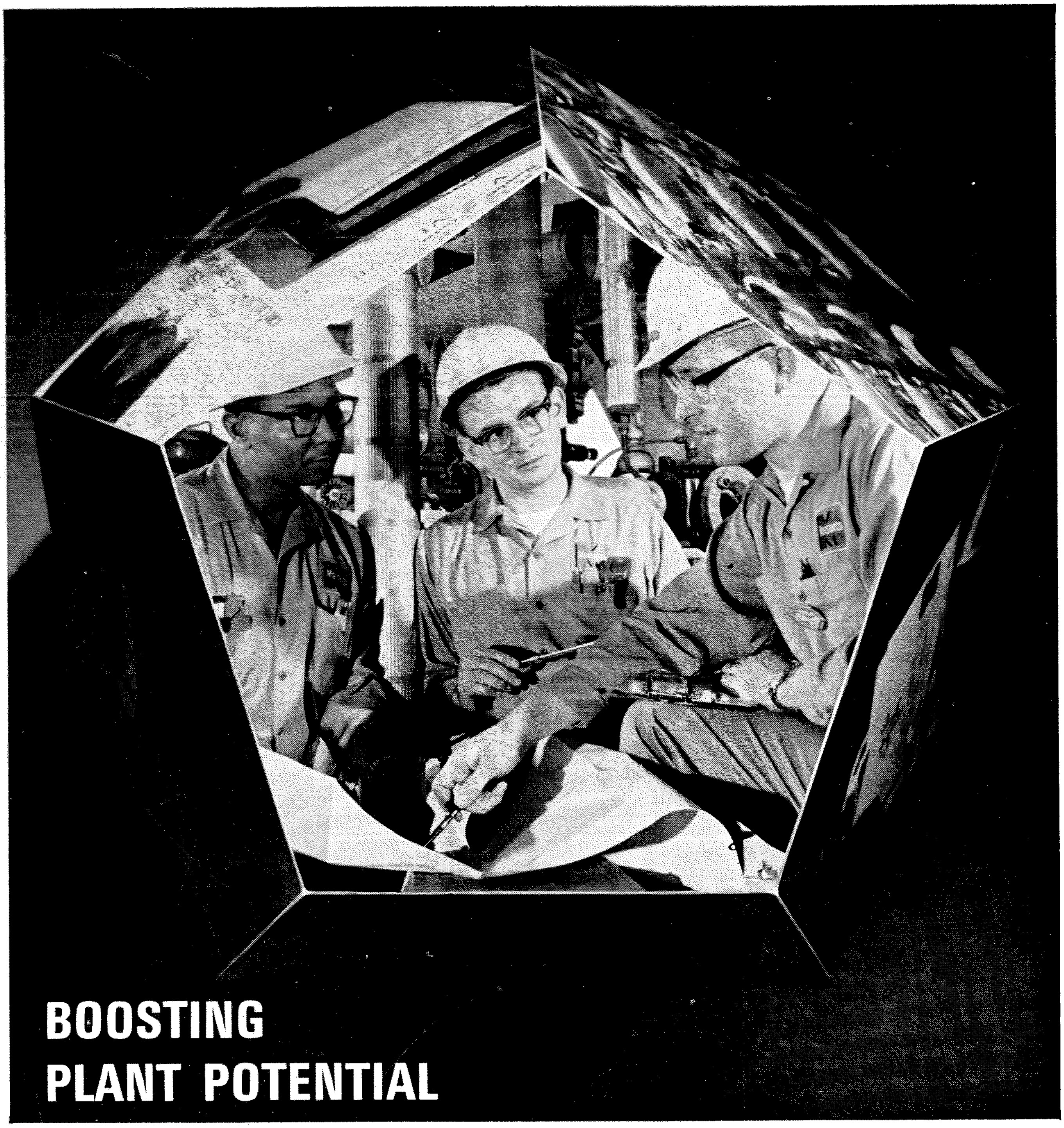
1906
Norton, Frank E.
1907
Miller, James C., Jr.
1911
Lewis, Stanley M.
1918
Lavagnino, John F.
1921
Arnold, Jesse
Seaver, Edward D.
1922
Bruce, Robert M.
Cox, Edwin P.
1923
Neil, W. Harvey
Skinner, Richmond H.
1924
Carr, John
Henderson, William G.
Tracy, Willard H.
Young, David R.
1925
Waller, Conrad J.
Winckel, Edmond E.
1926
Chang, Hung-Yuan
Yang, Kai Jin
1927
Evjen, Haakon M.
Marsland, John E.
Moore, Bernard N.
Peterson, Frank F.
Riggs, Eugene H.
1928
Chou, P'ei-Yuan
Martin, Francis C.
Morgan, Stanley C.
Wingfield, Baker
1930
Allison, Donald K.
Chao, Chung-Yao
Forney, Morgan T.
Kelley, William
Moyers, Frank N.
Shields, John C.
White, Dudley
1931
Hall, Marvin W.
Ho, Tseng-Loh
West, William T.
Yoshioka, Carl K.
1932
Patterson, J. W.
Schroeder, L. D.
1933
Applegate, Lindsay M.
Downie, Arthur J.
Koch, A. Arthur
Larsen, William A.
Michal, Edwin B.
Murdock, Keith A.
Rice, Winston R.
Shappell, Maple D.
Smith, Warren H.
1934
Core, Edwin J.
Harshberger, John D.
Liu, Yun Pu
Moore, Morton E.
1935
Bertram, Edward A.
Huang, Fun-Chang
McCoy, Howard M.
McNeal, Don
Ricketts, Donald H.
1936
Chu, Djen-Yuen
Kelch, Maxwell
Van Riper, Dale H.
Young, Larry L.
1937
Burnight, Thomas R.
Cheng, Ju-Yung
Eastou, Anthony
Fan, Hsu Tsi
Jones, Paul F.
Lotzkar, Harry
Maginnis, Jack
Munier, Jack
Nojima, Noble
Odell, Raymond H.
Penn, William Lee, Jr.
Servet, Abdurahim
Shaw, Thomas N.
1938
Goodman, Hyman D.
Gross, Arthur G.
Gutierrez, Arnulfe G.
Kanemitsu, Sunao
Lowe, Frank Clare
Rhett, William
Rynearson, Garn A.
Tsao, Chi-Cheng
Wang, Tsun-Kuei
Watson, James W.
1939
Aime, Edgar A.
Gombotz, Joseph J.
Hsueh, Chao-Wang
Kazan, Benjamin
Liang, Carr Chia-Chang
Weinstein, Joseph
Wilson, Harry D.
1940
Abraham, Lewis
Batu, Buhtar
Compton, Arthur M.
Gentner, William E.
Gibson, Arville C.
Green, William J.
Hsu, Chang-Pen
Karubian, Ruhollah Y.
King, James L.
Lovoff, Adolph
Menis, Luigi
Paul, Ralph G.
Tao, Shih Chen
Torrey, Preston C.
Wang, Tsung-Su
1941
Clark, Morris R.
Easley, Samuel J.
Geitz, Robert C.
Gould, Martin
Green, Jerome M.
Hardenbergh, George A.
Harvey, Donald L.
Helmick, Benjamin W.
Hubbard, Jack M.
Nicholson, George H.
Noland, Robert L.
