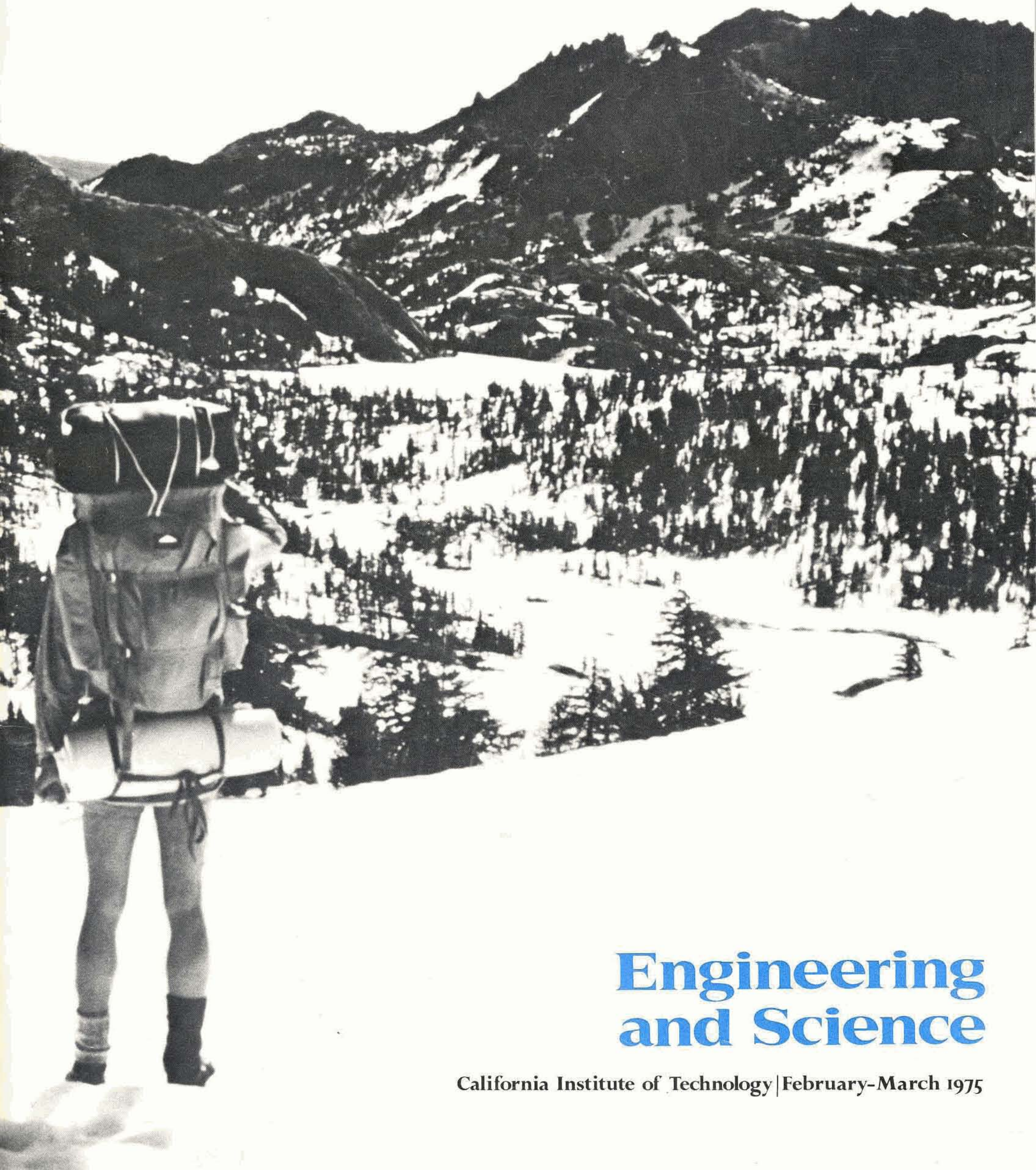
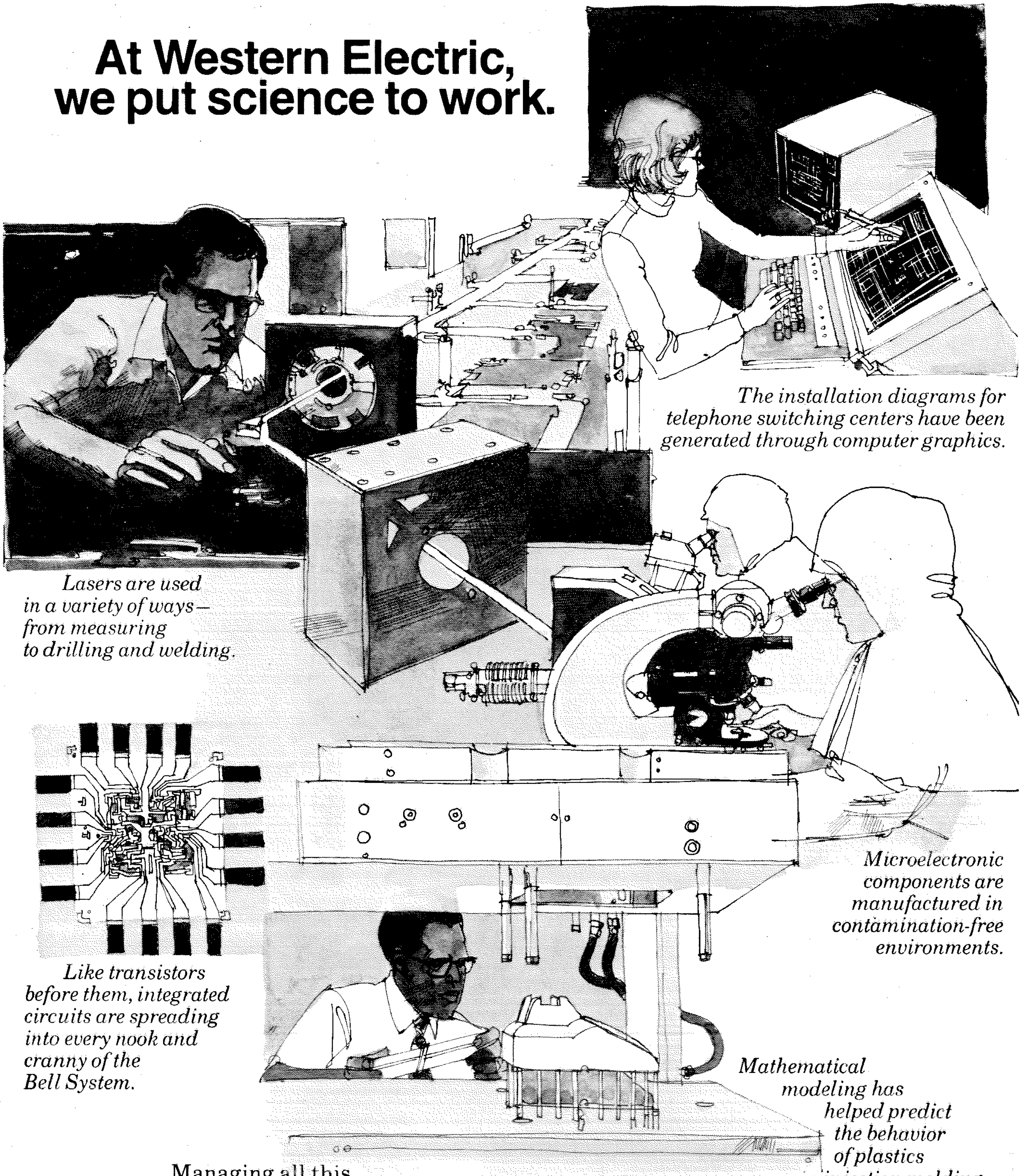


Engineering and Science

California Institute of Technology | February-March 1975

At Western Electric, we put science to work.



The installation diagrams for telephone switching centers have been generated through computer graphics.

Lasers are used in a variety of ways—from measuring to drilling and welding.

Microelectronic components are manufactured in contamination-free environments.

Like transistors before them, integrated circuits are spreading into every nook and cranny of the Bell System.

Mathematical modeling has helped predict the behavior of plastics in injection molding.

Managing all this is a new breed of talented people. Whatever their specialties, they also have to be comfortable working in other fundamental disciplines once left only to "pure scientists". At Western Electric, we put science to work.

Western Electric

We make things that bring people closer.

Engineering and Science

February-March 1975/Volume XXXVIII/Number 3

4 **Some Problems in Medicine that Present a Challenge to Technology**
by Rachmiel Levine, MD
We need to make a concerted effort to communicate across the barriers set up by the technical jargons and traditions of each field.

6 **Lead Pollution in the High Sierra**
A pioneering study of the pollution of a pristine environment.

11 **Go or Tell: The Future of Communication and Transportation**
by John R. Pierce
Communication and transportation are essential to the human condition. How will they evolve and interact in the future?

16 **Bush Babies in Beckman**
A troop of tiny primates may hold a key to improving our understanding of the neuroanatomical bases of behavior.

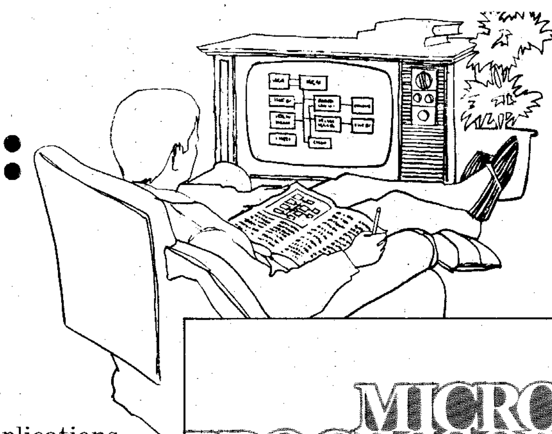
18 **Keynesian Economics and Inflation**
by Alan R. Sweezy
We are not going to stimulate the economy if we take away with one hand what we give with the other.

23 **Do You Know Where You Are?**
A look at Pasadena's topographic backyard through the eyes of geologist Robert Sharp.

28 **The Monster That Took On Walt Lee**

30 **Letters**

Designing with Microprocessors: A 2-hour home TV course April 15-18...



This is your chance to get authoritative answers to questions about today's hottest design topic: microprocessors. Read TI's Microprocessor Handbook. Then watch our 2-hour TV lecture series right in your own home. You'll learn what the microprocessor revolution is all about and how it can affect future electronic design. Plus you'll get valuable reference information on the leading edge of the technology.

Two hours of microprocessor information . . . on your TV set.

Tune-in your television to two hours of microprocessor technical lectures presented by the Texas Instruments Learning Center, April 15-18. You'll see four half-hour sessions—one each morning, Tuesday through Friday—timed so they won't interfere with your regular work day:

TUESDAY April 15: System architecture

A discussion of digital computer system architecture as a basis for understanding microprocessors. Evolution of microprocessors . . . peripheral controllers . . . parallel processors . . . Direct Memory Access.

WEDNESDAY April 16: Microprocessor logic—what type?

Chip fabrication technologies are reviewed—including most MOS forms, TTL, Schottky TTL and the new Integrated Injection Logic (I^2L) which has the density and power dissipation of MOS and the speed and driving capabilities of bipolar.

THURSDAY April 17: Potential applications for microprocessors.

Guidelines for using microprocessors, including both advantages and limitations for certain types of equipments. Shows how microprocessors can lower costs, shorten design cycles, improve performance and reliability in practical applications.

FRIDAY April 18: Using microprocessors in communications systems.

Discusses problems of digital communications and typical hardware solutions. In-depth applications guidelines show how microprocessors can be used economically within this broad field.

Don't miss this opportunity to explore this dynamic new technology—with only two hours of early morning television. Check TI's broadcast schedule for your city:

CITY	CHANNEL	TIME
Boston	7	6:20 AM
Chicago	9	6:00 AM
Cleveland	8	6:00 AM
Dallas	5	6:00 AM
Dayton	7	6:00 AM
Denver	4	6:30 AM
Detroit	2	6:00 AM
Houston	11	6:30 AM
Los Angeles	11	6:30 AM
Miami	4	6:00 AM
Minneapolis	11	6:30 AM
New York City	5	6:30 AM
Orlando	6	6:00 AM
Philadelphia	To be announced*	
Phoenix	5	6:00 AM
Rochester	10	6:00 AM
San Diego	6	6:30 AM
San Jose	11	6:00 AM
Seattle	11	6:30 AM
Washington, D.C.	5	6:30 AM

*See our ad on the TV page of your April 14 newspaper.

Order your Handbook now . . . before the TV presentation.

To: Texas Instruments Incorporated
P. O. Box 3640, M/S 84, Dallas, Texas 75285

Please send me ________ copies of the Microprocessor Handbook (LCB1761). I enclose ☐ check, ☐ money order for ________
(students: $19.95 for each book ordered. Others: $24.95 for each book ordered.*)

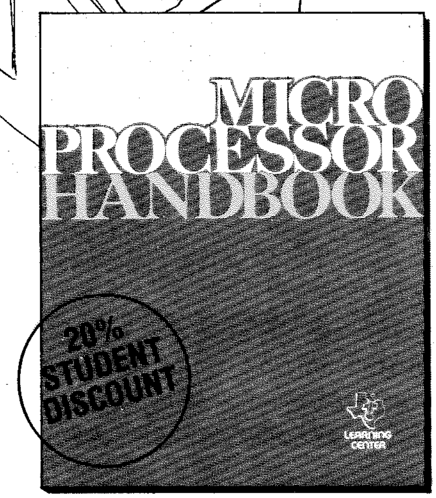
Name ______________________________

College/University ______________________________

Street ________________ City ________________

State ________________ ZIP Code ________________

*Texas residents please add 5% sales tax. 40



. . . and this fact-filled book.

Student discount gives you $24.95 book for $19.95.

The Microprocessor Handbook is your source for up-to-date microprocessor information—fully objective, concentrated, use-oriented data that might take you months to assemble on your own:

ALU's • Controllers • Memories • Timing • Microprocessor Selection Guide • Microprocessor Comparison Chart • In-depth discussion of I^2L technology • Digital Computer System Architecture • Chip Architecture • Chip Fabrication Technologies • How to Use a Microprocessor • Potential Applications and Limitations • Microprocessors in Communications • Microprocessor Supplier Listing • Glossary of Microprocessor Terms • Bibliography

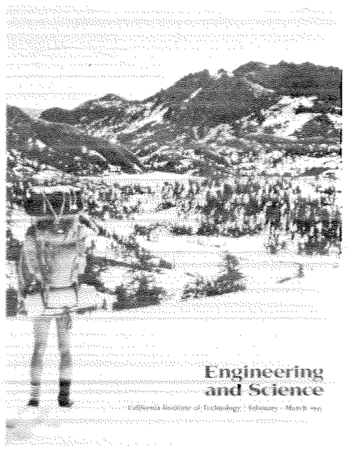
Microprocessors have the potential to revolutionize electronic system design and replace many mechanical and electro-mechanical systems. That's why TI's information-packed Microprocessor Handbook is a must for your personal library. Review it before you watch TI's TV presentation. Use it to jot down notes during the lectures. Then keep it as a permanent reference. Order your copy now to allow ample time for delivery before TI's April 15-18 telecast.

