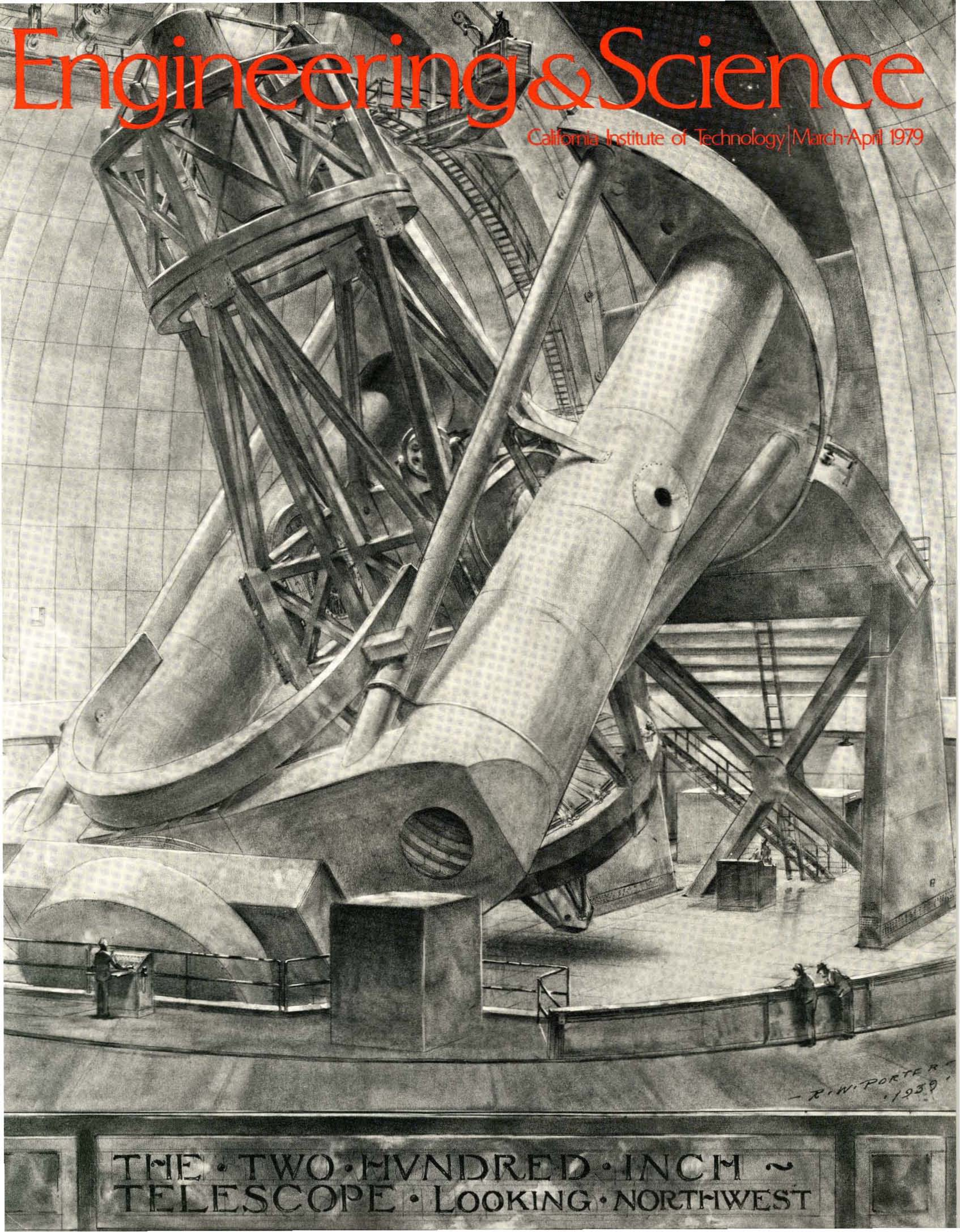
Engineering & Science

California Institute of Technology | March-April 1979



Don Hartman found a "model" way to troubleshoot the network.

The nationwide telecommunications network carries over 515 million phone calls on an average business day. Only a small number of them run into trouble, such as failing to go through the network, getting noise on the line, or being disconnected prematurely. Craftspeople in Bell telephone companies fix most of these problems quickly. But the causes of some can be difficult to find among one-billion-plus miles of circuits and thousands of switching offices.

For several years the Bell System used its computerized Network Operations Trouble Information System (NOTIS) to try to pinpoint those causes by analyzing trouble reports from all over the country. NOTIS was good. But Bell System managers wanted it to be better, more precise in identifying possible trouble spots. And they wanted the data in compact, easy-to-use form.

We assigned a new employee, Don Hartman, to improve NOTIS. Don came to us with a B.S. from the University of Texas and an M.S. and Ph.D. from Massachusetts Institute of Technology. He and his associates developed a second-generation system (NOTIS II) that does the job superbly.

For the new system, Don developed a mathematical model of the telecommunications network, including 28,000 local and long-distance switching offices and nearly a half-million circuit groups. Don also designed the system software and served as a consultant to the team of Bell System programmers assigned to the project.

Each day trouble reports from the entire country are sent to the NOTIS II center in Atlanta. Overnight, the system analyzes the reports, processes them through the network model, and discerns trouble "patterns" which help identify potentially faulty equipment. By 8 a.m. the next day, via data links, analysts at phone company service centers receive information on troubles traceable to circuits or switching equipment in their territories. Result: Better equipment maintenance. And better service.

With NOTIS II up and running, Don has moved on to other projects. Today he's a supervisor with broad responsibilities for planning the telecommunications network of the future.

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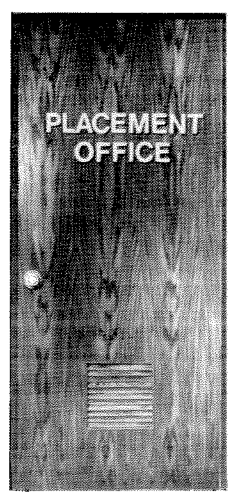

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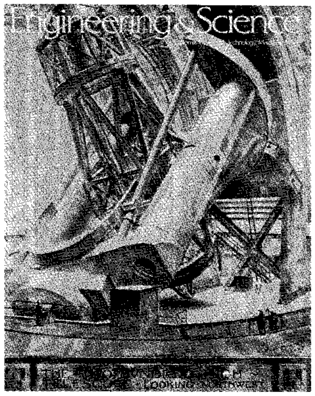
In This Issue



Happy Anniversary
On the cover — in honor of the 30th birthday of the 200-inch Hale Telescope, a drawing made ten years before it became a working reality. Artist Russell W. Porter, associate in optics and instrument design at Caltech from 1929 until his death in 1949, was a member of the team that created and erected the great astronomical instrument. He was also the developer of a "cutaway" drawing technique that made it possible to visualize details of the Hale project with extraordinary precision. Fortunately, many of the series of drawings he made of the telescope and its associated buildings and adjuncts survive and can still be seen at Caltech.

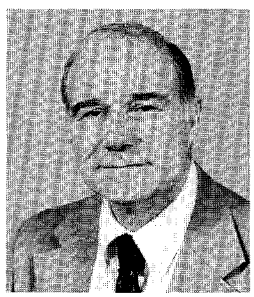
While the Hale Telescope still looks much as Porter depicted it, the 30 years since it began operations have seen almost incredible changes and advances in astronomy. Many of these were made possible by the intensive use of the 200-inch, plus all the other superb instruments at the Palomar Observatory.

"A Giant's Birthday" on page 6, by Dennis L. Meredith, director of Caltech's News Bureau, tells the story of some of those achievements. Meredith came to Caltech in 1977 from MIT, where he was managing editor of *Technology Review*. He is the author of *Search at Loch Ness*, published in 1977 by Quadrangle/The New York Times Book Co.

Russell W. Porter

Norman Horowitz

Summary Proceeding
As chairman of the division, Norman Horowitz headed up the planning and did a lot of the presiding at the 50th anniversary symposium of Caltech's biology division held on the campus last fall. The end of the symposium, however, didn't end Horowitz's dealings with it. He is now at work on the preparations for publishing the proceedings. This has included making summaries of all the 18 talks by distinguished Caltech alumni. "Genes, Cells, and Behavior: A View of Biology Fifty Years Later" on page 11 presents the first seven of those summaries. The rest will appear in our next issue.



Carel Otte

Some Like It Hot
The July 31, 1978, issue of *Fortune* magazine carried an article by John Quirt entitled "Union Oil Gets Up Steam for Geothermal Energy," in which two staunch friends of the Institute are key figures. They are Caltech trustee Fred L. Hartley, who is chairman and president of Union Oil Company of California, and alumnus Carel Otte, who is president of Union's Geothermal Division. Otte is the author of "Developing Our Geothermal Energy" on page 16.

The *Fortune* article describes Union's leading role in making geothermal energy a reality in the United States today and Otte as a "Dutch-born World War II pilot with a doctorate in geology." Otte's training in geology began at the University of Amsterdam, where he took his BS in 1943. He entered Caltech in 1948 and received his MS in 1950 and his PhD in 1954. While at the Institute he was Resident Associate of Blacker House. He has been active in alumni affairs and is president-elect of the Caltech Alumni Association.

At a professional level, Otte is a fellow of the Geological Society of America and a member of the American Association of Petroleum Geologists, the author of several technical publications, and co-editor of a book on geothermal energy published by the Stanford University Press. For three years he served as chairman of the Advisory Committee on Geothermal Energy to ERDA, and then the Department of Energy. He has also been selected as Distinguished Lecturer for the Society of Petroleum Engineers of AIME for 1980.

The Good Old Days
"Henry Borsook — How It Was" on page 23 is the second and final installment of an interview with the Institute's first professor of biochemistry, now professor emeritus. Borsook's recollections are a part of the oral history project now under way at Caltech.

An oral history is, of course, made up of more than memories. It takes the diverse skills of the researcher, interviewer, transcriber, editor, and typist to produce an edited, indexed, and bound transcript from the interviews. The two people, interviewer and subject, typically spend three or four sessions, each an hour or so in length, talking to each other. Once transcribed, the manuscript is edited by both people; the subject signs an agreement regarding its use, and the transcript is then deposited in the archives — a deposit from which *E&S* looks forward to drawing other chapters in the future.

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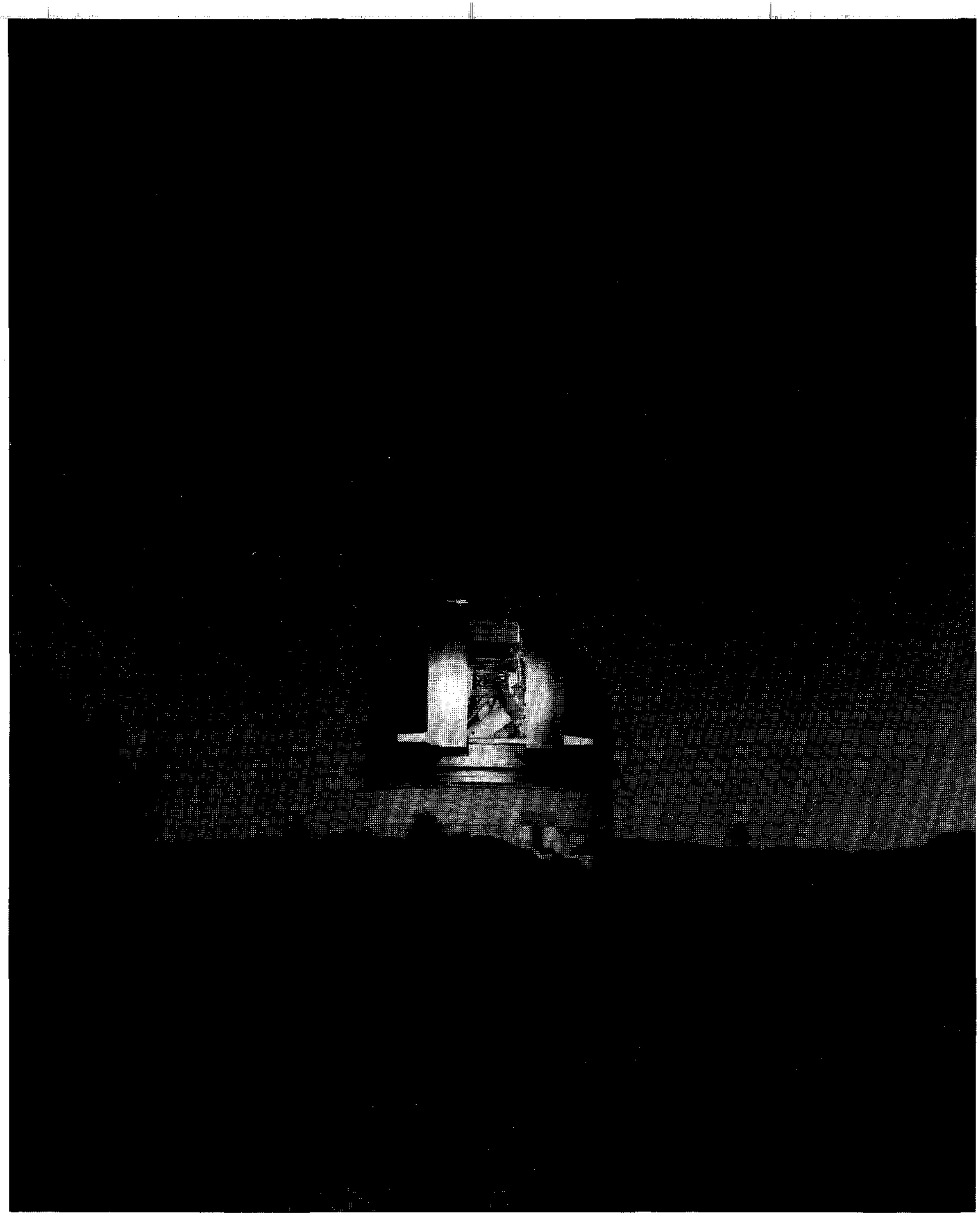


A Giant's Birthday

The Hale Telescope—30 years of distinguished service to science

by Dennis Meredith

This year marks the 30th anniversary of the first use of one of the premier scientific instruments of all time — the giant 200-inch Hale Telescope at Palomar Mountain. Since 1949, at every opportunity, the shutter on the massive dome has opened to the night sky, and the 500-ton telescope has captured and recorded light from stars millions of times fainter than can be seen by the unaided eye. Both technological progress and the brilliant engineering that first went into its construction have kept the instrument one of the most important in astronomy.

