ENGINEERING AND SCIENCE

JANUARY/1957

Miller's mushrooms . . . page 3

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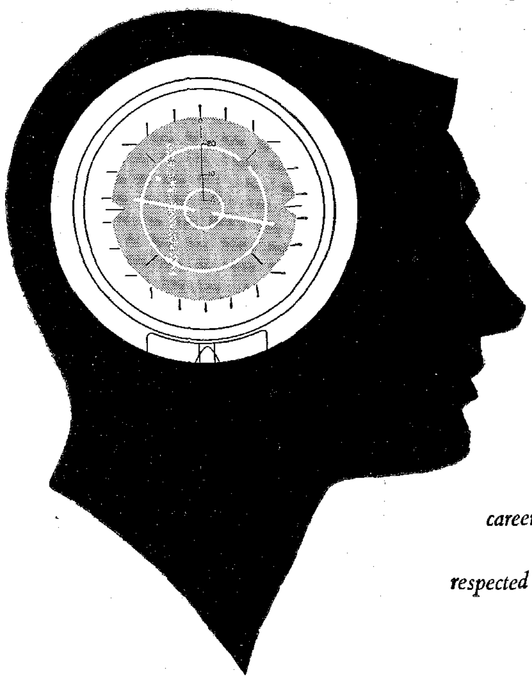

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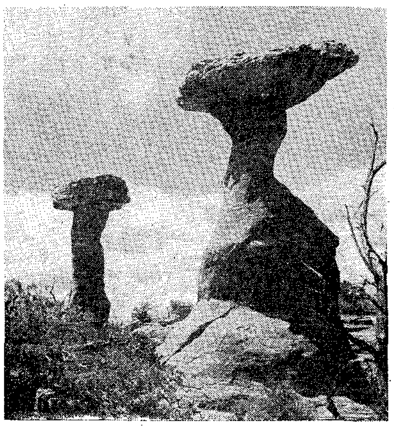
ENGINEERING AND SCIENCE

IN THIS ISSUE



On the cover this month—some rock formations discovered by William C. Miller, official photographer for the Mount Wilson and Palomar Observatories. Mr. Miller's avocation is to look for prehistoric Indian ruins in Arizona, and he came across the two objects pictured on our cover when he was exploring in the Navaho country of northern Arizona several summers ago.

These distorted shapes, which look like giant mushrooms, have been formed by centuries of falling rain. The tops are actually fragments of the hard cap rock of the mesa, which fell from cliffs centuries ago. The stems are soft sandstone, which has survived under the protection of these durable umbrellas.

Officially, Bill Miller has been with the Mount Wilson and Palomar Observatories since 1949. Unofficially, he worked as a volunteer observer on Mount Wilson for 15 years before that. He was an optical engineer then, designing optical instruments and, during the war, periscopes and bombsights. On weekends and holidays, though, he worked on Mount Wilson, photographing the stars.

In recent years, Bill Miller's spare time has been devoted to exploration—mostly in the inaccessible areas of Arizona's Navaho country. These are never mere pleasure trips—as almost any of the Caltech graduate students who have accompanied Miller can tell you. In fact, Miller and his companions did

CONTINUED ON PAGE 6

PICTURE CREDITS

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More graduate engineers moving up in the GAS industry ...the nation's sixth largest

The Gas industry—the sixth largest in the nation—has a total investment of over $15 billion. Last year the industry set a new all-time record in number of customers, volume of gas sold, and dollar revenue. In fact, Gas contributed 25% of the total energy needs of the nation as compared with 11.3% in 1940. The Gas industry is a major force in the growth development and economic health of this country.

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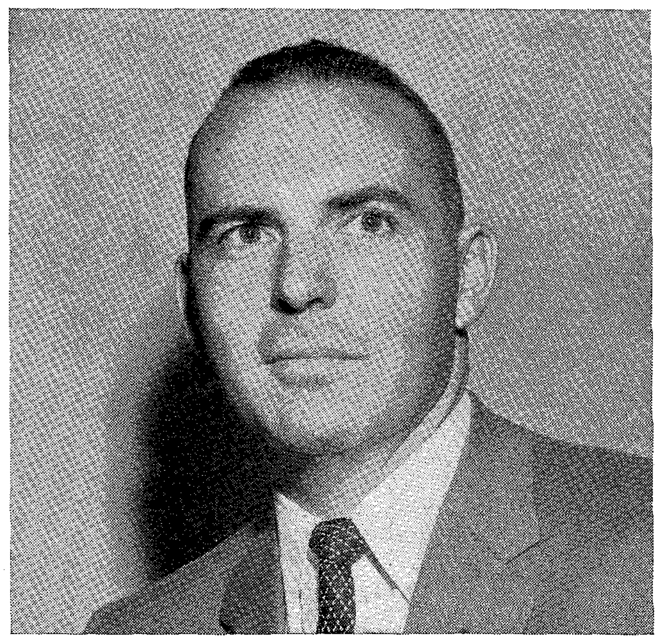
JOSEPH J. DRECHSLER
B.S. in Mechanical Engineering, 1948, Johns Hopkins University

Joe Drechsler, after 8 years with Baltimore Gas and Electric Company, is now Assistant Superintendent in a department with over 450 employees

After completing the company's Student Engineering Training Program, Joe spent one year in the Gas and Steam Testing Laboratory. He was then promoted through various levels of engineering and supervisory assignments, to his present job of Assistant Superintendent on April 1, 1956. This department has over 450 employees and is responsible for the installation and servicing of industrial, commercial and domestic gas appliances on customers' property, and the installation and servicing of gas and steam metering and pressure recording equipment.

ROBERT K. VON DER LOHE
B.E. in Industrial Engineering, 1948, University of Southern California



In just 6½ years with Southern Counties Gas Company of California, Robert K. Von Der Lohe has become Manager of Commercial and Industrial Sales

After two years with a construction engineering firm, Bob Von Der Lohe joined the gas company and began his steady climb to his current position. Starting as an assistant technician in 1950, Bob has moved up through the jobs of industrial sales engineer and staff representative-industrial sales, to his present post as Manager, Commercial and Industrial Sales. Bob does more than "sell" industries and commercial operations on the use of gas. He also supervises a staff which advises restaurant and hotel owners on ways to improve their gas operations and over-all productive efficiency.

In This Issue . . . CONTINUED

Expedition to Navaho Canyon, 1955. Top row: Bill Miller and Barclay Ray, geology grad student. Seated: Dr. Robert C. Euler, archaeologist, and Ronald Shreve, geology grad student.

such impressive work that, in 1952, their annual expeditions began to be made in conjunction with the Museum of Northern Arizona in Flagstaff.

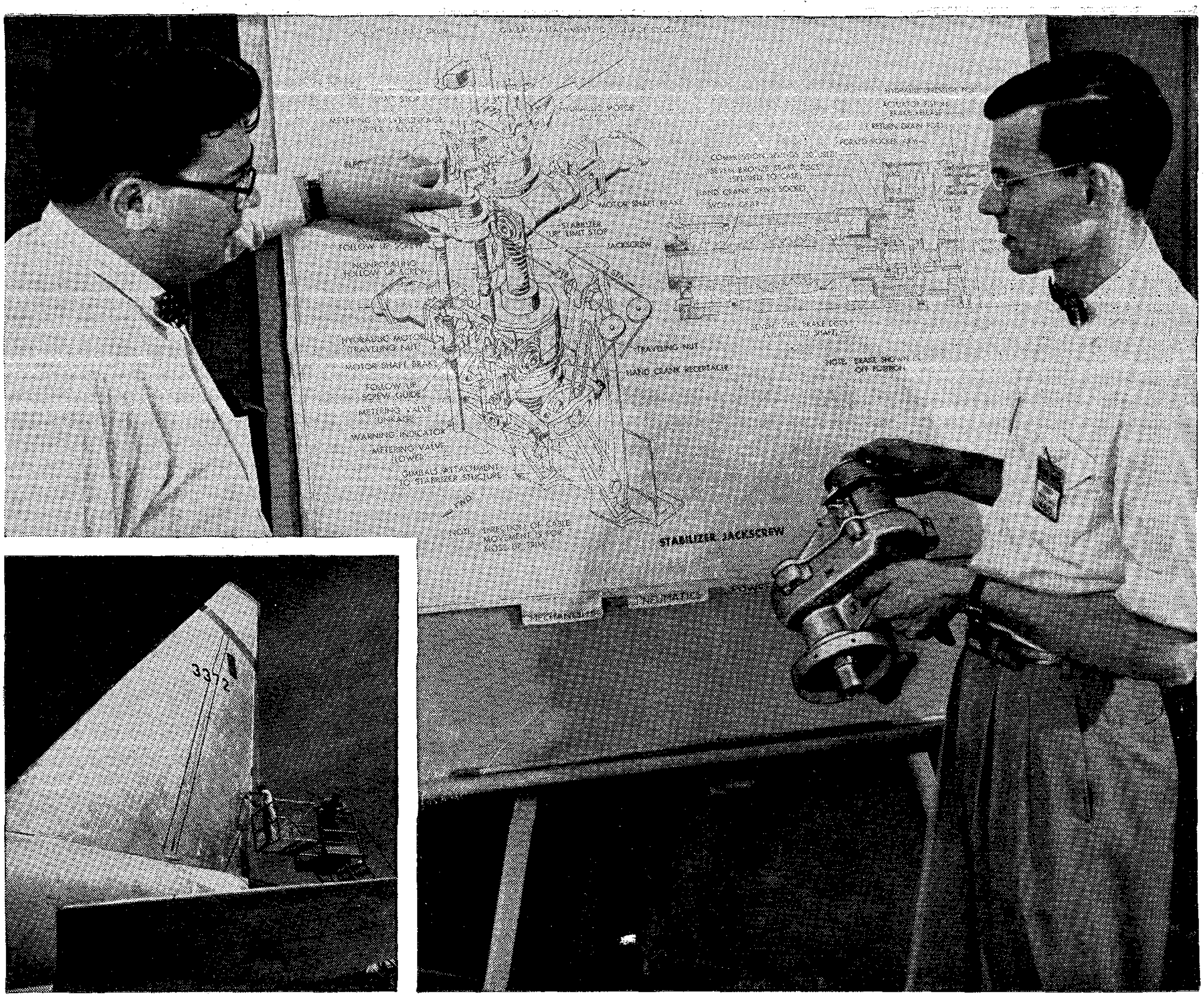
Bill Miller's major objective, since then, has been to survey the intricate canyon network in Navaho Canyon, and to locate, map, and record all the prehistoric ruins he could find. A few samples of his extensive photographic record of these explorations are shown on pages 22-25.

"The Birth and Death of a Star," on page 17, was originally given as a talk by Allan Sandage, before the trustees and staff of the Carnegie Institution of Washington, last month. Dr. Sandage, who was graduated from the University of Illinois in 1948, received his PhD in astronomy from Caltech in 1953. He served as an assistant in astronomy here from 1949 to 1952, when he became a staff member of the Mount Wilson and Palomar Observatories.

Herschel K. Mitchell, who wrote "Vitamins Are Here to Stay," on page 26, came to Caltech from the staff of Stanford University in 1946. He is now professor of biology here.

A good part of Dr. Mitchell's early research was done on the B-complex vitamins, and he played a major role in the isolation and identification of the vitamin, folic acid. He was also one of the group which first determined the structure and then worked out the synthesis of pantothenic acid, another important member of the Vitamin-B group.

"The Uniqueness of Man," on page 34, is the text of a speech given by George W. Beadle at the annual meeting of the American Association for the Advancement of Science in New York City last month. This was, in fact, Dr. Beadle's retiring presidential address before the society. Chairman of the Division of the Biological Sciences at Caltech, Dr. Beadle was president of the AAAS in 1955-56.



B-52 jack screw—a typical Boeing design challenge

On Boeing B-52 bombers, the horizontal tail surface has more area than the wing of a standard twin-engine airliner. Yet it can be moved in flight, up or down, to trim the aircraft.

The device that performs this function is a jack screw, which, though it weighs only 255 pounds, can exert a force of approximately 225 *tons!*

Many kinds of engineering skills went into designing and developing a jack screw so precise that it automatically compensates for stretch and compression under load. Civil, electrical, mechanical and aeronautical engineers, and mathematicians and physicists — all find challenging work on Boeing design projects for the B-52 global jet bomber, and for the 707 jet tanker-transport, the BOMARC IM-99 pilotless interceptor, and aircraft of the future.

Because of Boeing's steady expansion, there is continuing need for additional engineers. There are more than twice as many engineers with the company now as at the peak of World War II. Because Boeing is an "engineers' company," and promotes from within, these men find unusual opportunities for advancement.

Design engineers at Boeing work with other topnotch engineers in close-knit project teams. They obtain broad experience with outstanding men in many fields, and have full scope for creative expression, professional growth and individual recognition. And they find satisfaction in the high engineering integrity that is a Boeing byword.

In addition to design engineering, there are openings on other Boeing teams in research and production. Engineers like the life in the "just-right" size communities of Seattle and Wichita. They may pursue advanced studies with company assistance in tuition and participate in a most liberal retirement plan. There may be a place for *you* at Boeing-Seattle or Boeing-Wichita.