LEARNING CENTER

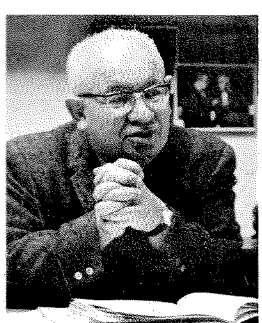
TEXAS INSTRUMENTS
INCORPORATED

81074 A

In This Issue



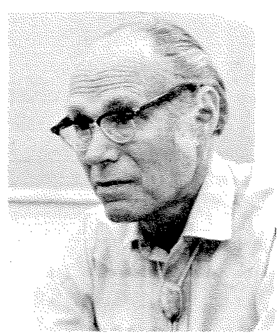
Valuable Valley
On the cover—that's not an arctic oil prospector; it's a researcher working in Caltech's biogeochemical metal research project in the High Sierra, which requires an area as far as possible from the source of any form of lead pollution. The project is directed by Clair Patterson, a geochemist who came to Caltech in 1952. He found that a remote corner of the mountains of Yosemite National Park was just right for this work. Having staked out this super-sized laboratory, he and four associates—Yoshimitsu Hirao, a visiting scientist from Ayoma Gakuin University in Japan; Robert Elias, research fellow in geochemistry; graduate student Todd Hinkley; and Dorothy Settle, analytical chemist—have been studying the occurrence of both natural and industrial lead in the area. "Lead Pollution in the High Sierra" on page 6 tells some of their findings.



Medicine and Technology
Rachmiel Levine, MD, is executive medical director of the City of Hope National Medical Center in Duarte, and a visiting associate in biomedical engineering at Caltech. He received his MD degree from McGill University in 1936, then spent 25 years in Chicago at Michael Reese Hospital, and in the department of physiology at the University of Chicago. From 1950 to 1960 he served as chief of medicine at Michael Reese.

In 1960 Dr. Levine became chairman of the department of medicine at New York Medical College in New York City. He came to the City of Hope in 1971 and joined the Caltech staff in 1973. A specialist in the study of diabetes, he has been working with Harold Wayland, professor of engineering science, in research concerned with the problems of small blood vessels. He also serves as a member of the Caltech committee that has been exploring ways in which the Institute and the Jet Propulsion Laboratory might combine their special talents and abilities to strengthen the practice of medicine.

In "Some Problems in Medicine that Present a Challenge to Technology" on page 4 Dr. Levine shares some of his own thoughts along these lines. The article is adapted from a talk given at a conference on "New Technology in Medical Research," held at Caltech, October 14-15.



Educated Guesser
Predicting the future may seem to be a risky business even for someone like John Pierce, professor of engineering who is also an old hand at writing science fiction. He has the credentials, however, to speculate —as he does in "Go or Tell: The Future of Communication and Transportation" on page 11, which is adapted from his Watson Lecture on November 25 at Beckman Auditorium. Alumnus Pierce (BS '33, MS '34, PhD '36) spent 35 years in electronics research at Bell Telephone Laboratories. He was a pioneer in the development of communication by satellite, holds nearly 100 patents, and is the author of 13 books and scores of technical papers.

Alan Sweezy
Alan Sweezy has been professor of economics at Caltech since 1949 and now also serves as associate director of the Caltech population program. He received his BS in history in 1929 and his PhD in economics in 1934 from Harvard University. He taught economics at Harvard from 1934 to 1938, and at Williams College from 1940 to 1947. From 1947 to 1949 he was in the Division of Research and Statistics of the Federal Reserve Board in Washington, D.C.

Since he got most of his professional training in the years when the economics of John Maynard Keynes was being widely discussed, Alan Sweezy is particularly well qualified to discuss "Keynesian Economics and Inflation," which he does on page 18 of this issue. The article is based on a talk given in Caltech's Perspectives Lecture Series, on February 12. The series features discussions of current issues and is sponsored by the Faculty Committee on Programs and the Caltech Y.

STAFF: *Editor and Business Manager*—Edward Hutchings Jr.
Managing Editor—Jacquelyn Bonner
Photographer—Floyd Clark

PICTURE CREDITS: Cover—George A. Jackson/6, 8, 10—Todd Hinkley/ 7—James Hinkley/9—Yoshimitsu Hirao/10—Clair Patterson/16-17, 23-28—Floyd Clark.

Published four times a year, in October-November, December-January, February-March, and April-May, at the California Institute of Technology, 1201 East California Boulevard, Pasadena, California 91125. Annual subscription $4.50 domestic, $5.50 foreign, single copies $1.25. Second class postage paid at Pasadena, California, under the Act of August 24, 1912.

Some Problems in Medicine that Present a Challenge to Technology

RACHMIEL LEVINE, MD
Visiting Associate in Biomedical Engineering

In the 20th century, life expectancy in the industrialized sections of human society has risen from about 50 to 72 years. Perinatal and infant mortality have been drastically lowered, and the age-distribution pattern has changed radically.

These results were achieved by the application of a fairly small number of technical advances.

1. The use of safe and potent vaccines and antitoxin preparations assured survival and healthy development during infancy and childhood.

2. The extensive use of chemicals to kill bacteria or halt their growth, especially since the early 1930's, practically eliminated the threat of septicemias, bacterial pneumonia, tuberculosis, and rheumatic fever, and made possible certain major surgical procedures without the great risk of fatal infections.

3. Extensive surgical repairs, reconstructions, and resections became feasible because of blood transfusions in bulk without the risk of infection or immunological reaction.

4. A greater variety of safer anesthetic and analgesic agents permitted the use of diagnostic and treatment methods to be carried out with much less risk to the patient.

5. More detailed knowledge of kidney and liver functions and an understanding of metabolic needs permitted the use of fluid and nutritional replacements to maintain and strengthen the body's defense mechanisms.

6. Proper use of certain insecticides interrupted the life cycle of pathogenic parasites and thus led to checks upon diseases such as malaria.

7. The development of safe and accurately controlled radiation devices provided powerful diagnostic tools, as well as palliative and often more definitive treatment measures for malignant disorders.

8. The recognition that many bodily processes are regulated by chemical messengers—the hormones—has spurred their use in specific endocrine disorders (diabetes, hypothyroidism, menopause) and in "stress" situations.

9. Preventive medicine benefited greatly from the demonstration of the necessity for the ingestion of essential nutrients (vitamins, minerals, essential aminoacids, fats).

Thus the benefits have been many and the results rather spectacular. However, when we consider our present major health problems, we find that the very achievements of the last 75 years have to a significant extent generated or uncovered the problems of today.

The improving survival rate and the gradually aging population, which is the hallmark of the nutritionally adequate or affluent societies of today, have placed heart disease in general, and coronary arteriosclerosis in particular, in the forefront in both the mortality and morbidity categories.

Progressive hardening of the arteries (arteriosclerosis) is the end result of a host of interlocking factors: (1) familial predisposition; (2) inherited patterns of fat (lipoprotein) transport and disposition; (3) high blood pressure; (4) environmental chemicals such as those arising from smoking; (5) the diabetic state; and (6) excessive fat deposits. Hypertension and diabetes, each in its own fashion, affect the structure and function of the kidneys and of the retinas of the eyes. Ultimately a significant percentage of kidney failures and of adult cases of blindness are traceable to these disorders.

It is evident that the so-called degenerative disorders are not easily partitioned into distinct, neat disease classifications. They develop over a long period of time. The generating forces are multiple. Symptoms arise only in gradual fashion. And the damage may be irreversible when detected. The medical facets of aging in general are, of course, related to the state of the heart and of the blood vessels and to the gradual deterioration of metabolic control systems.

Another group of catastrophic health hazards consists of the malignant growths arising from the blood cell systems and from the cells of the solid organs. Again, we are faced by an involved process that is influenced by a variety of factors and develops slowly: (1) familial predisposition; (2) environmental tumor-producing chemicals; (3) latent tumor-producing viruses; (4) repeated local injuries; and (5) hormones with specific proliferative powers.

The third most significant health problem in our society consists of the fatal, near-fatal, and disabling accidents on the road and in homes and industrial establishments.

The fourth large category of dis-ease belongs to the disorders of motor, sensory, and personality control and integration systems: neurological and psychological malfunction. While these disorders do not loom large as causes of mortality, they account for a major portion of all our ills.

Last, in this general classification, are the genetic disorders—that is, diseases in which the genetic transmission of a biochemical or structural defect forms the core of the problem. These disordered bodily functions are looming ever larger in our time because medical progress has allowed significant survival into adolescence and adulthood.

The splendid and rapid developments of modern biology during the last 30-40 years have already increased our understanding of some aspects of the medical problems we face. Our diagnostic measures have improved greatly; the categorization of disease is now on a firmer biological basis. However, the knowledge of causal mechanisms or of effective therapeutic approaches has not kept pace.

Medical progress since 1900 was achieved in the main by the technology derived from the scientific advances in microbiology and chemistry of the previous 75 years. We are, I believe, now confronted with the need to mobilize the forces made possible by present-day understanding and the techniques of chemistry, electronic engineering, information theory, and molecular biology to the formidable task of prevention and treatment of heart and blood vessel disease, cancer, the metabolic disorders, the disorders of the nervous system, and the more direct genetic disorders.

Major tasks in this continuing fight are the attempts to solve a set of difficult, but accessible, problems:

1. Organ transplantation without rejection.

2. The successful miniaturization of artificial organs or of functional organ parts, such as the kidneys, pancreatic islets, and peripheral sense organs.

3. An understanding of the pathological effects on the structure and behavior of cells and tissues of small but cumulative control errors—the effects of hypertension, hyperglycemia, and hyperlipidemia, for example, over a span of years.

4. The production and use of artificial biocatalysts which would *not* generate immune reactions.

5. The devising of control mechanisms for the extension or substitution of peripheral nerve functions.

Because these problems are so complex and require expertise in so many fields, their solution could be greatly hastened by the conscious formation of laboratory and hospital groups consisting of clinicians, biologists, and engineers who would study each facet jointly, in depth. Such groups have rarely functioned in a cohesive fashion, but more often as individuals "consulting" with each other. The results have not been satisfactory. What seems necessary is a concerted, joint, continuous effort with proper communication across the barriers set up by the technical jargons and traditions of each field. Out of such groups should evolve not only some immediate solutions to diagnostic and therapeutic problems, but also a better definition of the gaps that exist in basic scientific information. This should provide potent stimuli to basic research in the biological sciences.

I may be justly accused of undue and unrealistic expectations that solutions to the ravages of heart disease, cancer, and other degenerative conditions could come from application based upon partial knowledge. But this has always been the case. In my own field of medical practice, we learned to treat diabetes and gout in fairly satisfactory fashion before we understood the underlying biochemical mechanisms. The progress in basic endocrinology and metabolism was in turn immeasurably stimulated by these therapeutic successes. Let us hope that this principle will hold true for some of the health problems of today. □

A January view of the canyon in a remote corner of Yosemite National Park that serves as a laboratory for lead-pollution research.

Lead Pollution in the High Sierra

A pioneering study of the pollution of a pristine environment

"Lead Pollution in the High Sierra" is a transcript of a radio interview with Clair C. Patterson, senior research associate in geochemistry. This is one of a series of interviews with Caltech faculty members, broadcast regularly (Mondays, 7:15 p.m.) over KPCS (89.3 FM), Pasadena. The program, "Frontiers of Science," is conducted by Irving Bengelsdorf, Caltech director of science communication.

BENGELSDORF: Everything in the world is made up of submicroscopically tiny building blocks called atoms. We now know of 104 different kinds of atoms—possibly 105—one of which is called lead. Lead atoms are poisonous. They can interfere with many of the normal processes of life. One of the world's authorities who is keeping track of how much lead we have accumulated in our bodies is Clair Patterson, senior research associate in geochemistry at Caltech. Dr. Patterson, could you tell us some of the history of man's relationship with lead? When and how did lead first become useful?

PATTERSON: Lead first became important in man's history when he discovered that lead ores contain tiny amounts of silver. This was back about 2000 B.C.

B: Therefore, he went after the silver?

P: He went after the silver, and huge piles of lead were left over. He finally worked out methods for utilizing these piles of residue lead, and then there is a gap in our knowledge for about 1,500 years. About 500 or 600 B.C. there is written evidence and archeological artifacts of the multitudinous uses of lead: paints, gutters, cisterns, cosmetics—they put it in old ships to keep the worms out.

B: There are some people, I understand, who feel that lead actually had something to do with the decline of the Roman Empire.

P: Yes, Dr. Collum Gilfillan, who is a friend of mine—a sociologist and an elderly man now—has proposed that the Roman Empire fell largely because of lead in the wine they drank. The aristocracy drank a better type of wine than the rest of the population—a more expensive kind that wasn't sour. It contained an ingredient called—from the Greek word—sapa. Sapa was simply sweet grape juice boiled down in lead pots. It took several days to boil it down very slowly and gently, and they didn't know it but the process incorporated a whole lot of lead.

B: They were dissolving lead atoms into the sapa.

P: And then they put that into the wine as a preservative, and the lead killed the bacteria and kept the wine from souring. They couldn't taste the lead, of course, and it

Wearing plastic gloves and a plastic parka, graduate student Todd Hinkley takes samples from various depths in the winter snow pack for metals analysis.

A researcher on snowshoes uses a corer to measure the depth and density of snow in the canyon.

Todd Hinkley uses a stream gauge to measure the rate of water flow to determine the amount of metals that leave the valley each year.

poisoned them over a period of weeks or months or years. This is what Dr. Gilfillan thinks. He got the formula, and we made some in the laboratory according to Roman recipes and analyzed it, and our sapa had huge, poisonous amounts of lead in it.

B: It sounds like a reasonable idea. You have also been keeping a lead calendar, so to speak, by looking at the snow that has, for example, fallen on Greenland during past centuries. Can you tell us how that works?

P: When we smelt ores, part of the lead in fine particles goes out of the chimney into the atmosphere in various places, and it's brought back here in various kinds of precipitation. Sometimes it's incorporated in snowflakes and snowfalls which bring it to the earth. Again, when we burn gasoline, the lead in the gasoline goes out the tail-pipe in small particles and wafts around, and is finally returned to the earth—some of it incorporated in snow-flakes. Now, up near northern Greenland these annual layers of snow never melt; they just simply accumulate like pages in a book. So you have a record of the concentration of lead in the air when the snow falls, because it is automatically recorded. If there's a high amount of lead in the air, you see a high amount of lead in the snow of each annual layer.