Robinson, Frederick G.
Standridge, Clyde T.
Taylor, D. Francis
Vaughan, Richard
Wolfe, Samuel
Yui, En-Ying
1942
Bebe, Mehmet F.
Devault, Robert T.
Drake, John A.
Emre, Orhan M.
Go, Chong-Hu
Johnston, William C.
Levin, Daniel
MacKenzie, Robert E.
Martinez, Victor H.
1943
Angel, Edgar P.
Brown, Glenn H., Jr.
Brown, James M.
Bryant, Eschol A.
Burlington, William J.
Carlson, Arthur V.
Colvin, James H.
Eaton, Warren V., Jr.
Gaffney, Thomas A.
Gould, Jack E.
Hamilton, William M.
Hillyard, Roy L.
Hilsenrod, Arthur
Johnsen, Edwin G.
King, Edward G.
Koch, Robert H.
Kong, Robert W.
LaForge, Gene R.
Lee, Edwin S., Jr.
Leeds, Wm. Lodowick
Ling, Shih-Sang
Lundquist, Roland E.
Mampell, Klaus
McNeil, Raymond F.
Mixsell, Joseph W.
Mowery, Irl H., Jr.
Nesley, Wm Lewis
Neuschwander, Leo Z.
O'Brien, Robert E.
Pearson, John E.
Rivers, Nairn E.
Roberts, Fred B.
Rupert, James W., Jr.
Scholz, Dan R.
Shannon, Leslie A.
Smitherman, Thomas B.
Tindle, Albert W., Jr.
Vicente, Ernesto
Waldrop, Nathan S.
Walsh, Joseph R.
Washburn, Courtland L.
Weis, William Thomas
Wheeler, Rodney S.
Wood, Stanley G.
1944
Alpan, Rasit H.
Baranowski, Francisco D.
Bell, William E.
Benjamin, Donald G.
Berkant, Mehmet N.
Birlik, Ertugrul
Burch, Joseph E.
Burke, William G.
Clendenen, Frank B.
Cebeci, Ahmed
Cooke, Charles M.
De Medeiros, Carlos A.
Fu, Ch'eng Yi
Harrison, Charles P.
Hu, Ning
Johnson, William M.
Labanauskas, Paul J.
Leenerts, Lester O.
Mapel, Robert W.
Mattinson, Carl O.
Onstad, Merrill E.
Pi, Te-Hsien
Pischel, Eugene F.
Ridlehuber, Jim M.
Shults, Mayo G.
Stanford, Harry W.
Stein, Roberto L.
Sullivan, Richard B.
Sunalp, Halit
Trimble, Wm M.
Unayral, Nustafa A.
Wadsworth, Joseph F., Jr.
Wight, D. Roger
Williams, Robert S.
Wolf, Paul L.
Writt, John J.
Yik, George
1945
Ari, Victor A.
Bryner, Dean L.
Budney, George S.
Bunze, Harry F.
Clementson, Gerhardt C.
Fanz, Martin C.
Fox, Harrison W.
Gibson, Charles E.
Grossling, Bernardo F.
Jenkins, Robert P.
Knapp, Norman E.
Kuo, Yung-Huai
Levy, Charles N.
Rice, Jonathan F.
Tseu, Payson S.
Turkbas, Necat
Yank, Frank A.
1946
Allison, Charles W., Jr.
Barber, John H.
Behroon, Khosrow
Bowen, Mark E.
Brinkhaus, Harvey H.
Burger, Glenn W.
Chen, Ke-Yuan