Astronomers using the Hale Telescope have contributed enormously to the understanding of the universe, and a

1948: Dedication of the 200-inch Hale Telescope, June 3. Actual use began in the winter of 1949.

complete listing of the advances due to the instrument would be voluminous. Such studies, which could only have been done with the 200-inch telescope, include:

- The determination to great distances of the Hubble constant, which is the measure of the rate at which the universe is expanding,
- Studies of the rate at which that expansion is slowing,
- Studies of star clusters, which made possible an understanding of how stars evolve, and
- Discovery of quasars and the first determinations of their redshift.

"We have found that those parts of the instrument that one is bound to — the basic structure of the telescope — are really superb," says Maarten Schmidt, director of the Hale Observatories, which is run by Caltech jointly with the Carnegie Institution of Washington. Schmidt is the astronomer responsible for the discovery of the large redshift in the light from quasars, which indicated that they are the most distant objects in the universe. "The 200-inch is as good as telescopes that were built only recently," he says.

A visit to Palomar Mountain reveals how lightly three decades of almost constant use have touched the telescope. The massive gears that allow the giant to track the slow movement of the stars across the sky each night are as unmarred as the day they were installed, and spare gears still hang on the wall where they were placed decades ago. The 1,000-ton dome rotates with a silky smoothness, emitting only a faint hiss and a delicate rumble as it moves.

"The instrument is in excellent shape," says Gary Tuton, superintendent of the five telescopes on Palomar Mountain, which also include 18-, 20-, 48-, and 60-inch telescopes used in various research modes. "The amount of downtime for this mass of equipment is quite minimal, and can only be attributed to the genius of the designers."

Maintenance of the big telescope includes washing the mirror with distilled water and then drying it with soft

A Giant's Birthday

1910: Andrew Carnegie and George Ellery Hale in front of the 60-inch dome on Mt. Wilson.

towels four times a year, and realuminizing the mirror about once every three years.

The battleship-gray telescope looks every bit the modern, efficient scientific device, but there are touches here and there in the dome that remind one of old-time craftsmanship. Doors in the observatory are made of richly polished black walnut, and the electrical power system consists of massive wiring linked solidly to heavy, old-fashioned terminals.

"That electrical system hasn't given us a moment of worry since the day it was built," says Tuton, who was a night assistant at Palomar for 17 years before becoming superintendent.

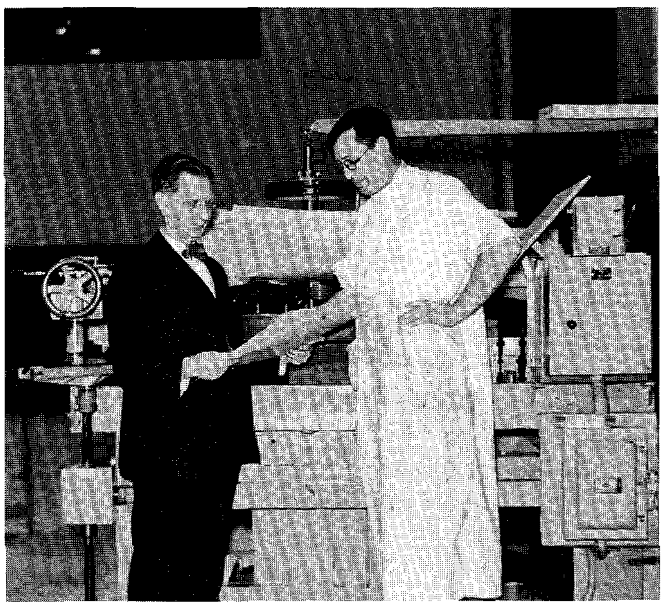
The history of the design and construction of the 200-inch telescope features a plot worthy of an epic thriller — and with characters just as colorful.

The central figure was, of course, George Ellery Hale, the prominent scientist and masterful fundraiser who, despite a chronic and debilitating illness, launched the 200-inch telescope project and saw it safely on its way. He first issued the challenge of building an enormous astronomical instrument in 1928 in an article in *Harper's* magazine:

"Like buried treasure, the outposts of the Universe have beckoned to the adventurous from immemorial times. Princes and potentates, political or industrial, equally with men of science have felt the lure of the uncharted seas of space. If the cost of gathering celestial treasures exceeds that of searching for the buried chests of a Morgan or a Flint, the expectation of rich return is surely greater.

"Starlight is falling on every square mile of the earth's surface, and the best we can do is to gather up and concentrate the rays that strike an area 100 inches in diameter," he wrote, proposing a telescope twice the diameter of the Mount Wilson telescope, the giant of that period.

Hale persuaded officials of the Rockefeller Foundation to fund the telescope, and the adventure was on. A fascinating group of scientists, engineers, and technicians participated in the great project, which was that era's version of a major space shot. There was, for example, Francis Pease, the engineer and astronomer who dreamed along with Hale of a gigantic telescope; and there was John A. Anderson, physicist and executive officer who supervised the project from 1930 to World War II. There was also the gifted artist Russell W. Porter, the taciturn New Eng-



1934: Under the supervision of John A. Anderson (left), Marcus H. Brown saw to the grinding of the 200-inch mirror.

lander, brilliant inventor, architect, and Arctic explorer who once made a telescope out of an obsolete automobile.

There was Marcus H. Brown, who had worked his way from chicken farmer and truck driver to become one of the most obsessively perfectionist opticians in the world. As chief optician, under Anderson's supervision, he saw to the grinding of the 200-inch mirror. There was Sinclair Smith, the astronomer and engineer who, while dying of cancer, designed the precise control system for the telescope. After Smith's death, the control system was perfected by Ed Poitras.

The construction of the telescope, which one science magazine described later as "a kind of overachievement for its time, an astronomical tour de force," was fraught with adventure and peril. The huge mirror was to be made from Pyrex, after experiments with fused quartz failed. The blank was successfully poured on the second try, after the first attempt failed when weight-reducing cores broke loose and bobbed to the surface of the molten glass. After its pouring, the disk was menaced, not once but twice, by rising floodwaters of the Chemung River, which ran beside the Corning Glass Works in Pennsylvania where it was formed. At one point, workmen pulled the disk clear only hours before the river inundated the spot where it had rested.

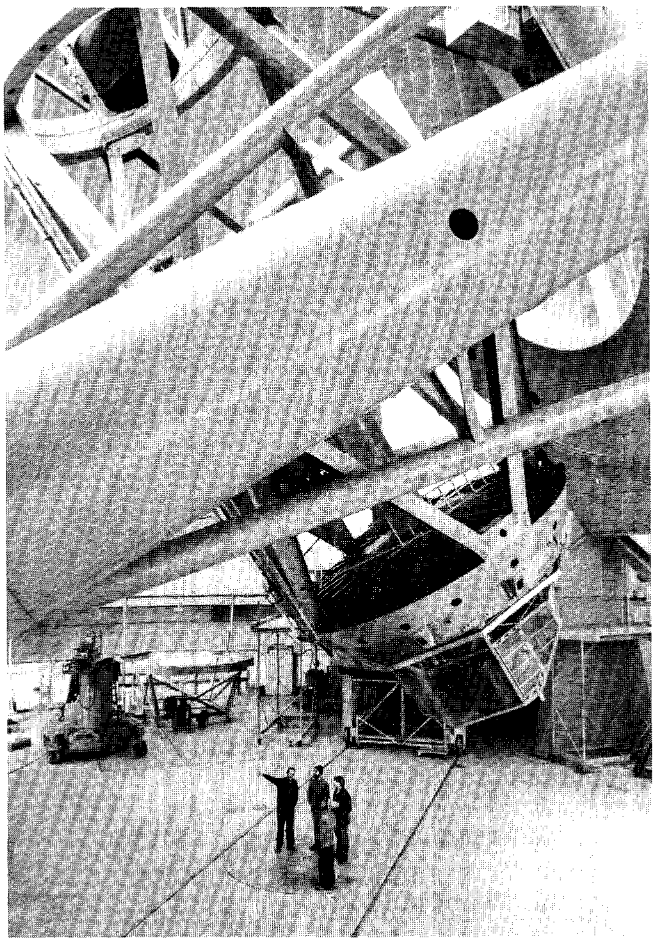
Once safely in the workshop at Caltech in Pasadena, the disk was ground by a team of technicians who, over four years, removed 5¼ tons of glass from the 20-ton blank, bit by laborious bit.

The construction of the telescope was also a harrowing ordeal, with each huge piece of structural steel having to be hauled up the side of Palomar Mountain.

Many new engineering concepts had to be developed for the telescope. The oil-film bearing, in which the weight of the telescope rode on a thin film of oil pumped between the sliding surfaces, was one such innovation. Another was the Serrurier truss, a structural concept that insured that, as the telescope swung, the optical axis remained in alignment, despite unavoidable sag in the structure. These and other features have been adapted for practically all more recent telescopes.

Active construction began at Palomar in 1935, was interrupted by World War II in 1941, and continued upon the end of hostilities to completion in 1948. The first pictures were taken throughout the winter of 1949. Unfortunately Hale, Pease, and Smith died in 1938, more than a decade before completion of the telescope, and never lived to see their dream realized.

Besides its immense scientific contributions, the 200-inch Hale Telescope has served over the years as an inspiration for later telescopes. "I believe the fact that one could build a successful 200-inch telescope made it possible for other groups to plan large telescopes without hesitation," says Maarten Schmidt.

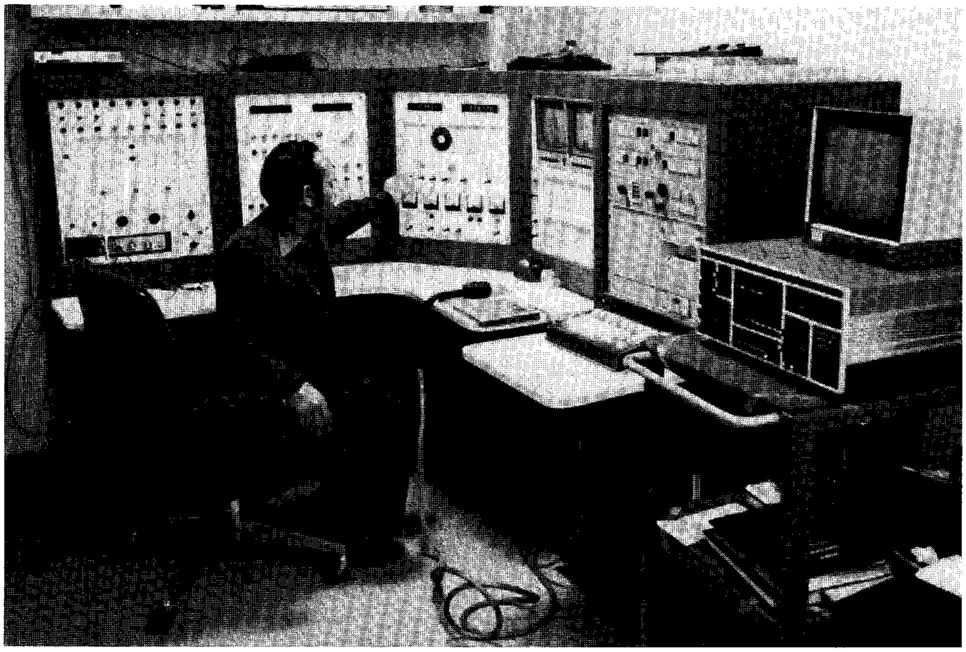

1979: The 200-inch telescope today.

The 200-inch has even produced nationalistic envy — as evidenced by the Soviet 234-inch telescope. "This telescope, which has not proved to be a particularly successful scientific instrument, was exclusively a matter of national pride," Schmidt says. "The Soviets use the metric system, and one cannot help but notice that their 234-inch (or six-meter) telescope is precisely one meter larger than our 200-inch (that is, approximately five-meter) Hale Telescope."

The 200-inch telescope's place in astronomy today is as solid as its construction, one reason being its continuing modernization. When the telescope was built, photographic plates were the predominant data-recording method. Photographic plates can record enormous amounts

A Giant's Birthday

Palomar Superintendent Gary Tuton adjusts the controls of the Hale Telescope. These are not the original controls but updated ones that were installed in 1976.



of data, but they have their drawbacks. Hundreds of photons of light are required to activate a single grain on a photographic plate, so that, for very faint objects, exposure times can range up to several nights. However, even if long exposures can be accomplished, photographic plates are nonlinear in their response; twice the exposure does not result in twice the number of grains being activated. Also, the plates become saturated after too long an exposure.

Since the mid-1960s, scientists at Hale Observatories and Caltech have applied numerous sophisticated electronic devices to overcome those limitations. Electronic detectors can record far more sensitively, so that objects which formerly required hours of exposure, now require only minutes. Whereas photographic plates are only about 2 percent efficient in terms of the translation of photons of light into a signal, most current electronic detectors can reach about 25 percent efficiency, and increases to 80 percent have been achieved with new imaging systems based on charge-coupled devices.

Such electronic devices can perform some neat tricks to make an astronomer's life far easier. For example, the electronic target-acquisition system now installed on the telescope allows it to be accurately pointed at objects too faint to be seen by the human eye even through the 200-inch. Light from such an object is collected over a long period, and the integrated signal is displayed to allow the telescope to be centered on the object. Another photoelectric system allows the airglow from the night sky to be subtracted from observations, and still other detectors make possible sophisticated observations at infrared wavelengths.

Another factor in the continuing success of the 200-inch telescope is the management philosophy that allows its use in long-term studies. "Members of the Hale Observatories staff have little hesitation about embarking on projects that will last many years, because they can be assured of observing time to carry them out," says Schmidt. "The national observatories have similar large telescopes, but their style is one of allowing only short observing runs, say a few nights, which does not permit astronomers to address any problems very deeply."

Even with the enormous advances in astronomy over the last three decades, Hale Observatories astronomers expect the Hale Telescope to continue as an important scientific instrument.

"Astronomy is data-limited," says Schmidt, "which means that if you doubled the number of telescopes of 100 inches or so, I think the output of astronomy would almost double, because there is so much to be asked of the universe."

Technology will no doubt continue to advance the science of astronomy, but the giant telescope at Palomar will remain a preeminent scientific instrument. And perhaps just as importantly, it will continue as a reminder of what daring scientist-entrepreneurs like George Ellery Hale and his team of gifted colleagues can do for science. ☐

Genes, Cells, and Behavior
A View of Biology Fifty Years Later

by Norman H. Horowitz
Chairman of the Division of Biology

A symposium on "Genes, Cells, and Behavior: A View of Biology Fifty Years Later," marking the 50th anniversary of the founding of the Division of Biology, was held on the Caltech campus on November 1-3, 1978. Eighteen papers, covering topics ranging from molecular genetics of bacteriophage to human behavior, were presented in five sessions. The speakers were all alumni or former members of the Division. Over 700 alumni, students, and friends of the Division attended the symposium, which was moved to Beckman Auditorium after overflowing Ramo.