So we dug a very deep shaft going back down through these layers—through the centuries—and took samples out and analyzed them for lead. We found that the concentration of lead has increased by a factor of about 500 over the natural levels in the snow during about the last 300 to 400 years. Most of the increase has occurred recently. We could see the effects of industrial civilization. For example, in 1750, when they began smelting lead, we could see an abrupt rise—and it sort of held there for quite a long while, a century or so. Then about 1940 there's another abrupt rise, which is due to the sudden effect of leaded gasoline, which man started to manufacture in 1920. The reason the level didn't change much in the period before about 1940 was that two factors were opposing each other: The amount of lead being smelted was increasing, and they were also recovering ever increasing amounts of it from the fumes coming out. That was valuable, so they kept on recovering larger and larger fractions of it. So, with both increasing production and increasing recovery, it pretty well held its own for about a century.

B: But, of course, from automobile exhausts you don't have this recovery operating.

P: No, it's emitted directly. About two-thirds of the lead in your gasoline is emitted out the tailpipe.

B: What does this amount to each year—the total tonnage?

P: On a world basis, about 500,000 tons of lead per year are burned as lead alkyls in gasoline. It's not a lead metal in gasoline, it's a compound—tetraethyl.

B: Now you undoubtedly have one of the more sophisticated laboratories in the world for looking at the problem of lead contamination. And I understand that recently you have taken your analytical techniques and concepts up to a canyon in the High Sierra. Can you tell us about that, and what the study was supposed to show?

P: We chose an area in the United States that was one of the most pristine areas we could find—located at an altitude of 10,000 feet in a remote corner of the mountains of Yosemite National Park. It was as free as possible

Clair Patterson checks a stand of plastic grass, used in measuring the accumulation of lead from the air.

from any form of lead pollution. There aren't very many places like this because almost every place you go has been farmed, has been grazed, and trees have been cut down, or there's a road nearby. So you have to go to the National Parks—or to the tops of mountains.

It happens that we chose the top of a mountain because that's the last place man has gone to pollute. This one is about two miles high, 300 miles from Los Angeles and 150 miles from San Francisco. We studied the following thing. You see, lead is a toxic metal, but it belongs to a family of metals in which one member—calcium—is nutritious. We need it for good health. We are in a food chain. We get our nutritious metal and our toxic metal from rocks—ultimately we have to go back to the earth. The sun shines on the earth and there's interaction, and these nutrient metals end up in our bodies through a food chain—from soil, to plants, to herbivores, and then into us. So, standing between us and rocks are these other things, and we don't get either the calcium or the lead directly from rocks. What happens is that in the travel of these metals to our bodies the calcium is kept but the lead is rejected at each step along this progression—this chain. Each one tends to keep the calcium and throw out the lead by a biological mechanism.

B: This would be unlike DDT, where there's an accumulation all the way up along the chain.

P: That's correct. It has been commonly assumed that lead does accumulate at the ends of food chains like DDT, but this has never been studied before. We have tested the assumption and find that it is apparently incorrect. We studied the components of the food chain—the rocks, the soil, the plants, and the animals. We had to choose a valley that had only one kind of rock in it, where hikers don't camp, and so forth. We measured the amount of lead coming in with the snow. But these little particles that zoom around in the air are not brought down to earth just by snow or rain; they also bounce around and finally hit the surface of a tree leaf or a blade of grass, where they stick and don't come off. That's called aerosol impact.

B: So you have two kinds of industrial-lead input, and also a natural source of lead coming from the rocks that are forming the soil.

P: And lead would leave the canyon by stream runoff. So we measured the amount leaving and the amount entering, and we found that the amount coming in was about 25 pounds per year in this 14-kilometer-square canyon. But the amount leaving was less than 1 percent of that which came in. Industrial lead is therefore accumulating in the canyon. We knew that the lead coming in was industrial because industrial lead is different from natural lead, and we can measure them separately.

B: So you can tell the difference between lead coming from rocks and lead coming from automobile exhausts, and so on?

P: Yes. And most of this lead entering the canyon came from auto exhausts by air and snow. We found that it collected on the grass, and that the meadow mice we were studying ate that grass, and as a consequence the mice and grass contained substantial concentrations of industrial lead. We believe that at least 95 percent of the lead in the mice and grass came from industrial sources. So this entire canyon in this remote area is heavily polluted by industrial lead—and this lead comes from gasoline exhausts originating in Los Angeles and San Francisco.

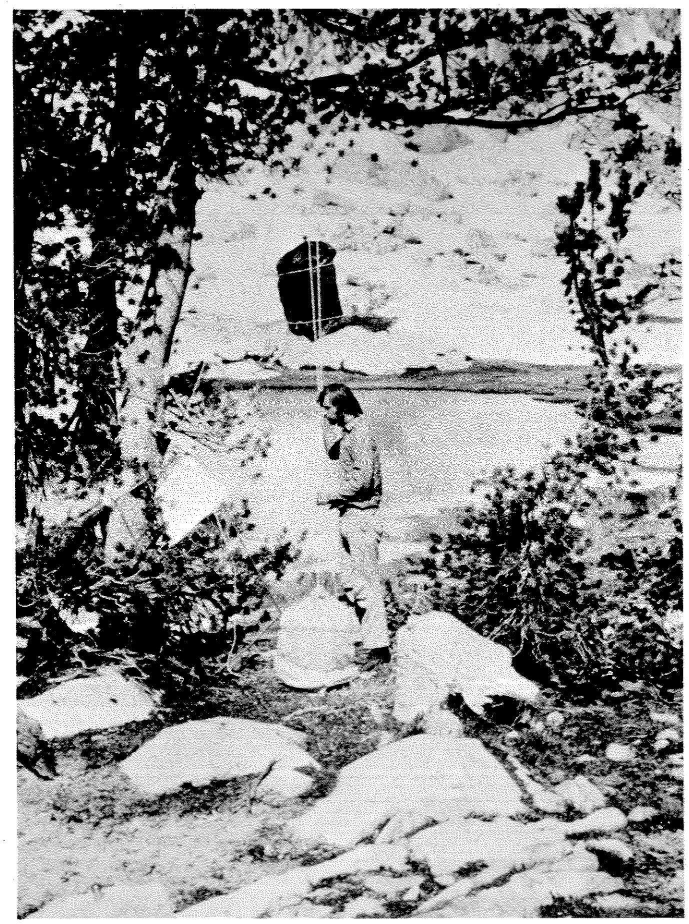
Lead Pollution in the High Sierra

. . . continued

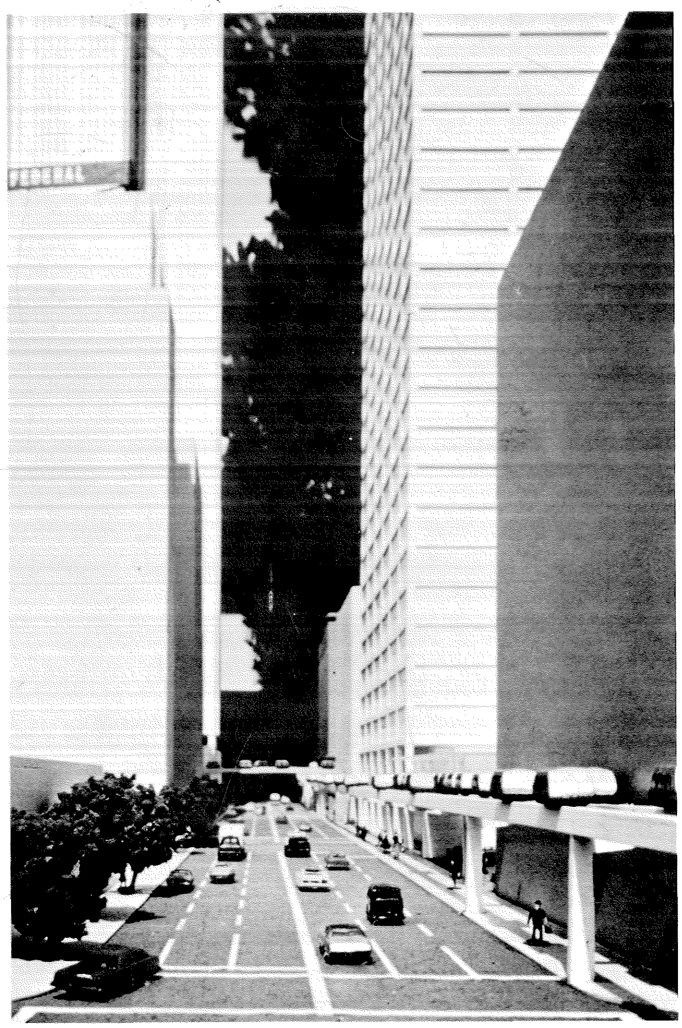
B: So this is really a pioneering study to show that even in what would be considered a pristine environment there already is considerable lead pollution.

P: Yes. Most people today are aware that lead pollution exists, but they seem to think it's only near freeways and in the centers of cities. That's not true. Lead pollution is pervasive throughout the whole United States. It has increased. You and I have about 100 times as much lead in our bodies as we should have—as would be expected from natural sources.

Results from the Sierra Nevada experiment are helping researchers in other universities and public agencies recognize that modern industrial metal pollution is extensive in remote, wild, and so-called natural regions of the earth, instead of just near freeways and downwind from smelters. Sampling and analytical techniques developed in the Sierra project are helping other investigators of environmental problems to improve the quality of their work by increasing the accuracy of their measurements and the significance of their samples. The Sierra project has also fostered similar investigations in foreign countries. □



Autumn chore (above): hanging supplies and equipment in the trees to protect them from bears and snow-burial.
Winter chore (below): digging out the tent. As a pollution-control measure, the camp is located outside the valley.



Mass transit along Grand Street in Los Angeles could look like this in 2020. With the Personal Rapid Transit (PRT) guideway installed over the curblines, neither sidewalk nor street need be cluttered with tracks, trolleys, or buses. Small PRT cars, automatically routed, would take a person or party to within walking distance of his destination with no intermediate stops.

Go or Tell:

The Future of Communication and Transportation

JOHN R. PIERCE

Without human communication we would be ignorant, lonely individuals. We would have neither the inspiration of accumulated skills and knowledge nor the support of society.

Without transportation we would be without the wealth of the world. The ivory of Africa, the tea of the East, the oil of Araby, the copper of South America, and the arts and culture of all continents could be no more than fabulous tales.

Without communication there would be no intellectual world. Without transportation there could be no real sharing among men. Communication and transportation are essential to the human condition. How will they evolve and interact in the future? Will they advance or retrogress? Will one displace the other? What can we say of the networks of communication and transportation in the year 2020?

In some sense, men of the past could envisage mechanical travel and electrical communication, but they did not and could not have envisaged the nature of the scattered yet unified life that the automobile, freeways, the telephone and television have created. Men of the past could envision human flight—usually birdlike—but they could not and did not envisage flight as all but completely replacing long-distance surface travel over land and sea.

We cannot foresee the future because it will be shaped by society, by human responses, by political and social actions and constraints—and by the potentialities inherent in discoveries and inventions. For instance, in some senses the United States, Japan, the Soviet Union, and India exist in the same age of science and technology. Yet life is very different in these countries. The use and impact of science and technology differ in each of these nations in ways that are very complex.

Thus, I shall not try to predict the future of communication or transportation in our country, let alone in our world. Rather, I shall say something about past and present trends, and indicate where I think we may be going in the short run.

Let us take as an example the rise and fall of a technological service—telegraphy. Telegraphy came into a world of slow travel and abundant labor, and it cut drastically the time to deliver a message. In those days, the message was really delivered, right to the home and hand of the recipient. But if the telegraph was so successful, why did its use decline? Clearly, the invention of the telephone had something to do with this. We can say that the telephone is more convenient for some purposes. But basically the telegram declined because the telephone is cheaper.

When you send a telegram, you have to write or dictate the text. Someone has to count the words, make out the bill, and charge it or collect the money. Someone else has to key the message in for transmission by means of a teletype machine or other device. And, at the far end, someone else has to deliver the message by phone or through the mail. All this labor makes communication by telegram expensive.

By contrast, the telephone is a do-it-yourself service. You dial the call, local or long distance, without the intervention of an operator. Once you reach your party, you simply talk; no keyboard operator need intervene. Billing is largely computerized and automatic.

I believe the use of public transit has fallen because, like the telegraph and the sedan chair, it uses too much labor in a day in which labor is extremely expensive. Of course, people find automobiles convenient, but also they themselves do much of the work. They drive their own cars, and they spend time and do clerical work in connection with their cars' purchase, maintenance, and insurance. People do these things partly because they don't mind doing them, and partly because, in a world of high labor costs, it's too expensive to pay anyone else to do them. Thus, we can afford telephony because it is an automatic, do-it-yourself service; we cannot afford telegrams because they are labor-intensive. Private cars, carpools, and vanpools succeed because the driver contributes his services.

Where they are not forbidden by law, jitneys that pick up and carry several passengers are cheaper and more widely used than taxis that carry only one passenger. Chartered commuter buses, which take groups of people to and from work, succeed better than public line-haul buses because they carry a full load. Airplanes are more economical than trains because fewer man-hours are required per passenger mile.

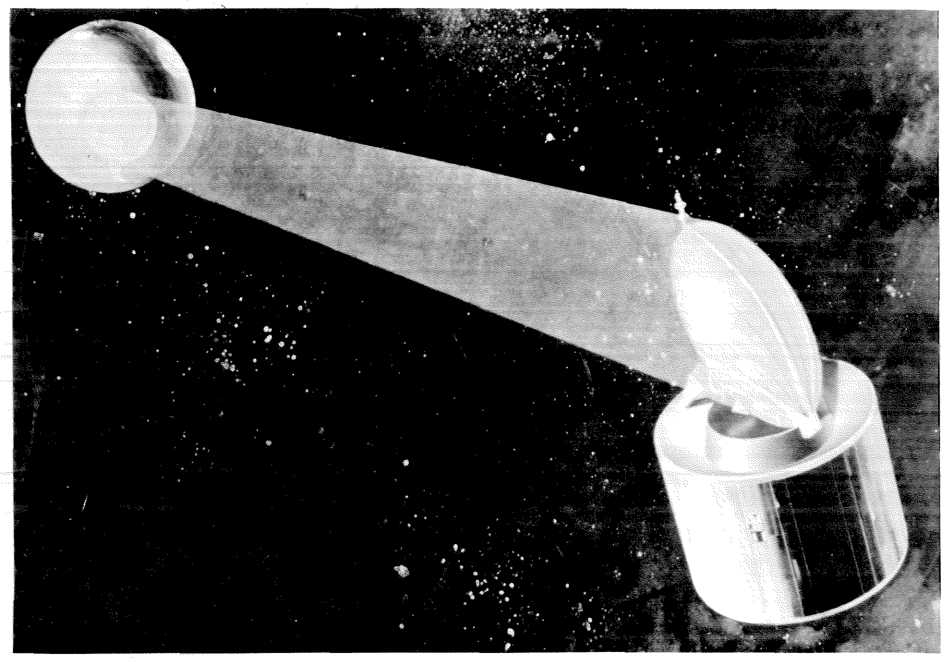
A reversion to a less even distribution of wealth, the creation of a servant class, or drastic changes in our tax structure might create a new pattern of services. But unless our governmental and social structures change drastically, we will continue to be unable to afford the labor of others.