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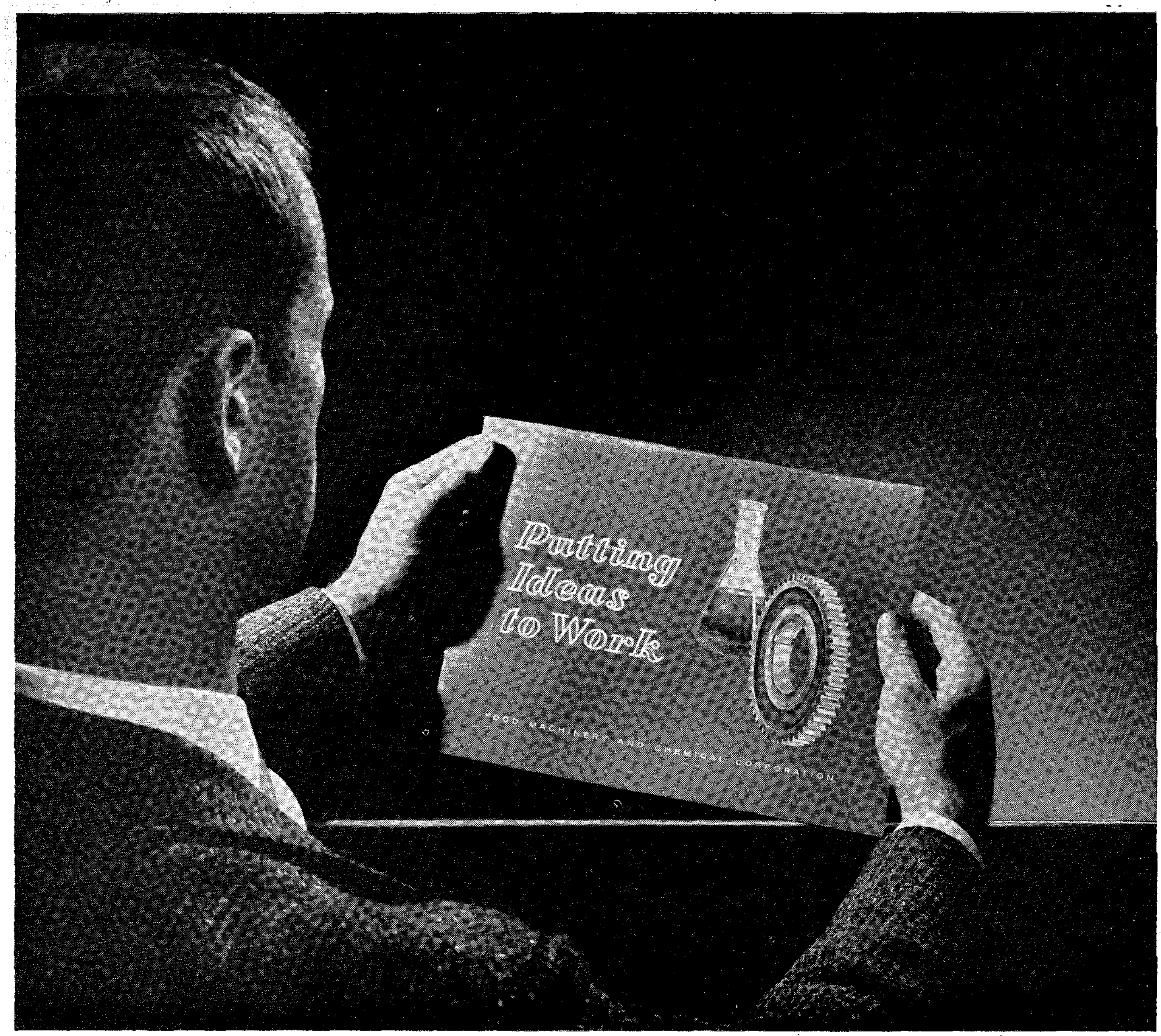
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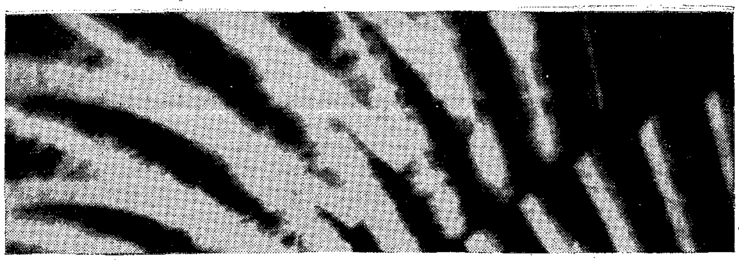
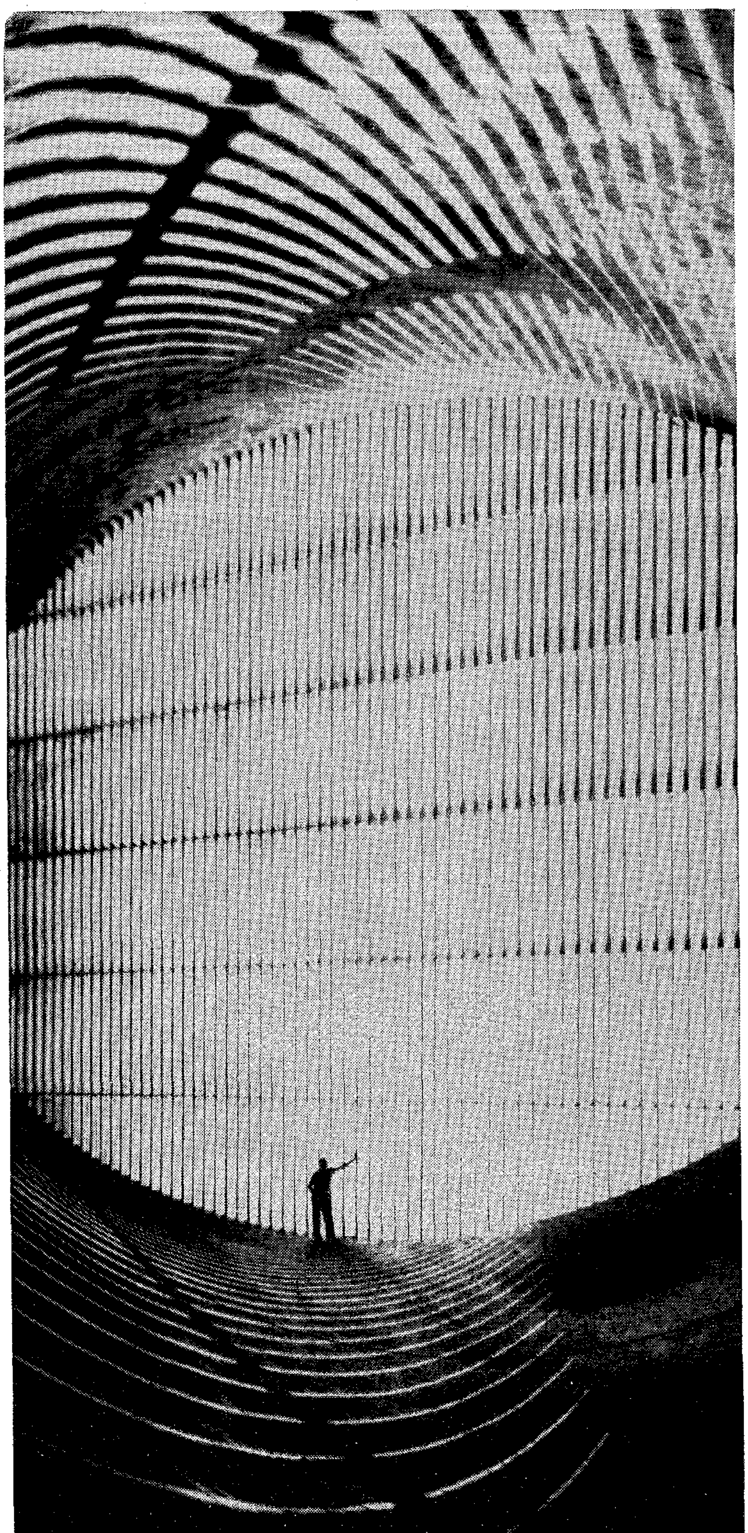
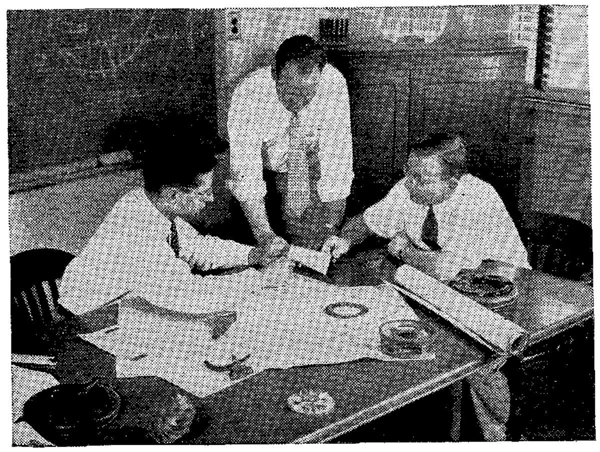
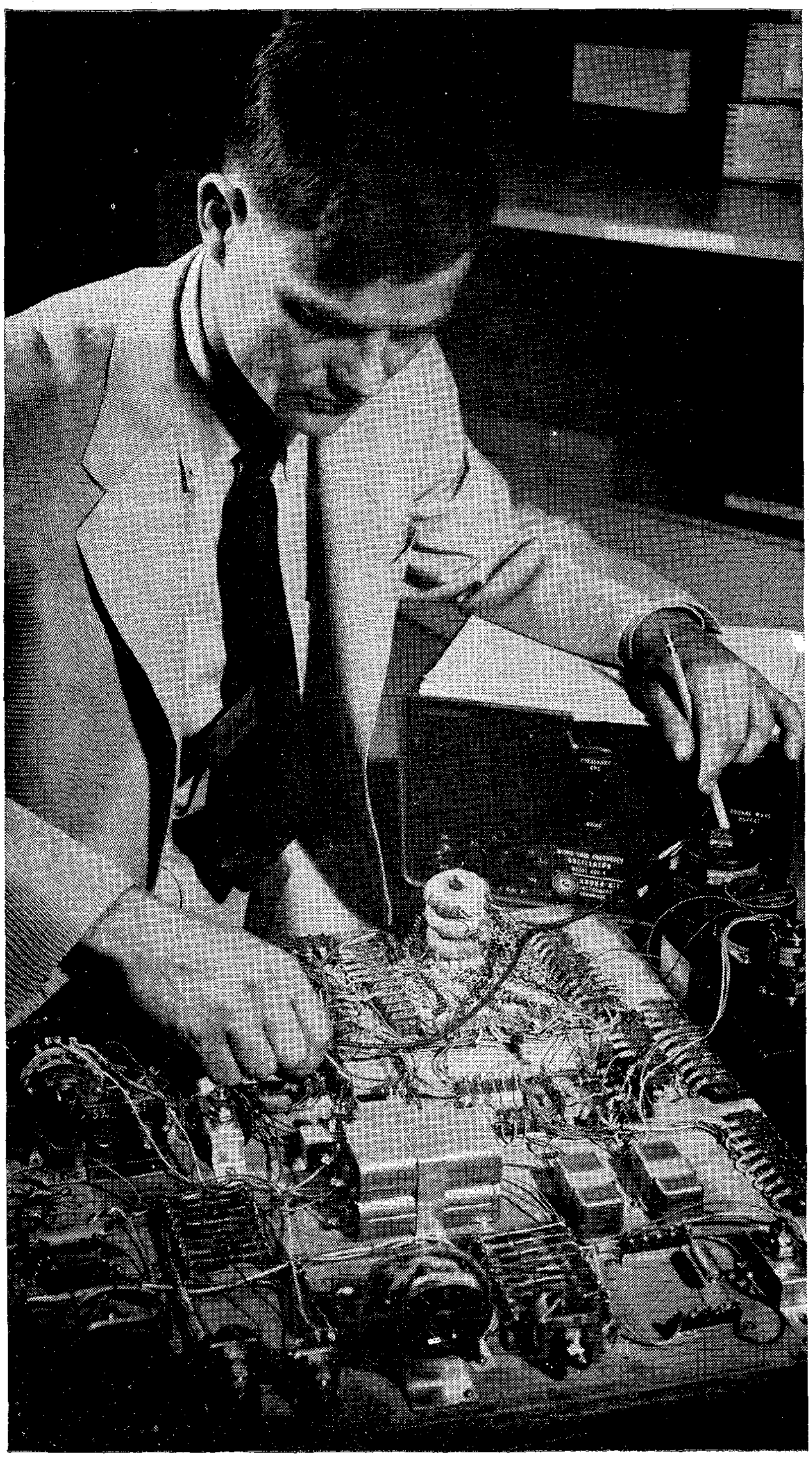






How keen is your

IMAGINEERING?



This young Sperry engineer is developing a component in a new control system to be used on intercontinental multi-jet bombers. Can your imagination tell you what it is?

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ANSWER:
This Sperry engineer is testing transistor-magnetic amplifier servomechanism used in computer of advanced turbine control system.

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BOOKS

GEOLOGY AND OURSELVES
by F. H. Edmunds
Philosophical Library, N.Y. $10

Reviewed by Robert P. Sharp, Chairman of the Division of Geological Sciences

An author should be judged largely upon what he sets out to do. The announced aim of this book is "to show how the science of geology enters into our everyday life." Mr. Edmunds enjoys a modest success in this endeavor.

Man of experience

The strongest fibers in the book spring from the author's experiences during more than 30 years of service on the staff of the Geological Survey of Great Britain in which he developed a varied and extended acquaintance with many practical applications of geology such as water supply, building materials, and civil and structural engineering. Much of the virtue of these chapters arises from the citation of actual examples and occurrences pertinent to the subject matter.

The first third of the book is devoted to an introduction on material, scope, and concepts of geology. It is necessarily so brief that the book might be better without it, especially since the remaining two-thirds is not heavily dependent upon this introductory material. Fortunately, the author has an informal, easy style which produces the effect of a person-to-person conversation, and some statements are as good as any to be found in the geological literature, as for example the paragraph comparing topographical and geological maps (p. 80). However, the treatment of subjects is spotty and uneven. This book is clearly something Mr. Edmunds has had in mind for a long time, and as a consequence some of the material and some of the illustrations are not of the most recent vintage.

For non-professionals

The professional, either geologist or engineer, will probably not find this volume a must for his book shelf, but the person unversed in earth science will find parts of the last eight chapters both good and easy reading.

THE BIRTH AND DEATH OF A STAR

Astronomical studies of the life histories of the stars lead to some interesting speculations about our own future

by ALLAN SANDAGE

THE MASTER PROBLEM in the field of stellar evolution is to describe, explain, and understand the life histories of the stars, from the time they were created and began to shine, until the time they exhaust their fuel supply and become dark clinkers on the stellar ash heap.

It was not so many years ago that the topic of stellar evolution was considered to be nothing but speculation—a fit subject of conversation on those dark and stormy nights when observational astronomers have leisure. But today, stellar evolution is a rapidly developing field of astronomical research, touching almost every branch of astrophysics. The genesis of this change occurred in 1938 when the physicist Hans Bethe found that the source of stellar energy is atomic. Reasoning from general principles of nuclear physics, Bethe outlined the now famous set of catalytic nuclear reactions called the carbon cycle, which operates in the stars and which converts four hydrogen atoms into one helium nucleus with a subsequent release of energy. This discovery opened the door to detailed studies, both by the theoretical astrophysicists and the observational astronomers, of the way in which the structures of the stars change as they age.

The problem of tracing the life history of a single star like the sun is most difficult because the time scale for stellar evolution is enormous. Put in familiar terms, the astronomical problem is similar to the dilemma of a biologist if he were required to describe the aging process in human beings by observing the human scene for half a minute. We shall later see that the life-span of the sun is about 12 billion years. Because the human span is short, any particular astronomer can observe the sun for less than one part in a hundred million of the total solar lifetime.

Now, obviously, the biologist cannot direct his attention to a single individual and expect to find evidence of aging in 30 seconds. He must rather devise some indirect method to solve his problem, such as surveying a large sample of the human population and noting age parameters among this sample. Variations in the size of individuals could be one difference which depends upon age. The degree of wrinkling of the face or the baldness of the human head would be others. A careful study of such differences would permit our biologist to construct a reasonable picture of human development. This snapshot method of solution is the only one available to the astronomer, and by its use a theory of stellar development has emerged.

Inspection of the stars in our immediate neighborhood gives evidence of a large diversity of age. Unmistakable signs of extreme youth are found side by side with extreme old age. The oldest stars date to nearly the beginning of the universe, while the youngest are less than a million years old. Astronomers determine stellar ages the same way that a heat engineer finds the burning time of a coal furnace, when he knows the amount of coal

"The Birth and Death of a Star" was adapted from a talk given before the trustees and staff members of the Carnegie Institution of Washington in Washington, D.C., on December 13, 1956.

Messier 16, a region in the Milky Way Galaxy, is one of the many places where stars are being born today. The bright areas are large clouds of gas and dust illuminated by nearby stars.

contained within his furnace and knows the rate at which his fuel is being consumed.

As we have seen, the source of stellar energy is atomic, obtained from the conversion of hydrogen into helium. We know from nuclear physics how much energy is released per nuclear conversion. We also know how many hydrogen atoms are available in a given star (that is to say, we know the star's mass). We therefore know the total potential energy content of the stars. For any particular star, observational astronomy gives the *rate* at which this available energy is being used up and radiated into space. Ipso facto, the age of that star is determined.

Direct measurements of stellar distances and light intensities show that some stars are spendthrift of their fuel supply. They release into space over one-millionth of their energy store every year. At this rate, their entire available energy supply will be exhausted in a million years and they will die of fuel starvation. Because such stars are visible in our skies today we know they must have been created less than a million years ago.

A million years is an extremely short time in terms of the total age of the universe. It is about equal to the time that has elapsed since some rudimentary form of man first emerged upon earth. We therefore have good evidence for the creation of stars within very recent geological times. It is indirect evidence to be sure, because a star has never actually been seen in the process of creation, but something almost as convincing is observed.

It is a remarkable fact that these very young and highly luminous stars are found in and *only* in regions of our galaxy containing large amounts of free cosmic gas and dust. This strongly suggests that the birthplace of new stars is in the dust clouds between the older stars, and that this dust is the material out of which stars condense.

These observations are so suggestive that astronomers now believe (perhaps somewhat optimistically) that they know what physical processes must take place in the creation of new stars. Presumably, when the density of a cloud of gas and dust becomes large enough, a sizable segment of the cloud becomes gravitationally unstable and begins to collapse under its own weight. The packing of matter into a smaller and smaller space due to slow collapse releases energy from the gravitational field and the gas and dust becomes hot. And as this pre-star condenses more and more, the central temperature within the globule goes higher and higher until, at the stage where the volume has shrunk a billion, billion times, the temperature and density are large enough for collisions between the hydrogen atoms to begin. These collisions lead to nuclear reactions of the same type as in a hydrogen bomb. At this stage an explosion does *not* occur, however, because a new star has the unfailing ability to adjust itself to release this energy gradually, contrary to the conditions inside a bomb. When nuclear reactions begin, the contraction of our protostar stops and a stable star is born.

Stable stars

A stable star is one of nature's most magnificent inventions. The large amount of matter within a star is in equilibrium at every point; that is to say, it neither collapses nor expands. This means that a star arranges itself so that the forces acting on every small element of volume in the interior just balance. These forces are the gravitational force tending to pull the material toward the center, and the pressure of the gas tending to push the material outward. From the laws of physics we know that the pressure of the gas is determined by the temperature, and the gravitational pull by the total mass. The higher the mass of the star, the higher the central temperature must be to overcome the increased gravitational force.

But this is not the whole story, because the rate of nuclear reactions also depends critically on temperature. At high temperatures the hydrogen atoms are speeding about at breakneck speeds and collisions are frequent. High temperature therefore means high energy production and a very luminous star is the result. From similar arguments it can be shown that the final radius of our stable star depends upon the distribution of pressure, which is also given once the mass is known. Hence all the conditions of a stable star—i.e., its radius, its luminosity, and, as a direct consequence, its surface temperature—are determined by the total mass.

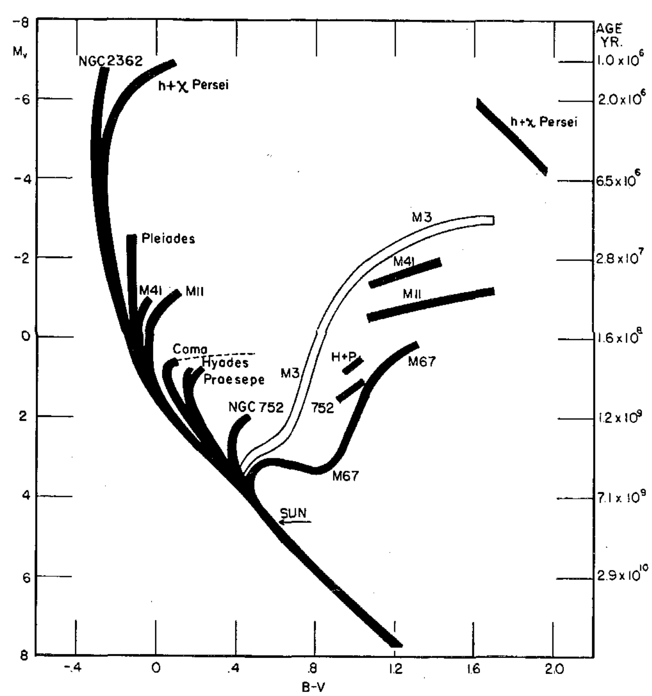
This means that there is a unique relation between surface temperature and the luminosity of the stars, and these are quantities which can be found directly by observation. The astronomer summarizes this information in the so-called color magnitude diagram (right), where the observed data are plotted for all stars. New stars which are just at the beginning of their evolutionary life lie on a line in this diagram which is called the main sequence.