Social events of the celebration included a reception held in the Athenaeum on November 1 and a Reunion Dinner, also in the Athenaeum, on November 2. The dinner provided the setting for a sentimental journey into the past, since so many alumni and retired faculty members were there.

The original biology faculty consisted of four geneticists, including Thomas Hunt Morgan, its almost legendary chairman. Of the four, only Sterling Emerson, now Professor Emeritus, survives. He and his wife, Mary, were present, as were Phoebe Sturtevant and Florence Anderson, the widows of Alfred Sturtevant and Ernest Anderson, the other members of the original faculty.

Other old timers included Professor Emeritus Henry Borsook, who came to Pasadena in 1929 as Caltech's first professor of biochemistry, and his wife Lisl; George Beadle, who arrived as a National Research Council Fellow in 1931 and later succeeded Morgan as chairman of the Division; and a number of early alumni, including Donald Poulson (BS '33, PhD '36), Herman Schott (PhD '33), and Charles Schneider (BS '34). Two Chinese alumni, Chia-Chen Tan (PhD '36) and San-Chiun Shen (PhD '51), came from Shanghai to attend the celebration.

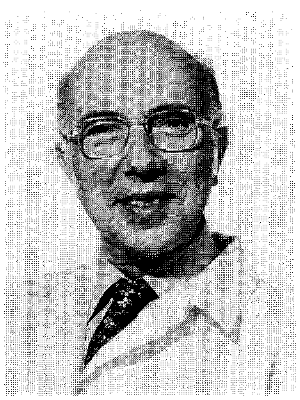
The main event of the evening was an illustrated talk by James Bonner entitled "Caltech and the Origins of Modern Biologists." Since Professor Bonner's Caltech career spans 49 of the Biology Division's 50 years, and since he has nearly total recall, he was in an especially favorable position to recount the history of the Division, which he did with his usual verve. He made the point that Caltech has been not only a source of excellent science and scientists, but also a fountain of inspiration to which its graduates often return — a compliment that we hope we deserve and will continue to deserve as we enter our second half century.

In the following article, we summarize the talks given in the first two sessions of the symposium. Summaries of the last three sessions will appear in the next issue of *E&S*.

Session I — Biology of Cancer

Cell Transformation and Cancer

Dr. Renato Dulbecco
Nobel Laureate
The Salk Institute
La Jolla, California



Renato Dulbecco's work on animal viruses began in Max Delbruck's laboratory at Caltech as an outgrowth of the bacteriophage research that was the major occupation there. He studied polio virus at first, but later he switched to tumor viruses. The latter, unlike polio virus, do not kill cells, but transform them into cancer cells. In this respect they resemble the so-called lysogenic phages, whose DNA is integrated into the DNA of the host bacterium and is thereafter transmitted from one generation to the next as part of the bacterial chromosome.

This analogy is an apt one, because it was subsequently shown that the genetic material of tumor viruses is, in fact, integrated into cellular DNA. The integrated viral DNA is transcribed into RNA, just as the cell's own genes are, and viral proteins are made. Transformation is thus seen to be a consequence of the expression of viral genes.

Mutations affecting transformation have been obtained, the most striking of which is in Rous sarcoma virus (a tumor virus of chickens). This mutant is temperature-sensitive: It induces cellular transformations in the usual way at low temperatures (32° C), but at high temperatures (40° C) the transformed cells revert to normal. The gene that gives rise to this mutant, and that is evidently responsible for maintenance of the transformed state, is called *sarc*. Recent work has shown that the product of the *sarc* gene is a protein kinase; that is, it is an enzyme that phosphorylates proteins. This finding may explain the complex action of the virus, since such an enzyme can alter many cell functions by modifying various proteins in the cell. There is some evidence that other tumor viruses may also produce kinases.

What is the relation between spontaneous or chemically induced cancers and viral transformation? Because the former are, as is now clear, caused by mutations in the genetic material of the cell (whereas transformation is induced by foreign genes imported into the cell), they seem at first sight to be different. The difference tends to disappear when the origin of the viral gene is considered, since there is strong evidence that the viral genes are of cellular origin.

Thus the base sequence of the *sarc* gene is very similar to that of a cellular gene, and the same is probably true of the transforming genes of other tumor viruses. These cellular genes may thus be potential cancer genes, normally controlled by repressor genes similar to those known in bacteria. Cancer may result from mutations in the repressor genes inactivating them and releasing the cancer genes. Since two repressor genes would have to be inactivated in a diploid cell, this hypothesis has certain statistical consequences, and these seem to be borne out in the work reported by Alfred G. Knudson (see page 13). Experimental evidence also supports this hypothesis. Thus, all cancer — viral, spontaneous, or chemically induced — can be attributed to the activation of cancer genes which determine enzymes with multiple effects.

Dulbecco concluded: "And so on this 50th anniversary we can contemplate with some satisfaction the progress made in the field of cell transformation and cancer. As in many other fields of biology, the experiments were initiated in these laboratories and then spread to many other places, forming a community of effort that looks at this Division as its alma mater."

RNA Viruses and Cancer

Professor Howard Temin
Nobel Laureate
McArdle Laboratory
for Cancer Research
University of Wisconsin

Retroviruses are those viruses whose genetic material is RNA, not DNA. In the course of their life cycle, retroviruses make a DNA copy of their RNA, and this copy becomes inserted into the DNA of the host cell. Rous sarcoma virus is the prototype of retroviruses. At the beginning of his talk, Temin predicted that there would be much convergence among the speakers at this session concerning the nature of cancer; but he would not say whether this means that we are now approaching the reality of the cancer problem, or whether it merely reflects the common Caltech backgrounds of the speakers.

Rous sarcoma virus is a strongly transforming or rapidly oncogenic (cancer-producing) virus, in contrast to most retroviruses, which take months to produce tumors. Rous virus differs from the weak viruses in having the *sarc* gene (see Dulbecco). It has been shown by DNA-RNA hybridization methods that Rous virus and other strongly transforming viruses arose from weakly transforming viruses, which in turn arose from the cellular DNA of the host. The *sarc* gene is apparently a cellular gene that was incorporated into the weak virus at a later time, making it strongly transforming. Weak viruses become oncogenic by acquiring genes like *sarc* by mutation, which explains why they are so slow to produce cancer. Considerable evidence indicates that weak viruses evolve from the genome of the host species, and various intermediate stages in this process of escape of the virus from the host DNA have been found. Weak viruses persist in nature, but strong ones do not because they kill their host. They are preserved in laboratories, however.

Retroviruses are exceptional in the ease with which they enter and leave the cellular DNA — going in as DNA, coming out as RNA. Much has been learned recently about the integration process. Studies with the spleen necrosis virus, a non-transforming retrovirus otherwise very similar to Rous virus, have shown that the viral DNA is inserted into many different sites of the host DNA. After a period of time during which the virus causes an acute infection, viral DNA disappears from all sites except one, where it remains during a long period of chronic infection. It thus appears that the behavior of the virus is influenced by the site of integration. By contrast, the integration process involves one specific site in the viral DNA sequence. These various mechanisms can throw light on the mode of evolution of tumor viruses and may also be relevant for the process of differentiation.

Environmental Chemicals Causing Cancer and Mutations

Professor Bruce Ames
Department of Biochemistry
University of California
Berkeley

The problem of exposure to toxic chemicals has taken on new proportions since the 1950's, when large-scale production of modern chemicals began. There are 50,000 chemicals in commerce at the present time, and 1,000 new ones are added every year. Some of these, such as vinyl chloride and ethylene dichloride, are produced at the rate of billions of pounds per year. Although structural considerations alone would suggest that these substances are carcinogens, vinyl chloride was being made at a rate of 4 billion pounds per year before it was tested and found to be carcinogenic. Ethylene dichloride was found to be a potent carcinogen after 100 billion pounds had been manufactured in the United States. It is not proposed that all such chemicals be banned, but it is suggested that they be recognized as dangerous and treated with respect.

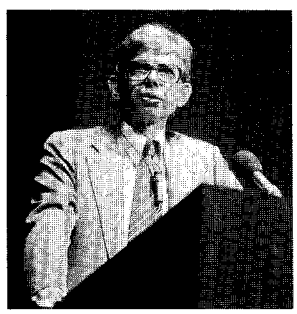
The problem in recognizing environmental carcinogens is that their effects in man are delayed for 20 to 25 years. This is the case with cigarette smoking, with radium, with various industrial chemicals, and with the radiation at Hiroshima. The majority of cancers induced by modern chemicals will not appear until the 1980's. It is not known whether low doses of chemicals are safe; the same is true for smoking. Quite possibly some chemicals will give linear response curves, and others will show a threshold.

Animal tests are too expensive and slow to be applied to every new chemical. They are also not very sensitive. A new test devised by Ames is based on the premise that carcinogens are basically mutagens. The test measures the rate of mutation to histidine-independence of a histidine-requiring mutant of the bacterium *Salmonella typhimurium*. The test strain has been modified genetically to make it exquisitely sensitive to mutagens. Furthermore, since some chemicals become carcinogenic only after they have been acted on by enzymes in the liver (when they also become mutagens), the Salmonella test incorporates liver extract in the medium. Of 175 known carcinogens assayed, the test detects 90 percent as mutagens. Of the 10 percent missed, some are probably beyond the reach of a bacterial assay because their carcinogenicity is related to metabolic functions not found in bacteria. Griseofulvin, for example, is a carcinogen that deranges mitosis in animal cells by reacting with tubulin; bacteria do not have mitosis. The Salmonella test also fails to pick up carcinogenic glycosides, since they are processed by bacterial glycosidases in the gut before they become carcinogenic. The test is being modified to detect such compounds. The most important class of carcinogens not recognized by the Salmonella test is that of chlorinated hydrocarbons. This may have to do with the short half-life of free radicals through which these compounds act.

Most non-carcinogens are negative in the Salmonella test, but a few are positive. These are probably carcinogens that were missed by animals tests. An example is an antibacterial agent, a nitrofuran, that was widely used in Japan as a preservative in *tofu*. This compound had given negative results in animal tests, but it was found to be mutagenic in several systems. More careful animal tests were positive, and the compound is now banned. Other examples are some hair dyes and Tris, a flame-retardant.

Carcinogens are also found in nature. Dietary fat is a known factor in colon and breast cancer. Charred protein, as in charcoal-broiled steak, contains mutagens. Quercetin, a flavonol widely occurring in plants as the glycoside, is also a mutagen. Thus, one should not assume that chemical industry is the only source of dangerous chemicals. To decide on priorities, we first need estimates of the potency of the various carcinogens we come in contact with.

Heredity and Cancer in Man



Dr. Alfred G. Knudson, Jr.
Director
Institute for Cancer Research
Philadelphia

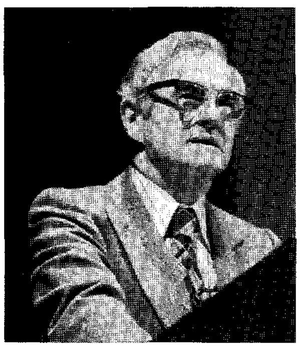
According to some estimates, 80 percent of cancer is of environmental origin and is preventable. The known environmental agents are irradiation, chemicals, and viruses. Since these agents are also known to be mutagens or to alter the host genes in some way, they provide strong support for the idea that induced cancer arises by mutation. Besides environmentally caused cancer, there is inherited cancer. It is possible, in fact, that most human cancer results from the action of environmental agents on genetically susceptible hosts. Finally, there are cancers in which neither environmental nor hereditary factors seem to play a role. These spontaneous cancers apparently result from spontaneous mutations in the host tissues. Their frequency of occurrence forms a lower limit below which the incidence of cancer cannot fall.

The most important variable of all in cancer is age. The incidence of most cancers rises sharply with age. Cancer of the colon and stomach increases as a power function of age, suggesting that a certain number of mutations must occur in a cell before it is transformed into a cancer cell. This hypothesis explains much that is known about the epidemiology of cancer, and although it cannot be tested directly, indirect tests support the hypothesis. This proposal leads also to the intriguing consideration that, besides mutation, the number of defective genes in a cell can be increased by the chromosomal process called mitotic recombination. The point of major interest is that this mechanism may explain the action of certain chemicals that are not carcinogens by themselves but that are known to enhance the effectiveness of carcinogens. The possibility that these "promoters" act by increasing the frequency of mitotic recombination has some experimental support.

Session II — Phage

ϕX174 A Research Odyssey: From Plaque to Particle and Mutant to Molecule

Dr. Robert L. Sinsheimer
Chancellor
University of California
Santa Cruz



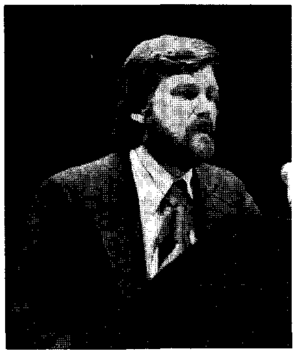
ΦX174 is one of the smallest bacteriophages. Largely owing to that circumstance, more is known about it than about any other DNA-containing virus. The ΦX174 particle has a diameter of 25 nanometers, and it consists of a protein coat enclosing a single-stranded ring of DNA. The coat contains four kinds of proteins, including a small basic protein that is internal and is believed to provide a counter-ion to the negatively charged DNA. After the viral DNA enters a bacterial cell, it is converted into a double-stranded ring. Following this, viral proteins are made from the information contained in the viral DNA; the double-stranded ring is replicated a number of times; single-stranded rings are made by a separate process and packaged into viral coats; and the host cell is lysed, allowing the progeny virus to escape.

The DNA of the virus has recently been completely sequenced — i.e., the order of its 5386 nucleotides has been determined — thanks principally to work in Sanger's laboratory in England. Ten genes have been identified. Four of them encode the coat proteins, four are involved in DNA replication, one functions in lysis of the host cell, and one produces a protein whose role is unknown. Examination of the sequence of the viral DNA shows that the genes are not composed of simple segments of DNA, one following on the other around the circle. Rather, there is considerable overlap among the different genes. Gene B, for instance, is completely contained within gene A: The same sequence of nucleotides read in one phase gives protein B; read in another phase it gives a portion of protein A. One segment of the viral DNA is read in three phases — the maximum possible with a triplet code — allowing three different proteins to be encoded in the same segment of DNA. This compression of genetic information is clearly advantageous for a small virus, but it is difficult to see how the system evolved. Further study of the sequence with the feasibility of gene overlap in mind reveals a number of opportunities for the production of proteins that are not known to be made, but that exist as possibilities in the sequence.