Looking ahead, we must ever keep the cost of labor in mind as we consider what is either plausible or desirable. And we must keep in mind new technological potentialities that may provide more or better services without excessive labor of others.

One example of such potentialities is the new field of data communication and processing. Data—alphabetic and numeric—is written rather than spoken information. It is akin to telegraphy rather than telephony. But, unlike the telegram, the transmission and processing of data can be automated. Thus it is reasonable to expect greater use of data communication and processing when certain technological limitations are overcome.

Today we have no keyboard or display in our homes to

The home communication center of the year 2020 could have a wall-sized TV screen; and news, entertainment, and educational courses would be available as they are now. The handy chairside remote control keyboard would not be simply for switching channels without getting up, but for asking for more detailed information, either spoken or written. Telephones will be both audio and video, and the Gra-Flash will be a convenient and quick source of information and instruction and a means for transacting business at a distance.



Today satellites beam signals to continents. By 2020 sharper beams will be used between city and city. Thus, bandwidths of the same frequency can be used over and over. Switchboards in the sky will provide an almost unlimited amount of cheap long-distance data, telephone, and video communication.

link us to a distant computer, and so we don't use that device to perform computations, to make reservations, to order goods, to retrieve information, or to learn lessons. Instead we use hand calculators and old-fashioned typewriters. We read books. We call people on the telephone, and we go to see them. A secretary doesn't use a computer to edit manuscripts and get fresh, corrected, repaginated copies. Instead, she either retypes manuscripts completely, adding a few new errors as she removes the old, or she patches up the pages with the aid of a white, opaque fluid. When the manuscript goes to a publisher, there is a whole new keyboarding operation before it appears in print.

Why can't we make large-scale integration and data communication do our bidding? They are cheap, but the command chain isn't. To send and receive information costs so much that it really isn't worthwhile.

All the things one asks of a computer terminal have been done, some experimentally, some even commercially. Computers do edit manuscripts and make fresh, corrected, repaginated copies. In the process they produce magnetic tapes or other machine-readable records. With a little further editing, these same records can operate typesetting or photocomposing machines—or the material on the tapes can be transmitted from office to office over a data circuit.

Computerized reservation, ordering, and information-retrieval services are available. People do learn by computerized instruction. But these things are not yet in most offices or in many homes.

Until we have suitable terminals, data communication systems and computers will not be fully exploited. Yet I believe that the problem of cheap, attractive, flexible data terminals will be solved. In the not-too-distant future we will have them in most offices, and they will begin to enter our homes. Some day we will use automatic services to make reservations, purchase goods, acquire information, add to our knowledge, and learn skills.

But there is more to the future of communications than data communication and processing. Telephony itself is still incomplete in two ways. We have no mobile telephone service. And we can't see as well as hear on the telephone.

Our lack of effective mobile telephony is partly the result of a longstanding government bias toward mass communication as opposed to personal communication. Partly, however, it is because an electronic art based on vacuum tubes, or even on individual transistors, is simply too difficult.

Thus, an effective mobile communication system requires complex equipment in vehicles and an even more complex system on the ground—to set up calls, to monitor location or signal strength, and to transfer a call from one base station to another. Effective mobile telephony, indeed, requires all the complexity of present telephony—and a great deal more. Someday we may have it, or we may not, for mobile communication is the toy of those who allocate frequencies. Technology opens up potentialities, but governments increasingly control what we actually have.

Aside from mobile communication, the most serious limitation of the telephone would seem to be that we cannot see as well as hear. At present the dominating problems are those of terminal and transmission costs. Continuing advances in integrated circuits should lead to cheaper, better terminals, which could well include coders and decoders for economical digital transmission of video and audio signals. Such terminals could be sold rather than rented, and they could be compatible in some way with the standard TV format. They might gain added appeal through providing high-definition intermittent transmission of detailed documents and pictures.

Widespread video transmission also calls for cheaper transmission, and happily there are two assured approaches to it. One of these is optical fibers. The production of uniform, low-attenuation optical fibers in large quantities has not yet been attained. Problems of assembling fibers into cables and of splicing and connecting have still to be solved. While the life of photodiodes and light-emitting diodes is satisfactory, initially the life of semiconductors in lasers necessary for single-mode operation was low. Happily, now some such lasers have been developed that have lasted several thousand hours.

Tiny glass optical fibers, which transmit high-speed signals with less loss than copper wires, will become important communication pathways.

The eventual overwhelming success of optical fibers seems assured, but it must evolve through applications, the earliest of which may be simply to provide more trunk circuits between nearby telephone central offices. Or fibers may be used to replace complicated, heavy, fallible wiring harnesses in spacecraft and aircraft. Whatever the evolutionary course of optical fibers, by the year 2020 they will be used widely for both short- and long-distance communication. And this use of optical fibers will reduce profoundly the cost of broadband transmission.

The second approach to cheaper transmission lies in domestic communication satellites. The technology of satellite communication is excellent, and it is advancing rapidly. Satellites using very short microwaves could provide cheap, high-volume communication between cities. Such communication could make intercity video communication attractively cheap. Whether this will come about depends on whether the regulatory and economic problems can be solved.

The regulatory problem is that of licensing some organization that has the resources to build a technologically advanced, high-frequency system to carry volumes of traffic between city centers and also somehow develop increasing volumes of traffic. Some organizations have now been given permission to build domestic satellite systems, but not the very high frequency system that could have a truly revolutionary effect. The economic problem of domestic satellite communication is to find a means of pricing—introductory and continuing—that will lead to the full and economical utilization of a large-capacity satellite system.

It appears that video telephony can be an inevitable outcome of technological advances, in terminals and in broadband transmission. Thus, perhaps by the year 2020 we can expect to have the universal home communication center that many have dreamed of. Data, video, and voice will provide us with services, and entertainment too, far beyond anything the world has seen. This will come, but technological, regulatory, and social constraints lie in the way.

The idea that communication may eventually take the place of travel is an intriguing one. If we eventually have very cheap, very good long-distance video, audio, and graphic communication, we may someday confer electronically rather than fly to conferences.

Will we actually someday work at home, attached to an office by wire? Or will we, instead, have neighborhood offices, linked together by communication? This depends not only on communication itself but on a host of other factors, including zoning, the nature and amount of taxes, the quality and nature of living conditions, and the attitudes of business management.

Communication has already made possible a great deal of decentralization of highly integrated industries and activities. But our areas of interest and action are also spreading over larger and longer geographical areas. The number of local telephone calls per person per year, for example, is rising slowly. But long-distance calls are increasing rapidly, and overseas calls more rapidly still.

Most air travel is over considerable distances, and overseas air traffic increases at about the same rate as domestic air traffic. Both have nearly tripled in the last ten years. Beyond this, the communication to and from, and the travel to and from, urban areas appear to go hand in hand. On a large scale, at least, we may expect the future to bring increases in both communication and transportation.

In long-distance travel presumably we will use jet aircraft, supersonic aircraft, and—eventually—ballistic, sub-orbital rocket vehicles. Will the automobile disappear in local travel? I think not. Rather, we will have lighter, more economical cars that are smaller outside if not inside, and they will be propelled by more economical engines. As more effective batteries or other energy storage means are developed, some will be electric.

What of mass transit? Taxis will persist, and jitneys will triumph where they are not forbidden by law. Buses and demand-responsive buses will continue to provide an essential but costly service. Subways and conventional rail systems will be built by communities that love dinosaurs and will have them at any cost. Mass transit that is successful in any reasonable sense of the word must be automated, for that is the only way it can escape the economic disaster of increasing labor cost.

Can automated mass transit succeed? An automated system at Morgantown, West Virginia, has been a financial disaster. BART, the Bay Area Rapid Transit System in northern California, has had troubles. Such difficulties should not be overemphasized; automatic elevators are a form of mass transit that is an unqualified success.

Automated mass transit is a new and difficult field that must be explored experimentally before it can succeed commercially. In the cases of Morgantown and BART, an effort was made to provide service with untried vehicles and control techniques. The canny Japanese are building two and a half miles of track and 80 vehicles simply to *experiment* with automatic mass transit. Perhaps we can learn from them.

What, then, does lie ahead of us? In part we will have more of the same—more telephones, more long-distance and overseas calls, more cars and freeways, and more and longer travel by air. We may even have super-fast, guided surface vehicles.

At opposite ends of today's automobile spectrum—the Honda and the Cadillac. Automobiles will not disappear by 2020, they will merely become smaller and more economical in terms of fuel consumption.

In part we will have more and better communication. We will have more data communication; we will have mobile communication and, eventually, video communication as well.

We may have new forms of transportation that are as do-it-yourself as automobiles, telephones, and automatic elevators. What we will not have, unless our world changes drastically, is much costly, labor-intensive transportation like sedan chairs and present forms of mass transit.

We may see new patterns of life and work in which we do not travel so far to earn our living. Perhaps, as communication is perfected, travel will no longer grow hand in hand with it. In fact, easy communication may ultimately substitute for arduous travel.

As ever, the future remains a closed book. How radically the world will change by 2020 depends on technological and sociological forces beyond my comprehension or ability to evaluate. □

Bush Babies in Beckman

John Allman's maxi-eyed, mini-sized companion is an African Galago, or bush baby, who happily substitutes the interior of a tin can for a nest in a hollow tree trunk. The bush baby is a primate, and Allman's interest in this mammalian order goes back at least as far as his high school days. He did both his undergraduate and graduate work in anthropology (BA '65, University of Virginia; AM '68, PhD '70, University of Chicago). He then went to the University of Wisconsin where he did studies on the evolution of the primate brain and the cortical basis of visual perception.

Allman came to Caltech last fall as an assistant professor of biology, bringing a pair of prized possessions with him—his pet monkey and a 135-year-old, cut-velvet-upholstered Victorian sofa. This family heirloom may seem a bit incongruous in his office in the ultramodern Beckman Laboratories of Behavioral Biology, but—with a pillow and a blanket—it's handy for a man who sits up nights with bush babies.

Like monkeys, apes, and man, Galagos are members of the mammalian order of primates, but they occupy one of the lowest rungs on the ladder in terms of complexity of brain organization. To John Allman this relative cerebral simplicity is one of their most valuable attributes for his research into the functions and evolution of the primate visual system. Fringe benefits include their size (an adult weighs about half a pound), equable dispositions(some are feistier than others, but they are all basically harmless), simple diets (cat chow and bananas for the most part, with a little raw meat for those who like it), and general hardihood.

The nocturnal bush babies breed readily in captivity, usually having two gestation periods a year and often producing twins. Allman would like to capitalize on this trait to enlarge Caltech's stock, which numbers 48 at the moment. It is expensive and difficult to import the increasingly rare animals because their natural habitat—and that of many other non-human primates—is being wiped out. In a relentless spiral, the economic development of many of the countries in which jungle animals are found has led to human overpopulation, with concurrent destruction of the forests for timbering operations and the creation of farmlands. It has also inevitably led to the near-extinction of some species.

Allman is particularly interested in primates because his studies indicate that the visual system of their brains is distinctive when compared to that of other mammals. His research on the nature of these differences could lead to an improved understanding of the neuroanatomical bases of behavior.□

It's Not As Easy As It Looks

Not many animals can turn a door frame into a jungle gym, but it's easy for the tiny, agile Galago, or bush baby. He finds as many footholds there as on the tree trunks of his native habitat in the equatorial forests of Africa, and his initial five-foot jump from the floor is only about a third of his range.

Keynesian Economics and Inflation

ALAN R. SWEEZY

A first and essential step in the development of Keynesian economics took place in the 1920's when several economists, both in England and in the U.S., succeeded in clarifying how our modern monetary system works, i.e., how the banking system operates to create money in the process of making loans and investments.

What we use for money is an abstraction—deposits, we call them, in banks. Actually, nothing has been deposited. They are simply credits that are chalked up on the books when the banks expand their loans and investments. The intricacy of the banks' relation to each other obscures the way in which this is done, so that each bank thinks it is only lending out what has been deposited with it. If you look at the banking system as a whole, however, that is not what happens.

The process of expanding the money supply through the lending and investing mechanism is controlled by the central bank—the Federal Reserve in the case of the U.S. —through its control of the total amount of reserves. The banks are required to keep reserves equal to a certain percentage of their deposits. That sets a ceiling on the total expansion of deposits that it is possible to undertake.

The intricacies of this system require about three weeks in an introductory economics course, and I'll assume you are willing to take it on faith that it really works. Incidentally, I believe all modern economists are agreed that this is the way the banking system works to create money.

I suppose what is really important about this is that you don't need to worry about money. If it seems like a good idea to create money, we'll create it. So if you at any point along the way have a sort of hesitant feeling about where the money will come from, just forget it.

The second major step occurred in the early 1930's, when Keynes and several of his associates succeeded in getting rid of the prejudices that had up to that time attached to the concept of spending, and achieved an objective analysis of the spending process in the economy. I can well remember in the early 1930's, in debates about how we could get out of the Depression, it was popular to say that you could no more spend your way into prosperity than you could drink yourself sober. Spending was almost always coupled with some such adjective as "wild," "loose," "excessive"—and the general atmosphere that surrounded it was nothing good could be associated with spending.

An objective analysis of the economy makes it clear that spending is necessary in a market economy for the successful functioning of the production and employment system. What we have, in effect, is a flow of goods and services in one direction against the flow of spending in the other. Unless the flow of spending is adequate, the flow of goods and services drops off, and you have unused production capacity and unemployment.

It follows from this general conception of the economy that in the case of inadequate spending—which causes a fall in production and in employment—the government can do something about it. There are two major ways in which government policy can influence the flow of spending. One is through monetary policy, making money cheaper and easier to get through the operation of the Federal Reserve and the banking system, which has the tendency to stimulate private spending on investments, on residential building, and perhaps on consumer borrowing. The other way is for the government itself either to cut taxes or to increase its own spending. If it cuts taxes, it releases some of the money that would otherwise be taken away from private spenders—it gives them more to spend. If it increases its own spending, obviously this adds to the total stream. That is, it adds if the government does not at the same time take action which counteracts the beneficial effect of the tax cut or the spending increase.

There was a great deal of confusion about this in the 1930's, and I'm interested to see that there seems to be, even today, a certain amount of the same type of confusion. It won't do any good to cut taxes if at the same time you cut spending. The one will roughly offset the other. In the early days of the New Deal this wasn't clearly seen, and those of you who are of my generation may remember that at the same time the Roosevelt administration appropriated money for an expanded public works program they cut government salaries. Now I admit that building bridges or dams or roads is much more glamorous than doing clerical work, and the notion that somehow or other it would be better for the economy is one that I can understand, but it has no foundation in fact. The people—the lowly clerks whose salaries were cut—spent the money just as much as the construction workers who were employed on the public works. So that to the extent that government salaries were cut at the same time that public works were increased, the benefit of the second step was nullified. Fortunately it wasn't to a very large extent, and fortunately also, the President, being flexible, being empirically oriented, was not insistent in sticking to his orthodox notions.