It is now of interest to follow the history of a star as time goes on. By fairly easy calculation it can be shown from the theory of stable gas masses that the internal conditions of an aging star must change with time because of the presence of the waste products of the nuclear burning—namely the created helium atoms. These helium atoms are the ashes of the nuclear flame and remain deep in the stellar interior, close to their place of formation.

At first glance it would seem that helium atoms replacing the original hydrogen would not make much difference to the balance of forces within the star but this is not correct. Atom for atom, helium weighs four times as much as hydrogen and this weight difference per particle means that, for the same temperature, there is a difference in pressure of hydrogen and helium gas.

Detailed consideration of the relevant physical processes shows that the star compensates for the change in its internal chemical composition by increasing in radius and luminosity. It must brighten and expand to remain stable as the helium content increases. This change occurs quite gradually until 12 percent of the original hydrogen supply has been transferred into helium. During this period of gradual change, the star remains close to the main sequence. The sun is now in this stage of its evolution, because it has converted only 6 percent of its available hydrogen supply into helium.

Theory tells us that when 12 percent of the fuel has been exhausted, the star can no longer compensate for its increased helium content by small changes, but must drastically increase in radius and move rapidly



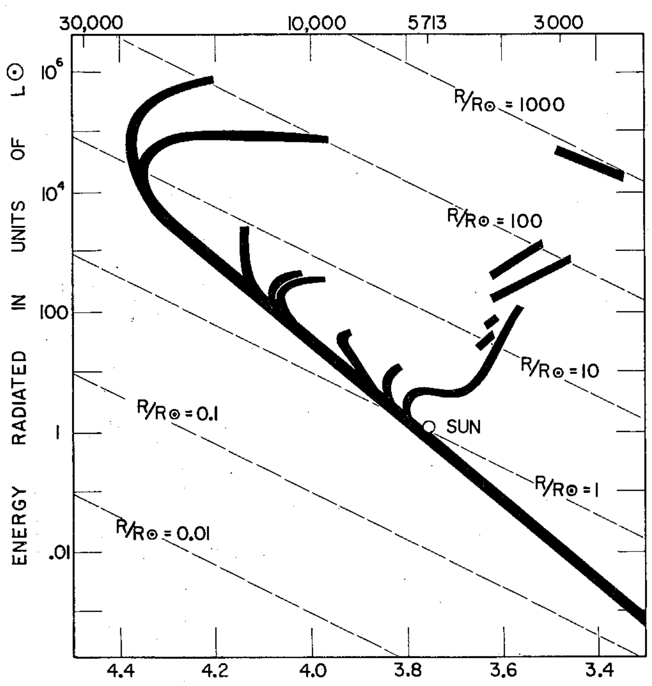
Color-magnitude diagram for stars in the individual clusters named above. The horizontal scale (B-V) is a measure of color or surface temperature. Blue stars are to the left, red stars to the right. The vertical scale is a logarithmic measure of the energy output.

from the main sequence. At this point the star is near the end of its life, because it swiftly increases in luminosity, consumes its remaining fuel at a tremendous rate, and finally sinks into obscurity and death as its fuel is depleted.

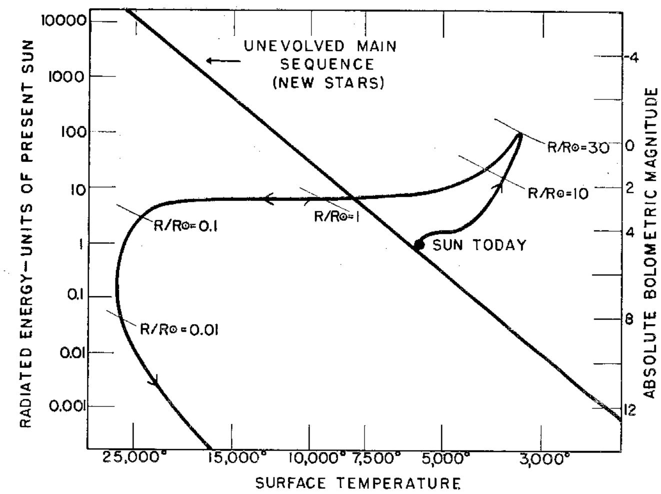
These predictions from the theory of stellar structure are *not* idle speculation. First, they follow from very basic principles of physics, and second, *they are observed to occur* in clusters of stars. We cannot, of course, follow the evolution of a single star for reasons of time scale already explained. However, individual stars in a group are all the same age but have an initial range of mass. They evolve at different rates because the rate of hydrogen consumption increases rapidly with the mass. Hence, in a cluster, we find stars at all different stages in their evolutionary history. We follow the evolution by the snapshot method.

The observational data are shown in the diagram below. The data for a number of different clusters are superimposed on the same diagram. Some stars in this diagram are still near the main sequence, while others have reached the 12 percent limit and have increased rapidly in radius and moved to the right.

From the data in these diagrams we date the stars in the various clusters by the coal furnace method already described. In particular, we can determine the age of the oldest cluster, M 67, to be about 5 billion years. Notice



Temperature (Te)-luminosity (L) diagram showing the position of stars in certain clusters that were shown in the diagram on page 19. The main sequence is the straight line running from the upper left to lower right. New, unevolved stars lie on this sequence; evolved stars lie to the right. The radii of the stars in different parts of the diagram are shown by dotted lines. The unit R⊙ is the present radius of the sun; L⊙ is the luminosity of the present sun.



Temperature-luminosity diagram showing the evolutionary track of the sun. The radius of the sun, in terms of its present value, is shown along the track.

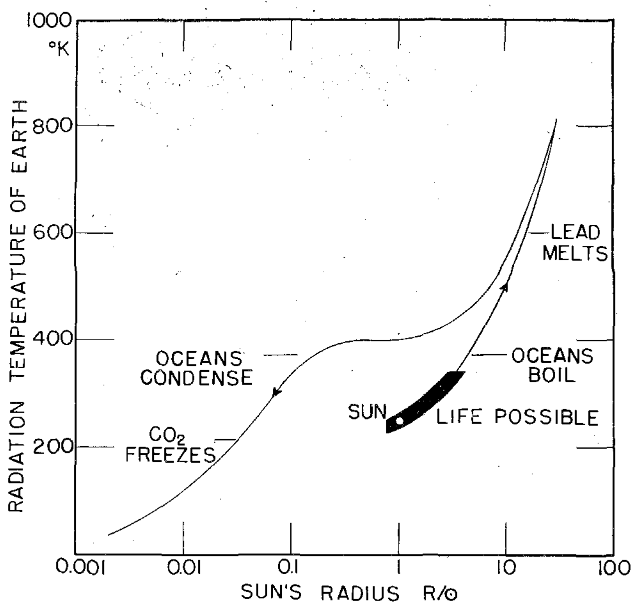
the position of the sun. It has moved slightly from the sequence because it has already consumed part of its fuel and is contaminated with helium. It is still below the 12 percent limit and is comfortably close to the main sequence. The sun has lived perhaps half of its total life span. It is now approaching middle age.

If the theory outlined above is correct, and observation confirms it at every point, we can predict the evolutionary track of the sun for future time and, in particular, determine the effect of such evolution on the conditions of the earth.

There is good reason to believe that the sun's evolutionary track in the color magnitude diagram should be quite similar to the tracks in M 67. From this similarity transformation we construct the predicted track of the sun, which is shown above.

In another 6 billion years the sun will have reached the 12 percent limit and will then begin to expand rapidly in radius, moving to the right in the color magnitude diagram. At its maximum size the aging sun will grow to 30 times its present radius, and will appear in the sky as a dull red globe 15 degrees in diameter, instead of its present ½ degree. In this stage, our sun is burning its fuel at a tremendous rate and will soon after exhaust its hydrogen supply. Now begins the slow decline in brightness along the nearly horizontal track shown in the diagram, until finally the sun must die and most likely will become a white dwarf.

During this interval, conditions on the earth will not remain as they are today but the temperature at the surface must go up. Our state of knowledge of stellar evolution is now advanced to a point where fairly definite predictions of these temperature changes can be made. The diagram at the top of page 21 shows the calculated values of the radiation temperature of the earth plotted against the radius of the sun. There will be a catastrophe to most forms of life when the sun reaches four times its present radius. At this point the earth's temperature will be about 70 degrees centigrade.



How the radiation temperature of the earth will change when the sun alters its radius. Temperature is on the absolute or Kelvin scale, where zero corresponds to minus 273 degrees centigrade.

As the sun continues to expand it will brighten and will drive the temperature first above the boiling point of water and then to the melting point of lead, until finally, at the sun's greatest brightness, the earth's temperature reaches more than 800 degrees centigrade. Life will have ceased, the oceans will have boiled away, and conditions will be miserable.

Under these conditions it would be interesting to compute what the atmosphere of the earth would be like. For one thing the oxygen-carbon equilibrium, which is now in operation due to plant life, will probably be destroyed. For another, the water originally in the oceans will exist as dense clouds high about the earth's surface. These clouds will reflect a large fraction of the sun's rays and the temperatures may be somewhat lower than those shown in the diagram, but not much lower.

From the high of 800 degrees centigrade, the temperature of the earth will decrease as the sun declines in brightness. It will eventually cool until the oceans rain down over the scorched land. This will be a brief period followed by continued cooling until the oceans freeze. And as the sun becomes dimmer and dimmer, the coldness on the earth will be profound.

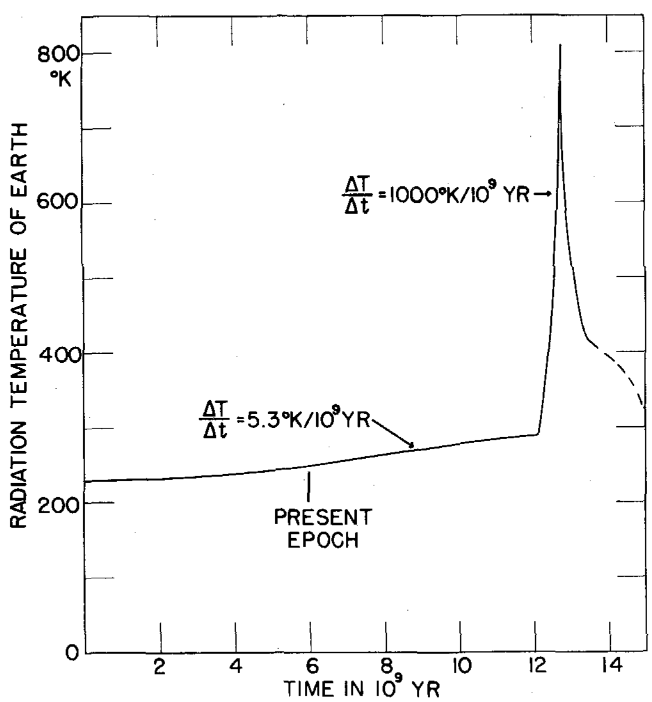
It is of great interest to compute the time scale of these future temperature changes. The diagram at the right shows the variation of the earth's temperature with time. The present age of the sun is taken to be 6 billion years. We see that the rise in the temperature of our planet has been gradual over the past 6 billion years—amounting to less than 20 degrees centigrade. The rise will continue in a gradual way for 6 billion years more and then the catastrophic rise begins which dooms civilization to the final heat death. The end comes rapidly when the temperature goes up 500 degrees in only 500 million years.

In the 6 billion years remaining it is conceivable that biological evolution by adaptive processes can change the human species sufficiently rapidly to compensate for the remaining gradual temperature rise of the earth. Presumably a biologist could in principle predict the course which evolution of the human species must take to meet the changing conditions.

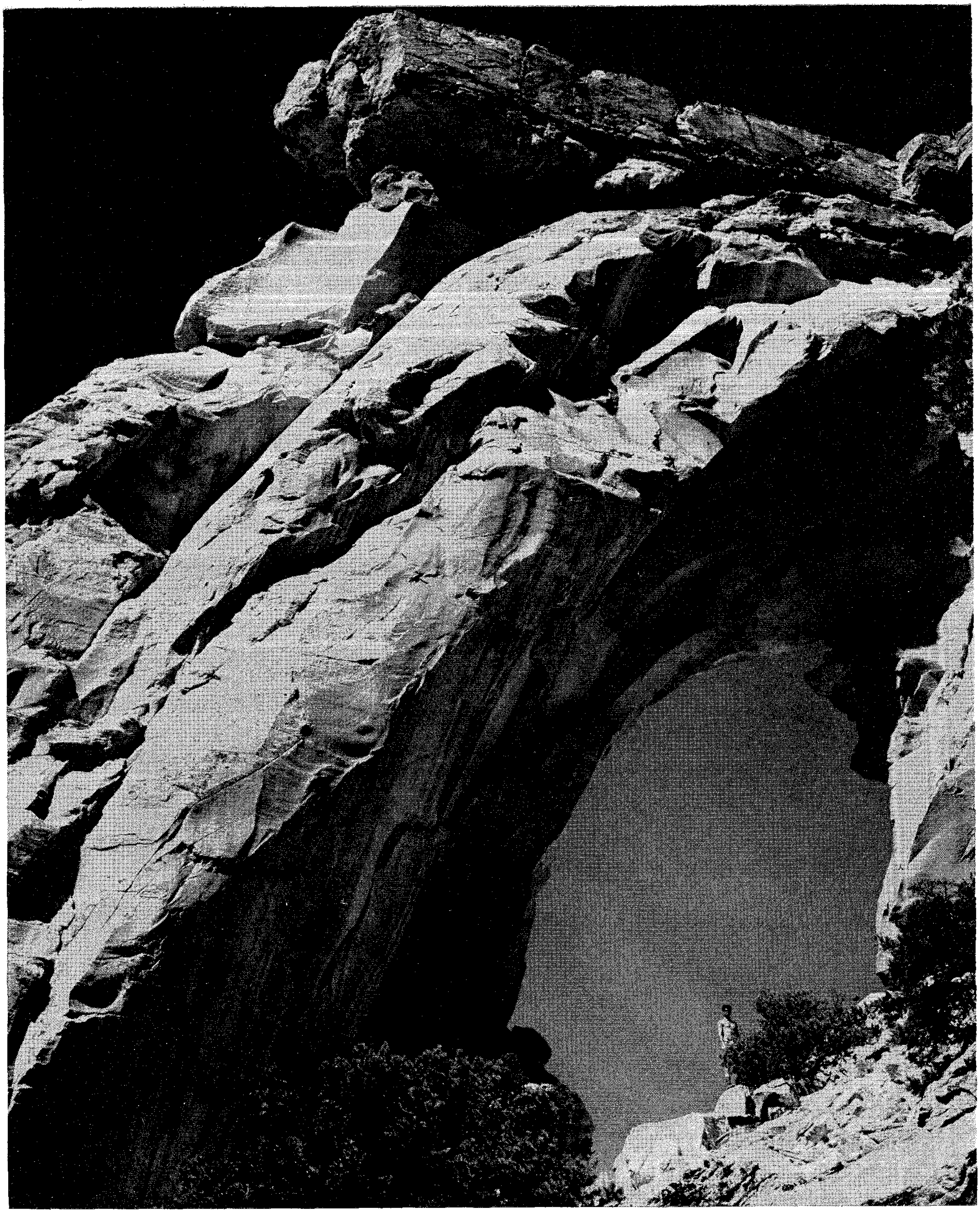
The picture which has just been painted may be one of great terror to sensitive people. From these facts of astrophysics it appears quite likely that human life is doomed by natural processes, if not by man's folly. It is as if the Lord were playing a mad game with things of his creation. After 12 billion years of trial and error, chance mutations and evolution of living matter, the Lord tires of this play and puts his toys away with fire.

But let us not despair of *our* plight. Our sun is only one among millions in our galaxy and our galaxy is but one among millions in the universe. Most astronomers now believe that solar systems like our own are common. If this view holds, then there may be other places much like our own where life exists.

We on this planet are lucky. The rate of aging of our sun is slow. We have another 6 billion years to live. Many stars more massive than the sun exist and here the rate of aging is more rapid. Planets circling these stars go through the same temperature cycles as ours but at a more rapid rate. It follows that there may be people in the universe *this very day* facing the dilemma of the heat death. God made the sun of such a mass that we yet have time ahead. A 10 percent increase of the original solar mass would put us today at the end of life. Is it chance, or does it have some purpose that our sun was not so massive?



How the radiation temperature of the earth will change as time goes on. Average change of temperature per unit time is shown here.