Knowledge of the sequence also makes it possible to introduce mutations into any gene or region of the DNA at will, in order to study their effects. Exploitation of this possibility can be expected to enhance our understanding of this virus in the future.

The Rise and Decline of T4 Phage Biology at Caltech: A Latter-Day View

Professor William B. Wood
Chairman, Department of Molecular, Cellular, and Developmental Biology
University of Colorado



The fundamental genetic problem of biology — how genes replicate and direct the synthesis of proteins — was solved in principle by the early 1960's, but the epigenetic problem remains; that is, how the individual protein products of gene action are organized to form a living organism. To state the question in another way: How does one go from the linear arrangement of information in DNA to a three-dimensional structure? This talk summarized experiments carried out with bacteriophage T4 (most of them in Wood's laboratory) to answer this question.

Compared to simple viruses like ΦX174, T4 is a baroque contraption with a complicated contractile tail that allows it to inject DNA into its host. Experiments with mutants defective in the ability to produce various parts of the phage have shown that T4 is put together from three independent sub-assemblies: head, tail, and tail fibers. Each sub-assembly is made independently of the others. Mutants that are unable to produce one sub-assembly accumulate the other two. The sub-assemblies are intermediates in phage assembly. If extracts of different mutants containing different sub-assemblies are mixed, the parts come together to form complete phage.

Different sets of genes are involved in the production of each sub-assembly. Altogether, about 50 genes participate in phage assembly, or more than the total number of proteins in the phage. Some proteins must have catalytic functions in the assembly process. The pathway of assembly has been worked out, and a strict order of steps is followed. It is clear that T4 construction requires more than spontaneous self-assembly of protein molecules as occurs, for example, in the case of the much simpler tobacco mosaic virus. The temporal order of events implies that the phage exerts kinetic control over the many possible reactions in such a way as to insure the correct outcome. These results show that there are still many intriguing problems to be worked out in bacteria and their viruses.

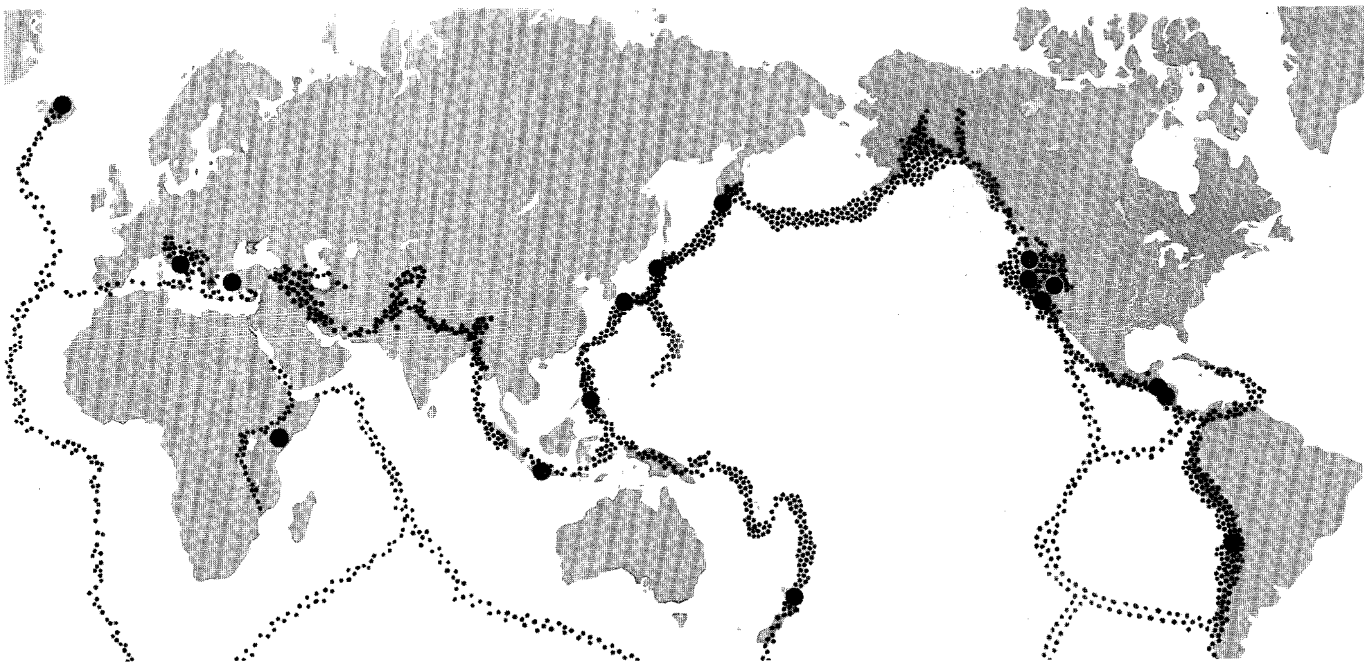
The Last of the T Phages

Dr. F. William Studier
Department of Biology
Brookhaven National Laboratory

T7 was the last of the T bacteriophages to be found, and it is the last to receive detailed study. The feature that has attracted Studier's attention is the high degree of variability among stocks of T7 that had originated from a common ancestor isolated in the 1940's. For example, in a study of 17 stocks of the phage being used in different laboratories around the world, Studier observed that only 8 were identical, and 9 were different from these and from each other. The criterion of identity used was the pattern of cleavage of the viral DNA by certain bacterial nucleases (so-called restriction enzymes). This is a very sensitive procedure, easily able to distinguish strains that differ in only a few percent of their DNA basis.

In an extension of this study, Studier collected a number of phages related to T7 and examined them in various ways. Morphologically they are all alike, and they have the same genetic organization — i.e., the order of genes controlling various functions is the same along all the viral chromosomes. Furthermore, the homologous genes are read at the same time following entrance of the phage particle into the host cell, and proteins with the same functions and of similar sizes are produced. These similarities extend to phage T3, a remote but recognizable relative of T7. When DNA's of the various strains were compared, however, they were quite diverse. This suggests that considerable genetic change had gone on beneath the surface, while the basic morphology, genetic structure, and functional organization were conserved. Studier referred to these changes as "neutral" evolution. The extent of divergence possible under this kind of evolution was revealed in a comparison of homologous enzymes of T3 and T7. Enzymes that are identical in function and position on the genetic map have diverged to the point where they perform their functions by different mechanisms.

A preliminary laboratory experiment indicated that T7 accumulates nonlethal mutations at a rate sufficient to account for this evolution. These studies may well throw light on the molecular mechanisms of evolution in general. □



Areas of geothermal potential and location of geothermal developments around the globe.

Developing Our Geothermal Energy

by Carel Otte

In the late 1960's, the United States entered into a critical period of energy supply. No longer able to be self-sustaining, we became dependent on large volumes of imported crude oil. By the time of the Arab Oil Embargo in 1973, we were importing over 30 percent of our oil. The nation should have learned an important lesson in 1973, but in spite of government efforts to conserve, and industry efforts to bring forth new conventional and alternative energy supplies, the United States today must import some 50 percent of its petroleum. And, with the Iranian crisis, the country is faced once again with curtailment of supplies and increased cost for its foreign oil.

The mandate to develop all the available new energy technology is clearly upon us. Of all the new types of energy from which to choose, geothermal energy is the one resource that is a viable commercial reality today. Geothermal is on the line — producing electricity. We know it works, and works well.

Geothermal energy is, in the broadest sense, the "natural heat of the earth," but as a practical matter this heat is not directly available to us for capture. Normally we think of geothermal energy in terms of the fluids that are in contact with hot rocks. It is these heated fluids that can be captured and from which energy can be extracted.

The temperature within the earth is considerably higher than at the surface, and this difference causes heat to flow toward the surface — a flow that occurs everywhere, though we are not normally aware of it. The normal geothermal gradient is about 1.5 degrees F per 100 feet, so at a depth of 15,000 feet the temperature is about 250 degrees F. This temperature is too low to be useful and too deep to capture. However, in certain areas, molten rock or magma, formed at great depths in the crust, succeeds in working itself very close to the surface, causing a sharp steepening of the geothermal gradient, which may be ten times the normal gradient, or more.

The areas of above-normal heat flow and steepening of the geothermal gradient occur in zones or belts that extend around the world. These are zones of crustal weakness, and they are characterized by such phenomena as high seismicity, evidence of volcanic activity, and geologically young mountains. One such belt extends from the tip of South America through Central and North America, Alaska, and around the Western Pacific, through Kamchatka, Japan, and the Philippines to Indonesia. Another belt extends from Indonesia along southern Asia into southern Europe. According to the newest theory of plate tectonics, these zones mark the borders of the stable, but moving, continental plates.

In these mobile areas of weakness, magma ascends closer to the surface. If groundwater is adjacent to these magmatic bodies or is mixed with hot gases and steam emanating from the crystallizing molten rock, the water will be heated and begins to rise toward the surface, sometimes causing hot springs, geysers, and fumaroles.

Hot water in a continuous column is subjected to the pressure of its own weight, raising the boiling point of water progressively with depth. For instance, at a depth of 1,000 feet, water boils at a temperature of about 420 degrees F. If a well is drilled deep into a fissure that is bringing thermal fluids to the surface, the hot water can be relieved of its overlying pressure; it will begin to boil, and then will flash into steam. The higher the temperature, the higher the ratio of steam to water when it comes to the surface. If the original heat content of the rocks is high, or the formation fluid pressures are below normal, the fluid may occur in super-heated form and be all in the steam phase, and from the well it can be directly piped into the generating plant. In case of flashed hot water a steam separator is required. The excess water is then disposed of on the surface or by reinjection. It is thought that the hot water geothermal reservoirs will be by far the most abundant.

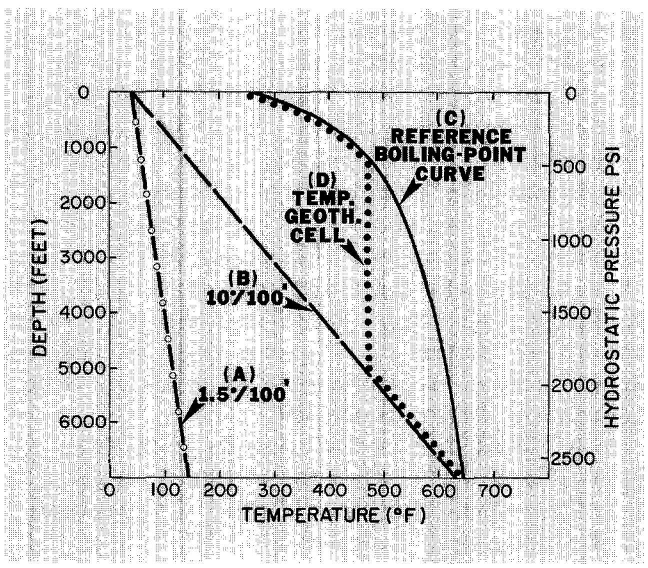
It is important to realize that it is *heat* that we are attempting to produce by means of fluids in the ground — either in the form of steam or hot water — not the direct heat of the magma itself. This, in turn, means that the rocks need to contain adequate void space so that they contain hot water or steam and that they are sufficiently permeable to yield these fluids.

Finally, the fluids should possess relatively suitable chemical composition so that they do not corrode or scale up the casing and piping systems. This is an important aspect of geothermal development; we need to locate a resource with all the suitable attributes.

The temperature of geothermal systems is normally in the range of 450 to 600 degrees F, which is considered low-quality heat by fossil fuel standards. For this reason, the most efficient utilization of the energy would be for the purpose of "process heat" in industrial applications. But the distance over which the energy can be transported is very limited — approximately one mile. Beyond this, there is too much heat or pressure loss. For this reason the utilization for process heat calls for a unique set of circumstances bringing the resource and the industrial application together in one single geographic setting. There are only a few such unique developments — for space heating in Iceland and in such towns in the United States as Klamath Falls, Oregon, and Boise, Idaho, and for the paper industry in New Zealand.

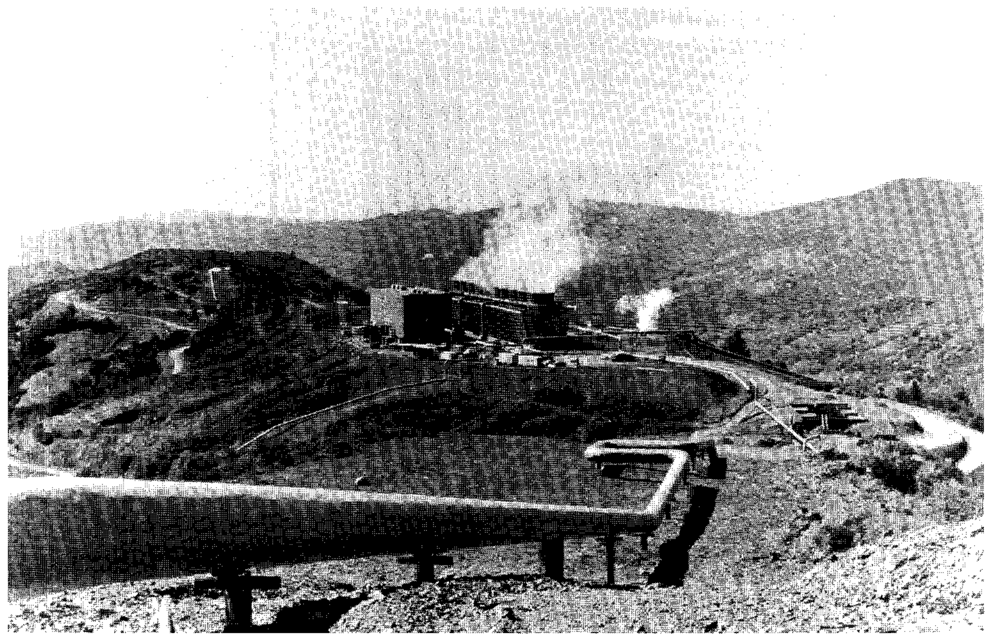
By far the largest application today of geothermal energy is for the generation of electric power. A pound of steam coming from a man-made boiler fired by conventional fuel or from the earth's boiler is undistinguishable, and the steam turbine does not know the difference. Accepting then that electric power can be generated, and transported over a transmission system, the development of a geothermal deposit will depend solely upon the available load centers requiring the energy. In the United States a dense power grid now brings every geothermal deposit within reach of such a load center, so good deposits will see ready development. In other areas of the world, however, the transmission cost to take the energy to the market is an additional factor in comparing the feasibility of

Geothermal Gradient



(A) depicts the normal geothermal gradient in the earth's crust of the stable areas, such as central North America and central Asia. (B) shows the gradient in geothermal areas. Curve (C) depicts the boiling depth curve, the temperature-versus-pressure relationship for boiling water. The field to the left of the curve delineates the liquid phase, to the right, the steam phase. Curve (D) is the temperature distribution in a typical geothermal cell.