We are not going to stimulate the economy if we take away with one hand what we give with the other

At the present time, as you've noticed, the President's budget has something of this same contradiction in it; it is proposed we should cut taxes, but it's also proposed that we should cut various types of spending—unfortunately, and particularly, those types of spending which are least suitable for cutting right now: Social Security, food stamps, and other welfare payments. This indicates either confusion about the policy or, possibly, the better explanation that a committe drew up the policy. In any case, we must remember that we are not going to stimulate the economy if we take away with one hand what we give with the other.

What this means is that for spending to be effective, either via the tax-cut or the spending-increase route, it has to be deficit spending. I suppose that still sounds bad. Every time I read a newspaper there's something about the gloomy budget, the big deficit, and how dreadful it is that we're going to have a deficit. Actually, deficits aren't bad. In a period in which we need to stimulate the economy, they are good. We *should* say, "Hurray, there's a big deficit coming up."

Friends of mine coined a phrase in the 1930's which put this whole thing very neatly. Instead of talking about the government deficit, they talked about the government's net contribution to buying power. As you think about it, you'll see that puts a different light on matters. It is a net contribution to buying power that's needed; and if we increase spending without raising taxes we will have it.

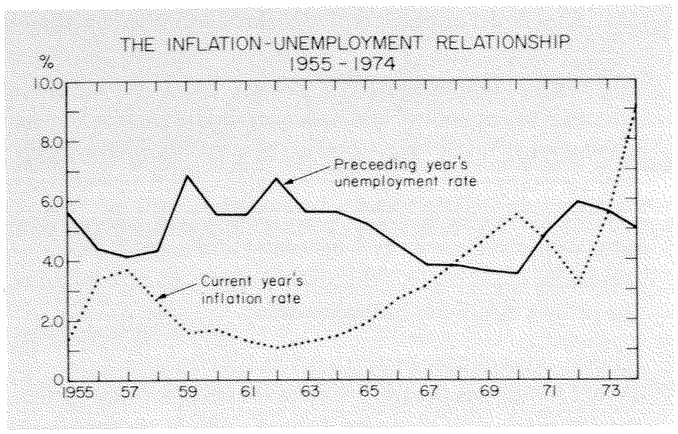
One final word about spending before I turn to the other side of the picture—the inflation side. Not only must the spending be deficit spending, but for maximum beneficial effect on the economy it should usually be financed by an expansion of the money supply. This will mean that the money that goes into the income stream through increased spending or tax reduction is not taken away from somebody who would otherwise be borrowing and using it. So, generally speaking, it's desirable to have an expansion in the money supply at the same time.

This also takes care of any worries that financing the deficit would, as the phrase runs these days, "dry up the capital market." Of course if there's only a certain amount of capital and the government borrows it, that will dry up the capital market and other would-be borrowers will not be able to get as much as they want, and the beneficial effect of the government action will be largely nullified again. But that's not necessary. The sensible thing to do is to expand the money supply to the extent that the government is going to call on the market for funds.

Now what about the other side of the picture? I've talked so far only about the danger of inadequate spending and the policies the government can pursue to offset that danger. The other extreme, of course, is excessive spending, and here's where things have gotten complicated.

Let's start with the simplest Keynesian model. As output and employment increase, prices remain stable until a magical point we call full employment is reached. At this point, since it is impossible in the short run to increase output any further, the result of any further increase in demand—whether public or private—will be inflation. Prices, in other words, don't rise at all as demand increases up to the limit of the economy's capacity to produce, and then pure inflation sets in. The policy conclusion is as simple as the model: Increase demand up to the point of full employment and then stop. If private demand goes on increasing, use restrictive monetary and fiscal measures to keep total demand within the limits of the economy's capacity to produce.

Now, this is too simple, as Keynes saw very clearly, and he later described the main sets of factors that will begin to influence prices before full employment is reached. One is that as employment increases, various inefficiencies creep into the operation of the system. Some bottlenecks will probably be reached in special industries or special occupations. Labor that is not as efficient as the labor already employed will be added to the work force, and for these and related reasons, marginal costs will tend to rise. The second factor, which in the modern world is even more important than the first, is that as we move toward higher levels of employment and lower levels of unemployment, the bargaining power of unions increases and the ability of large corporations to pass on the higher wages



likewise improves, so that we get a tendency to what is now called "cost-push" inflation as we move toward more satisfactory levels of operation for the economy. We could depict this by saying that instead of simply going along until we hit full employment and then having straight-out inflation, that at some stage—maybe at 90 percent of full employment—we begin to get price rises and that those will become more marked as employment increases still further.

One final element has to be added to this—an element that is related to the bargaining power of unions but goes beyond it. It is a kind of automatic wage-price spiral which becomes particularly difficult to cope with when it is the result, as the one we now have, of an attempt to catch up after an external shock has hit the system, leaving labor short of its goals in terms of real earnings. And that element has now come prominently into the system.

A simple little chart, shown here above, demonstrates the inflation-*un*employment trade-off. The broken line is the current year's inflation rate. The solid line is the preceding year's unemployment rate, which assumes there is some lag in the effect of changes in the unemployment situation on inflation. You can see two things. One, that in the 1950's and up to the middle 1960's the inverse relation between unemployment and inflation was rather neat.

When unemployment was high—in the 5½ to 6½ percent range—the inflation rate was low. (That's 1 percent down there. In the memory of living people we actually had a time when we were only having a 1-percent-a-year inflation rate.) Then, in the late 1960's, things began to change.

Let me say a bit more first, however, about the period of the early and middle 1960's. That now seems in some ways to have been a golden age, except that of course it didn't strike people then as a golden age, and I really would be reluctant to say that we should be willing to settle permanently for conditions as they were then. Unemployment was what was then considered to be undesirably high —over 5 percent most of the time. The target unemployment rate in that time was 4 percent. We weren't willing to accept 5½ or 6 percent as the norm for the economy, and some of you will remember there was great emphasis on the part of the Kennedy administration in getting the economy going and bringing the unemployment rate down to what would be a more acceptable figure.

In addition to the relatively high unemployment rate, there were two other things in this period that helped to give us the low inflation rate. One was that farm prices tended to sag. Remember when we used to complain about farm surpluses? Do you think we could get along without complaining if we had some nice big farm surpluses hanging over the market to keep prices from rising, and there was never anybody starving anywhere, and we were sure we could send X millions tons to keep them alive? But such is our perversity that we used to curse our fate and say how dreadful it was to have this big surplus. Actually it was a very useful thing and I hope, although I don't expect, that we will again see something like that develop.

The other thing we had was the wage-price guideposts which operated on a so-called voluntary basis—a good deal of pressure from the White House and from the government generally on corporations and on unions to keep their demands within the limits of moderation. This was greatly facilitated, of course, by the relatively high unemployment rate. Then came the Vietnam War and the rapid acceleration of expansion. The unemployment rate dropped below 4 percent, in and of itself not a bad thing, but it may be that it dropped a little too fast. The unions decided the chance was too good to break the guideposts and they did it, and the guideposts became ineffective along about 1966-67.

So, as we moved into the latter part of the 1960's we found that inflation was beginning to pick up strength, both on the price front, and even more on the wage front. Wages were rising at an increasingly rapid rate and in fact so much so that it was not possible to offset the increase in wages with rising productivity, which—to make things even worse —slowed down at this particular point. So we find at the end of the 1960's that the trade-off is much worse.

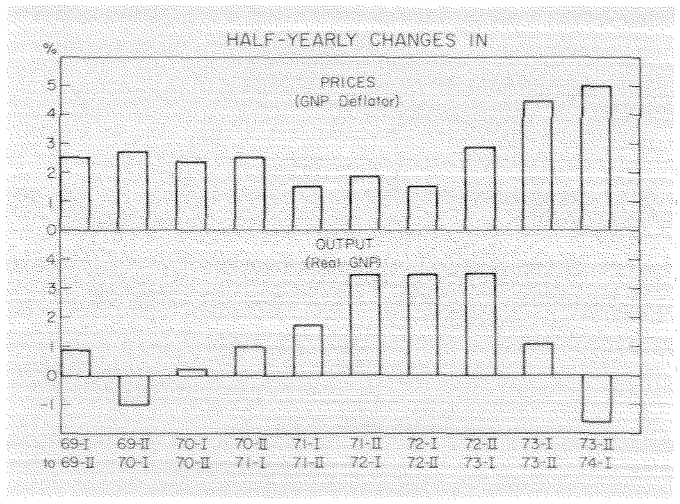
We had an unemployment rate going into 1970-71-72 which would have been associated with a relatively low inflation rate back a few years earlier. It was at this time that the Nixon administration decided to try a restrictive monetary and fiscal policy in order to counteract the inflation. The war spending had leveled off, and it became possible to experiment with the traditional methods of policy. They tightened up on monetary policy, and fiscal policy became also mildly restrictive. The consequence wasn't what you'd expect—it did slow the economy down, but it didn't do much to stop inflation. By the middle of 1971, the discontent in the country in general with the level of unemployment and with the slowdown in production and the economy had become such that the administration decided to shift its policy.

The trouble with a restrictive policy as a method of counteracting inflation was very well described by Art Buchwald in a column in February 1970 entitled, "It's *Hard to Be a Hero in the War Against Inflation.*" He has a government official talking to a freshly unemployed worker. He starts off by saying:

"I beg your pardon, is that a pink slip in your hand?"
"Yeh."
"Well, congratulations. You can consider yourself a front-line soldier in the President's fight against inflation."
"I can?"
"Yes sir . . . Incidentally, you will be happy to know that your being laid off came as no surprise to us."
"It didn't?"
"No sir! Your government predicted that, given high interest rates and a tight money situation, you would be out of work by February. Here it is, right on the graph."
"I'll be darned. You guys really know your stuff. But what do I tell my family?"
"You can tell them that although they will have to put up with a certain amount of inconvenience, the upward spiral in unemployment—to which I might say you've made such a valuable contribution—will have a very definite effect on the stabilization of prices."
"They'll be happy to hear that."
"If it weren't for people like you, I'm afraid the economy would have kept overheating and your dollars would have lost their purchasing power . . . "
"But why me?"
"Everyone says 'why me?' It has to be somebody. If we are to take strong anti-inflation measures, we have to have a citizenry ready to make financial sacrifices. All we're asking of you is to stay unemployed until the economy cools off."
"How long will that be?"
"Well, we're projecting 18 months, but I'd count on two years to be on the safe side."
"What am I supposed to do in the meantime?"
"This is a Certificate of Unemployment which you can hang on the wall. It attests to the fact that your government appreciates all you are doing to keep the economy from spiraling sky-high."
"Gosh, it's beautiful!"

Well, I haven't yet seen a better description of the essential weakness of the tight-money-policy cure for inflation.

The Nixon administration shifted completely in the summer of 1971, and instead of restrictive monetary and fiscal policy, adopted a strongly stimulative policy, along with controls. What was the result? Well, unfortunately there are many difficulties about making controls work—particularly in a democracy. And we certainly experienced those difficulties in plentiful measure—so much so that many people will now tell you that controls were a complete failure. That's not quite true, however. Controls had plenty of problems connected with them, but there were also some strong pluses. The main thing was that the controls enabled us to reverse the tendency toward increased unemployment and increased slack in the economy and to move in the direction of higher employment, a better rate of operation, and at the same time to moderate the degree of inflation.



The chart above, which brings out this relation very nicely, shows half-yearly changes from 1969 to 1974. The top of the chart shows the percentage change in prices in each half-year period, and the bottom shows the change in output again from each half-year period to the next one. As you can see, the change in output from early 1969 until the beginning of 1970 was either negligible or actually negative. There was no strong increase until the second half of 1971 and then in 1972 and 1973 we see output moving ahead at a greatly increased rate. Now if we had not had controls, I think it is highly likely that the effect would have been to accentuate the inflation problem. Actually, though, the controls—while not completely effective—were sufficiently effective so that rather than accentuating the inflation problem, the problem was modified. You can see that it was precisely in the controls period there that the rise of prices subsided significantly. Inflation didn't disappear, but it did moderate.

I would like to give you one other fact on what was happening to wages. Wage increases had been picking up speed. A good index of not only what was happening but what was likely to happen in the near future is the size of the first-year wage increases in collective bargaining agreements covering a thousand or more workers. Here is the way those figures changed from 1968 to 1974.

AVERAGE FIRST-YEAR WAGE INCREASE

1968	1969	1970	1971	1972	1973	1974-3rd Q.
7.4%	9.2%	11.9%	11.6%	7.3%	5.8%	11.0%

You can see that they reinforce the picture of a swing from an increasing to a moderating inflation rate. The increase goes from 7 percent in 1968 to 11.9 percent in 1970. Then with controls in 1972 it drops to 7.3 percent and in 1973 to 5.8 percent. I submit that this is really a significant achievement for the wage control mechanism in that period to have moderated the increase in new union contracts from an average of 12 percent in 1970 to just below 6 percent—half as large—in 1973. Incidentally, I'm sorry to say, we're now back up to 11 percent.

So I think that controls were not a failure. But then you say, why didn't we keep them? And there I think the story is very sad. It's partly that the controllers weren't enthusiastic about them, and of course in a democracy, as I said, we have a great deal of difficulty with them. Controls in a sense really have to be voluntary, since nobody is strong enough to just issue orders. You have to have at least a large measure of consent on the part of the people who are being controlled, and they are—in our type of society—all very avid to see that somebody else doesn't get better treatment than they do. So there are these real problems—the lack of enthusiasm of the controllers, and the avid interest that each of the groups being controlled showed in making sure they didn't get short-changed compared to the other groups.

Those probably would have been enough to bring the controls to grief, but then they received a body-blow from the outside with the fuel and food crises in the summer of 1973. Food prices, which had been such a stabilizing influence on our economy through the 1950's and 1960's suddenly became an explosive element. To expect unions to simply accept this increase in the cost of living from the outside, without trying to make up for it with higher wages, is perhaps expecting more than we should in our type of society at this stage of its development—although I would like to submit that this may be a problem for the future that we somehow will have to learn to cope with.

I don't think we can assume any longer that it will always be true that our gross national product will increase from year to year, and that it will be possible for everybody to always have more than they had before.

But whatever the reasons, controls have been discredited, and in the middle of 1974 the administration again turned to a restrictive monetary and fiscal policy as a method of combating inflation. This worked awfully well again in terms of moderating inflation. It worked so well in terms of depressing the economy that I think it has even scared the people who were sponsoring it and they have reluctantly shifted to a policy of at least half-way stimulation.