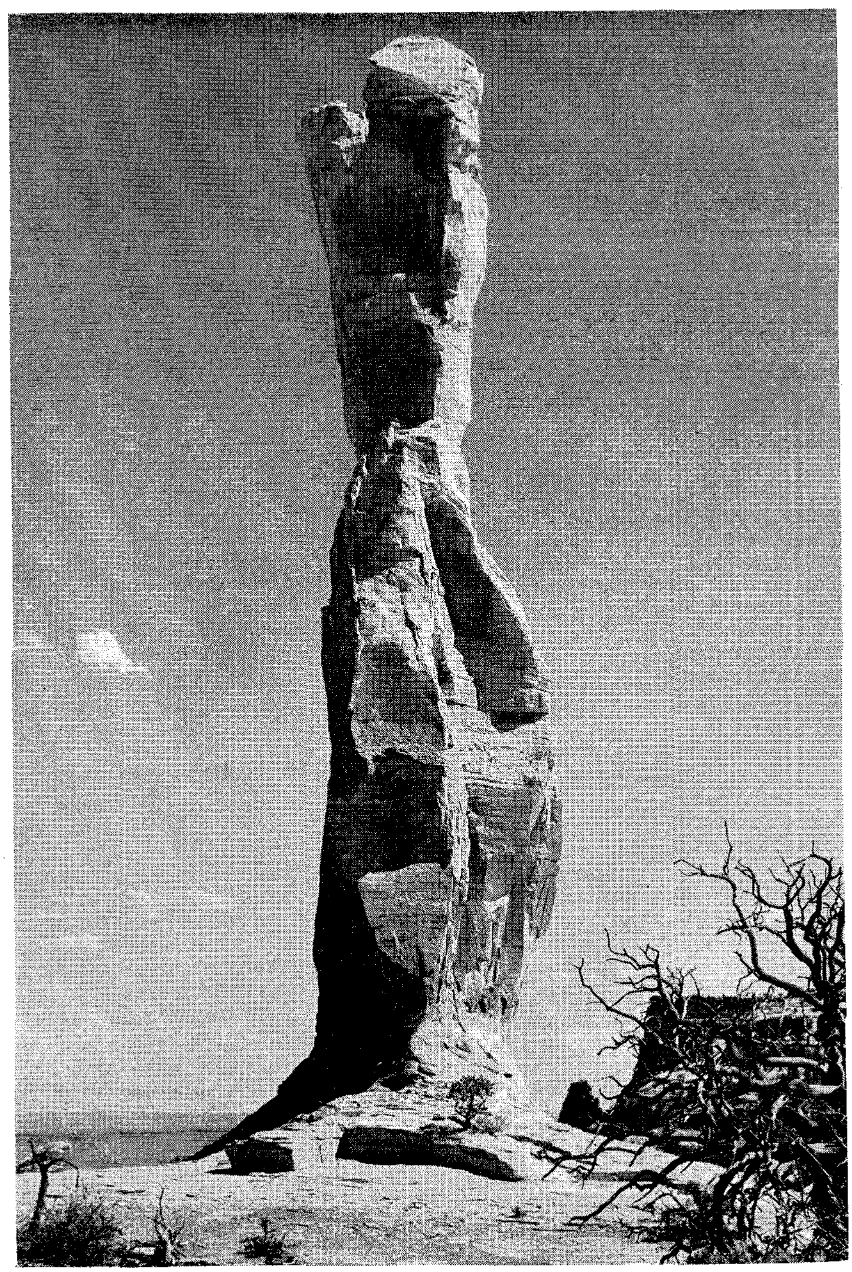
A natural arch, discovered in White Mesa, in the north central part of Arizona. From the canyon floor it looks like a small hole through the rock; close up it's a different story. The boy in the picture is standing 100 feet this side of the arch.

PART-TIME EXPLORER

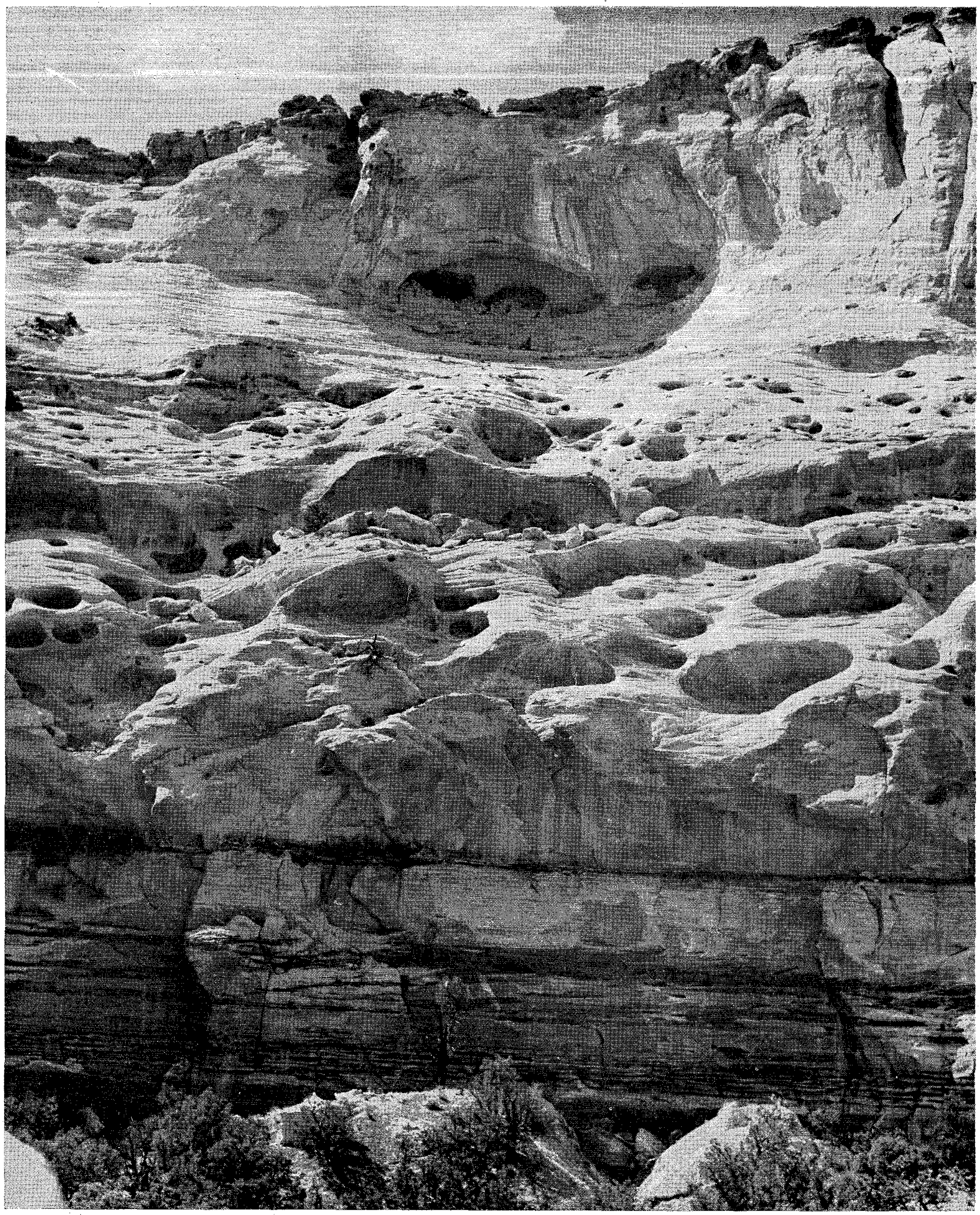
William C. Miller, photographer for the Mount Wilson and Palomar Observatories, leads a double life. Here's a look at the other one.

WILLIAM C. MILLER, official photographer for the Mount Wilson and Palomar Observatories, has been a summer explorer for most of his adult life. In recent years he has concentrated on the Navaho country of northern Arizona. Much of this country is inaccessible except by jeep, and some parts have apparently never been explored before. In fact, Miller and his companions turned up so many new prehistoric ruins that, in 1952, their annual expeditions began to be made in conjunction with the Museum of Northern Arizona.

Now the expeditions have taken on even greater importance because of the recently approved Glen Canyon Dam project. Exploration of some areas will now have to be completed before flood waters from the dam cover over all evidence of the past.

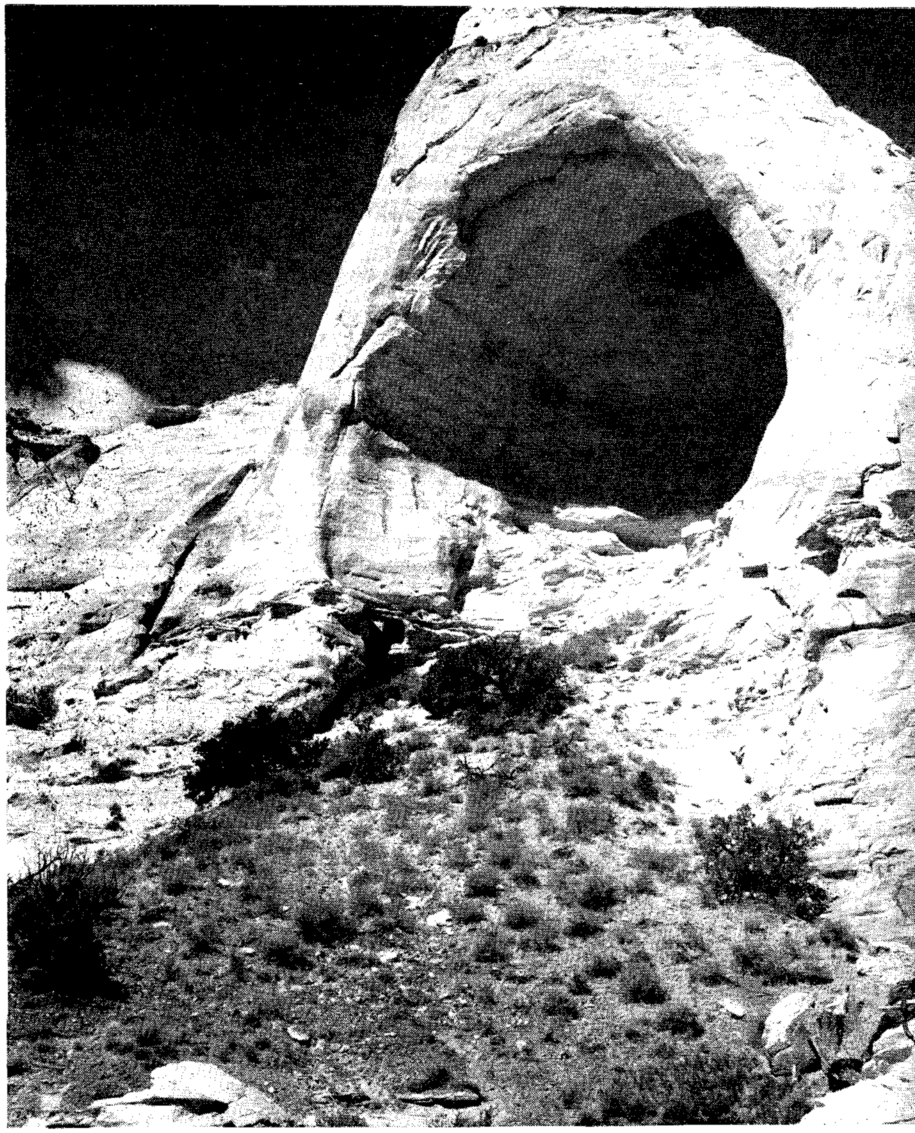


Fragments of pottery around the base of this huge rock indicate that people of the ancient Pueblo culture may have used it as a shrine seven or eight centuries ago.



The cave which lies just under the brow of this pock-marked cliff proved to be the site of some ancient cliff-dwellings. Last occupied between 1250 and 1276 A.D., the cave is all but inaccessible now. Miller and his party discovered it during their 1953 survey of White Mesa.

A thriving village once occupied this cave which is about 120 feet across, 50 feet deep, and nearly 100 feet high. Probably a hundred or more people lived here.



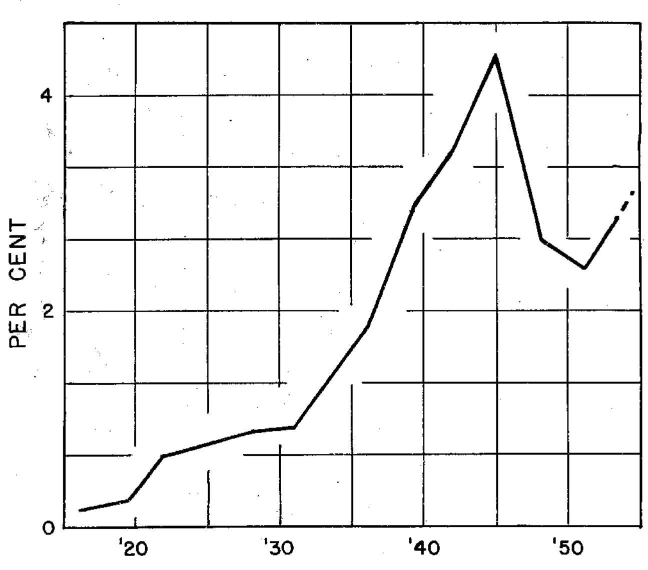
Built in 1247, the famous Betatakin ruins were occupied for only 35 years, until drought drove the people out. These well-preserved cliff dwellings are in the Navaho National Monument.

VITAMINS ARE HERE TO STAY

NEARLY EVERYONE now knows something about vitamins but it was only a few years ago that we really came to know very much about them. An approximate index of relative numbers of scientific investigations and discoveries concerning vitamins is given in the graph below. From this graph it is clear that, for some reason, in the early 1930's, vitamins quite suddenly became a focus of scientific interest. The reason for this is remarkably simple, but, like other scientific advances, this too was dependent on the painstaking accumulation of seemingly unimportant and unrelated facts over a period of many years.

Fossil bones give good evidence that prehistoric man suffered from rickets and scurvy—at least. Other vitamin deficiencies that do not leave such a record are by no means new inventions either. For example, written history of the first thousand years A.D. contains numerous references to the administration of goat liver for the cure of night-blindness—a practice by Greek, Roman, and Arab physicians that was quite sound.

In a similar category, the prevention and cure of scurvy was well known at least by the 16th century, and the Dutch navy practiced the art by providing oranges, lemons and fresh vegetables on long sea voyages. In 1665, a Dutch investigator recommended horseradish pickled in French brandy—a therapy now reminiscent of the tonic era in this country. It is of some interest that in vitaminology, as in many other fields, communication was poor and the records show that scurvy therapy was rediscovered by an Austrian, J. G. Henrici Kramer, in 1720 and again by an Englishman, James Lind, in 1757. Subsequently, as is common knowledge, British mariners acquired the nickname "limeys" from their use of lime juice as a scurvy preventative.



An approximate index of relative numbers of scientific investigations and discoveries concerning vitamins.

Even today it is sometimes difficult to determine who really discovered what in science—but to the best of our knowledge, the Dutch physicians, Christiaan Eijkman in 1897, and G. Grijuns in 1901, are responsible for the beginnings of experimental nutrition with small animals. In the East Indies, where they worked, beriberi was a prevalent disease and the Japanese Navy had already made use of fresh vegetables as a preventative measure.

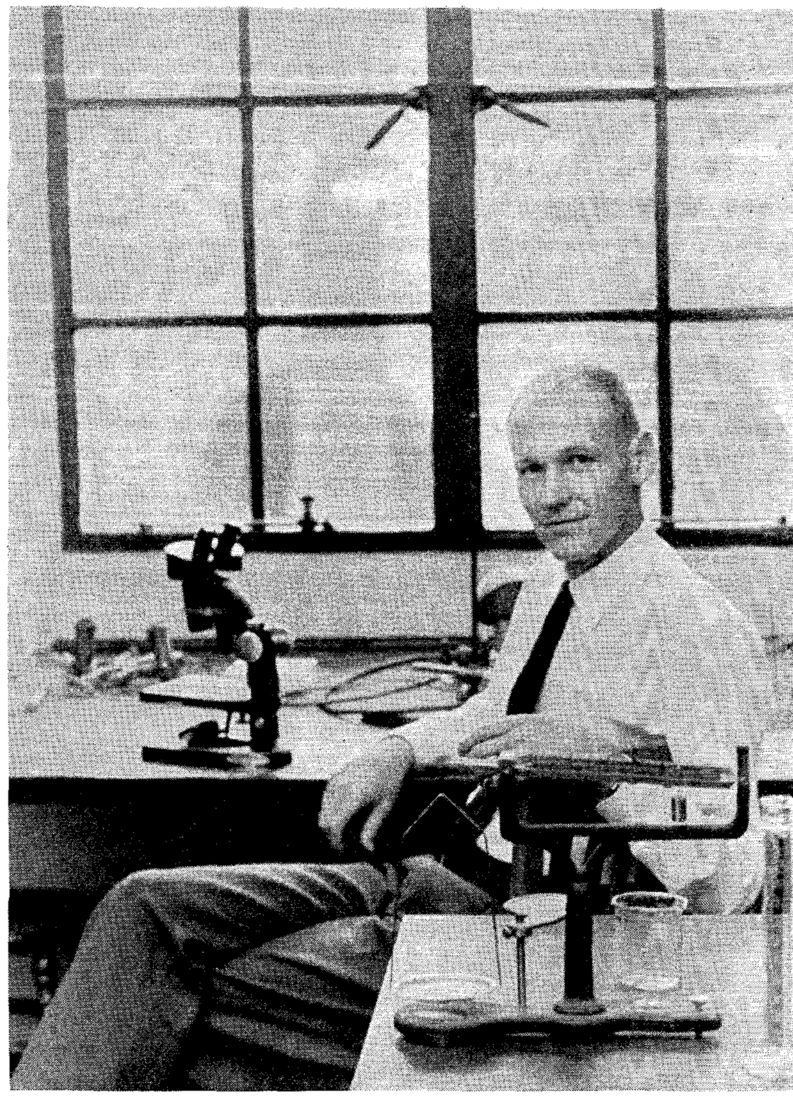
The Dutch investigators demonstrated that a beriberi-like disease was produced in birds fed a diet of polished rice. They established, furthermore, that small amounts of rice polishings would prevent and cure the condition, but there still remained an important question that was not resolved for many years to come: Did the polishings contain a substance that destroyed a beriberi-producing agent or did they contain a substance that is required for normal body functions?