Dethier, Bernard
Dougherty, Chas. B.
Dyson, Jerome P.
Esner, David R.
Foster, R. Bruce
Gould, Edwin S.
Halvorson, George G.
Hoffman, Charles C.
Huestis, Gerald S.
Ingram, Wilbur A.
Jacobsen, John R.
Ke Yuan, Chen
Lowery, Robert H.
Lewis, Frederick J.
Maxwell, Frederick W.
McConnaughhay, James W.
Miller, Jack N.
Olsen, Leslie R.
Parker, James F.
Prasad, K. V. Krishna
Rice, Jerry H.
Salbach, Carl K.
Shepard, Elmer R.
Sledge, Edward C.
Smith, Harvey F.
Stephenson, Robert E.
Tung, Yu-Sin
Webb, Milton G.
1947
Asher, Rolland S.
Atencio, Adolfo J.
Atkinson, Paul G., Jr.
Brown, Raymond A.
Clarke, Fredric B.
Clements, Robert E.
Clock, Raymond M.
Collins, Hugh H.
Dagnall, Brian D.
Darling, Donald A.
Darling, Rodney O.
Hammerle, Wm G.
Heppe, Ralph R.
Hsu, Chi-Nan
Lane, James F.
Leo, Fiorello R.
Lim, Vicente H., Jr.
MacAlister, Robert S.
Manoukian, John
McClellan, Thomas R.
Molloy, Michael K.
Moorehead, Basil E. A.
Olson, Raymond L.
Orr, John L.
Ray, Kamalesh
Rust, Clayton A.
Sanders, Lewis B.
Sappington, Merrill H.
Schroeder, Henry W.
Thompson, Russell A., Jr.
Torgerson, Warren S.
Wan, Pao Kang
Wellman, Alonzo H., Jr.
Wimberly, Clifford M.
Winters, Edward B., Jr.
Ying, Lai-Chao
1948
Agnew, Haddon W.
Bunce, James A.
Clark, Albert R.
Collins, Burgess F.
Cotton, Mitchell L.
Crawford, Wm D.
Herold, Henry L.
Holm, John D.
Hsiao, Chien
Hsieh, Chia Lin
Lambert, Peter C.
Latson, Harvey H., Jr.
Lawton, G.
Rhynard, Wayne E.
Stein, Paul G.
Swain, John S.
Voelker, William H.
Woods, Marion C.
Wray, Robert M.
Yanak, Joseph D.
1949
Abramovitz, Marvin
Barker, Edwin F., Jr.
Bauman, John L., Jr.
Bottenberg, William R.
Brown, John R.
Bryan, Wharton W.
Cheng, Che-Min
Clancy, Albert H., Jr.
Clendening, Herbert C.
Cooper, Harold D.
Dieter, Darrell W.
Dodge, John A.
Foster, Francis C.
Galstan, Robert H.
Gilkeson, Fillmore B.
Hardy, Donald J.
Heiman, Jarvin R.
Krasin, Fred E.
Krauss, Max
Leroux, Pierre J.
Lowrey, Richard O.
MacKinnon, Neil A.
McElligott, Richard H.
Merrell, Richard L.
Parker, Dan M.
Petty, Charles C.
Rinehart, Marion C.
Ringness, William M.
Saari, Albert E.
Sinker, Robert A.
Stappler, Robert F.
Weiss, Mitchell
Winniford, Robert S.
Wilkening, John W.
Yu, Sien-Chiue
