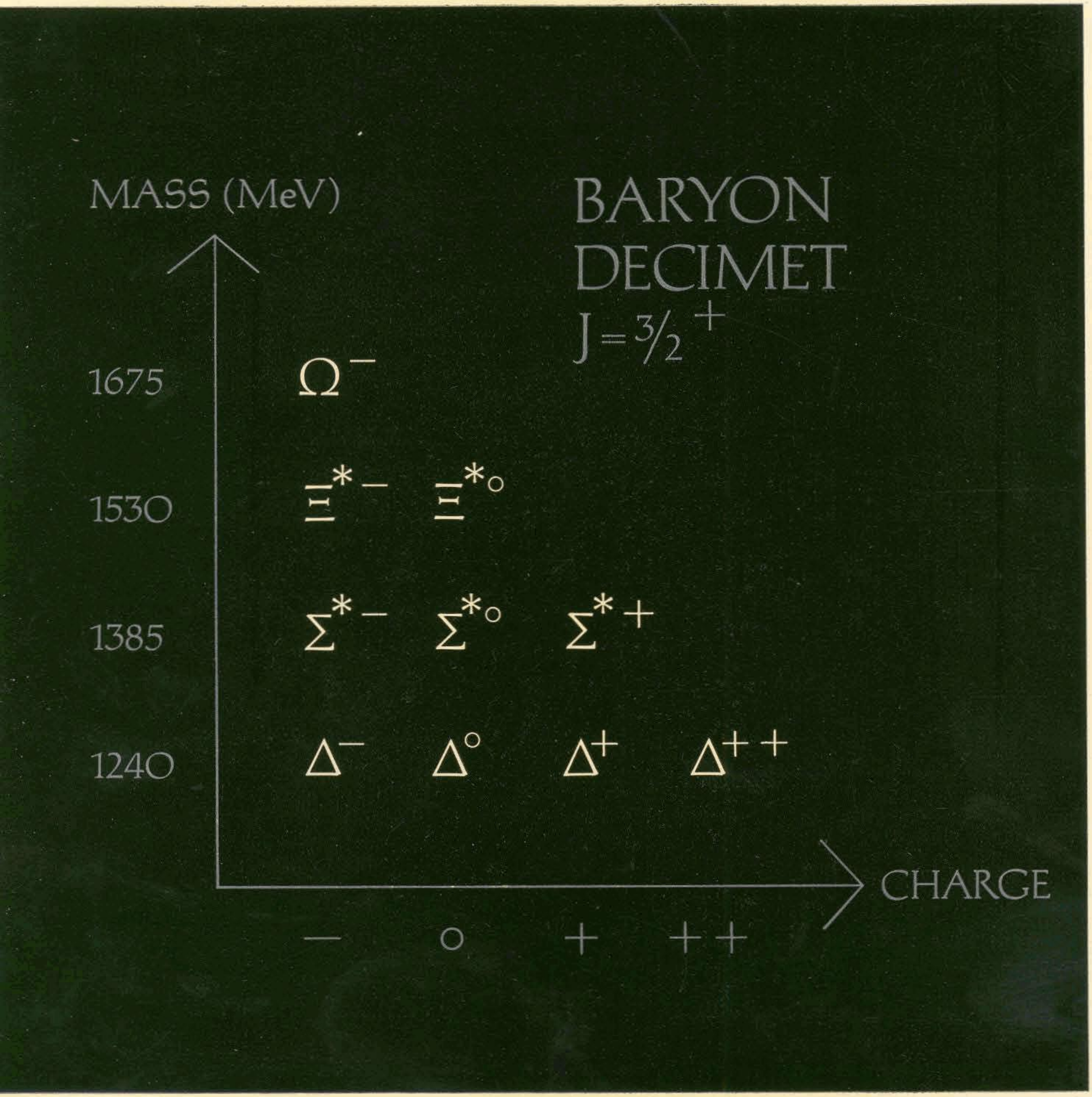
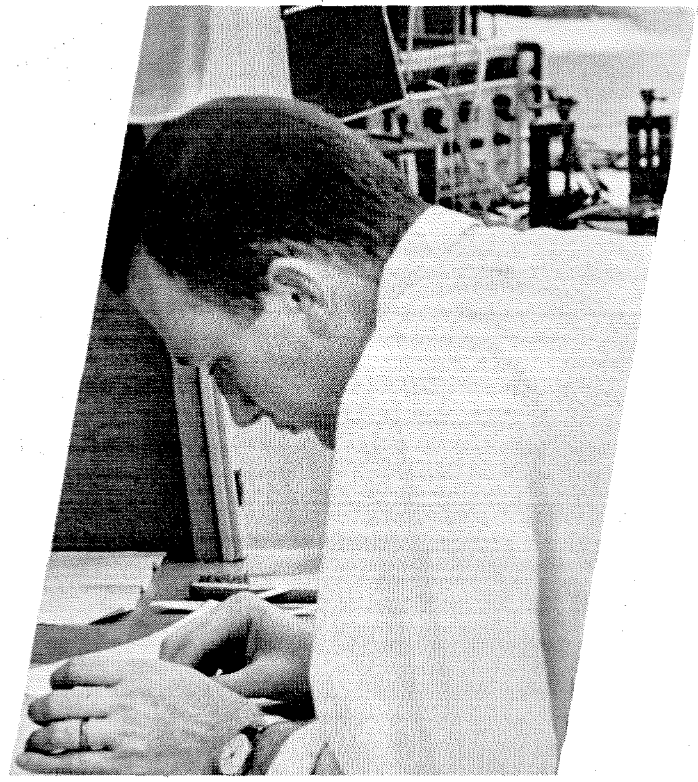
JANUARY 1967

ENGINEERING AND SCIENCE



PUBLISHED AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY



HEWLETT-PACKARD IS COMING FEBRUARY 1-2

IF YOU THINK IT UP, YOU'LL PROBABLY HAVE TO MAKE IT—That is why, at Hewlett-Packard, an R&D engineer's desk and workbench are side by side.