Perhaps this was, or should have been, the seed from which the idea of antibiotics grew, but the nutritional explanation was soon proven and the other went into obscurity. In 1907, the small animal experimental approach moved ahead with an attempt by Axel Holst and Theodor Frölich to produce beriberi in guinea pigs. A deficiency was indeed produced but it turned out to be cured by lemon juice instead of rice polishings, and thus scurvy as well as beriberi became subject to the experimental approach.

Shortly thereafter, in reviewing nutritional problems, in 1912 Casimir Funk proposed the name vitamine (from *vita*, meaning life, and amine, which is a class of chemical substances) for nutritionally necessary materials needed in small amounts, but not for energy or structure building. The *e* was dropped in later years when many of the vitamins were found not to belong to the class of compounds called amines.

During the ensuing two decades, the vitamins were given increased attention with such developments as:

by HERSCHEL K. MITCHELL



purified diets for animals by Sir Frederick Hopkins in 1912; the distinction between "fat soluble vitamin A" and "water soluble vitamin B" by Elmer V. McCollum in 1915; and the production of experimental rickets in rats by May Mellamby in 1918. During this period also there occurred some confusion between vitamin needs and "trace element" requirements (such as iron, copper, cobalt and iodine) but gradually it developed that all are important.

And then too, little by little, the evidence accumulated that the vitamin picture was more complex than it seemed at first. "Fat soluble A" clearly contained more than one active substance and even "water soluble B" was suspected of being multiple in nature. This is how things stood in the late 1920's. There was progress in vitamin nutrition but it was slow. Animal assays to detect vitamins in general took from weeks to months to perform, and progress toward the isolation of vitamins as pure chemical substances was limited by the biological methods. But then the explosion occurred, and to see what set it off it is necessary to go back again to some other matters in history.

For micro-organisms, we usually go back in history to Louis Pasteur, and indeed that is where this part of the story began. Following his demonstration of the origin of microbes from other microbes, in 1871 Pasteur described a procedure for cultivating yeast in a medium containing only purified chemical substances. He reported if such a medium was inoculated with a pinhead *(tête d' épingle)* of yeast, the organism would multiply and flourish.

This experiment led to a heated controversy when Justus Liebig, a prominent biochemist of that time, tried to repeat it and failed. It seems incredible now but the argument was not resolved satisfactorily until 30 years later, in 1901, when Eugene Wildiers brought forth a new principle, with experiments, to explain the discrepancy. He concluded, in effect, that Pasteur's pinhead was larger than Liebig's, and that the larger inoculum (containing probably several million yeast cells) carried along with it traces of a material that was required for continued growth even in the presence of sugar and minerals. This material, which he called "bios," became the subject of investigation by a number of scientists.

Still, a link to vitamins was missing, and there was little reason to think that the lowly yeast might need in its diet the same kinds of substances as animals. Such a link came in 1919, however, when Roger J. Williams demonstrated that the pure anti-beriberi factor (vitamin B_1) was required for the growth of a strain of yeast. But relatively few scientists got excited over this observation. Its significance was not immediately obvious, since it depended on the idea that, if animal vitamins were growth factors for micro-organisms, then perhaps compounds required by micro-organisms would be vitamins for animals.

This idea alone is not sufficient to explain the great outburst of activity in vitamin research that occurred shortly after 1930. There is an additional simple fact of great importance. The rate of growth of micro-organisms can be determined in hours, whereas weeks are usually needed for an equivalent determination using experimental animals. Now, in order to isolate a vitamin in a pure form, it is necessary to try innumerable procedures for purification, and equally necessary to evaluate each step on a quantitative basis by means of a biological assay. The rate of progress on such a problem, though not directly proportional to the speed of bio-assays is certainly strongly dependent on them.

In retrospect, the idea (that growth factors for micro-organisms would also be vitamins for animals) was an excellent one, and few, if any, exceptions have been found. It is a significant fact, however, that the common ground includes only the water soluble vitamins. Requirements for the fat soluble group are peculiar to animals, even though micro-organisms produce some of them. In the great vitamin outburst of 1931 to 1945, animal assays and biological determinations using yeast and bacteria went hand in hand, but there can be little doubt that much of the explosion of activity and discovery was due to the use of micro-organisms.

By 1930, a good many people had the idea that microbial growth factors might be vitamins and a feverish competitive period began. Basic science temporarily ran away with itself in competition with industrial research and development. There appeared to be economic gain in vitamins, and indeed, the business adds up to several hundred million dollars a year today.

Along with the vitamins, the science of microbiology grew by leaps and bounds as investigators made use of all sorts of yeasts, bacteria, and molds in an effort to find new growth factors. Once found, the substances had to be isolated as pure chemicals, and a new methodology for isolations grew also. This isolation was no mean task, since raw materials usually contain vitamins in amounts in the order of one part per million. The easiest way to illustrate this phase—the isolation—is from personal experience.

Vitamins and microbiology

Following the observation that vitamin B_1 (thiamine) was required for yeast, Roger Williams proceeded to examine tissue extract for other yeast growth substances, and, in 1933, published a paper describing some of the properties of a new substance which he called pantothenic acid. In 1937 I had the good fortune to join the Williams group in the later stages of the work on isolation and synthesis of this vitamin. Following its completion, I began at the beginning for the first time, with a liver extract that seemed to contain a new growth factor for a strain of lactic acid bacteria. This is a nerve-racking stage for the tyro, since it is necessary to test repeatedly all the possible known compounds in order to be sure the growth factor is new. Insomnia is not unknown under such circumstances.

We started with liver—a few pounds at a time—and applied all sorts of extraction, adsorption and precipitating procedures, in an effort to separate the growth factor from the million parts of impurity it contained. Each possible procedure was evaluated by bio-assays with the bacteria. There is some logical science in it, but not as much as one would hope for. Pig liver was a satisfactory source of the factor, and from 100 lbs. we obtained several milligrams of highly purified material—but it looked like a ton or more of liver would become necessary. The war years were on the way then, and for some reason I don't understand, the pig liver supply failed.

I put down the phone after learning this and looked out of the window into the middle distance where a gardener was piling grass cuttings into a heap. By the next morning we knew that grass was a good source of the growth factor, and by the end of the week we knew that a major crop of that area (Austin, Texas)—namely spinach—was an excellent source, and at least as good as pig liver.

There were some odd things about spinach, however. If picked in the early morning, the growth factor was far higher than in the afternoon, and, at any time of day, a treatment with chloroform approximately doubled the activity. Following these salient observations, I spent a good many hours at dawn, gathering spinach in a tarpaulin, with a bottle of chloroform in hand to provide for a maximum yield. The farmer, whose spinach field had been rented, didn't understand these details—nor did I at the time. But they all have a reasonable explanation now.

Some eighteen months, about 10,000 bio-assays, and four tons of spinach later, we obtained a few milligrams of crystalline growth factor. This was approximately 200,000 times as pure as the initial extract of spinach, and in order to obtain a gram or so (about ½ teaspoon) for work on chemical structure, it was estimated that about ten times as much spinach would be needed. Accordingly, about 30 more tons (two carloads), were processed with the assistance and equipment made available by one of the drug houses.

Soon after it was established that the lactic acid bacteria growth factor was a new compound, it acquired a name based on its abundance in spinach. The suggestion, folic acid (from *folium*=leaf) by Williams seemed suitable, and this name has been retained by common usage.

A crowded field

As in all cases during this period of great activity in the isolation of growth factors, we were not alone in the field for long, and probably we were not the first to recognize the existence of folic acid. A group of investigators working on substances that would prevent and cure certain types of anemia in monkeys were dealing principally with folic acid in a concentrate they called vitamin M. As subsequently established, folic acid is indeed a vitamin for animals, being effective in man for the cure of certain kinds of anemias.

I expect that this yarn about the isolation of folic acid is more or less typical of many others that could be told of vitamin work during this period of time, although each must have had its own peculiarities. The field became commercialized very rapidly, to the point where industrial research teams took it over almost entirely. By 1945, the rate of discovery of new growth factors had dropped to a low level, although the search is still in progress. Vitamin B_{12} is relatively recent, and only six months ago one of the industrial laboratories announced the isolation of a new growth substance (biopterin) for a species of protozoa. For other reasons, the same substance was isolated and synthesized here at Caltech last year by Hugh S. Forrest, a senior research fellow. Vitamin activity for higher animals remains to be established.

A further point of some interest, already touched on, concerns the quantity of vitamins in tissues. The folic acid case is somewhat representative, and tons of raw materials were needed for isolation of a small amount. Vitamin B_{12} usually occurs in an even lower concentration, while at the other extreme, only a few pounds of raw material is needed for vitamin C isolation.

At the present time, both vitamin B_{12} and riboflavin are produced commercially as a byproduct of mold fermentation. B_{12} comes from a fungus that also produces the antibiotic, streptomycin, whereas the riboflavin is produced in such fantastic quantities by a cotton parasite that it crystallizes out in the vacuoles within the mold and sometimes in the culture medium.

However, in general, there is rough parallelism between concentration in tissues and nutritional requirements. One pound of the least abundant vitamin (B_{12}) is sufficient to provide one day's requirement for about one third of the population of the United States.

A remarkable result of the great upsurge of vitaminology is that now, in this country, we have the best fed chickens and pigs in the world. There is still much to be done with people. One would think that the economic value of productivity by people would be almost as obvious as that of domestic animals, but it is more subtle, of course. In any case, chickens and pigs are the animals of economic value that were used extensively for evaluating new vitamin discoveries, and in terms of eggs and meat, vitamin supplements pay good dividends.

The human side

The human population is somewhat better off too. Through the efforts of some government agencies and private organizations, such as the Nutrition Foundation (industrial support) and the Williams-Waterman Fund (from vitamin B_1 patent royalties) there is now a widespread practice of restoration of vitamins removed during the processing of food for human consumption. This has helped, as has the prescription of vitamins by medical practitioners. Nevertheless, there is little doubt but that additional vitamin supplements would benefit some three quarters of the population of this country, and almost all of the population in many parts of the world.

A summary of some basic information on human vitamin requirements is given in the table at the right. It is well established that all of these substances are essential for human existence, but good diets supply maintenance quantities of most of them, and clear-cut deficiencies in man are not even known for all of them.

Herein lies a subtlety that is most difficult to evaluate for humans, but which has been well documented for chickens and pigs. This has to do with the fact that there is a considerable difference between maintenance and maximum productivity. This question was properly raised and evaluated in an excellent popular book, *Vitamins, What They Are and How They Can Benefit You,* written in 1941 by Henry Borsook, Caltech professor of biochemistry. The value of dietary vitamin supplements for people who live in good economic circumstances was considered in terms of the difference between just existing and existing with the zest of well being. We are appreciably better off now than we were in 1941, but there

VITAMINS
What they are—and what they do

FAT SOLUBLE VITAMINS	DEFICIENCY DISEASE IN MAN	SPECIFIC METABOLIC FUNCTION
Vitamin A	Night blindness	
	Xerophthalmia (degeneration of eye parts)	
	Skin Keratinization	
Vitamin D	Rickets (malformation of bones and teeth)	
	Osteomalacia (decalcification of bones)	
Vitamin E		Indications of involvement in oxidation.
Vitamin K	Hemorrhage	
WATER SOLUBLE VITAMINS		
Vitamin C (ascorbic acid)	Scurvy (multiple abnormalities in tissues and bones)	
Thiamine (Vitamin B_1)	Beriberi (polyneuritis, mental and physical depression, etc.)	Removal of carbon dioxide from and oxidation of keto acids.
Riboflavin (Vitamin B_2)	Mouth sores, vision impairment, dermatitis, etc.	Biochemical oxidations
Niacin (Nicotinic acid)	Pellagra (dermatitis, inflamation, psychic changes, etc.)	Removal of hydrogen atoms from a variety of biochemical compounds.
Pyridoxine (Vitamin B_6)	Mental depression, blood disturbances, etc.	Utilization of amino acids. Nitrogen metabolism.
Pantothenic acid		Metabolism of organic acids and fats. Transfer reactions.
Choline	Liver disease	
Inositol		
Biotin	Dermatitis, muscle pains, etc. (Produced in man by feeding raw egg white.)	
Folic acid and citrovorum factor (Folinic acid)	Anemia, diarrhea, etc.	Utilization of one-carbon compounds. Synthesis of nucleic acids. (Exact cofactor not known)
Vitamin B_{12}	Pernicious anemia	

is still room for improvement. In this country it is within the reach of each of us.

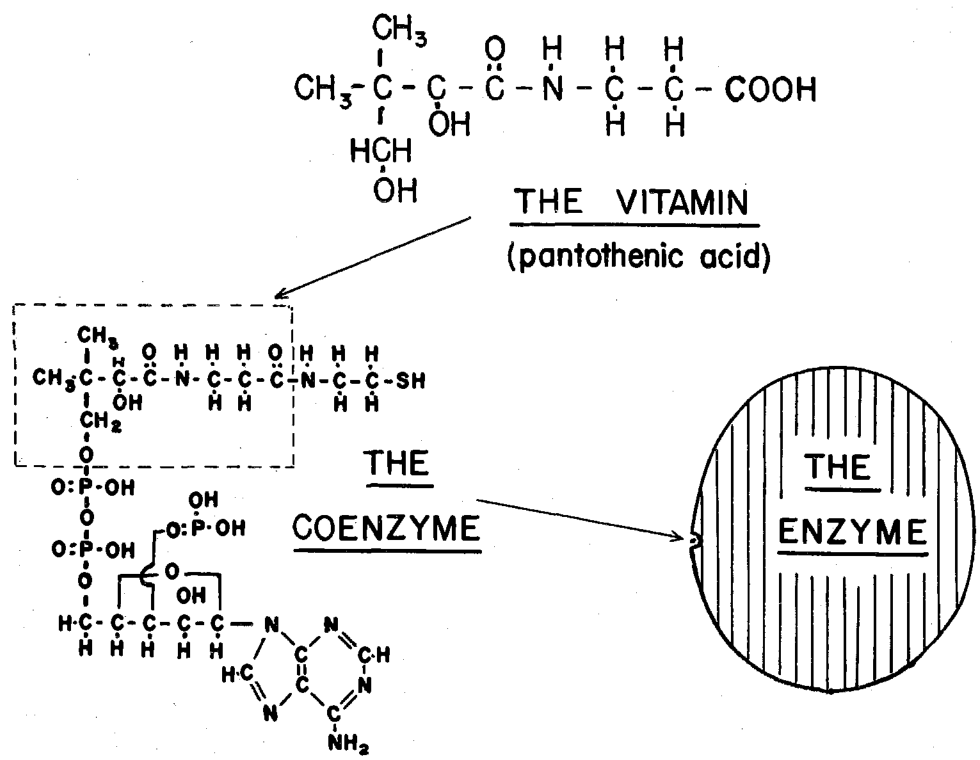
The total number of publications per year on vitamins is now at an all-time high, and even on a percentage basis there is a decided upswing. Although part of this is due to increased interest in nutrition as such, the principal reason is derived from recognition of the importance of finding out just exactly how the vitamins function. The need for understanding function is not nearly as obvious as that for obtaining vitamins in order to cure clear-cut dietary deficiencies. It rests on the fact that vitamins are absolutely essential in all living organisms, whether healthy or not, in order to build or replace tissue, and in order to burn food to obtain energy.

Diseases of all kinds influence the balance of the very complex pattern of chemical reactions that produce tissue or energy, and in order to combat such adverse influences in an understanding way, it is necessary to know what chemical reactions occur and what determines their rates. The vitamins are key substances in this picture in that they are rate-controlling materials.

We have made only a beginning in understanding exactly how the vitamins function, but it is a fair generalization at present that they go to make up part of the biological catalysts, the enzymes. An example of how this comes about is diagrammed below. The vitamin, in this example, is pantothenic acid and it has the arrangement of atoms shown. This substance cannot be made by the tissue and it must be provided in the diet in order to combine, first with other substances to produce the co-enzyme, and then with a certain kind of protein to give the enzyme. As indicated in the diagram, the enzyme is very much larger than the co-enzyme, but the most specific functional part of the enzyme is the —SH group of the co-enzyme. This actually was not even part of the vitamin, nor was it directly a dietary essential. Nevertheless, for its function, the enzyme requires all of the parts put together in this particular structure.