1950
Bryan, William C.
Edelsteih, Leonard
Gimpel, Donald J.
Li, Chung Hsien
Mayner, Gerald S.
McDaniel, Edward F.
McMillan, Robert
Mesara, R. Reha
Montemezzi, Marco A.
Pao, Wen Kwe
Paulson, Robert W.
Petzold, Robert F.
Scherer, Lee R., Jr.
Schmidt, Howard R.
Soldate, Albert M.
1951
Arosemena, Ricardo M.
Chong, Kwok-Ying
Davison, Walter F.
Goodell, Howard C.
Hawk, Riddell L.
Lafdjian, Jacob Parseh
Li, Cheng-Wu
Merkel, George
Padgett, Joseph E., Jr.
Palmer, John M., Jr.
Sjodin, Raymond A.
Summers, Allan J.
1952
Abbott, John R.
Arcoulis, Elias G.
Bucy, Smith V.
Harrison, Marvin E.
Helmer, John C.
Helmuth, James G.
Lunday, Adrian C.
Meyer, Robert F.
Primbs, Charles L.
Robieux, Jean
Robison, Wm C.
Schaufele, Roger D.
Shelly, Thomas L.
Sutton, Donald E.
Wiberg, Edgar
Wilson, Howard E.
Woods, Joseph F.
Zacha, Richard B.
1953
Bhanjdeo, Swaroop C.
Crespo, Manuel J.
Elliott, David D.
Lennox, Stuart G.
Robkin, Morris A.
Schroeder, Norman M.
Wilburn, Norman P.
1954
Coughlin, John T., II
Feuchtwang, Thomas E.
Graves, Jack C.
Guebert, Wesley R.
Gutierrez, Reinaldo V.
Heiser, David A.
Mertz, Charles, III
Rogers, Berdine H.
Seele, Gordon D.
Sergeyevsky, Andrew
Von Gerichten, Robert L.
1955
Barman, Mervyn L.
Campbell, Douglas D.
Engels, Eugene
Huber, William E.
Lim, Macrobio
Moore, William T.
Roman, Basil P.
1956
Edward, Robert W.
Frignac, Jean-Paul
Garnault, Andre F.
Kelly, James L.
Kontaratos, Antonios N.
McAllister, Don F.
Spence, William N.
Tang, Chung-Liang
1957
Brust, David
Goebel, Charles V.
Howie, Archibald
Lawrence, Alfred F., Jr.
Schwartz, Lowell M.
Stuteville, Joseph E.
Wong, Chi-hsiang
1958
Ackley, David A.
Chang, Berken
Dundzila, Antanas V.
Jones, Laurence G.
Khamis, Mitri G.
Knight, Harold G.
Saffouri, Mohammad H.
Wille, Milton G.
1959
Baekelandt, Victor
Bailey, John S.
Byun, Chai B.
Cheng, Hung
Guillemet, Michel P.
Gustafson, Herold
Havey, James H., Jr.
Idriss, Izzat M.
Monroe, Louis L.
Muraoka, Kenneth A.
Weber, Walter V.
1960
Bieniewski, Thomas M.
Farha, Norman S.
Lindquist, David M.
Mauger, Richard L.
Purnell, Lannes S.
1961
Dombey, Norman
Hecht, Robert J.
Richter, Rolf
Steinberg, Charles M.
1962
Dorlhac, Jean-Pierre
Dubois, Jean Claude