Developing Our Geothermal Energy



Specially insulated pipelines carry geothermal energy to a 100-Mw electrical generating plant in The Geysers field in northern California.

geothermal power with an alternative source of electric generation such as coal, nuclear, or oil, where the fuel can be transported to its point of utilization at the generating plants.

In the United States, geothermal power is now developed in increments of 50 to 100 Mw (megawatts), which appear to be optimum blocks of power for the number of wells required, the pipeline distance, and the size and cost of the turbine. At increments of 100 Mw, geothermal power is economically competitive with energy produced by fossil fuel and nuclear plants of about 1000-Mw size that enjoy the advantage of economy of scale.

Many developing countries cannot handle such large increments to their installed capacity as 1000 Mw, and smaller blocks of fossil power are uneconomic. This makes geothermal power a very attractive form of power generation in those countries that have the geologic potential. Some 50 countries around the world are now active or interested in geothermal exploration.

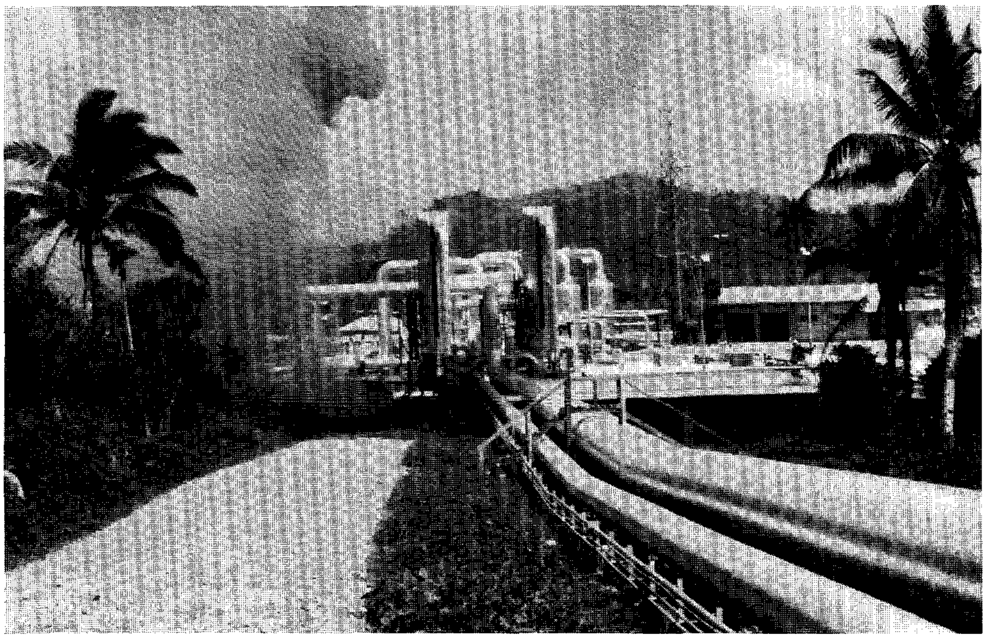
In the United States, the best areas for geothermal potential are found in the states west of the Great Plains from Canada to the Mexican border, and along a geopressured zone extending along the Gulf Coast.

Our major geothermal development is The Geysers project in Sonoma County, California, the largest geothermal project in the world. This development began in 1957, and by 1960 it was producing enough steam to power a 12.5-Mw generating plant. Today, enough steam is produced to power a generating capacity exceeding 630 Mw, which is sufficient to supply *all* the electrical requirements of a typical city of over 600,000 people. Currently, an additional 330 Mw of generating capacity is under construction, to be on line by 1980, bringing the total generating capability of the field to over 900 Mw.

The Geysers field is an example of a steam field, with water occurring in the vapor phase underground and ready to be used directly in the turbines when brought to the surface. The fact that this particular resource can be used so directly and efficiently has been a key element in the successful development of The Geysers to its current size.

Another area with the potential for major development is the Imperial Valley of California. Current activities there are a resumption of an effort that began in the early 1960's in the Salton Sea area to develop hot geothermal brines for their potash and heat content, for both electric and non-electric application. However, the fluids found there were so highly corrosive they proved impossible to handle with the equipment and technology available to industry at that time, and so the efforts were suspended. A renewed exploration effort started in the early 1970's, stimulated by the Mexican geothermal power production just south of the American border.

Test wells have indicated a decreasing amount of dissolved solids in fluids found southward from the Salton Sea approaching the Mexican border, and discoveries have been made in the Brawley, Heber, and East Mesa areas. Working in the Brawley area, Union Oil has drilled ten wells and is now conducting extensive tests to evaluate the



High- and low-pressure steam pipelines carry geothermal energy to a power plant in Tiwi, Philippines, equipped with a double inlet turbine; the scrubbers in the background eliminate moisture and dissolved constituents from the steam before delivery to the plant.

productive capacity and control the corrosion and scaling tendencies. Union has entered into a contract with the Southern California Edison Company to build a 10-Mw pilot generating facility to demonstrate the feasibility of utilizing the resource. If successful, this unit will be followed by units of 50- to 100-Mw size.

In the Heber area the problems are not so much technical as economic. Early drilling by Magma Power and Chevron, followed by Union, delineated a relatively low temperature deposit of about 350 degrees. A deposit with this low a temperature requires the drilling of many more wells to recover the needed quantity of heat energy. If the plans for cooperative field development between the resource producers are realized, commercial development could start soon. Edison has announced plans jointly with Chevron for the installation of a 50-Mw double flash steam unit by 1982. There are also test operations under way in the East Mesa field where Magma Power is installing an 11-Mw binary cycle power plant for completion in April 1979, and Republic Geothermal has announced plans for a 48-Mw facility under the Federal Loan Guaranty Program with the 10-Mw portion scheduled for completion in 1980. Like the Heber field, this is also a low-temperature deposit, and Magma and Republic are planning to pump the wells under back pressure to prevent flashing. Magma will heat-exchange the geothermal fluids against isopropane and isobutane that will drive the turbo-expander. Thus the name "binary cycle." Republic's plants will be steam-turbine type.

In 1976, San Diego Gas and Electric, jointly with the Department of Energy (DOE), resumed activities on the Salton Sea brines with the installation of a small unit for research and testing purposes — the Geothermal Loop Experimental Facility — utilizing brines from wells drilled by Magma Power. Recently, Union joined Edison and Southern Pacific Land on acreage in the same area. Four wells are being drilled and tested, and Edison has agreed to install a 10-Mw power plant to demonstrate that the technology has been developed to utilize the resource.

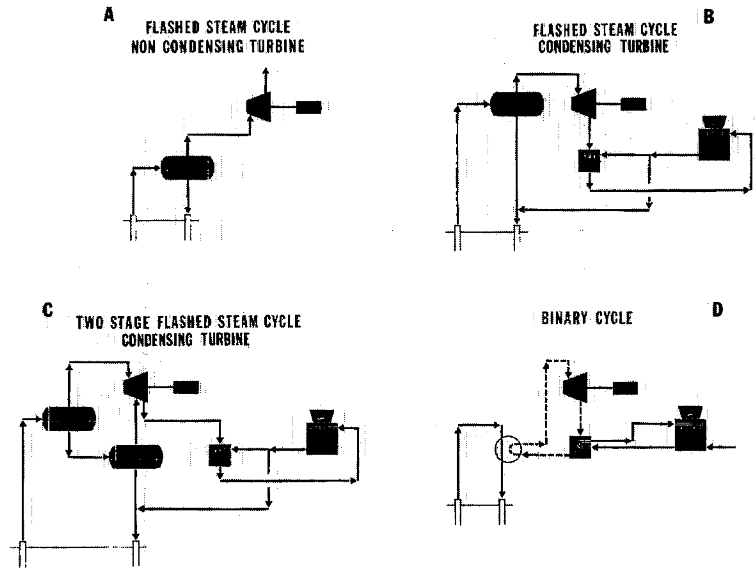
With all this activity in the Imperial Valley, solutions to the technical problems should be forthcoming soon, and this area should take its place as one of the major geothermal developments in the United States.

Outside California, Union and the Public Service Company of New Mexico have been selected by DOE to install a 50-Mw flashed steam demonstration plant in the Jemez Mountains 60 miles northwest of Albuquerque as the first step in what could become a major development of the resource that has been identified there.

In Utah, Phillips Petroleum has a hot water discovery in the Roosevelt area near Milford, and a 50-Mw plant is being planned jointly with Utah Power and Light.

A 10-Mw binary cycle unit is being planned in Raft River, Idaho, to operate on waters of approximately 300 degrees F, which should determine whether fluids of such a low temperature can be developed commercially.

These research and development activities, and the near-commercial demonstration facilities, add up to an-



Geothermal Power Cycles

Geothermal Power Cycles A, B, and C are examples of flashed steam cycles of increasing complexity, cost, and efficiency in heat recovery. In Cycle D, the geothermal fluid exchanges its "heat" against a secondary (binary) fluid that is contained in a completely separate and "closed" system. This cycle can be employed in relatively low temperature ranges of 300 to 400 degrees F.

nounced plans for nine geothermal power projects at seven sites with a total generating capacity of almost 300 Mw. The importance here is the number of sites involved, because the first power plant on a newly discovered resource is the most significant step in its development, as it demonstrates technical and commercial feasibility.

In addition to all these developments there is also exploration in Nevada, Utah, Idaho, and other places in California that should result in additional discovery of resources. Phillips Petroleum, for example, has apparently already located significant geothermal resources in western Nevada.

Special mention should be made of the very large geopressured water resources of the Gulf Coast, which are of an unusual nature because of the elevated temperature and the dissolved methane gas. Experiments are currently being conducted with DOE funds primarily for the recovery of methane and to identify the technical, environmental, and economic problems associated with the development of these resources.

Finally, mention should be made of the Hot Dry Rock (HDR) Program carried out by the Los Alamos Scientific Laboratory.

The resource base is considered to be immense, and consists of hot rocks devoid of fluids. LASL has drilled several wells in such rocks in New Mexico and established communication by artificial fracturing between two of them. The objective is to circulate water down one bore hole and through the formation, and then up the other well — "mining" the heat contained in the rocks in the process. If this can be carried out on a routine basis commercially, these resources can make significant contributions to our energy base.

On a nationwide scale, experts believe that there is a geological opportunity to produce enough geothermal energy to supply 20,000 Mw of generating capacity in the next two decades, which is equivalent to about 700,000 barrels of oil per day, or 8.5 percent of today's crude oil production in the United States. As technological advances are made, there is the potential for several times this capacity in succeeding decades.

All these activities indicate that the development of geothermal resources is now a reality. The resource is coming of age. The question now is, what size is the industry going to be and at what rate will it grow? The factors holding back development fall into two areas, technical and institutional. Technical problems play an important role in impeding geothermal development. Of the many technical problems, I would like to single out two areas of research where improvement of technology can make significant contributions to reduction of the investment costs associated with geothermal developments. One is in the area of drilling, the other in well or reservoir stimulation. Success in these areas could result in resource development cost savings of up to 50 percent.

The drilling of geothermal wells can be plagued with many problems — unusually hard and tough rocks, crooked holes, and abnormal formation fluid pressures that can cause lost-circulation conditions of the drilling fluids, for example. The elevated temperatures affect the drilling fluids and drilling tools, and the naturally occurring gases (such as carbon dioxide and hydrogen sulfide) can lead to corrosion of the steel drill pipe and other equipment. Consequently, geothermal wells are commonly twice as expensive to drill as oil and gas wells of equivalent depths. DOE has now joined industry on a program of improving drilling technology, equipment, and tools, and the program appears well formulated and closely coordinated with industry. DOE is also sponsoring a parallel program in the development of logging tools.

Increasing the productivity of wells by subsurface stimulation of the reservoir — mechanical, explosive, or chemical — would reduce the number of wells needed to provide the necessary steam of a power plant, reduce the cost of resource development, and make production of geothermal energy more cost competitive. Fracturing of rocks should be tested in known hydrothermal systems where the subsurface geology is well understood and success in increasing permeability can be immediately observed. Perfection of these technologies is very much needed to make existing systems economically viable.

LASL's work in the Hot Dry Rock (HDR) Program should be coordinated with the program on reservoir stimulation, the first priority being to prove that we can develop already known hydrothermal systems that have natural but inadequate fractures associated with them; then we can embark on exploring for new HDR resources. Such exploration has associated costs and risks that require major technological developments and that additionally require a water source for underground circulation in the areas of the Western states where water is normally scarce.

Of course, scaling and corrosion problems associated with certain geothermal developments can be serious. Positive results from industry's efforts in the Imperial Valley would stimulate geothermal developments in general because the technology would be transferable.

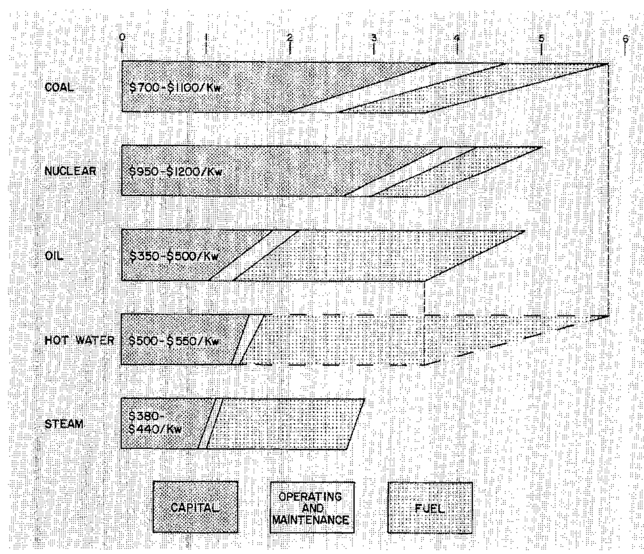
However, all our exploration successes and possible solutions to technical problems will be in vain if we do not resolve the institutional issues that are currently a great obstacle to geothermal development. One way the state and federal governments can take positive action is by reducing procedural red tape from government. Duplication of jurisdiction should be removed, and permitting processes should be streamlined. Federal and state environmental laws have become formidable obstacles, particularly in the hands of special interest groups. I fervently believe that we can proceed with development while protecting the environment, but I believe we must spend less money on studies and more on actual environmental improvements.