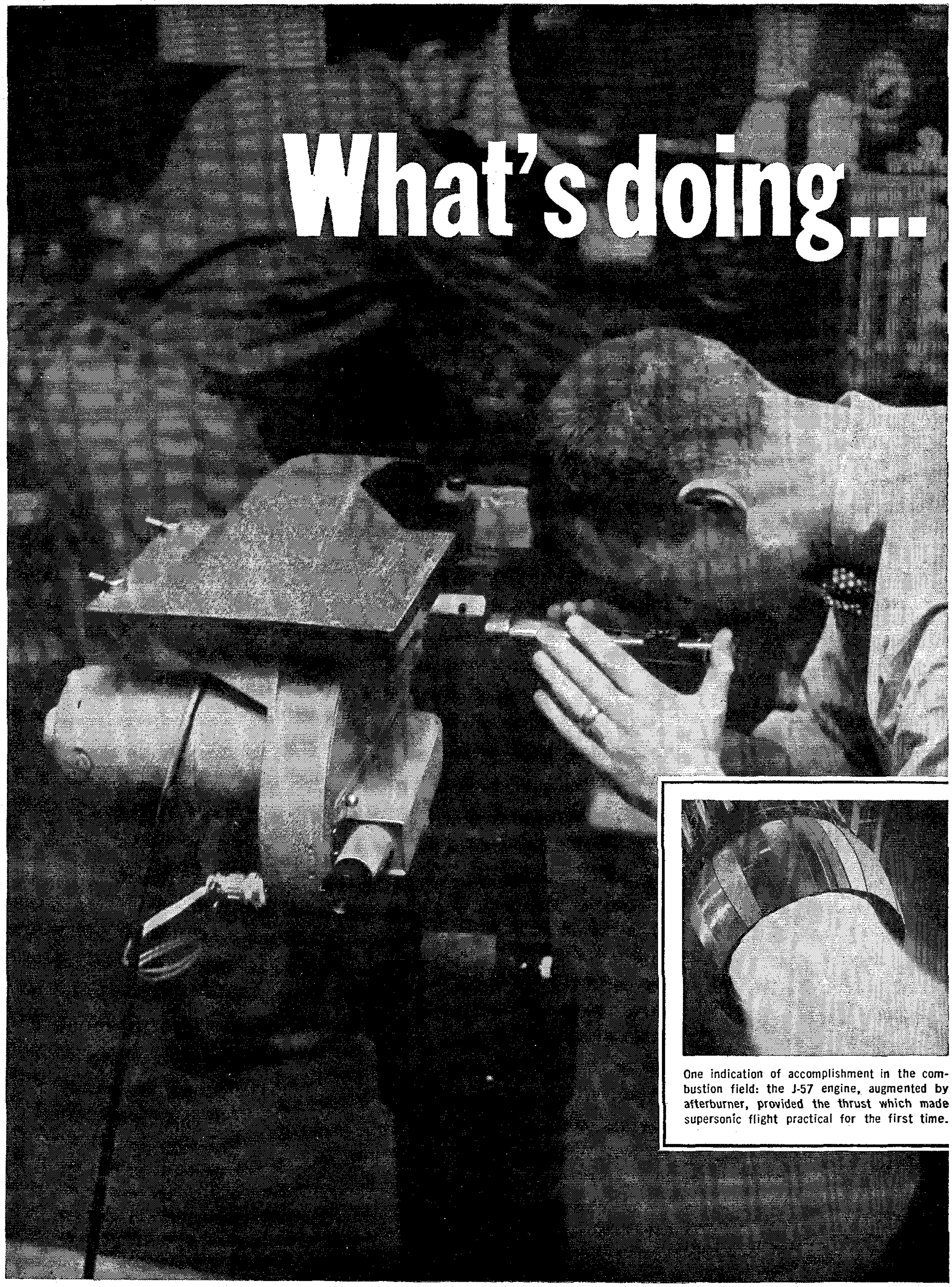
The body contains hundreds of specific enzymes and a great many of these carry vitamin co-enzymes. It is their function to speed up biochemical reactions, and the utilization of all foods requires enzyme action, some beginning the instant food enters the mouth. In the example given here, a combination of a variety of organic acids with the —SH group of the enzyme permits rapid chemical reactions such as those needed for the formation and combustion of fats.

The water soluble vitamins particularly are known for their co-enzyme functions and these have to be supplied daily. A considerable excess intake is harmless, and of no real value except in some pathological conditions. The specific functions of the fat soluble vitamins, in general, are not known. These can be stored in body tissue and some may have toxic effects when taken in great excess. A reasonable daily intake is probably the best procedure here too. In the immediate future much remains to be done to establish further the specific kinds of biochemical mechanisms in which the vitamins participate. Then too we need to know what contribution each potential mechanism makes to maintenance of and to well-being in the living organism.



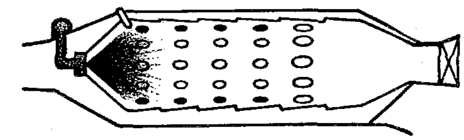
An example of how vitamins go to make up part of the biological catalysts, the enzymes. Pantothenic acid cannot be made by the tissue, so it must be provided in the diet in order to combine, first with other substances to produce the co-enzyme, and then with a particular protein to give the enzyme.

What's doing...



One indication of accomplishment in the combustion field: the J-57 engine, augmented by afterburner, provided the thrust which made supersonic flight practical for the first time.

This special periscope gives Pratt & Whitney Aircraft engineer a close-up view of combustion process actually taking place within the afterburner of an advanced jet engine on test. What the engineer observes is simultaneously recorded by a high-speed motion picture camera.

at Pratt & Whitney Aircraft 
in the field of Combustion*

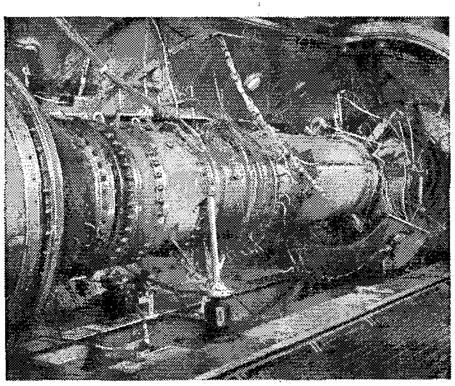
Historically, the process of combustion has excited man's insatiable hunger for knowledge. Since his most primitive attempts to make use of this phenomenon, he has found tremendous fascination in its potentials.

Perhaps at no time in history has that fascination been greater than it is today with respect to the use of combustion principles in the modern aircraft engine.

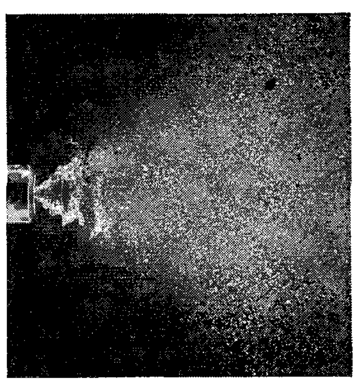
At Pratt & Whitney Aircraft, theorems of many sciences are being applied to the design and development of high heat release rate devices. In spite of the apparent simplicity of a combustion system, the bringing together of fuel and air in proper proportions, the ignition of the mixture, and the rapid mixing of burned and unburned gases involves a most complex series of interrelated events — events ocurring simultaneously in time and space.

Although the combustion engineer draws on many fields of science (including thermodynamics, aerodynamics, fluid mechanics, heat transfer, applied mechanics, metallurgy and chemistry), the design of combustion systems has not yet been reduced to really scientific principles. Therefore, the highly successful performance of engines like the J-57, J-75 and others stands as a tribute to the vision, imagination and pioneering efforts of those at Pratt & Whitney Aircraft engaged in combustion work.

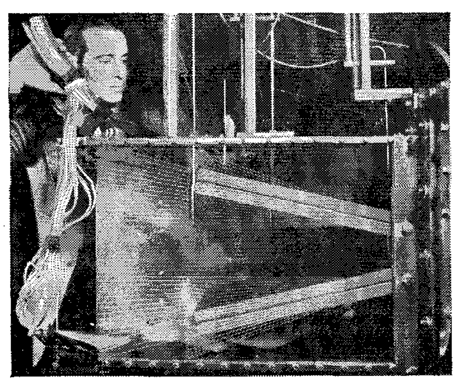
While combustion assignments, themselves, involve a diversity of engineering talent, the field is only one of a broadly diversified engineering program at Pratt & Whitney Aircraft. That program—with other far-reaching activities in the fields of instrumentation, materials problems, mechanical design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



Mounting an afterburner in a special high-altitude test chamber in P&WA's Willgoos Turbine Laboratory permits study of a variety of combustion problems which may be encountered during later development stages.



Microflash photo illustrates one continuing problem: design and development of fuel injection systems which properly atomize and distribute under all flight conditions.



Pratt & Whitney Aircraft engineer manipulates probe in exit of two-dimensional research diffuser. Diffuser design for advanced power plants is one of many air flow problems that exist in combustion work.

**Watch for campus availability of P & WA color strip film on combustion.*

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THE UNIQUENESS OF MAN

Man's evolutionary future—biologically and culturally—is unlimited. Even more important, it lies within man's own power to determine its direction.

by GEORGE W. BEADLE

ALTHOUGH MAN'S widening horizons of understanding have made it increasingly clear that his own importance as measured in terms of cosmic space and time is vanishingly small, it is still true that on the planet Earth his attainments and influence have been matched by no other species. Among the many other respects in which he is unique, he alone is able to investigate his evolutionary past and to speculate intelligently about those aspects of it that he cannot directly explore.

The quest for his own origins has led man to the concept of organic evolution—a concept that is surely one of his greatest intellectual achievements. It is a concept that challenges him to push further and further backward, in his search for understanding, to the very beginning of life on earth—and beyond that to the pre-life evolution that must have been before. Short of the origin of the universe, there is no point in the process beyond which his urge to explore no longer extends.

There is as yet no general agreement among cosmologists as to how, exactly, the universe is built, or how it began. Some would believe that it began some five to seven billion years ago as a giant explosion of enormously dense "primeval nucleus"[1]. The present expanding universe is then believed to be a continuation of that explosion. Others prefer to believe that matter is being, and always has been, created continuously, and that the universe is in a steady state of expansion, without beginning and without end[2].

Observational evidence is being accumulated by astrophysicists that may before too long answer such questions. Whatever the answers may prove to be, there is increasing reason to believe that the elements have evolved and are now evolving in orderly ways, beginning with hydrogen. The detailed mechanisms by which they thus arise are becoming more and more clearly understood as nuclear physicists and astrophysicists continue their collaborative investigations[3].

At the time the crust of the earth became solid, presumably some 4 to 5 billion years ago, conditions favored the accumulation of molecules, and these in turn went through an evolutionary sequence as the environment changed. In the early phases of the molecular stage of evolution only simple molecules were formed. At one period there were probably present in abundance such gases as hydrogen, ammonia, methane and water—with perhaps little or no free oxygen[4]. Later more complex molecules were formed—like amino acids and perhaps simple peptides[5].

In the more advanced phases of this period it is believed that there appeared a molecule with two entirely new properties: the ability systematically to direct the formation of copies of itself from an array of simpler building blocks, and the property of acquiring new chemical configurations without loss of ability to reproduce. These properties, self-duplication and mutation, are characteristics of all living systems and they may

"The Uniqueness of Man" was given by Dr. Beadle as his retiring presidential address at the meeting of the American Association for the Advancement of Science in New York City on December 27, 1956. The talk also appears in the January 4 issue of "Science."

therefore be said to provide an objective basis for defining the living state.

Evidence is accumulating that the nucleic acids of present day organisms possess these two properties[6], and it is perhaps no longer useless to speculate that the first "living" molecule might have been a simple nucleic acid, perhaps protected by an associated simple protein. From such a virus-like system it is possible to conceive how present-day organisms might have evolved. Although the details were surely complicated far beyond the ability of man in his present knowledge to comprehend, it is possible that no principles other than those known to modern biology need be invoked to explain the entire process.

Through mutation and aggregation of these first "living" molecules, which might be called primitive genes, multimolecular forms that depended for reproduction on preformed building blocks would be expected to arise with the ability to catalyze some of the reactions by which their building blocks were derived from simpler molecules. In a stepwise manner, with each step consisting of a mutation conferring a selective advantage, complete autonomy could be achieved[7]. The single-celled green algae represent such an evolutionary stage, with perhaps each cell containing tens of hundreds of thousands of times as much replicating genetic material as the original ancestral form did. This phase of evolution may have lasted a billion years or more.

Division of labor

The evolutionary gap between unicellular forms and the most complex multicellular organisms may have been much more easily and rapidly bridged than was that between the unimolecular and unicellular systems. Presumably the early stages in the origin of multicellular plants and animals consisted of simple colonies of like cells. Division of labor among such cells—cellular differentiation, biologists call it—was a logical next step.

In the animal line of descent, differentiation of cells and subsequent evolution of tissue and organ systems made possible the nervous system. It is the extraordinary development of this system in man that sets him apart by such a wide gap from all his contemporary species. It underlies the remarkable development of his intellect—his ability to carry through complex reasoning processes and his highly developed systems of communication.

The ability to acquire and communicate knowledge has enabled man to supplement biological inheritance with cultural inheritance. No other species has ever developed this type of inheritance to any appreciable extent. The reactions of individuals and groups of the human species to various environmental situations are obviously a result of complex interactions of the two types of inheritance[8]. Although cultural inheritance may have had its first beginnings a half-million years or more ago, it has expressed itself most spectacularly in the last half-dozen millenia. Ancient and modern civilizations with their techniques, arts, music, literatures, sciences, and religions are its products.

Modern technology and science have evolved within a period of a few thousand years. They in turn have made possible the industrialization that has in the past few centuries developed to such a high degree in a few nations of the world.

The recent evolution of cultures, especially in technological and industrial directions, has created for man an entirely new set of opportunities, together with a closely interrelated group of problems. As agriculture provided more food, populations grew. Further technology was catalyzed. Tools evolved, first of stone and wood, then of bronze and copper, and finally of iron and steel. Manpower was supplemented by domestic animals and by machines driven with the energy of burning wood, coal, and oil. At the same time, the art and science of medicine was responsible for spectacular increases in life expectancies. This helped populations to grow still more rapidly.

The demographic transition

All this is an old and well known story. It is also well known that with urbanization, industrialization, and improved health practices, birth rates tend to fall off, but only after a lag of several generations. This lag is especially marked in those cultures in which, for one reason or another, education and accompanying industrialization develop most slowly. This is because in general it is easier to introduce drugs and doctors to such cultures than it is to raise markedly their levels of education and technology. Thus, as the demographic transition is made in one culture after another, populations tend to increase sharply and then become stable.

For a world with half its nations industrialized and half not, and with its natural resources very unequally distributed, the present population of two and a half billion is far too large. More than half of the people of the world are underfed, poorly housed, receive little modern medical care, and are inadequately educated. It is small wonder that populations who see so little hope in other directions can be so easily stirred to rebellion and led to war by power-hungry demagogues, charlatans and other persuasive men of little wisdom.

Overcrowding of hungry people who see little hope for a brighter future is by no means the only cause of war, but it is surely an important one. And without the slightest doubt, war is the most serious of civilization's immediate problems.

Human warfare is as old as man himself. As a part

of man's culture, it has evolved from primitive forms of man-to-man combat through the many intermediate stages to its present highly perfected state. During this course wars have become progressively larger and more devastating. With the development of nuclear weapons we see a significant discontinuity in this evolutionary sequence. Up to this point wars were largely self-regulating in one way or another, usually through the achievement of victory, hollow though it might have been, by one party. With wars of nuclear weapons it is entirely conceivable that there will no longer be victors. Participants and onlookers, too, may perish from blast, radiation, and starvation.

The unthinkable war

That is why a war of nuclear weapons is said to be unthinkable—why there is now "no alternative to peace." Logically it is so. But war never has been logical. In the present state of armament there can be no guarantee that an illogical lunatic or madman in a position of power will not pull the trigger that will set one off.

Aside from the fact that the present maintenance of peace through mutual threat of annihilation is intolerably dangerous, the pyramiding cost of supporting superior military strength and defenses against potential enemies seriously competes with alternative activities that would decrease the probability of war. It is no new thought that if the intelligence, imagination, creativity, and drive that now go to maintain military might, not to mention the raw materials and energy devoted to the same purpose, were widely used for peacetime purposes, the incentives to war could be largely abolished.

In spite of the fact that there is wide agreement with this thesis that war is more nearly than ever synonymous with madness, and that decreasing its likelihood is the greatest need of our time, progress is made with discouraging slowness. The obvious solution through mutual disarmament fails because there is no mutual trust among nations.

The contributions of science

While the task of preventing a major war in the immediate future is assigned to the statesmen of the world, with special responsibility in the hands of the more powerful nations, there are many ways in which science can and must contribute toward basic and long-term solutions.

It is difficult for men with empty stomachs to know right from wrong. If presently available scientific knowledge of agriculture were applied on a world-wide basis, hunger could become unnecessary. But the economic, political and social problems inherent in doing so are made enormously more difficult by the fact that they must be solved in terms of a world divided into many nations. Solutions are possible and every possible effort should be devoted to attempts now being made to arrive at them.

More mouths to feed

In the time required to increase food production sufficiently to feed two and a half billion people adequately, there will, unfortunately, be many more than that to feed. With the present excess of births over deaths, the world's population is annually increasing by 30 to 40 million. Food production must therefore more than catch up with present needs. This will require that efforts be stepped up by even larger factors. More land must be brought under cultivation and yields must be increased. This means more fertilizer, more water for irrigation—perhaps through recovery from sea water—and more plant and animal breeding. The food of the oceans will have to be harvested in increasing amounts, and the practicability of entirely new methods of agriculture, such as those of algal farms, will have to be explored.

All of this will require more technology and a great extension and evolution of industry. Consumption of raw materials and energy will rise markedly. The general level of education will have to be raised on a world-wide basis. Better use of manpower resources, especially at the intellectual level, will be increasingly necessary.

Working together

If the peoples of the world can somehow be induced to work together, there is no apparent reason why all of this cannot be done[9]. While it is being done, what will be the trend of population growth? With the spread of technology and education, will birth rates in fact fall off until populations reach approximate equilibrium in size? It is a widespread belief that they will. The decreased birth rates that accompany education are attributed to an increased desire to limit family size plus greater knowledge of birth control techniques. If so, education and the discovery and development of improved methods of birth control may in time largely solve the quantitative problem of population growth.

However, the hope that prosperity and education will continue automatically to lead to population stabilization through voluntary birth control has been considerably dimmed by the marked postwar increases in birth rates in the United States and other industrialized nations. Indeed, this phenomenon raises the question of whether Malthus was not fundamentally right, [10,11,12] in spite of his many detractors of recent times.