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Alumni News

Hallan Neil Marsh (1899-1964)

Hallan N. Marsh, BS '22, a prominent petroleum engineer, inventor, author, and a director of the Caltech Alumni Association during the years 1951 to 1953, died suddenly in Whittier, California, of a heart attack on July 24, 1964.

Born April 21, 1899, in Neillsville. Wisconsin, he became a Californian in 1914. His father, Spencer M. Marsh, was a lawyer and state senator in Wisconsin who came west to become District Attorney and later Judge of the Superior Court in San Diego County.

Hal Marsh served in the Army in 1918 and received his BS in mechanical engineering from Caltech in 1922. He was elected to Tau Beta Pi and Sigma Xi. He worked as an engineer for the San Diego and Arizona Railway, spent a year in graduate work at Caltech, and then entered the engineering department of the General Petroleum Corporation in Los Angeles.

After 37 years with General Petroleum (now Mobil Oil Co.), he retired in 1960 as manager of its Production Engineering and Equipment Section. He was a national authority on how to measure and control the underground conditions encountered in oil and gas production. His papers have enriched the technical literature. He held eleven patents on drilling or producing instruments and equipment, and it was he who long ago developed the "Marsh funnel," which is now used in rotary drilling all over the world.

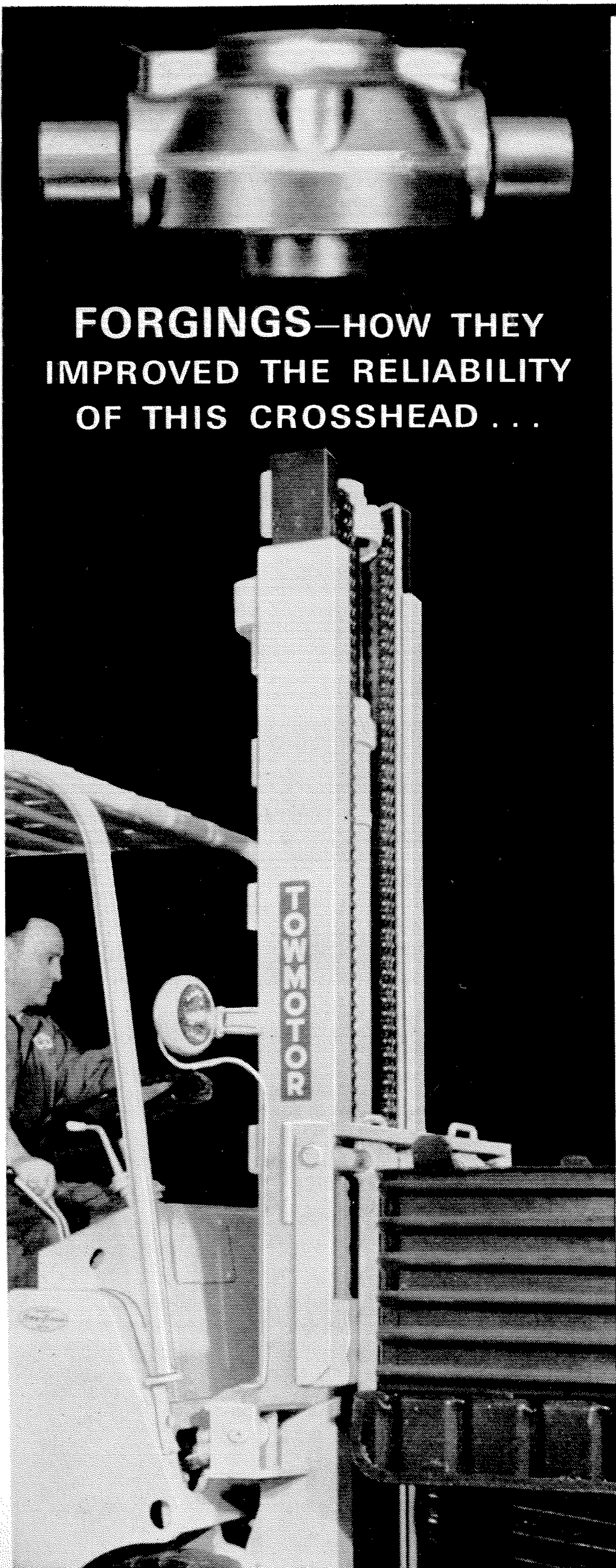
Hallan N. Marsh

In 1961, the AIME gave him the John Franklin Caril Award for distinguished contributions to petroleum engineering. The citation, which summarizes his contributions to the engineering profession, was "in recognition of his contributions to the art of petroleum engineering, his advancement of the professional status of the engineer in oil producing operations, and his inspirational teaching and development of junior engineers—all accomplished through a dedicated adherence to the simple, basic concepts of science, economics, and professional integrity." He was active in the American Petroleum Institute, served as the chairman of the Central Committee on Drilling and Production Practice, and was a leader for more than 30 years in the institute's program of standardization.