For example, the original plan for The Geysers project as a whole was to reach a generating capacity of 16,000 Mw by 1980. This would result in a savings of 18,400,000 barrels of low sulphur fuel oil per year that would *not* be needed to generate electricity, and a foreign exchange savings of about $280 million each year by reducing oil imports by that amount. But because of governmental red tape this goal will not be reached until 1990 — 10 years behind schedule.

Contrary to what many think, geothermal developments are very costly, calling for high and extensive investments and long lead time. Years of delay because of bureaucratic red tape adds to the costs of the development and adversely affects the economics.

The projected costs for achieving the national goal of producing enough geothermal energy to power 20,000 Mw of electrical generating capacity by 1990 illustrate the whole economic problem. To find and develop this capacity will require the drilling of at least 1,200 exploratory wells and 8,000 development wells at a minimum average cost of $825,000 per well or a total of $7.6 billion in 1978 dollars in drilling costs alone. Investment in hookup facilities will add another $4 billion, bringing the total investment requirement to about $11 billion, plus the necessary cost of capital itself. Moreover, a like investment will be required for replacement production wells and facilities through the approximately 30-year operating life of each

New Electrical Power Generation Costs ¢/KWH



Ranges of comparative electricity costs for new electrical power generation based on published cost information. The graph suggests the cost range for hot water geothermal that would make it competitive with conventional energy sources.

development as the resource depletes.

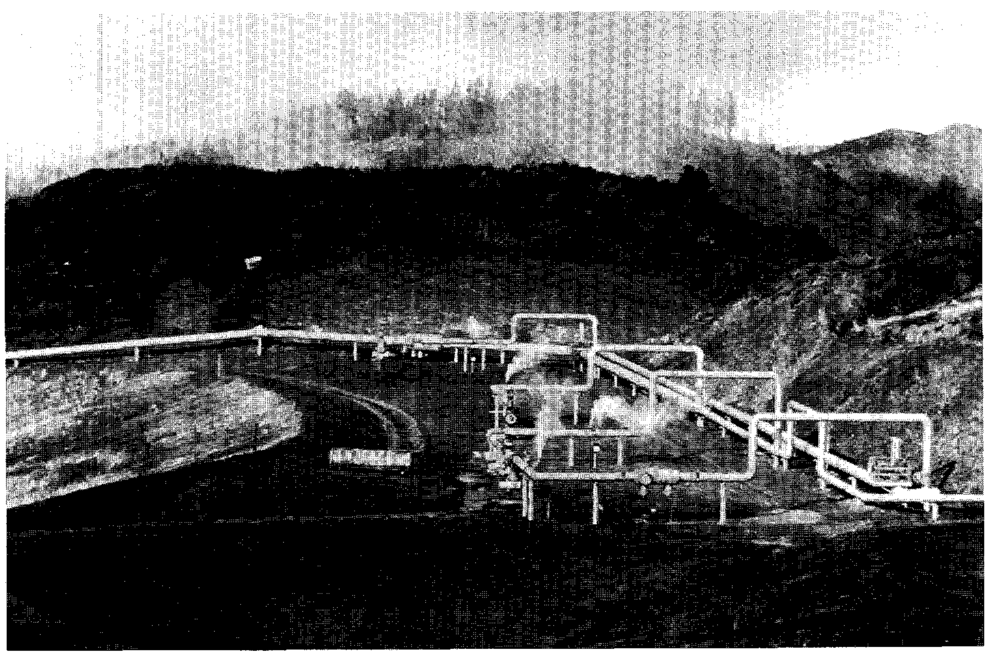
In this regard, the threat of forced divestiture has discouraged large energy companies from entering the geothermal business and thus has been counterproductive in fostering the growth of the industry. These investment requirements are awesome sums of money, and I fail to see where they will come from if not from the energy companies. Outside financial sources do not come forth if technical expertise is not also available. Fortunately, this threat appears to have subsided in the last year.

There is no doubt that geothermal development can be a significant factor in the effort to change our current energy consumption patterns. We burn too much valuable oil and natural gas in utility boilers, and in so doing starve other uses such as transportation, residential heating, and petrochemicals. By backing oil and gas out of the boiler feed stream for central station power generation, we achieve a double gain of reducing both imports and domestic oil and gas consumption. For instance, the 20,000 Mw of geothermal generating capacity that could be developed in the next two decades would be equal to almost 700,000 barrels of oil per day — more than the amount the nation will attempt to save by conservation in an agreement reached with the major industrial nations of Europe and Japan as a result of the recent Iranian crisis. Furthermore, development of this amount of power would result in a foreign exchange savings of about $4.0 billion annually for us.

While the industry has had — and still faces — frustrating conditions, there are some encouraging efforts at the federal and state levels to deal with some of the institutional barriers. On the federal level the President made a commitment to Congress that "the Departments of the Interior and Agriculture will streamline leasing and environmental review procedures to remove unnecessary barriers to development of geothermal resources." To carry out this mandate, an Interagency Geothermal Streamlining Task Force was formed to identify sources of delay in existing procedures and make recommendations for change. For many years the federal income tax treatment of geothermal well costs and production was in doubt, acting as a disincentive on development; in the face of uncertainty there is inaction. However, this uncertainty has now been resolved as part of the National Energy Act of 1978.

A state of California joint legislative and administration task force has also made detailed assessments of the obstacles to geothermal development in the state, and in late 1978 two bills were enacted that will accelerate the permit-approval process for energy production and power plants. Ideally, local government will cooperate with these federal and state initiatives and follow suit in reducing red tape burdens.

If the United States is to carry out its commitment to become more energy self-sufficient and protect itself against future international petroleum crises, alternative sources of energy such as geothermal must be allowed to grow. This will require cooperation between industry and government, not confrontation, and practical approaches to protecting the public interest must be adopted. □



A cluster of wells directionally drilled from one pad at The Geysers in northern California

Henry Borsook

—How It Was

The Institute Archives under the direction of Judith Goodstein has now initiated an oral history program. The staff began by inviting a number of emeritus professors to share their memories with them. One of the first completed accounts in this program is from Henry Borsook, professor of biochemistry emeritus, who was interviewed by Mary Terrall. Borsook, noted for his work in protein synthesis and for his contributions to the field of nutrition, was born in London, England, in 1897, and came to Caltech in 1929. After his retirement from Caltech in 1968, he continued his research until 1978 at the University of California at Berkeley. The Borsooks are now living in Santa Barbara.

E&S *has made a shortened version of the original transcript and presents here the second of two parts.*

Mary Terrall: When did you begin working on vitamins?

Henry Borsook: The work on vitamins was extracurricular, and it began when I first came to Pasadena in 1929. I found that the doctors around town really didn't know anything about nutrition and certainly didn't know anything about vitamins, and I felt that vitamins were among the most important medical discoveries of the century. So I used to do a lot of public lecturing in the evenings to groups of doctors and nurses and teachers, and then we did a little medical research on the effects of this vitamin or that vitamin.

Then the war came and I was asked to serve as a member of the Food and Nutrition Board, on which I served all through the war. The most important work that Board did was drawing up the table of Recommended Daily Allowances of proteins, vitamins, calories, and so on. This was of practical importance, yes, but it also had a profound ideological importance because it said that a good diet doesn't consist of food but consists of providing amounts of certain essential nutrients, if you like, and it doesn't matter where you get them from.

This was really a revolution in the whole nutritional concept. It was resisted by some people on the Board and by the Department of Agriculture. At first, because of the great political influence of some of these people, the Recommended Daily Allowances were tailored in some respects to what a person could get from what was considered to be a good diet, rather than what you need. But on the whole we succeeded in making this important distinction between what is needed to prevent or protect against a disease — like beriberi or rickets or scurvy — and how much would be desirable for what we would say was approximately an optimal diet.

Take vitamin B_1. You give people a certain minimum amount, and they won't have beriberi or B_1 deficiency disease, but their growth curve is moderate. If you give them three times that much, the curve is much steeper, and more importantly, senility is postponed, though they don't actually live longer. So this is why they were called Recommended Daily Allowances, whereas the Department of Agriculture and the Food and Drug Administration held out for some years for what they called Minimum Daily Requirements, which were the minimum required to protect you against disease.

MT: So the Recommended Daily Allowances would be much higher.

HB: Yes. For instance, it's known that an average-sized man or woman needs 0.6 of a milligram of vitamin B_1 to protect against getting beriberi, but the Recommended Daily Allowance is 1.5 milligrams. Ten milligrams of vitamin C will prevent anybody getting scurvy, but the Recommended Daily Allowance is 50 milligrams; 2 milligrams of niacin — nicotinic acid — will protect against pellagra, but the Recommended Daily Allowance is 20 milligrams; and so on all the way through.

Of course, one had to take into account some individual variations, so this was a kind of safe figure for most people in the population, to give them what we thought was an optimal diet. But the Department of Agriculture had said, "You can't get these allowances from just any reasonably good diet." So this led to enrichment; we enriched flour, we enriched milk, and so on.

MT: There was a lot of opposition to that, wasn't there?

HB: A great deal of opposition. I think that is largely gone now, but for a number of years there was a continual argument. We pointed out that if people are going to get all their vitamins and minerals as well as protein and calories from their food, they'd have to eat altogether too much — much more than what is really good for them. You couldn't get the Recommended Daily Allowances of vitamins and minerals short of 3,000 calories a day, and for the kind of sedentary life that most of us live that's altogether too much.

The field of nutrition that's been most neglected is the calorie requirement. There has been only one good determination of what the calorie requirement is in humans, and this was in young men, 25 years of age on the average, doing 400 calories of physical work a day. And it was shown with them that if you make sure they get all the vitamins and minerals and protein, their calorie requirement, with about 10 percent surplus, is only 2,200 calories. Now when you think we've taken on a kind of responsibility to prevent calorie malnutrition (I won't give it a fancy name like starvation) in Third World countries, the difference between 2,200 calories and 2,500 calories represents hundreds of 10,000-ton ships of food when you're dealing with millions of people.

MT: Let me go back just a bit to before we were in the war, when you wrote that long document, the Memorandum on National Defense. Do you remember that? It was June 15, 1940.

HB: Yes. It was that memo that had me invited to serve on the Food and Nutrition Board.

MT: What prompted you to write that memo originally?

HB: Just from my observations of patients, reading the literature of malnutrition, and studying the results of feeding different levels of vitamins, particularly, and of minerals too, to experimental animals. It was clear to me that most of us who weren't using vitamin concentrates were not getting enough. This is what led to that memorandum.

MT: And what response did you get?

HB: It was resisted, of course, but nevertheless there was a really enterprising and liberal member of the Department of Agriculture who had a lot of influence; his name was Wilson. And he read it and although he was a little uncertain about whether he would agree with me or not, he felt that I would be a good influence on the Board. And so I was invited to serve on the Food and Nutrition Board. They listened to me, but this memo didn't mean they paid much attention. I was not a lone voice, though; there were other people who felt, as I did, that we couldn't rely on diet to provide all the vitamins and minerals we needed.

MT: One of the things that you said in that memo was the importance of a national nutrition program.

HB: Yes, because the troops should have a good diet and so should people working in munitions factories and airplane factories. I think the fact that those people couldn't get enough vitamins and minerals contributed toward acceptance of the Recommended Daily Allowances.

Even in the 1940's it was so easy to add synthetic vitamins and minerals. People could see that all the bread and flour the troops got was enriched, and vitamins A and D were added to the milk they got, and so on. They were playing it safe. Why not, you know?

Then I did a study among aircraft workers at Lockheed. Considering that we were doing it with human beings, the plan of the experiment was all right. There were two groups, and no one knew which group he was in. Half of them got placebos and half of them got the vitamins, and we kept track of their records. At the end of the year it was clear that though there was no dramatic effect of the vitamins — because after all they were not vitamin-deficient people — the performance of those who got the vitamins was better than that of those who got the placebos.

MT: On the job, you mean?

HB: On the job, yes. Their production, absenteeism, morale in general — however you measured it — was definitely better. But when the war was over, all of that stopped. Of course, vitamins now are staples; everybody buys them; they even get them at the supermarket.

MT: I have just a few more questions on the war business. Was it directly the result of the National Research Council committee that the food for the troops was fortified?

HB: Yes. It was partly that Memorandum on National Defense that led to my being invited to come to Washington to talk to some Army and Navy officers, and even to the

Army base in Los Angeles, in terms of what they needed and of how they could get it. And of course I am still, I think, with the minority among nutritionists who insist that the easiest, cheapest, best way to get your vitamins is in a pill. Then you're sure, it's much cheaper, and you can then eat what you like.

You know, it's curious — sometimes when I talked to women about nutrition I'd tell them this, and I'd say, "You get an additional freedom then," and they didn't like it. They felt, I suppose, it was a reflection on their housekeeping and their preparation of meals. I'd say, "You can just give your husband and children vitamin pills for breakfast. Then all you have to be sure of after that is that they get milk or cheese. They can eat what they like after that, as long as they get enough to eat and there's enough variety." And they didn't like that.

MT: Who were the other people on the NRC Board?

HB: I should say the two most important people were Jolliffe and Wilder. They were doctors. Elvehjem later joined the Board. He was from Wisconsin, and he was there chiefly to protect the agricultural interests. I would say he was responsible for having the riboflavin in the Recommended Daily Allowances so high. It was amusing to us: Every man who worked on a given vitamin, like Glen King on vitamin C, or Elvehjem on riboflavin, or Jolliffe on B_1, always wanted the Recommended Daily Allowance for that vitamin way up — and they probably were right. They knew the benefits from giving a lot, especially when it was cheap. And yet the resistance — I remember one time during the war there was an outbreak of scurvy in Maine in the winter. So we said, "Well, that's easy to fix. You just send a truck up there with a load of synthetic ascorbic acid. It's made in the United States, so it's available. You'll wipe that scurvy out in a day." And would you believe it, one of the members of the Board got up and said, "No. I would rather see them have scurvy than not get their vitamin C from food."

What they did was to drag a lot of concentrated orange and lemon juice up there. I said, "Well, that's all right. It's a lot more expensive, but it's all right with us."

MT: You had worked on vitamin B_1, hadn't you?

HB: Yes, I'd worked on it in two respects. One of them was for the treatment of a disease called trigeminal neuralgia, which is a disease of the nerve that affects the face.

MT: Is that the same thing as tic douloureux?

HB: Yes, and it's very painful. I thought I'd like to see whether giving these people massive doses would help them. The clinic, as it were, was at Caltech, right opposite Morgan's office, so he took a great interest in it.

MT: What was the feeling about having clinical experiments going on at Caltech?