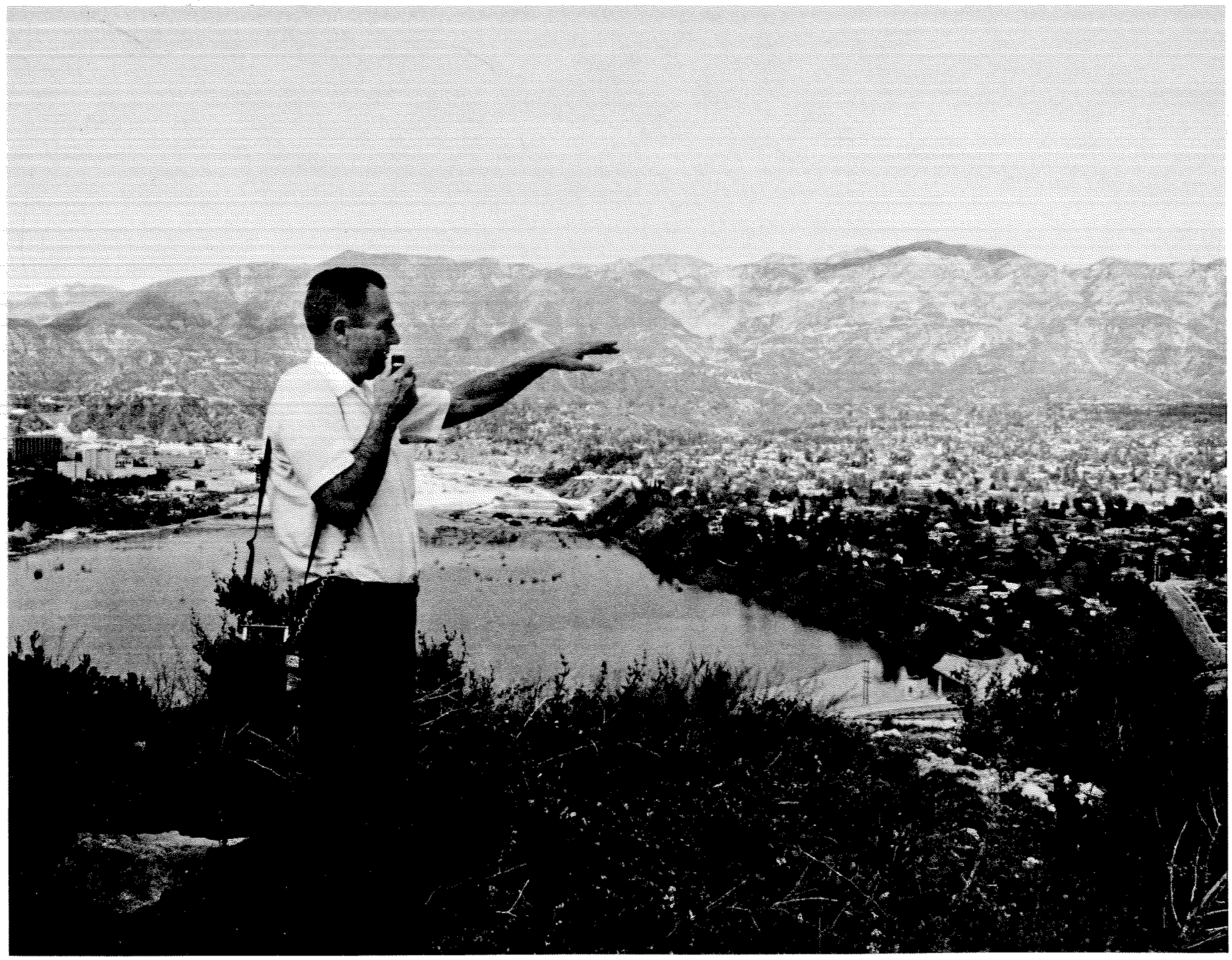
In reading recent editorials I have noticed three different positions on what should be done. *Fortune* in its December issue came out flatly in favor of continuing to fight inflation by allowing the economy to remain depressed. "Only a few months into a declared war on inflation the U.S., or at least many of its visible spokesmen, seems to have lost sight of the goal and to have become transfixed instead by the recession that is now upon us. This recession was not unexpected. It was deemed by many students of the economy to be a necessary evil—a burden that must somehow be shouldered—probably for an extended period if we are to bring inflation under control." That is obviously the Spartan view of the thing. It's always a little easier to take that position if it's somebody else who is out of a job.

The *London Economist* reaches a completely different conclusion as to the proper policy on the basis of a basically similar analysis of the economic situation. "There are only two ways to deal with inflation. Effective wage and price controls, or the pursuit of financial rectitude to a point that will cause unemployment to soar." The *Economist's* view is that we should have controls, the sooner the better.

The third position is based on the assumption that we can have it both ways—both stimulate the economy to overcome recession and at the same time experience a declining inflation rate. In its February 10 issue *Business Week* criticizes the President's program as "unrealistic because it ignores the need for more government spending in a recession. The demand for new programs or expanded programs to ease the impact of unemployment and increase the purchasing power of bottom-bracket incomes simply cannot be denied." But although recession is the most urgent immediate issue, "uncontrollable inflation remains the chronic threat to the U.S. system." We must therefore have a program "that offers the greatest possible stimulation with the least inflationary side effects." How, without using controls, we are going to be able to stimulate the economy without at the same time reviving the threat of inflation *Business Week* unfortunately fails to explain. This is the more surprising in view of the fact that in its news columns *Business Week* has emphasized the stubborn character of our present wage-push inflation and the slow, grinding way in which recession, if it continues long enough, may be expected to sap the vigor of the inflationary process.

"The economy is slipping deeper into recession . . . Though there will be a lag, wage demands should begin to moderate as 1975 wears on. That will be the key to winding down inflation. Workers want to catch up on past price increases, but now they are worried about their jobs. The quit rate has come down sharply since last summer. Workers will soon become even more worried as the unemployment rate climbs . . . That is bound to take some of the edge off demands, even though the unions are still shooting for double digit wage gains." (Dec. 21, 1974, p. 19)

That's a clear-cut statement of what the connection is. It runs through weak markets, unemployment, people clamoring for jobs, all of this eroding, undermining the strength of wage demands. Maybe it would work in a year, two years, if we were willing to put up with that kind of an economy. It's everyone's choice, I suppose, as to what you consider really important. Personally, I would much prefer the problems connected with the renewal of controls (which could be limited to the key collective bargaining and the key corporation price sectors)—to the dragging unemployment, low production, and the discouragement of people's hopes and ambitions that would be involved in a continued policy of attrition. □



Geologist Robert Sharp and a sunny hill above Devils Gate Dam are the right combination for learning about Pasadena's geological setting.

Do You Know Where You Are?

If you subscribe to the belief that even your own backyard can be full of fascination when you know a little about its basic geology, one man to help you learn about southern California is Robert Sharp, professor of geology. Sharp has been hiking over, observing and interpreting, and writing and talking about it for years. So, when we presented him with a panorama of Pasadena (which you'll find on the next four pages), he produced this instantaneous description.

The eight photos that make up the panorama were assembled from a series taken recently by campus photographer Floyd Clark from a spot in the Flintridge Hills above Devils Gate Dam. Beginning by pointing his camera almost due north, Clark swung it clockwise in stages for approximately 160 degrees until the last photo is south-southeast.

Gould Mesa

Jet Propulsion Laboratory

Devils Gate Reservoir

Arroyo Seco Canyon

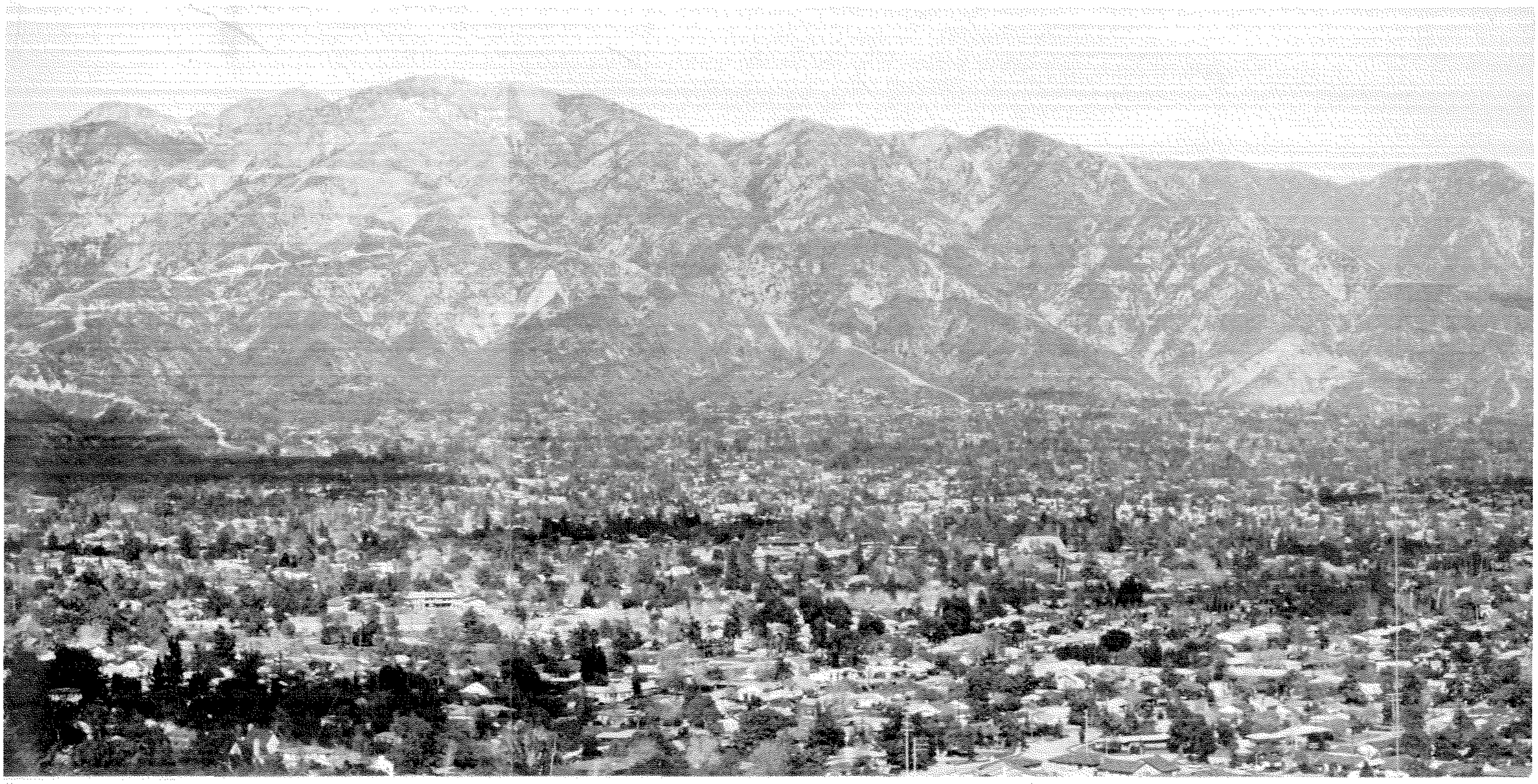
Millard Canyon

The first thing to remember is that the geology of any small area is something like a single piece of a jigsaw puzzle—hard to understand if you don't have the whole picture in mind. But a few key pieces of information can help to clarify Pasadena's place in the larger geologic scheme. Speaking in global terms, Pasadena is on the Pacific Plate, as is all of California west of the San Andreas fault, which both divides it from and sutures it to the North American Plate.

Though it is at the north edge of the Los Angeles Basin, geologically Pasadena is not a part of the basin. The basin is a part of the Peninsular Ranges that rise in Baja California and run in a generally northwesterly direction along the coastal area. Pasadena belongs to the Transverse Ranges, a 300-mile-long, east-west topographical province that lies crosswise to the general northwest grain of southern California.

Another important aspect of the Pasadena area is its location in a region that is crisscrossed with a network of faults. These many fault lines not only define distinct large and small areas, but they are both sources and expressions of southern California's restless, complex, and youthful geology. Pasadena sits in the Raymond Basin, bounded on the south by the Raymond fault and on the north by the Foothill fault. At least two or three smaller faults run through the city proper.

The backdrop for the Pasadena scene is the magnificent fault scarp of the Sierra Madres, the front range of the San Gabriel Mountains. Rising about 3,000 to 3,500 feet above the San Gabriel Valley, the scarp is the result of repeated displacements along the Foothill fault. The motion has thrust the ancient crystalline rocks, of which the mountains are made, up and over the rounded boulders, gravel, and sand deposited on the valley floor by mountain streams.



Mount Lowe
Sunset Ridge
Echo Mountain
Las Flores Canyon
Rubio Canyon

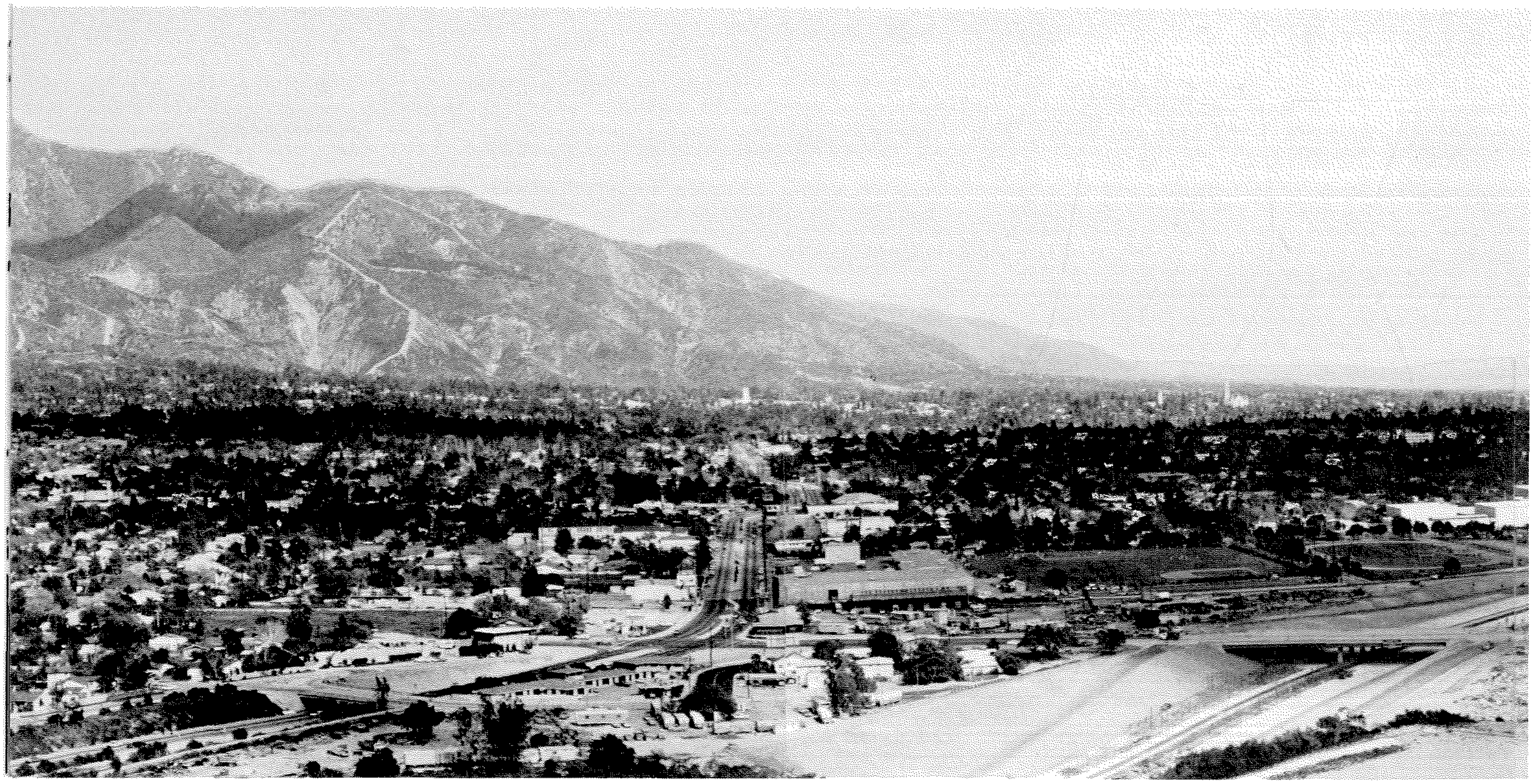
Those streams pouring out of mountain canyons have also built the alluvial surface on which Pasadena sits. At first the streams simply deposited their debris as "fans" at the canyon mouths. But the continuation of this process over at least 100,000 years (and it is still going on) has thickened, widened, and extended the fans until they now form a continuous gently sloping "apron" about 1,000 feet thick and four to five miles broad.