Hallan Marsh was elected to the Executive Council of Tau Beta Pi in 1961. He served as secretary of the council from December 1962, until his death. He was very active in Tau Beta Pi activities and was most concerned with financial matters of the association.

He was a person of extraordinary integrity. He recognized no degrees of integrity—saying that honesty, like pregnancy, is either present or absent. Once asked if he was a cynic, he quoted a Chinese proverb saying that if a man has both ideals and intelligence, he is bound to become a cynic when he discovers how far short mankind fails of its ideals, and then his happiness will depend on mixing his cynicism with kindness.

Hal Marsh's greatest success was in the selection and development of junior engineers. Before World War II, he was instrumental in setting up a training program for newly hired engineering graduates. From 1937 until Marsh's retirement, 71 graduates had entered the program and 54 of them were still with the company. Of these, one was then a division vice president, one an operations superintendent, one a joint interest manager, one a division controller, and five were district superintendents. About half of the 54 were supervisors or managers of field operations and half were staff engineers, some with great responsibility. Two were in foreign operations of Socony



yet cut cost 20%

Originally, this crosshead for a lift truck was not a forging. Now it is **forged** in steel. Here's why . . .

The lift truck builder wanted to increase the safety factor to meet greater bending and shear stresses. He also wanted to increase the fatigue strength of the part. And all without any increase in weight or cost. He also wanted to reduce tool breakage caused by irregularities, voids, and inclusions.

He changed over to FORGED crossheads.

Now the crosshead has the required strength and stress-resistance, costs 20% less when machined and ready to assemble, increases production rates 14% by reducing tool breakage and increasing machining speeds.