Whether or not the present high birth rates in industrialized nations are temporary and will in the long run be smoothed out at a lower level, the whole question of the adequacy of voluntary family limitation in regu-

lating the growth of populations will have to be faced sooner or later. This is because the problem of control may not be wholly a quantitative one. Because it will inevitably be uneven in its application, voluntary and individual family control is bound to lead to changes in population composition. Differences in net reproductive rates may depend on such factors as genetic background, cultural history, and economic status. Whatever their cause, they may well produce population changes of the greatest significance to man's future. For example, it has many times been pointed out that under a system of voluntary birth control the less fit intellectually may be low in social responsibility and might therefore have a higher than average net reproductive rate. If differences in intelligence of this kind have an important genetic component, there is a theoretical possibility that progressive intellectual disintegration could become an important factor in shaping the nature of future populations.

Unpleasant problem

Alternatives to population control through voluntary decisions on the part of individuals—society-imposed family quota schemes, to mention one conceivable possibility—raise religious, moral and ethical questions of such magnitude that no responsible society has ever given them serious consideration except under the most unusual and special circumstances. It could well be that societies may eventually be forced to face this unpleasant problem more realistically than they so far have[11,12].

At the same time that solutions are being sought to problems of natural growth, food production, raw material supplies, energy resources, and the training of manpower, effective ways must be found to abolish the threat of war that has so long and so constantly plagued man. All responsible statesmen know this and they have pointed out repeatedly that the one formula most likely to succeed is the development of a union of nations in which authority and power are commensurate with responsibility[13]. There appears to be no other way to protect individual nations against those unwise and irresponsible acts of other nations that are the precursors of violence. It is of course now a common hope of many nations and many individuals that the United Nations will evolve into just such a union. If it is to do so, the hope must spread widely and grow to the intensity of a demand.

Closing the gaps

There is no reason why, under such a union, individual nations cannot continue to approach their internal problems in a variety of ways and with the hope that ultimately the wide gaps that now exist among nations of differing political, social, and economic ideologies will be closed through convergent social evolution.

Man's evolutionary future, biologically and culturally, is unlimited. But far more important, it lies within his own power to determine its direction. This is a challenge and an opportunity never before presented to any species on earth.

It has been clear for a long time that man is potentially capable of cultural self-direction—that he could, to a much greater extent than he now does, consciously select his cultural objectives. What is not so obvious is that it has now become possible to exercise a comparable degree of control over his purely biological evolution.

Understanding—and the future

Through the understanding of heredity that man has gained within the past half century he has acquired the power to direct the evolutionary futures of the animals he domesticates and the plants he cultivates. At the same time, and in the same way, he has won the knowledge that makes it possible deliberately to determine the course of his own biological evolution. He is in a position to transcend the limitations of the natural selection that have for so long set his course[8].

But knowledge alone is not sufficient. To carry the human species on to a future of biological and cultural freedom, knowledge must be accompanied by collective wisdom and courage of an order not yet demonstrated by any society of men[11]. And beyond knowledge, wisdom, and courage, faith too will be essential. Man must have faith in himself. He must have faith in the rightness and goodness of his goals. And many would add that he must continue to have spiritual faith.

Faith, belief, and the urge to go on and on have themselves come out of man's past as a part of the evolutionary pattern that has fashioned him into the unique being he is. In this uniqueness he is capable of attaining heights far greater than his most magnificent cultural achievements of the past.

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Year	*Sales*	*Net Earnings*	*Plant Space (Square Ft.)*	*Employees*				
	($000,000)	*($000,000)*	*(000)*	*Total*	*Hourly*	*%*	*Salaried*	*%*
1926	1.1	.4	158	720*	540*	75*	180*	25
1931	5.4	.6	200	1,150	839*	73*	311*	27*
1936	13.5	3.0	432	3,139	2,200	70	933	30
1941	24.3	2.6	603	4,240	2,859	67	1,381	33
1946	45.9	5.7	1,284	9,474	6,490	68	2,984	32
1951	135.2	8.9	2,296	17,182	10,796	63	6,386	37
1955	244.5	19.3	3,460	25,608	14,853	58	10,755	42

**Estimated*

THE MONTH AT CALTECH

Biology Building

A GRANT OF $477,000 from the Public Health Service in Washington, D.C., will enable the Institute to provide needed additions to the new Church Laboratory of Chemical Biology. Under the terms of the grant, the Institute must match the federal funds. About $170,000 will be used immediately to complete equipment needs in the laboratory. As soon as the remainder of the grant is matched, construction will begin on a building to serve as a connecting wing between the Kerckhoff and Church Laboratories.

Economic Values

JOHN KENNETH GALBRAITH, professor of economics at Harvard University, comes to Caltech this month to present the Haynes Foundation Lectures on "Economic Values," on January 15, 17 and 21.

Professor Galbraith has long been recognized for his far-reaching interpretation of modern wartime economic policy, and for his writing on agricultural, industrial, and financial topics. He received his education at the University of Toronto and the University of California, and continued his post-doctoral study at Cambridge University in England. He taught economics at Harvard from 1934 to 1939, and at Princeton from 1939 to 1942. He has been professor of economics at Harvard since 1949.

During World War II, Galbraith was deputy administrator of the Office of Price Administration, then served as director of the Strategic Bombing Survey, and later worked for the State Department. He has been an editor of *Fortune* magazine, and he is the author of such books as *American Capitalism, The Concept of Countervailing Power*, and *The Great Crash, 1929.*

The John Randolph Haynes and Dora Haynes Foundation, established in 1949, is devoting most of its resources to research in the social sciences, and to encourage the study of problems in this field by making grants to educational institutions. Each year, as part of a program of community education, the Foundation has brought a distinguished scholar to one of the southern California colleges or universities for a series of lectures on important problems of contemporary life.

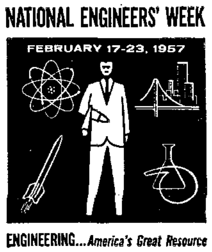
Alden Roach

ALDEN C. ROACH, president of the Columbia-Geneva Steel Co., and a trustee of the Institute, was killed on December 21 when his New York-bound plane crashed on a Pennsylvania mountainside. He was 55 years old.

A graduate of the University of Illinois, Roach began his career in the steel industry in 1924, when he became a master mechanic for the Laclede Steel Co. in St. Louis. In 1927 he joined the Union Iron Works in Los Angeles and became manager of the industrial building department when it merged with two other firms to form the Consolidated Steel Corp.

He rose to vice-president for sales and engineering and, in 1941, was elected president of the mammoth shipbuilding corporation. In 1948 he became president of the Columbia Steel Corp., and was made president of Columbia-Geneva Steel, a subsidiary of U.S. Steel, in 1951.

Mr. Roach was also a director of many companies and organizations, including Southern California Edison, North American Aviation, and the Stanford Research Institute.



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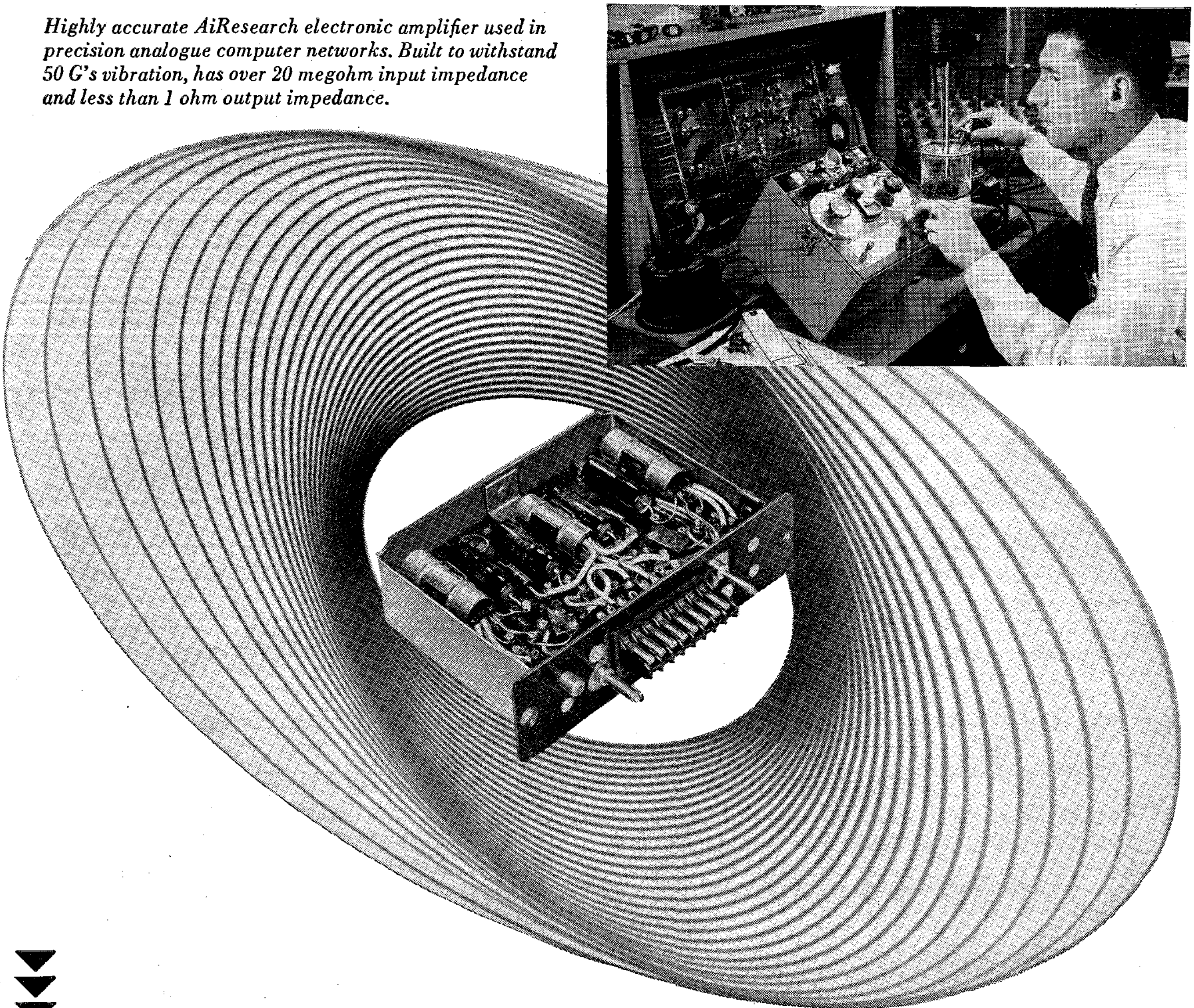

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PERSONALS

1918

Carlyle H. Ridenour, Brig. Gen., U.S.A.F., (Ret.) writes that he has been with Lockheed Aircraft's Georgia Division in Marietta for nearly six years. He's been retired from the Army since 1945.

1923

Loren E. Blakely is the southern California representative for the No Joint Concrete Pipe Company of Yuba City, California. The company has a new system of continuous construction which produces finished concrete pipe at the rate of about 500 feet in 3 hours.

1926

Joseph Matson Jr., is still working as civil engineer with the Waialua Agricultural Company, Ltd., in Waialua, Hawaii. and is also a colonel in the U.S. Army Reserve.

1928

Harvey E. Billig, Jr. MD, FICS, medical director of the Billig Clinic in Los Angeles, and professor of physical rehabilitation at Pepperdine College, officiates this month at Pepperdine at a symposium on "Foot Problems."

1929

Homer G. McWilliams of West Covina, who was plane division manager for the Pacific Telephone and Telegraph Company in Los Angeles, died on December 11. A native of Iowa, he had been a resident of California for the past 45 years and an employe of Pacific Telephone for 33 years. He is survived by his wife, Edythe; a daughter, Barbara; and a son, Michael.

1930

Melvin L. Leppert has been with the U.S. Naval Research Laboratory in Washington, D.C., since 1940, and is now head of the antenna circuitry section. The Lepperts' daughter is a freshman at George Washington University.

1931

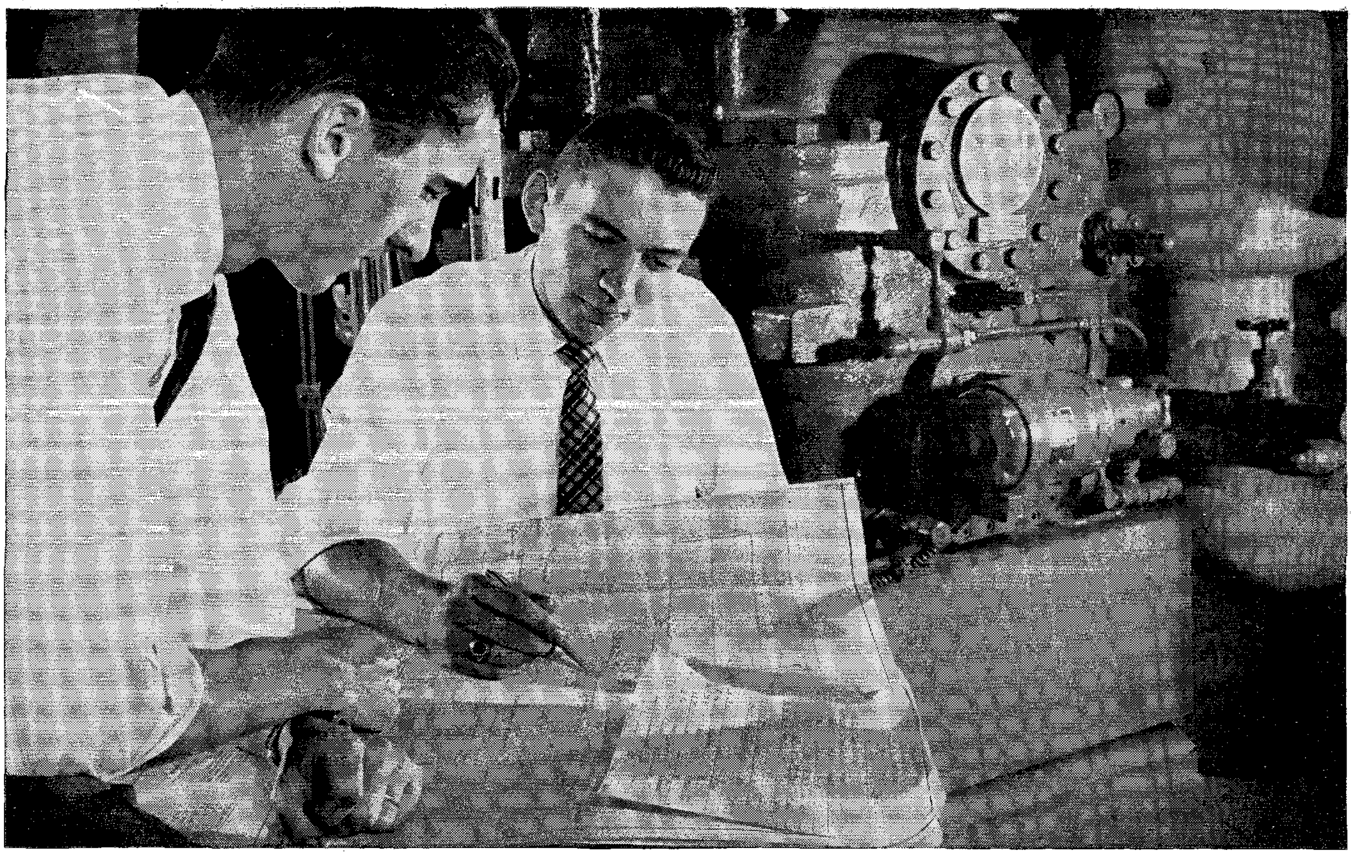
Adam T. Zahorski, MS, is chief of structures for the Aerophysics Development Corporation, which recently moved from Santa Monica to Santa Barbara, California.

Howard Smits, MS '33, writes that "the Pacific Iron and Steel Company, of which I am president, has sold its fabricating business here in Los Angeles and in the Belgian Congo, and is now engaged in the development of Green Valley, south of Escondido. This activity takes two forms—first, the development of a 200-acre orchard as an agricultural enterprise; second, the development of a subdivision."

1933

David L. Clark, Jr., has been promoted to the position of Northeast Region sales manager for the New Departure Division of the General Motors Corporation. Dave has beeu with the company since 1940, and was located in Los Angeles until this recent promotion which transferred him to the firm's main office in Bristol, Connecticut. The Clarks have two sons, Jay and Jeffrey, and are now living in West Simsbury, Connecticut.

Robert C. Kendall, MS, senior geophysi-



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cist in the Denver Area exploration department of the Shell Oil Company, completed 20 years with the company in September. Bob has been in the Denver Area since 1953. The Kendalls have 16-year-old twins, Robert and Elizabeth.

Charles E. Tillman, after two-and-a-half years as director of operations for Lockheed Aircraft activities at the Holloman Air Development Center, has returned to Lockheed's California Division in Burbank, where he is now staff engineer in the military operations research division.

1935

William B. McLean, MS '37, PhD '39, was presented with a $25,000 cash award for development of the Navy's air-to-air guided missile (the Sidewinder) in New York last month. The award, made under the Incentive Awards program, was the highest monetary prize ever given by the government in recognition of an employe's superior accomplishment. Bill has been working for the Naval Ordnance Test Station since 1945, first at the Pasadena Annex, and lately as technical director at China Lake.

E. Paul De Garmo, MS, professor of industrial engineering and chairman of the industrial engineering division at the University of California at Berkeley, is chairman of the Berkeley planning committee for the Ninth Annual Industrial Engineering Institute, which is being held, simultaneously, at UCLA and Berkeley in early February.

John Ritter is now supervising highway engineer in the Sacramento headquarters of the California Division of Highways.