Three kinds of rocks lie beneath and around Pasadena. At the lowest level is the crystalline basement, which is made up of igneous and metamorphic rock 80 million to 1,800 million years old. The road cuts shown at the extreme right on page 27 expose some of the crystalline basement rocks, here deeply decomposed by weathering. Pasadena's Washington Junior High School on North Raymond Avenue is built on a large protruding island of crystalline rock known as Monk's Hill. Though darkened by cloud shadows, it can be seen on page 27.

Covering the crystalline basement is a thick layer of sedimentary rock, largely composed of shales, sandstones, and conglomerates and known locally as the Topanga Formation, about 15 million years old. Rocks of this formation are exposed here and there along the west side of the Arroyo Seco south of Colorado Boulevard, and the local landmark "Eagle Rock" is made up of a mass of this rock formation.

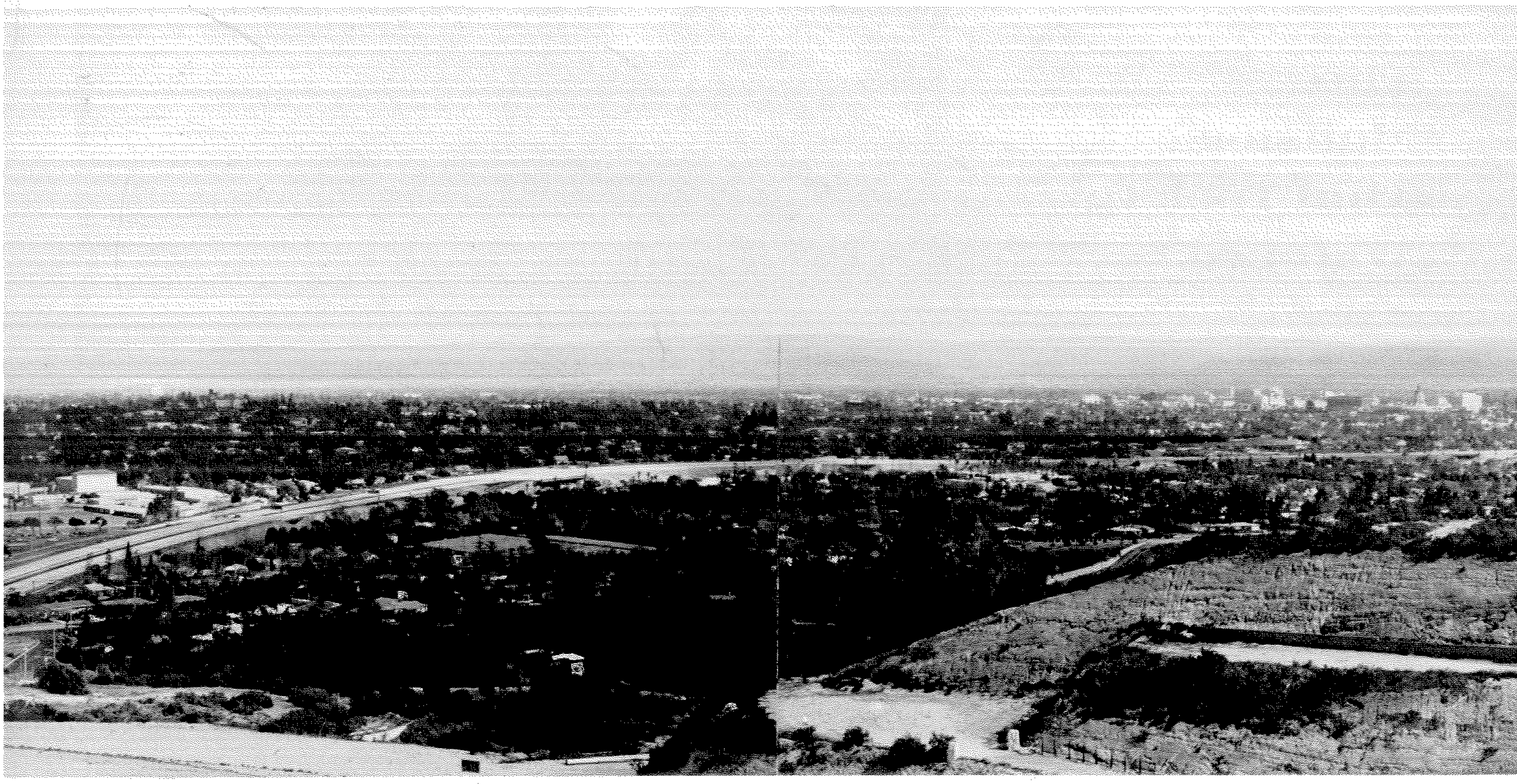
The third and much the youngest of the local rock formations is the 1,000-foot-thick blanket of alluvial deposits spreading out across the valley from the base of the mountains.

continued on page 26



Ages ago many of the streams that ran out of mountain canyons simply spread out and disappeared on the fan surface—and most of these streams still do just that though they have flowed farther and farther out as the slope of the alluvial deposits has become gradually steeper. The unique exception is the Arroyo Seco, which flows in an entrenched course all the way across the alluvial fan. Beginning just above the Jet Propulsion Laboratory, shown on page 24, the Arroyo Seco runs southward, sculpturing a canyon, which in plan view is somewhat like a series of free-form hourglasses along the west side of Pasadena; it then turns more westerly and provides the present route of the Pasadena Freeway to Los Angeles.

At one time the Arroyo Seco, like the streams from all the other canyons in the Pasadena area, wound its way across the surface of the alluvial apron. It eventually ran south-southeastward (perhaps by way of the Alhambra Wash) into the Rio Hondo, as the other drainage lines still do, through the Whittier Narrows and thence southwestward into the Los Angeles River. Then some kind of historical accident changed its course and its character. What probably happened is that an upstream tributary of the Los Angeles River working headward from Elysian Park found its way to the Arroyo Seco and captured the stream, diverting it into a shorter and more direct course to the Los Angeles River. This shorter route made it possible for the Arroyo Seco to lower its stream bed, thus entrenching the Pasadena alluvial apron.



Washington Junior High (Monk's Hill)

Downtown Pasadena

John Muir High School

Foothill Freeway

Road Cuts on Devon Road

As the waters of the Arroyo Seco flowed along cutting through the alluvial deposits, the ease of the lateral erosion created the wide areas that we know in today's Arroyo Seco—Oak Grove Park, Brookside Park, and the Rose Bowl area, for example. But every now and then in its downcutting, the stream met buried spurs of hard crystalline rock jutting eastward from the San Rafael Hills, making erosion a much harder task and restricting lateral cutting. The results are the hourglass waistlines of the waterway, which today are spanned by bridges.

As important in Pasadena's geology as the scarp of the Sierra Madres to the north or the Arroyo Seco to the west is the Raymond fault to the south. The Huntington Library and Huntington Hotel perch on the brink of the scarp that marks the trace of this fault through the Pasadena-San Marino area, and Lacey Park is at its base.

What is really important overall to remember about Pasadena's geological backyard, Sharp says, is that it is young, varied, and active—characteristics that are typical of our way of life. "We live," he says in his book Geology Field Guide to Southern California, *"in a geologically dynamic area, and it shows. In subtle psychological ways our youthful geology may be partly responsible for the high basal metabolism and mobility of our west-coast culture."* □

The Monster That Took On Walt Lee

At the age of 4, Walt Lee developed a consuming interest in insects. By the time he was 8 he had switched to astronomy. At 10 it was chemistry. And by 14 it was atomic and nuclear physics.

In other words, Walt was a natural for Caltech. He came here as a freshman in 1950, majored in physics, and graduated with honor in 1954. After a year of grad school at the University of California at Berkeley, Walt joined the technical staff of the Hughes Aircraft Company, where he is currently writing and coordinating their technical publications and films.

This compressed biography makes Walt sound like a lot of other Caltech alumni. But there is one staggering difference. From the time he could read, Walt was addicted to comic books and science fiction. It's an addiction he has never shaken off. At the moment, it's got Walt at its mercy. If he makes one false move, in fact, it will take over his life.

It all began back in a simpler time, 1958, when Walt took it into his head to work up a *Science Fiction and Fantasy Films Checklist*—a small pamphlet that sold for $2, and was soon out of print. (Ten years after its publication, rare copies were sold for as much as $75.) Walt was thus encouraged to try putting together a really comprehensive (he is enough of a realist to avoid using the word "complete") listing of all the films ever made that had some content involving science fiction, fantasy, or horror. His life hasn't been the same since.

For more than 15 years now, the Lee homestead in West Los Angeles has been engulfed by science fiction, fantasy, and horror. The Lee cars have never been in the garage, because that has become a library and work room, crowded with complete runs of science fiction magazines, books on films, motion picture stills, and cartons and shoeboxes stuffed to the brim with index cards.

The cards, of course, contain information on the films, and they include everything from *Cauldron of Blood* and *Wrestling Women vs. the Aztec Mummy* to *The Seventh Seal* and *2001*—even such esoterica as *Girls Scouts vs. the Cookie Creature,* a 10-minute silent film, in color, made by Girl Scout Troop 370, under the supervision of Walt and Eve Lee, with this crisp plot description: "Girl steals Girl Scout cookies, eats too many, turns into monster."

The three-volume *Reference Guide to Fantastic Films: Science Fiction, Fantasy, and Horror* based on data from all those cards is now in print—and selling fast—so the project has outgrown the Lee garage. What was once a den in the house has now become a storage and mail room. The *Guide* is available, by mail, from Walt himself. A first printing is already running low, and a second printing is scheduled. A revised and much enlarged second edition, though still far in the future, is a frightening possibility that can't be ignored. If the Lee family ever thought they were going to recover some spare time after publication of the *Guide,* they don't think so now. Eve Lee and the two Lee children, Steven and Cindy, are doing as much indexing, filing, and mailing as ever. (The *Guide* carries a sentimental dedication "To my wife, Eve, whose valuable help is especially appreciated since she feels so strongly that the vast majority of fantastic films are junk.")

Publication of the *Guide* has stimulated people all over the world to enter into correspondence with Walt and give him new listings and information for future editions.

It's quite clear that things have changed since 1958, when Walt had only a few hundred films to deal with. The film business, books about films, and the interest in films have all exploded since then. Walt's 1974 *Guide* has more than 20,000 listings.

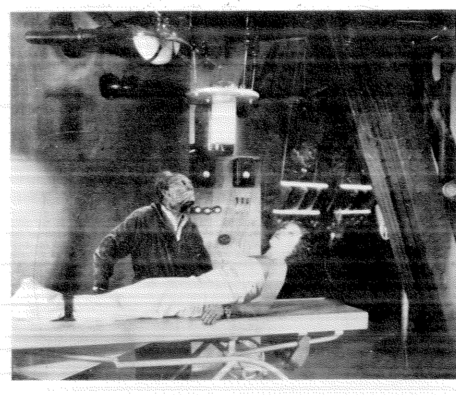
It should be noted that Walt has anticipated us all, in his introduction to Volume I of the *Guide*, by answering the question he knows we will inevitably ask: Why did he do it?

First of all, he says, because these films have held a particular fascination for him all his life. "In my view, the unique appeal of the fantastic stems from our curiosity about things beyond our normal experience and knowledge, possibly beyond the limits of our knowledge.

"What lies beyond death? Are there other intelligent beings in the universe? Could humans turn into beasts or beasts into humans? Can we create artificial beings? What does the future hold? Can it be foretold by supernatural means? Can the dead return?

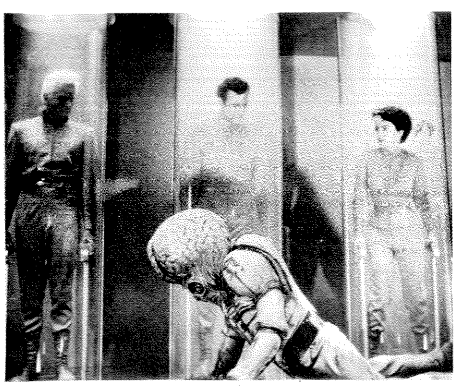
"... How the tremendously popular motion picture medium has treated these subjects is fundamentally important."

Walt wrote that in 1972. In spite of everything, he still stands by it in 1975.□



The Mystery of the Wax Museum - 1932

The Bride of Frankenstein - 1935

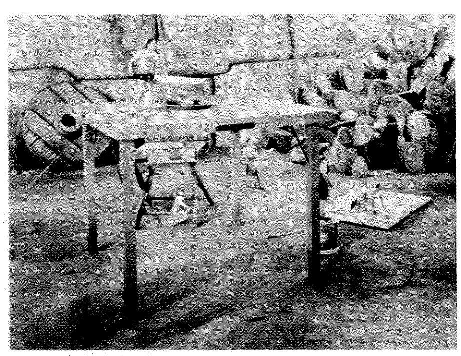


This Island Earth - 1954

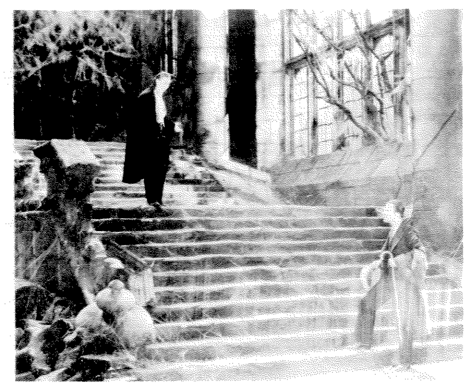
King Dinosaur - 1955

The Phantom of the Opera - 1925

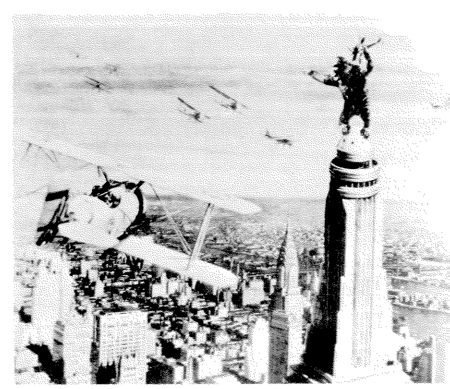
Dr. Jekyll and Mr. Hyde - 1931



Dr. Cyclops - 1939



Dracula - 1930



King Kong - 1933

Some Classic Stills From The Lee Collection

Letters

Help from Hibbs

South Pasadena

I am a Caltech fan, a member of the Associates, and a devoted reader of *Engineering and Science*. Your magazine does more for me than any other periodical.