HB: Morgan didn't care. He was very easygoing and, you see, this was done under the nominal auspices of Dr. Kremers, who was the Institute physician, and I was sitting in on it too. I think the outcome of it all was that about 25 percent of the patients were definitely benefited.

MT: Was this with very high doses?

HB: Yes, we were giving 50 milligrams by injection daily, and the patients would come five days a week. And, as I say, we were satisfied that about 25 percent of these people were definitely benefited. Maybe that's all you have a right to expect, because the fundamental lesion is a restriction of the blood supply to that particular part of the brain.

MT: How did people hear about it?

HB: Through their dentists. People with trigeminal neuralgia would commonly got to a dentist because it looked like a toothache. And there was one dentist, by the name of Wiggins (he is now dead, I think) in Pasadena, who had a special interest in that disease. He used to inject alcohol into the nerve and destroy the nerve that way, which destroyed the pain but usually caused some paralysis as well. He was very good about it, and he sent us many patients, so it spread around.

MT: At this time were there other people at the Institute working with vitamins?

HB: No, I was the only one.

MT: I guess it was also around that time that you wrote the vitamin book. *(Vitamins: What They Are and How They Can Benefit You.)*

HB: Yes. As I say, for ten years I'd been lecturing on vitamins to medical audiences, nurses, and I had written it up thinking that it would be a good thing to get it published. It was turned down by one publisher. At one lecture, by chance Upton Sinclair was there, and afterwards he came up and he said, "Have you published this?" I said, "No. I've tried and failed." He said, "Would you mind, if you've got a manuscript, if I sent it to my publisher?" "Well," I said, "I'd be delighted." So we sent it to Viking Press with his recommendation, and they accepted it. That was very lucky because it was a kind of best seller. We sold about 40,000 copies. For those days, for that kind of a book, that was really remarkable. And it was very lucky in another respect because the royalties enabled me to send my daughter to college, which might have been difficult otherwise. It was the first nontechnical book on the subject written for the general public.

MT: Did you enjoy doing that sort of thing?

HB: Well, at that time I did, yes. Since then I've been asked to bring it up to date, and I don't feel like it. But it's still selling as a paperback. Just a month ago I got a $144 royalty check.

MT: You've never revised it?

HB: I've never revised it, and the reason I haven't — oh, it needs to be brought up to date in a number of respects, but there's nothing wrong in it even now. Whatever it said is true, but I could say much more than I did then, though it would have to be a book twice as thick. Since then there has been so much writing about nutrition I don't feel the same need any more.

MT: After the war, at the Institute, when Millikan really retired and DuBridge took over, can you point out any changes — like the ones you were talking about before — the loose way the Institute was governed?

HB: No, it changed very little. It had to change some because of our funding. Bookkeeping had to be much better, much tighter. After the war I got first an Office of Naval Research grant, and then a National Institutes of Health grant — and so did everybody else. And there was Institute overhead and tight bookkeeping. So that inevitably changed things. But as far as the actual administration of the Institute, we didn't feel it very much. I served a term on the Faculty Curriculum Committee, and DuBridge would come, but he was just one other member. He was very good; we all liked him.

Beadle introduced more administration in the Biology Division than we had when Morgan was running it. Beadle wanted to be the boss, whereas Morgan didn't. But it wasn't really serious. All my time at Caltech I felt the administration was there to help.

I learned how different it can be when I went up to Berkeley, because there you almost have the feeling that the University is run for the benefit of the administration. Caltech was the reverse.

MT: Let's talk about the isotope work a little bit. You've referred to it a few times. This was a direct outgrowth of your earlier protein synthesis work?

HB: Well, it was an outgrowth of my interest in the problem of the synthesis of protein, and isotopes seemed to be the way to do it. And so as soon as the war was over, and I was back in the lab, I could buy isotopes from the Atomic Energy Commission. They were made at Oak Ridge, and a private company handled the business for them. But it was at cost. We bought the isotopes from them — carbon-14, for instance, in the form of carbonate. We had to convert that into an amino acid before we could use it. I had Peter Lowy, who is an organic chemist, to do that part of the work. And then Geoff Keighley, who was an old friend from Toronto — I had him come out, as a matter of fact, years before — he was very good at mechanical things, so before we could buy Geiger counters and such like, he built them for us to use.

The outcome of the work on the synthesis of protein had an unexpected development. I was studying the synthesis of hemoglobin, and I found that if I added the serum of an anemic animal to the culture medium I was using, it greatly speeded up hemoglobin synthesis. This led to the discovery of the hormone erythropoietin, which is the hormone that regulates the production of red blood cells. That discovery was a direct outcome of the work with isotopes, studying the synthesis of hemoglobin.

MT: You worked with hemoglobin for quite a long time?

HB: Yes, and I have been ever since, as a matter of fact, because it seemed to me the best protein to work with for a number of reasons. There is the obvious intrinsic interest. It's a protein easy to isolate. And it was of clinical interest in anemia and such things.

MT: The medical application is one of the attractions?

HB: The curious thing is that there are no medical applications except by way of interpretation — for the reason that there isn't enough pure erythropoietin in the whole world to treat one patient. It's so hard to come by, and it's protein that hasn't been synthesized. And so its chief value is in understanding certain diseases, and the analysis of the blood for erythropoietin is one of the standard things that clinical labs now do. But to use it as a medicine, as was at one time hoped, is still not possible. How can they get enough erythropoietin? You collect the urine of people who have hookworm, and because you have to have an awful lot of urine, that means an awful lot of people. Then you extract it from the urine, purify it, and so on. The government still has a contract with the Children's Hospital in Los Angeles for making the concentrates. If you apply to NIH for a grant of this erythropoietin, they'll give you a few thousand units, but a few thousand units is only enough to treat mice; not enough even to treat rabbits.

MT: Did you then get into other areas of hemoglobin research?

HB: Yes. Hemoglobin is in the red cell, but it's not made in the mature red cell. (The mature red cell doesn't make any protein.) It's made in the bone marrow. The red cell is preceded by six nucleated cells and one cell that is not nucleated, so there are seven precursors. I was interested, and still am, in that process. In which of these precursor cells is hemoglobin made? It's not made in all of them. It's made in the middle of the series — not at the beginning, not at the end of the process. What regulates the rate? There are still a lot of unanswered questions about the method of going from one stage to the next.

MT: To get back to the 1940's again — that was when you started developing the multipurpose food?

HB: Yes, and that is really the story in its beginning of Clifford Clinton. Clifford Clinton was born of missionary parents and, as a child in China, he had seen famine, and he'd made a boyhood resolve that if he could ever do anything about helping hungry people, he would. So it was not surprising that when he grew up he went into the restaurant business. He has a couple in Los Angeles and I think one in San Francisco. (Clifford Clinton is not alive now, but the restaurants are still going, still using the name "Clifton.") During the depression — '30, '31, '32 — he advertised that anyone who would come to his cafeteria between 2:00 and 4:00 could get a free meal. Later he felt it was being taken advantage of, so he charged a nickel for a meal. The last time I ate there, which was more than ten years ago, the menu said, "You can order what you like — and you can pay what you like."

When the war came, with the enormous expansion of the armed forces from a couple of hundred thousand to twelve million, the Army needed advice on how to feed a lot of people in camps quickly. And so they called in consultants from the restaurant business, and Clinton was one of those consultants. We never met during the war, but we knew of each other.

Then, one afternoon in early 1945 — he'd phoned first — he and his wife and his public relations man came to see me. And before he began to talk, his wife intervened and said, "I want to apologize because my husband is coming here with a perfectly ridiculous proposal. I tried to dissuade him from coming, but he's very stubborn, and so I want you to know that I feel a bit ashamed." So I said, "Well, you needn't be. You're here. Make yourselves comfortable and let's listen."

So Clinton began to talk, and he said that anybody who thought about it could see the war was coming to an end, that in the countries where the war had been going on a lot of people were going to be hungry, that there was going to be a shortage of food in Europe and in Asia, and he wanted to do something about it. And he said he wanted me to do this — I was to devise a food where a meal would provide one-third of the Recommended Daily Allowances of everything, but it was to weigh not more than two ounces and it was to cost not more than three cents, it was not to offend any religious taboo, there should be an abundant supply of all the ingredients, and it wouldn't draw on the kinds of food Americans are accustomed to eat. (I said, "You needn't worry — at that price.") Also it had to have an indefinite shelf life, be possible to eat in a variety of ways, and not take any special equipment to cook — a can of water and a stick of wood underneath should do it.

And so he went on. And I turned to his wife, and I said, "Well, it's not so wild as you may think, but there are two restrictions I would put on it. It's scientifically impossible to provide a third of the Recommended Daily Allowance of calories in two ounces of anything. It is just not possible. We need about 700 or 800 calories as a minimum, and the most that two ounces would supply would be about 140 or 150 calories. Secondly," I said, "I don't think it would be practical to put vitamin C in because we really don't know how to keep it." At that time we didn't. But I said, "Otherwise, we could provide protein that's as good as meat or milk, and we could add all the vitamins and minerals that they need in two ounces, and I don't think it need cost more than about three cents a meal." So he agreed and gave Caltech the sum of $5,000, which I was to use to develop this food.

The food itself was no problem. I had a pretty good idea how to do it. It had to be a vegetable protein; animal proteins were too dear. The best vegetable protein was soybean protein, and I knew that during the war we — the government — had greatly expanded the growth of soybeans for their oil. But after the oil was extracted, what was left was thrown down the sewer. It was just wasted. So I knew this would be very cheap, and I knew it was available in large quantities. The vitamins and minerals I knew were also very cheap, and there would be no problem about adding them.

What I wanted the money for was to hire a cook who would develop recipes on how to use this food, how it should be cooked in different ways. And that was done. At the end of a year it was all ready, and we had a whole lot of recipes. One of the fruit and vegetable dehydrator companies in Los Angeles undertook to make it according to the recipe that I had drawn up, and that was done. We decided to call it "multipurpose food": MPF.

Neither Clinton nor I wanted to patent this food, and we agreed that we would give the information to anybody who asked for it. But that wasn't going to get the food to hungry people, so Clinton, who was a religious man, set up this Meals for Millions Foundation, a nonprofit organization. I was one of the cofounders with two or three others. He hired a woman by the name of Florence Rose and his publicity man, Ernest Chamberlain, was the other, who really were the Foundation. They sent out the appeals for money, they raised the money, bought the food, and so on.

MT: So they raised money from other sources. It wasn't just his money?

HB: No, I don't think he put in much money after that, but it was certainly his idea, both to get such a food and then to set up the Foundation to give the food to people who needed it. And I know when we had the food ready we thought it would be useful if the Food and Nutrition Board would approve of it. We sent some to them, and they said, "No. We believe that a good diet consists of meat, milk, fresh fruit, fresh vegetables, and this is not that." So for more than ten years, we had no government support — in fact, government opposition. So the money was raised from private groups. Two large charitable organizations very soon began to give us large sums of money — $50,000 to $100,000 at a time — and we would send the food where they told us to. They were Catholic World Relief and Church World Service.

MT: So other organizations made the arrangements with the countries where the food was going?

HB: Yes. After we had the food, they arranged for the shipping, but we were to attend to its being shipped to the places where they said they wanted it to go. We went along that way for a number of years.

There was one very gratifying experience. At one time my wife, my daughter, and I were traveling in Germany, and we were in a restaurant. You know how people talk to each other, and a man asked, "Where do you come from?" "We come from California." And he said, "Oh, in 1946-47 I was in an orphanage in Germany, and we were fed this wonder food from California." And it was our multipurpose food. And there were other like incidents.

From the very beginning I had insisted, and in our publicity made it clear, that the formula I had put together was only one example. I was confident that in many backward countries where there were many malnourished people, some other food just as nutritious could be put together from what they had, if they would only use what they had.

And in south Asiatic countries, India, they don't have soybeans. The actual director of the Foundation was Florence Rose, and we sent her around the world. She had no trouble getting the Japanese to make a Japanese equivalent, and they did a very good job. And then in India, she got the head of their Central Food Technological Institute to put together an Indian version of MPF, and he did a first-class job.

I think we gave this man about $5,000, and he put together — out of peanut meal and chick pea meal, adding vitamins and minerals — a food that was every bit as nutritious as ours. He did a very good job of testing first on mice and rats, then on children who were malnourished. Then he persuaded an Indian businessman who had some money to put up a pilot plant near Madras, and the city of Madras undertook to buy the whole production for use in their school lunch program. They got going, and the Minister for Agriculture for India from New Delhi told people from the provinces to come down to Madras, look, and copy it.

Then along came some representative from CARE, who said to the City Council of Madras, "Look, we'll give you all the dry skim milk you want for nothing. Why do you want to spend your money on this food?" That killed the project for quite a long time, but it has started up again. Two missionaries in northern India, where they have soybeans, have arranged for the manufacture, and they're beginning to get it used and widely distributed.

MT: Now?

HB: Yes. They did this entirely on their own, without any connection with us at all. But now, to come back a little, it was clear that charity would only go so far, and it would be much better if these people learned how to help themselves. So we set up a school at the Meals for Millions Foundation, in Santa Monica, where we teach three classes a year. It runs for 12 weeks with about a dozen students from different parts of the world, on scholarships of one kind or another, and they learn how to make food like MPF from what they have. We do more than that. (I say "we," but I have really nothing to do with it. The idea of the setting up of the school and so on was all the work of other people.) We devise machinery which they can use in their villages, and some of it they could even make themselves, so that they really can help themselves.

MT: When this program was being set up, how involved were you in the organizational part of it in terms of contacting foreign governments and getting programs started?

HB: I had nothing to do with that. The missionaries did that for us — Church World Service and Catholic World Relief.

MT: They were in it from the beginning?

HB: Very early. At first, Clinton with his church connections had connections with missionaries, and so we would send it out to them. I had nothing whatever to do with that, though later on I was in correspondence with Subramanjan, who did the job I mentioned in India, and with the Japanese people. But that was technical really, not much more than that, and also kept some people from making mistakes. You see, the soybean people had tried something like this, but they made the mistake of trying to make soy flour compete with wheat flour. Well, it doesn't make bread. It's not like wheat. And I persuaded them that the best way was not to make flour, but grits — small particles that could be used in soup or as a meat extender, lots of ways. And that is the way to use it. As a matter of fact there's a Texas hamburger chain that uses it in their hamburgers, and it's quite a good meat extender, has the right flavor and so on. The Meals for Millions Foundation was founded in 1946 and miraculously is still going, stronger than ever, really.