Forgings are better for these reasons; they:

1. Are solid, free from voids and inclusions
2. Have high fatigue resistance
3. Are strongest under impact and shock loads
4. Have a higher modulus of elasticity
5. Have a unique stress-oriented fiber structure
6. Are low in mechanical hysteresis

Memo to future engineers:

"Make it lighter and make it stronger" is the demand today. No other metalworking process meets these two requirements so well as the forging process. Be sure you know all about forgings, their design and production. Write for Case History No. 105, with engineering data on the lift truck crosshead forging shown above.

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Mobil. A Mobil executive commented that "Hal Marsh has multiplied his contribution to the company by multiplying the skills of his juniors, setting in motion a chain reaction that can continue for decades."

Hal Marsh was an ardent mountain climber and life member of the Sierra Club, a licensed pilot of private airplanes, a boating enthusiast, and a superb color photographer.

Hal Marsh had a clear concept of the distinction between the scientist and the engineer as follows: "A *scientist* is concerned with what happens from a given combination of materials and forces. An *engineer* starts with the particular result desired, and then determines what combinations of materials, forces, and human factors will produce the result, or something close to it, at an acceptable cost."

Mr. Marsh is survived by his wife and companion for 40 years, Kareen, of 16342 East Prudencia Drive, Whittier, California; their son, Dr. John S. Marsh, Whittier neurosurgeon; their two daughters, Mrs. Neila Gregory and Mrs. Janet Davis; and 6 grandchildren.

—Donald S. Clark

Ernest Maag Retires

Ernest Maag, principal structural engineer for the school section of the Office of Architecture and Construction of the State of California, is retiring on December 1. For the past ten years he has been in charge of the southern California office of the school section, which supervises approximately two million dollars worth of public school construction per year.

After graduating from Caltech, Mr. Maag got his first training at the Pasadena Building Department. From 1933 to 1945, he worked in the L.A. County Building Department as a research engineer, in charge of building code work. He joined the State of California in 1946.

He has been active in many engineering organizations, and served as president of the Structural Engineers Association of both California and southern California. He was president of the Caltech Alumni Association in 1943-44.

ALUMNI EVENTS

November 21	Interhouse Dinner-Dance
May 8	Annual Alumni Seminar
June 9	Annual Meeting

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There are two ways in which the Placement Service may be of assistance to you:

(1) To help you seek new employment or a change of employment.

(2) To inform you when outstanding opportunities arise.

This service is provided to Alumni by the Institute. A fee or charge is not involved.

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California Institute of Technology
Pasadena, California 91109

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☐ A form to report my field and operation so that I may be notified of any outstanding opportunities.

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Contact Mr. Farrar, EX 9-5277, on Thursday morning for reservations.

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Visiting alumni cordially invited—no reservation.

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Ed, Bob, and Hipparchus (their true identities hidden here against pitiless kidding by all-too-real colleagues) are three Kodak mechanical engineers on their way to a management meeting for the up-and-coming. Let us consider differences rather than similarities.

Ed works on those inexpensive, sure-fire cameras that Americans as well as citizens of the rest of the civilized world think of when "Kodak" is mentioned. The big boss who chose Ed for his department says: "Along with Ph.D.s in solid-state physics, I look for B.S. and M.S. mechanical engineers from whom I can expect the unexpected. The spots for sophisticated engineering don't always have a sign over the door that says 'SOPHISTICATED.' Who would ever have dreamed ten years ago that low-price zoom lenses and automatic exposure-setters and through-the-lens finders could deliver the performance they do today? The doozers we have ready to unveil next year and the year after that are well in hand, fortunately. Then what?" Then what is Ed's responsibility. He will need help from fellows now in college. Maybe you.

Bob works on data-recording and information-retrieval photographic systems. His work has to impress cost-minded brother engineers in other companies as well as banks and other hard-nosed commercial customers. He meets the requirements of a boss who says: "The type I need was called an 'inventor' a generation ago. The difference is that in 1965 he will need a lot more mathematics, engineering physics, chemistry, hydraulics, electronics, and other book-learning than an inventor needed in 1925. When it comes time to relax, though, you'll find him building something with his hands, and it's probably something pretty clever and unusual that works real well." As it happens, Bob's main hobby is neither bridge nor folk singing.