I was especially pleased that you published Dr. Hibbs's recent article on freedom of expression. It is my impression that a great many people have serious doubts about the theory of racial equality although they may be reticent about expressing them. At present the case for the equality theory appears to be based more on policy than on knowledge.

Perhaps Dr. Hibbs's article may be helpful in hastening the time when a strongly based effort will be made to ascertain the facts. The potential long-range benefits of an early, correct understanding seem overwhelming.

VERNON BARRETT

Scientists' Contribution

Pasadena

I rather enjoyed Albert Hibbs's piece on "Inquisition, Repression, and Ridicule." I cannot help but wonder to what extent scientists may contribute to this problem.

I first became aware of this problem, as I subscribe to a couple of military publications that carry technical and historical material; a friend of mine expressed interest, then commented that he was reluctant to subscribe, as he was uncertain that fellow academicians might read political connotations into it.

Be that as it may, it appears Mr. Hibbs is unaware of the precise background of the Oppenheimer case; this is a classic of its kind, to the extent to which it demonstrates how both the military and the academicians can be victimized in the same issue.

Oppenheimer's stand on the H-bomb was not a moral stand, but a militarily sound one.

At this time, only the D-T reaction was known to American scientists, and the adaptation of reactors to produce one pound of tritium would have cost 80 pounds of plutonium. In effect, it would have amounted to throwing away 95 percent of the kilotonnage striking power of the United States. Also, by this time, the Oraloy process was under development, which would have extended fission yields into the megaton range, in any event. This is critical to military projectiles and missiles, in maintaining the sectional density of the warhead, for aerodynamic efficiency.

When Ulam and Teller perfected the approach to the lithium bomb, Oppenheimer immediately announced that if he had known it could be done on the practical scale, he never would have opposed it. The Russians, of course, had perfected the catalyst for the lithium bomb a couple of years before, and thus claim the laurels for testing the first "drop" bomb.

The background on the Oppenheimer hearing is simply this: Oppenheimer gave a speech before the Council on Foreign Relations in New York City, stressing the need to develop tactical hardware to make up for American ground weakness in Europe and forestall Russian activity. Almost instantly, *Fortune* magazine, several editors of which were members of CFR, printed a particularly vicious attack on Oppenheimer and his views.

Don't ask why—I don't know. I do know that Lewis Strauss, the only member of the AEC to strongly support the H-bomb development at that time, was also a member of the Council on Foreign Relations. I am only too aware how a small number of members can impose on the organizations to which they belong, to obtain privileged information to exploit for personal political or social benefit.

The most likely explanation is that some pro-bomb party who attended the meeting had taken off on his own tangent afterward, riling the membership. In short, Oppenheimer had stepped on somebody's personal toes with his speech, and whoever it was made the rounds with a story of his own.

Oppenheimer brought to the military arts the same skill and competence that characterized his scientific work; it was not a coincidence that he justified Leslie Groves's confidence that he would make a good administrator. A military leader is made or broken by the skill and care with which he selects his staff, and Groves was a hot one at that.

Perhaps the greatest tribute to Oppenheimer's foresight here is that it was his, much-criticized, policy, which eventually became the accepted United States policy, leading to the country dropping out of the publicity-seeking megatonnage race, and to its eventual contentment with a militarily credible and realistic nuclear defense posture. Oppenheimer has never been given the credit as a molder of military policy that he deserves; too many people have mythologized his accomplishments, to conform to their political and social platforms.

Oppenheimer advocated the correct method to assure sound defense under the conditions of the times; city-busting was still a theory then, but the threat of the Russian hordes invading Europe was real. One of the most infuriating things about the case is precisely that the policy was adopted without giving its true author the credit for it. Iron hardware is rapidly reaching a degree of perfection that tactical "nukes" may well be viewed as obsolete within the next few years. The advances, indeed, may become so drastic that future generations may wonder why we ever bothered to fool with nuclear explosives in the first place.

But that is just the point. You know how people win a war, because it is visually spectacular; but you don't know how people keep a peace, precisely because it's peaceful, and doesn't attract attention. The perfect weapon is the one you never have to use. That was exactly what Oppenheimer provided. He got his throat cut, because he lived in a time when the most useful hardware didn't have any political or social publicity value.

JAMES J. GLACKIN

continued on page 32

Understanding Mormon

Cambridge, Mass.

Professor Rodman W. Paul, in his article "The Mormons of Yesterday and Today" in the December-January issue of *Engineering and Science,* presents an interesting account of the history of the Latter-Day Saints. I was very impressed with the depth of his understanding of these people, as few people who are not of the LDS faith seem to take time to try to understand the Church and the Saints, but rather rely on rumor and some of the more unreliable accounts written in turn by others who did not take time to find out very much before writing. I was very pleased overall with the article.

Yet, even with his knowledge of the Latter-Day Saints, Professor Paul has treated them as if they were merely a society of men rather than the Church of Jesus Christ. If he is closely acquainted with members of the Church, as his article implies, he almost certainly has been exposed to their personal faith. It was not just in the Church's early days that those joining the Church were required to take the "immense step of literal faith," to believe in the literal divine origin and divine authority of the Church. Although it is perhaps possible to grow up in the Church never questioning its divinity, few if any Latter-Day Saints of my personal acquaintance have managed to remain active in the Church unless at some point they have gained a personal knowledge (yes, knowledge) not only of its divine origin but also of its divine leadership today. The huge time and talent demands placed on an active Latter-Day Saint and the moral challenges that abound in the world insure that a choice must be made. And, my point is, it really is possible for one who really wants to make this choice to have personal and unmistakable divine confirmation of the "truthfulness" of the Church.

Once one is convinced that Joseph Smith and his successors actually act with divine authority and on the basis of real revelation and inspiration from the Lord, once one has learned to rely on that same inspiration and revelation —which does come when needed—on a personal level, then several of Professor Paul's statements about the organization of the Church, about the choice of Church leadership, and about the decisions of that leadership become almost humorous. If they were not misrepresenting things held most sacred, they would be quite funny. As it is, I feel a responsibility to try to fill out the record.

For instance, the priesthood is bestowed only on certain members of the Church because the Lord commanded that it be done that way. Polygamy was instituted and then was stopped because the Lord commanded it. Members of the Church have become more and more involved in the affairs of the world because the Lord commanded it. Sometimes the things the Lord commands make obvious sense, especially with the aid of a little hindsight. But other times the reasons for commandments are not at all obvious. In any case, even when the sense is obvious, the real reason for obeying the dictates of the Church is because they are literally commandments from God.

Professor Paul seems to have totally ignored this viewpoint. His history is written as though made up of observations from a great distance—as if he were watching a culture on another planet through a telescope and writing down all he could see, and, finding that an unknown proportion of events were occurring inside buildings where his telescope could not see, interpolating a whole culture from what he could see. What is the probability that his interpolated history could be accurate? If there are things going on there that simply never enter his mind, he cannot be entirely correct. And if those things are crucial to an understanding of that culture, he will not, no matter how hard he tries, understand it.

Since many things pertaining to the Church which are very sacred are simply not available to Professor Paul or anyone else who is not a member in good standing, it is not surprising that his history is very secular in its interpretations of the LDS culture. But that does not make his understanding of the Church correct.

So I would like you, Professor Paul, and anyone else who might read this letter, to know that I have personally had given to me by the power of the Lord a real knowledge of the divinity of the Church of Jesus Christ of Latter-Day Saints. And I am sure the Lord will give that same knowledge to anyone who sincerely seeks for it. The Gospel of John quotes Jesus as saying, "If any man will do his will, he shall know of the doctrine, whether it be of God, or whether I speak of myself." I have, and many others have, taken the Lord up on this offer and found that by trying to live the Gospel of Christ as embodied in the Church, it really is possible to have divine confirmation that it is of God. I bear my witness to this simple but beautiful fact in the name of Jesus Christ. Amen.

And perhaps this seems like a funny way for one claiming to be a scientist to talk—but is that not what science is all about, to look for knowledge of things as they really are? To test each bit of new-found data on its own terms to see if it holds up? And then, if it does, to add it to the body of knowledge which makes up one's understanding of reality? And then to try to publish each new conception of reality so that others might have the benefit of one's personal efforts?

I would have to lie to myself and erase knowledge from my mind to change my present course. As a scientist the very idea of ignoring facts pertinent to me, even if they make me change entirely my way of looking at things, is repulsive.

Again, a thank-you to Professor Paul for his article. And a hope that he might be able to see a little of the spiritual side of the Latter-day Saints, as well as the secular side, in the future.

ROGER J. JONES
BS '71 Physics
(Currently trying to finish up my PhD in Biology at Harvard)

We're looking for engineers who were born to lead.

Are you the kind of engineer who has what it takes to move into management someday? If you are, you already know it.

Now what you need to know is which companies can offer you the best opportunities. We think you'll find General Electric is one.

We're a high technology company. And that means we have to have managers who understand technology—women and men—to run the place.

Today, over 60% of the top managers at General Electric hold technical degrees. In fact, over 65% of the college graduates we hired last year held technical degrees.

Of course, just leadership ability and a technical degree won't get you into management. First, you're going to need solid engineering experience and a broad understanding of business.

And we have a lot of ways to help you get it.

One is our Manufacturing Management Program. A two-year program of rotating assignments that gives you broad experience with different products and manufacturing processes.

Another is our Engineering Program. For engineers with an interest in product and systems design and development. There's also a Field Engineering Program, a Technical Marketing Program, plus a number of programs sponsored by product operations.

And all with just one aim. To give you all the responsibility and all the perspective you need to move into management. As fast as you can manage it.

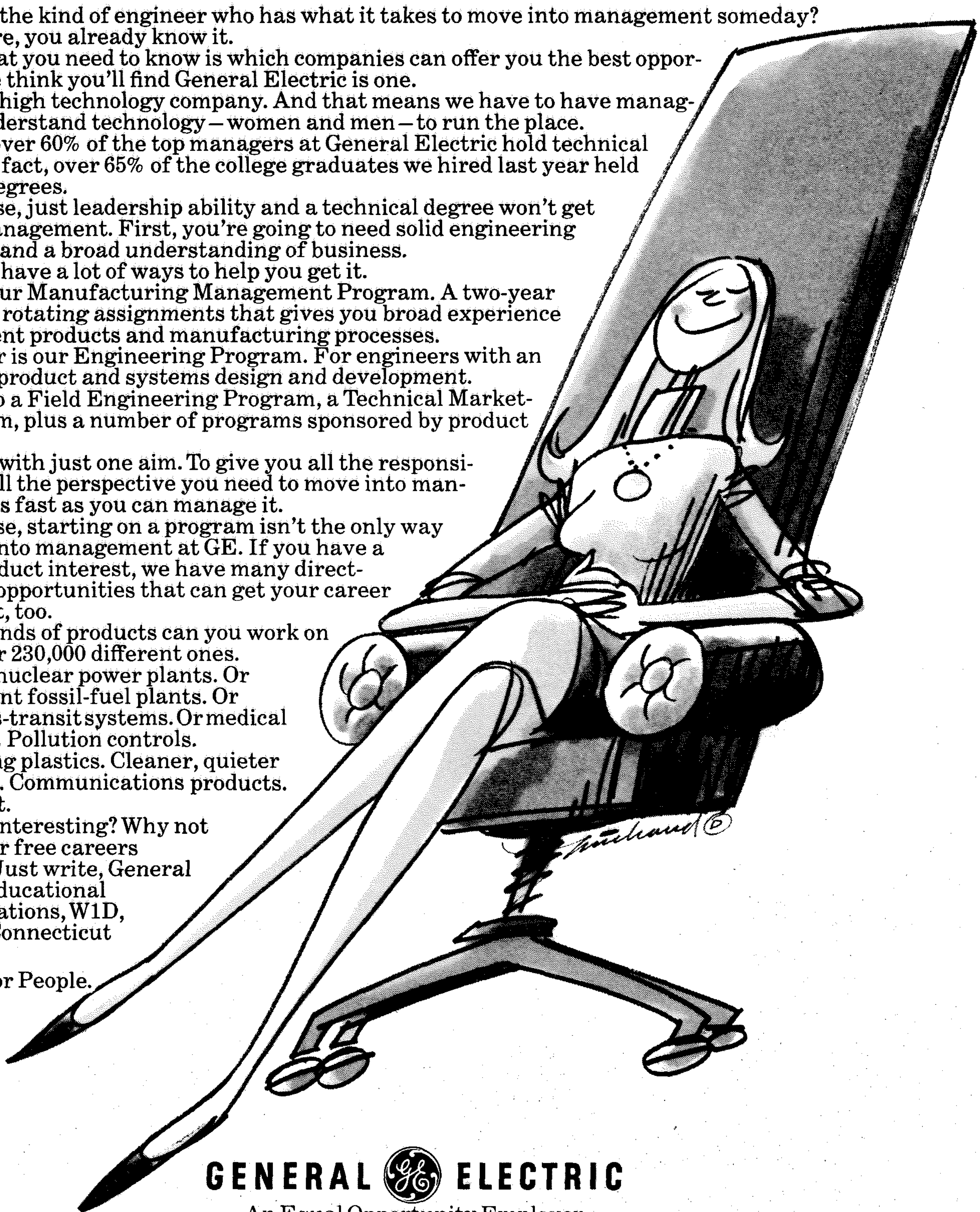
Of course, starting on a program isn't the only way to make it into management at GE. If you have a specific product interest, we have many direct-placement opportunities that can get your career started fast, too.

What kinds of products can you work on at GE? Over 230,000 different ones.

Maybe nuclear power plants. Or more efficient fossil-fuel plants. Or better mass-transit systems. Or medical equipment. Pollution controls. Engineering plastics. Cleaner, quieter jet engines. Communications products. You name it.

Sound interesting? Why not send for our free careers brochure? Just write, General Electric, Educational Communications, W1D, Fairfield, Connecticut 06431.

Progress for People.



GENERAL ELECTRIC

An Equal Opportunity Employer.