The Clinton family has nothing to do with it any more, and I think I'm probably the only one of the original group who's still alive. I'm a member of the Board still and on one of their committees. And now — and I must say I don't know the answer to this; maybe there isn't one — the most important cause, the serious cause of malnutrition in the Third World is poverty. We can overcome the ignorance if we can overcome the poverty. And maybe we could overcome the effect of the poverty to some extent, if we could persuade the governments to get a small businessman to set up a multipurpose food plant, and hand the food out. But I suspect these people are so poor that it would have to be subsidized.

MT: Even at three cents a meal?

HB: Oh, that's much too much. When you think of a man and his wife, with five children, on an annual income of $100 — they can't afford to spend 21 cents for each meal daily. So it's got to be much cheaper than that. This is where we are now. To overcome malnutrition is no technical problem. We know how to do that, and the means are available. But these people can't afford it.

MT: Has MPF ever been used in this country?

HB: It was used a little, not much now. In some places after the war when the GIs came back, as you know, many of them were married, there was a baby, and the amount of money they got wasn't much. So we set up a store near Columbia University in New York and sold quite a lot, and we kept it going until that generation of GIs had passed through. It's still being used, for instance, on Indian reservations near Tucson. There's a remarkable woman there, Mary Diamond, who's working with those Indians, and she is using it. There are a few other places like that, but for the most part there's no need for it in the United States.

MT: In the 1960's did your work continue along the lines of hemoglobin?

HB: Yes, along the lines of the hemoglobin and along the lines of the regulation of the process in the bone marrow. We had found, for instance, that under certain pathological conditions abnormally large cells were produced. How were they produced? At what stage in the process? This is the kind of thing. My work shifted from the mechanism of protein synthesis to the mechanism of the regulation of these various stages of the process by which the red cells of the bone marrow and final red cells are produced.

MT: Was this work funded by the Public Health Service?

HB: Yes, and the Atomic Energy Commission. All the way from right after the war until I left Caltech. As a matter of fact, I took both those grants with me when I went up to Berkeley.

MT: When you retired and went to Berkeley, how did that come about?

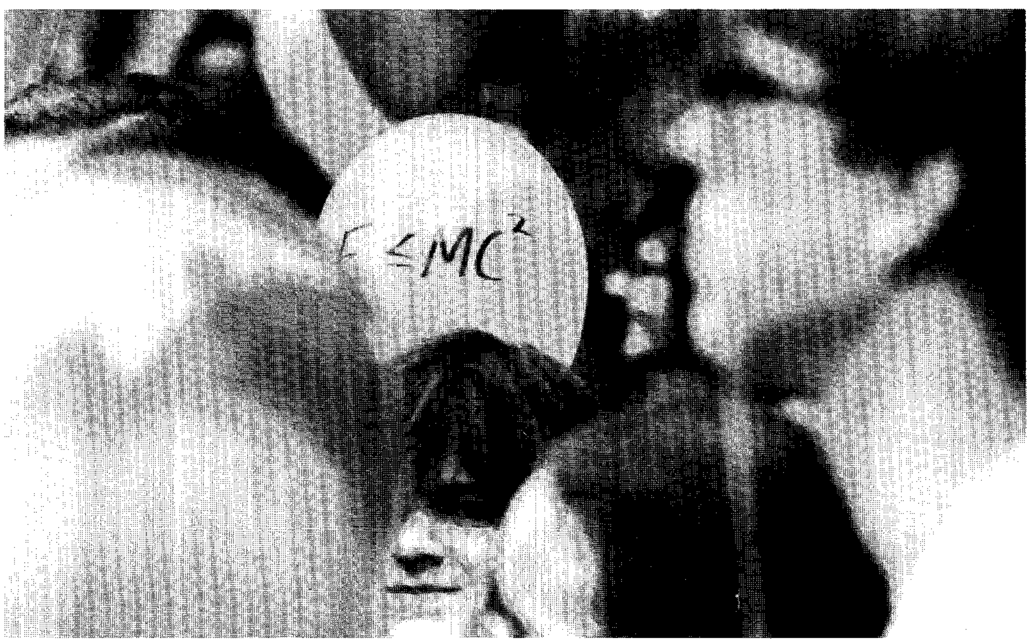
HB: I had reached the retirement age at Caltech and the rule was, and I still think it's a good rule, that when you reached that age you no longer can work in the lab. Caltech is a small place. Well, my friends at Berkeley put up a lab for me and equipped it, and so I just simply transferred my grants, and that went on for about ten years, until my grants came to an end in the spring of 1978.

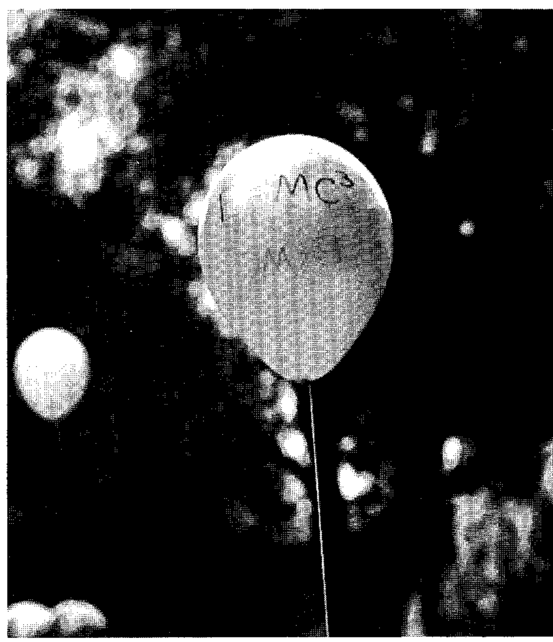
MT: You mentioned a bit about the comparison between Berkeley and Caltech.

HB: They are very different places. The impression I have still is that Berkeley is not a corporate entity. Caltech is a community. Berkeley is not. Berkeley is a number of individual departments, small groups, and their vision doesn't really extend beyond that group. The hand of the administration is very heavy. This is not to say that Berkeley isn't a great university, as judged by the number of really first-rate scholars they have there, but Berkeley isn't a place that you can feel you belong to or are loyal to. Caltech is. Or Caltech was, and I expect it still is. □

Centennial

Einstein's 100th birthday celebration, sponsored by the Master of Student Houses, turned into the undergraduate party of the year. Celebrated on March 14, right in the middle of second-term finals week, it lured not only students but faculty, staff, and JPL people to the Olive Walk with a feast (fried chicken, hamburgers, beer, brownies, and birthday cake), and a sideshow featuring the Great White Hunter, President Goldberger, riding an elephant. Birthday greetings were conveyed to Dr. Einstein by balloon.



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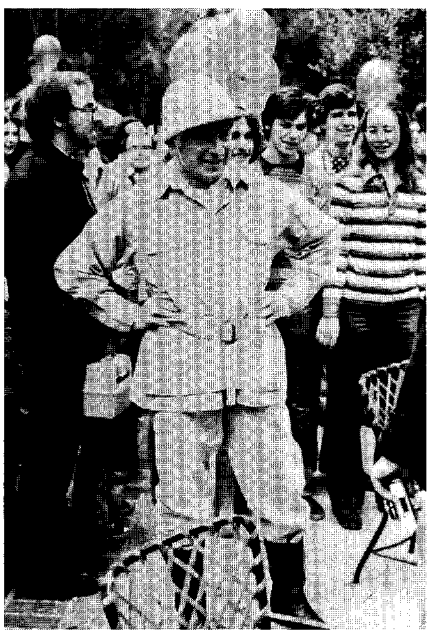


Richard F. Webb

1910-1979

A Tribute by Hallett Smith

Richard F. Webb, MD, FACP, died February 24 of a heart attack. From 1953 to 1973 Dr. Webb was director of Health Services at Caltech. He served as a consultant on the planning of the Young Health Center and was instrumental in arranging for physical and psychological counseling for Caltech students. He was a member of the Caltech Associates and in 1976-77 served on the Institute Committee on Research Involving Human Subjects.

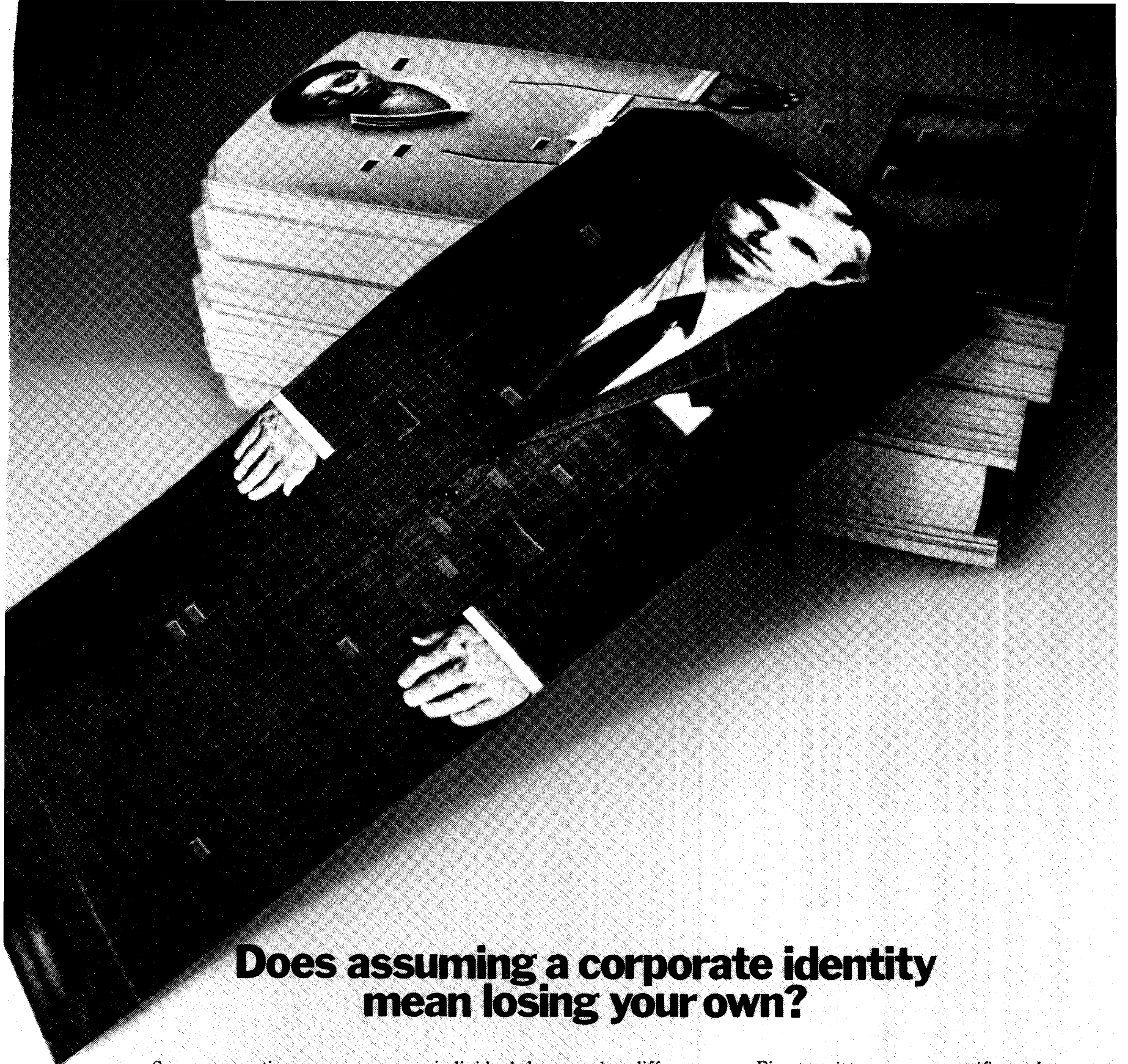
Dr. Webb was born in Covina, California, in 1910. He graduated from Stanford in 1932 and took his medical degree at the University of Pennsylvania in 1936. He interned at the University Hospital in Cleveland, Ohio, and was a resident in internal medicine at the University of California in San Francisco. In 1937 he married Janet Farrington; they had two sons, Charles, the author of *The Graduate* and other novels, and Sidney Webb, MD, of Las Cruces, New Mexico.

Dick's eminence in his field is indicated by his election as a Fellow of the American College of Physicians in 1950, his presidency of the Los Angeles Academy of Medicine in 1966-67, and his directorship of many organizations engaged in education and health care. He was a staff member of the Huntington Memorial Hospital in Pasadena for 40 years and was its president in 1955. A fund in his memory to support medical research and teaching has been established at the hospital.

Dr. Webb was on the faculty of the University of Southern California School of Medicine from 1940 to 1959. In 1968 he joined the medical teaching ship *Hope* and spent several months in Sri Lanka, teaching Ceylonese doctors and nurses the latest developments in American medicine. He was an enthusiastic traveler and photographer, gladly sharing his experiences with a host of friends. He gave up private practice in 1976 to become the first Medical Director for the Fluor Corporation and set up his office at the firm's headquarters in Irvine. He helped to establish the policies for executive health and employee health services and, to his delight, was able to guide Fluor's clinic and health services for its employees in Saudi Arabia, Algiers, and Venezuela. Between visits to Fluor operations abroad he wrote a "Medical Byline" for one of its publications, answering medical questions from any of its employees.

Dick's hobbies were golf and trout fishing. Anyone who has been on a trout stream with him (and I have been on many) knows that Dick's character was as evident when he was in waders as when he wore a white coat. He was a patient, gentle, humane man — the kind Izaak Walton portrayed as the good fisherman. He had a keen sense of humor. He loved nature; if he spent a whole afternoon without catching a trout (it didn't happen often), he would come back with his creel full of wild flowers. He was a good friend to Caltech; he will be missed. □

Hallett Smith is professor of English emeritus and former chairman of the division of the humanities and social sciences at Caltech.



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The best research you can do is to learn everything you can from your interview. Ask probing, well-thought-out questions; not to impress the interviewer, but to help you get information.

Here are a few suggestions:

• Would I really have any influence in a big company on the quality of services and products? How? Give me examples of how individuals have made a difference.

• What are internal communications like? Will my supervisor and management listen to me? Will they react to my suggestions and ideas? Can you give me examples?

• What about "red tape"? Are there endless levels of approval before ideas get implemented?

• What are the people that I'll be working with like? Where do they come from? What are they interested in?

These questions are only meant as a starting point. Add and subtract from this list. Fine-tune it to your own specific needs.

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2. *Steve O.* Design engineering. Design test equipment for attitude control system of new communications satellite.
3. *Norma L.* Steam-turbine manufacturing. Investigate, analyze and obtain funds for solution of shop problems.
4. *Stephanie B.* Medical systems service engineering. Installation and test of new hospital radiographic and fluoroscopic x-ray system.
5. *Mel D.* Field engineering. Appraisal load testing of low and medium-voltage switchgear and power transformers for utility and industrial applications.

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