Old Hip calls square dances and doesn't care who knows. Policy proscribes discussion of the nature but not of the philosophy of his engineering. His boss puts it: "In consumer and commercial products, where regular service can easily be part of the engineering plan, perfection would carry a price tag that made no sense. With us, a perfect score is the only acceptable goal. Nothing less makes economic sense. Before our guys can think of what is sensible, they have to think of what is possible. It can be very enjoyable for the right type of smart apple."

Drop us a line if you can see yourself as any of these three right types, whether in mechanical engineering, chemical engineering, electronic engineering, chemistry, or physics.

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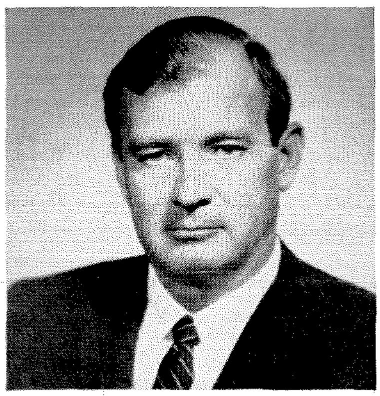
Advancement in a Big Company: How it Works

An Interview with General Electric's C. K. Rieger, Vice President and Group Executive, Electric Utility Group



C. K. Rieger

■ Charles K. Rieger joined General Electric's Technical Marketing Program after earning a BSEE at the University of Missouri in 1936. Following sales engineering assignments in motor, defense and home laundry operations, he became manager of the Heating Device and Fan Division in 1947. Other Consumer-industry management positions followed. In 1953 he was elected a vice president, one of the youngest men ever named a Company officer. Mr. Rieger became Vice President, Marketing Services in 1959 and was appointed to his present position in 1961. He is responsible for all the operations of some six divisions composed of 23 product operations oriented primarily toward the Electric Utility market.

Q. How can I be sure of getting the recognition I feel I'm capable of earning in a big company like G.E.?

A. We learned long ago we couldn't afford to let capable people get lost. That was one of the reasons why G.E. was decentralized into more than a hundred autonomous operating departments. These operations develop, engineer, manufacture and market products much as if they were independent companies. Since each department is responsible for its own success, each man's share of authority and responsibility is pinpointed. *Believe me, outstanding performance is recognized, and rewarded.*

Q. Can you tell me what the "promotional ladder" is at General Electric?

A. We regard each man individually. Whether you join us on a training program or are placed in a specific position opening, you'll first have to prove your ability to handle a job. Once you've done that, you'll be given more responsibility, more difficult projects—work that's important to the success of your organization and your personal development. Your ability will create a "promotional ladder" *of your own.*

Q. Will my development be confined to whatever department I start in?

A. Not at all! Here's where "big company" scope works to broaden your career outlook. Industry, and General Electric particularly, is constantly changing — adapting to market the fruits of research, reorganizing to maintain proper alignment with our customers, creating new operations to handle large projects. All this represents opportunity beyond the limits of any single department.

Q. Yes, but just how often do these opportunities arise?

A. To give you some idea, 25 percent *of G-E's gross sales last year came* from products that were unknown only five or ten years ago. These new products range from electric tooth brushes and silicone rubber compounds to atomic reactors and interplanetary space probes. This changing Company needs men with ambition and energy and talent who aren't afraid of a big job—who welcome the challenge of helping to start new businesses like these. Demonstrate your ability—whether to handle complex technical problems or to manage people, and you won't have long to wait for opportunities to fit your needs.

Q. How does General Electric help me prepare myself for advancement opportunity?

A. Programs in Engineering, Manufacturing or Technical Marketing give you valuable on-the-job training. We have Company-conducted courses to improve your professional ability no matter where you begin. Under Tuition Refund or Advanced Degree Programs you can continue your formal education. Throughout your career *with General Electric you'll receive* frequent appraisals to help your self-development. Your advancement will be largely up to you.

FOR MORE INFORMATION on careers for engineers and scientists at General Electric, write Personalized Career Planning, General Electric, Section 699-11, Schenectady, N. Y. 12305

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