1937

Fred Brunner, MS '41, will spend the next two years in Germany on an assignment for C. F. Braun & Co. He will be project engineer for the firm in the design and construction of a new grass-roots oil refinery for Esso, A.G., at Koln in Frankfurt am Main. Fred's wife and their four sons are accompanying him.

1939

Michael E. Hiehle has been appointed project manager for the Hughes Aircraft Company's weapons system development laboratories in Culver City. Mike has been with Hughes since 1950.

1940

Edward R. van Driest, PhD, is now chief scientist of technical sciences for the missile development division of North American Aviation, Inc., in Downey, California. He had formerly been staff specialist in the aerodynamics section of the division. Ed has been with North American since 1948, when he received his ScD in aerodynamics from the Swiss Federal Institute of Technology's Institute of Aerodynamics in Zurich. From 1940 through 1946, he was, successively, an instructor in fluid and solid mechanics at Cornell University; associate professor in civil engineering at the University of Connecticut; and an assistant-professor in mechanical engineering at MIT.

Theodore Weaver, MS '42, manager of the process development department of the Fluor Corporation, Ltd., in Los Angeles, was named winner of the 1956 Junior Award of the American Institute of Chemical Engineers at their 49th annual meeting in Boston last month. The award is given annually to encourage excellence in contributions to the publications of the Institute by its younger members. Ted has been with Fluor since 1944.

1941

John R. White, MS '42, has been appointed sales manager of the Aviation Products Division of Fenwal Inc., in Ashland, Massachusetts. He was formerly Western District manager of the company, with headquarters in Los Angeles.

1942

Roy C. Van Orden, division manager of A. C. Martin & Associates, Architects and Engineers, in Los Angeles, has now been made an associate member of the firm. The Van Ordens had a new addition to their family last June—a daughter, Gretchen Zale—their fourth child.

S. Kendall Gold writes that he and his wife and children are still in London and still enjoying it there. "I'm chief engineer for the California-Texas Oil Company, Ltd.," says Ken, "and from this office we supervise the design of major refinery additions in various parts of the world in which Caltex operates.

"My wife and I are looking forward to a home leave next year when we hope to be able to get back to southern California."

1944

Robert G. McAnlis has moved from Lompoc, California, to the general engineering headquarters of Johns-Manville Corporation in Manville, New Jersey. Bob is working on the air conditioning, ventilating

CONTINUED ON PAGE 56

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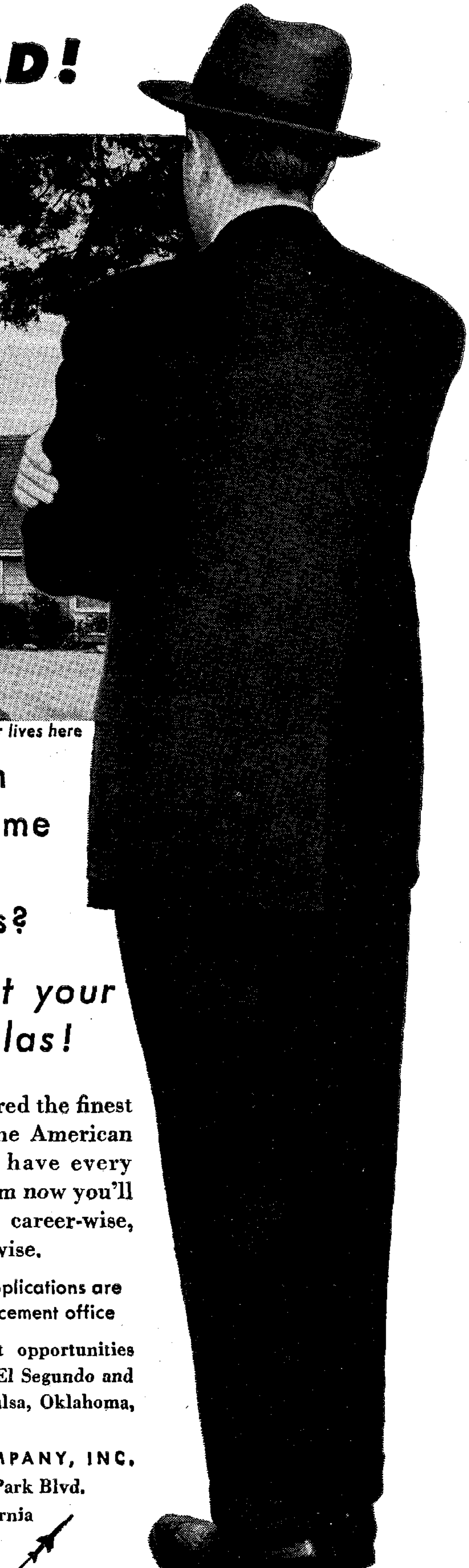

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and dust control problems of all the Johns-Manville plants.

1945

Jesse H. Zabriskie, MS. chief test engineer for the Bell Aircraft Corporation in Buffalo, New York, has been appointed manager of the guided missiles division of Bell's new weapon systems division. He has been with the company since 1951.

1946

Dansy T. Williams, MS, has moved from Oklahoma City, where he was principal assistant at the Weather Bureau Airport Station, to Kansas City, Missouri, where he is now research meteorologist with the Severe Local Storms unit of the U.S. Weather Bureau.

Philip H. Benton recently announced the opening of his new company, Benton Engineering, in San Diego, specializing in applied soil mechanics and foundations, including soil testing facilities.

Comdr. Joseph B. Deodati, MS, AE '47, has moved to Washington, D.C. where he is now in the Power Plant Division of the Navy's Bureau of Aeronautics.

1947

David O. Caldwell, assistant professor of physics at MIT, reports the birth of his first child, Bruce David, on October 26.

Morris Feigen, MS, has been appointed senior staff engineer of the design integration department of the guided missiles laboratory of the Hughes Aircraft Company in Culver City.

Eugene M. Shoemaker, MS '48, is still with the U.S. Geological Survey in Grand Junction, Colorado. He was married in 1951 to Carolyn Spellman, sister of *Richard Spellman,* '48, and they now have two children, and another on the way.

1949

William N. Harris, recently promoted to Lt. (j.g.) in the Navy, writes that he is still with the Naval Reactors Branch of the Atomic Energy Commission. In November he spent a week on the *Nautilus,* the Navy's first nuclear-propelled submarine, traveling to Bermuda and back.

Joseph A. Dobrowolski is now field representative of the Portland Cement Association at Sacramento, California. He was formerly a junior civil engineer for the State of California Division of Highways.

Bernard W. Shore was appointed assistant professor of biochemistry at the Medical College of Georgia in Augusta this fall. He received his PhD in 1955 from UC in Berkeley, where he was a biophysicist at the Donner Laboratories.

1950

Lt. Col. James H. Hottenroth, MS, has been appointed assistant district engineer of the Army's Fort Worth District Corps of Engineers. He was formerly executive officer of the supply and maintenance division of the Engineer Office at the headquarters of the Army Forces Far East and 8th U.S. Army.

1951

Robert G. Adler, Jr., has been in the Army since January, 1955. Now a Specialist Third Class in the 565th Medical Company, Bob is stationed in Germany.

1952

Richard R. Tracy writes that "for the past two years I have been employed by

CONTINUED ON PAGE 60

the Task Corporation (a fast rising newcomer in the research field) formerly of Pasadena but recently moved into new facilities in Anaheim. Among other Tech alumni at Task is a classmate, *Dud Wagner*, '52. My working efforts have slowed to a trickle, however, since I have returned to Caltech (the scene of the crime) and hope to receive my MS in aeronautics this June."

Paul D. Arthur, PhD, research scientist with the Marquardt Aircraft Company, is also a lecturer in aeronautics in the graduate schools of USC and UCLA. He had been a civilian scientist for the Air Force, at the Pentagon and in France, in 1952-53. In the summer of 1953 he was a visiting aeronautical research engineer in Amsterdam, Holland; and in 1953-54 he served as a Fulbright professor of engineering in Baghdad, Iraq.

Joseph Picornell, MS, writes from Manila, in the Philippines, that he was appointed assistant vice president of the Philippine Electrical Manufacturing Company last July. The firm is a Westinghouse licensee with a theoretical capacity of about 23,000 incandescent and 6,000 fluorescent lamps a day. Joe still has his old job, too, on a part-time basis, as production engineer of Industrial Textiles Manufacturing Company.

Tucker Carrington, PhD, is now doing postdoctoral research in kinetic spectroscopy at the National Bureau of Standards in Washington, D.C., on an associateship sponsored by the National Academy of Sciences—National Research Council and the Bureau of Standards. Prior to this, he was on active duty with the U.S. Army, assigned to the Ballistic Research Laboratory at the Aberdeen Proving Ground in Maryland.

1953

Robert J. Stanton, Jr., is back at Caltech, working for his PhD in geology. He got his MA in geology at Harvard last June.

Howard Boroughs, PhD, writes from Honolulu that "after I left Tech, I spent a year at the Sorbonne and decided the climate of Hawaii suited me better. I am now an associate professor of zoology (of all things!) and becoming zoological as all get out. My friends on the mainland are sick of seeing me because I'm on the National Academy of Sciences panel on the Biological Effects of Atomic Radiation. I became an expert in this field in about six months, because nobody knows anything about the subject with regard to marine organisms. To those friends I *don't* see, I send a warm aloha by way of the trade winds."

1954

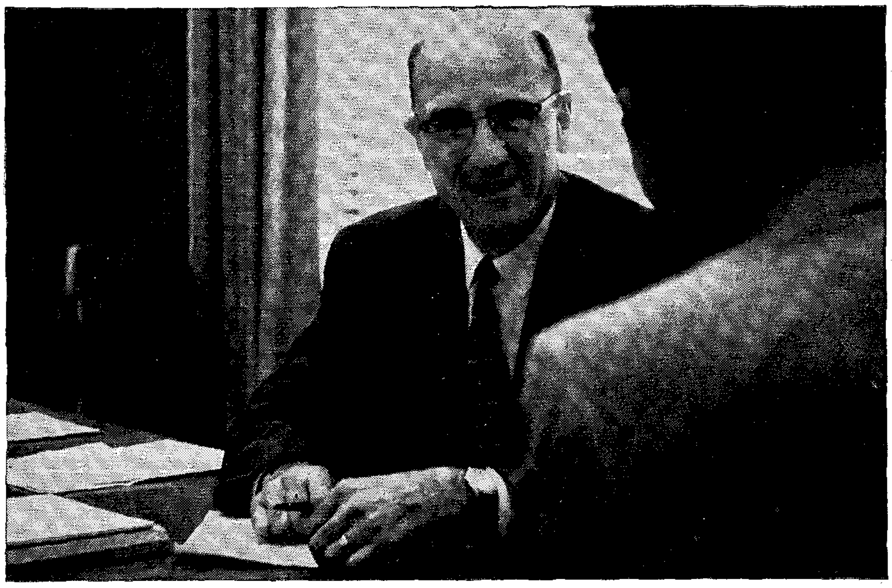
Eldon L. Knuth, PhD, is now an associate research engineer at ULCA. He's living in Topanga, California.

Robert D. Dikkers, MS, is now an assistant engineer for the National Concrete Masonry Association in Chicago. He was formerly a junior civil engineer with the Harza Engineering Company in Chicago.

1956

John K. Lansingh, who was formerly employed by the Oronite Chemical Company in San Francisco, is now a private in the Army, receiving his basic training with the 9th Infantry Division at Fort Carson, Colorado.

CAREERS WITH BECHTEL



KARL BAUSCH, *Chief Electrical Engineer, Power Division of the Bechtel Corporation.*

ELECTRICAL ENGINEERING

One of a series of interviews in which Bechtel Corporation executives discuss career opportunities for college men.

QUESTION: *Mr. Bausch, in considering a position with Bechtel, or any other firm, isn't it true that what most college men want to know first of all is "What will I be doing?"*

BAUSCH: That's true, and it isn't an easy question to answer. So much depends on individual preferences and abilities and the way a man develops. On joining us, he would be asked if he'd like to work on the drafting board doing layout work. As an alternate, he might prefer a starting assignment involving helping out on calculations, requisitioning materials, writing specifications, etc.

QUESTION: *In other words you try to give the new man some freedom of choice?*

BAUSCH: As far as possible. We know that the beginning period is a difficult one. It takes some time for him to get his feet on the ground and we try to "expose" him to many different activities. In that way he gets needed experience and familiarity that help him decide the work for which he feels best qualified. It also gives us the opportunity to evaluate his potential.

QUESTION: *Assuming a man shows the necessary ability and begins to produce, how does he branch out?*

BAUSCH: Generally, in either of two ways. He may work on the electrical portion of power plants, designing circuits, control and relaying systems, unit protection, etc. The other way is on the physical layout of power plants —that is, location of equipment, conduit and raceway systems, etc. In either case he would be put in charge of one section of the project.

QUESTION: *And his next advance would be...?*

BAUSCH: Assuming he progresses satisfactorily, he would ultimately move into a lead job as a group supervisor in charge of the design of the electrical system of the complete plant.

QUESTION: *Could you give an estimate of the time involved in the various steps?*

BAUSCH: That's impossible. We have no hard and fast schedule. In general, we have found that it takes a man about a year to get his feet on the ground and become a real producer. From that point on, it's up to him.

QUESTION: *In other words, he can advance in keeping with his individual ability?*

BAUSCH: That's right. Of course, there are many other factors involved, including the vitally important one of the great advancements being made in every phase of the electrical industry. These create new jobs and new types of jobs involving new skills. And for every opportunity existing today, it is safe to predict there will be at least two tomorrow.

Bechtel Corporation (and its Bechtel foreign subsidiaries) designs, engineers and constructs petroleum refineries, petrochemical and chemical plants; thermal, hydro and nuclear electric generating plants; pipelines for oil and natural gas transmission. Its large and diversified engineering organization offers opportunities for careers in many branches and specialties of engineering —Mechanical...Electrical...Structural ...Chemical...Hydraulic.

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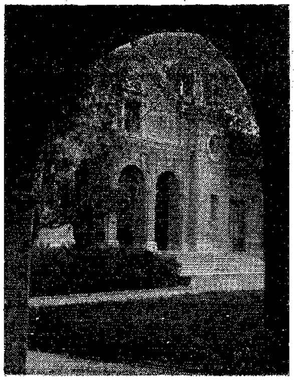

CALTECH CALENDAR

ALUMNI EVENTS

February 9	Dinner Dance
April 6	Alumni Seminar
June 5	Annual Meeting
June 29	Annual Picnic

ATHLETIC SCHEDULE

Varsity Basketball

January 22	PCC at Caltech
January 26	Whittier at Caltech
January 29	Cal Poly (SD) at Caltech
February 1	Redlands at Caltech
February 2	UC (Riverside) at Caltech

FRIDAY EVENING DEMONSTRATION LECTURES

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

January 25—
The History and Development of the Colorado River — by Dr. Alfred Ingersoll

February 1—
Elasticity — by Prof. David Wood

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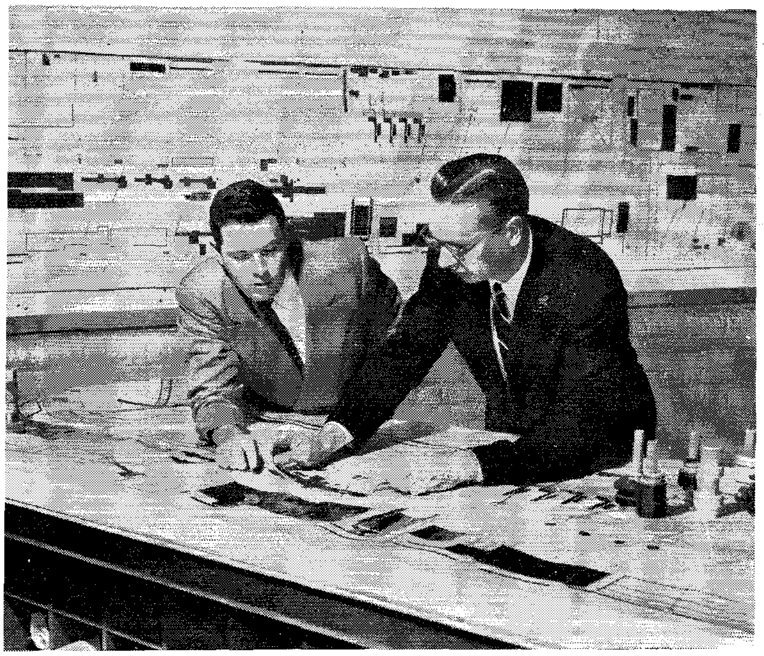

DESIGNING COMPLETE PLANT LAYOUT for a new manufacturing activity are Howard Jenkins, Maine '50, and Dick Rayve, Brooklyn Polytechnic '54. This manufacturing engineering problem involves operation planning, materials handling, and designing machine tools.

EXTENSIVE ENGINEERING INSIGHT and a firm knowledge of manufacturing problems guide Tom Robinson, Alabama Polytechnic Institute '54, in purchasing materials for operating departments. Tom, at left, discusses possible application of metal products with vendors.

AT GENERAL ELECTRIC . . .

Your engineering background fits you for expanding opportunities in manufacturing

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IN QUALITY CONTROL ENGINEERING Chuck Fehlau, Bates College '49, is responsible for devising test procedures and designing test equipment for this jet fighter gun-sighting system. Chuck also audits quality control tests to assure compliance with engineering requirements.

DESIGNING AUTOMATION EQUIPMENT for a new motor production line are these G-E manufacturing engineers. The high engineering content of operations in this manufacturing development laboratory requires the technical skill of outstanding young creative engineers.