One of the most exciting things about having an idea is the chance to lift it off the drawing board and take active part in translating it into a tangible, marketable product.

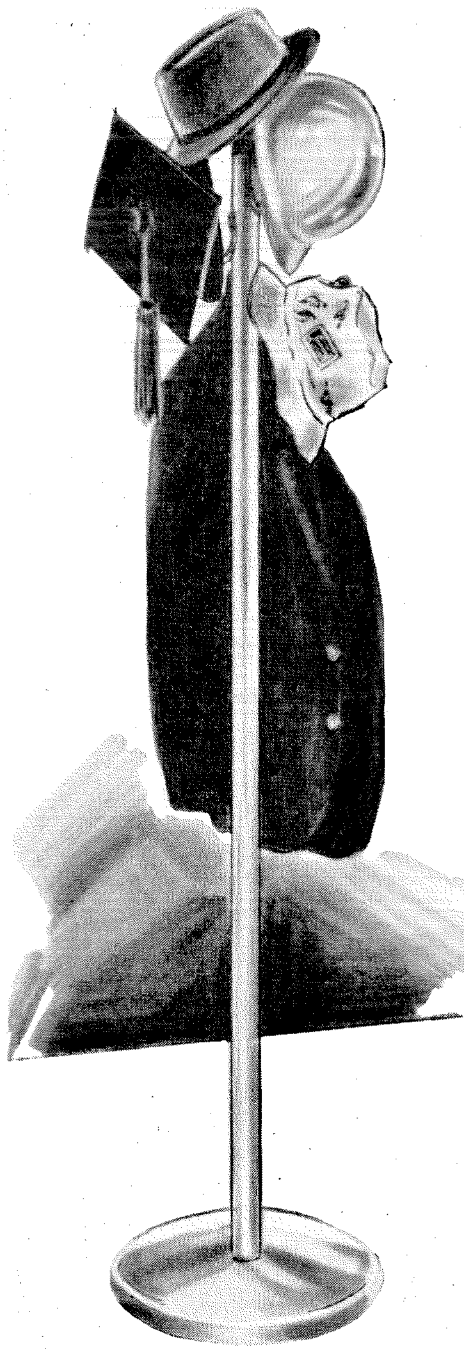
At Hewlett-Packard you will have the opportunity to do precisely that. If you have a good idea, you can design it, breadboard it, work out the chassis, see it through data sheet specs, do the pilot run. You could even separate yourself from the design and manufacture of the instrument—and concentrate on making it a marketable product. Marketing people at Hewlett-Packard are engineers, too.

This policy of total involvement is one reason Hewlett-Packard has been able to contribute so much to the science of measurement. Our growth is built on ideas—and the individual's ability to convert them to marketable products.

That's why at Hewlett-Packard you'll find so much flexibility, freedom of communication, and an unlimited opportunity to grow in any direction. Putting your desk and workbench side by side isn't just a convenient way to arrange the furniture. It's a way of life.

If this kind of working climate interests you, contact your Placement Officer for more information. If you're unable to come in for an interview on the scheduled dates, write Ray Wilbur, Vice President, Dept. 159, 1501 Page Mill Road, Palo Alto, California 94304. Your letter could give you a chance to marshal all of your resources—in stimulating, rewarding work. An equal opportunity employer.

HEWLETT hp PACKARD



Our Research Engineers wear many hats

By this we mean that each has an extended capability in discipline other than his original area of specialization.

This capability is not necessarily one the engineer brings with him **to** Foxboro — though, of course, it would be most welcome.

But it is one the engineer can gain **at** Foxboro.

The chemical engineer, for example, by adding a competence in computer control technology, can lead the way in process control research.

The physicist, who adds a competence in industrial processing to his knowledge of fluid dynamics and gas composition, is thus able to pioneer in process measurement techniques.

Other important disciplines — gas analysis, digital and analog control — can also be added at Foxboro.

They help the versatile engineers who acquire them — and ourselves — grow faster.

And this growth — for all practical purposes — is unlimited.

If you already have this extended capability — or the capacity and desire to gain it — Foxboro can offer you many ways to benefit by it.

We're especially looking for Bachelors, Masters or Doctors in:

- Physics (Electronics)
- Electronics (exploratory design)
- Mechanical (exploratory design)
- Chemical Systems Engineering
- Physical Chemistry
- Fluid Dynamics
- Chemistry
- Computer Design
- Mathematics/Programming
- Control Systems Analysis

See your placement officer. Or write:

W. W. Brown
Central Recruiting Office
The Foxboro Company
Foxboro, Massachusetts 02035

An Equal Opportunity Employer

FOXBORO®

***Specialists** in Process and Energy Control*

ENGINEERING AND SCIENCE

JANUARY 1967 / VOLUME XXX / NUMBER 4

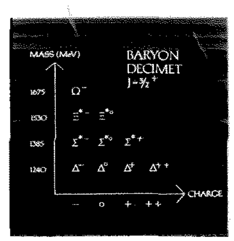
CONTENTS

PICTURE CREDITS: Cover—Doyald Young / 15-17, 28, 34—James McClanahan / 20—J. R. Eyerman / 29—Mt. Wilson and Palomar Observatories.

STAFF

Publisher . . . . Richard C. Armstrong '28
Editor and Business Manager . . Edward Hutchings, Jr.
Associate Editor . . . . Bruce R. Abell '62
Assistant to the Editor . . . . . . Phyllis Brewster
Photographer . . . . James McClanahan

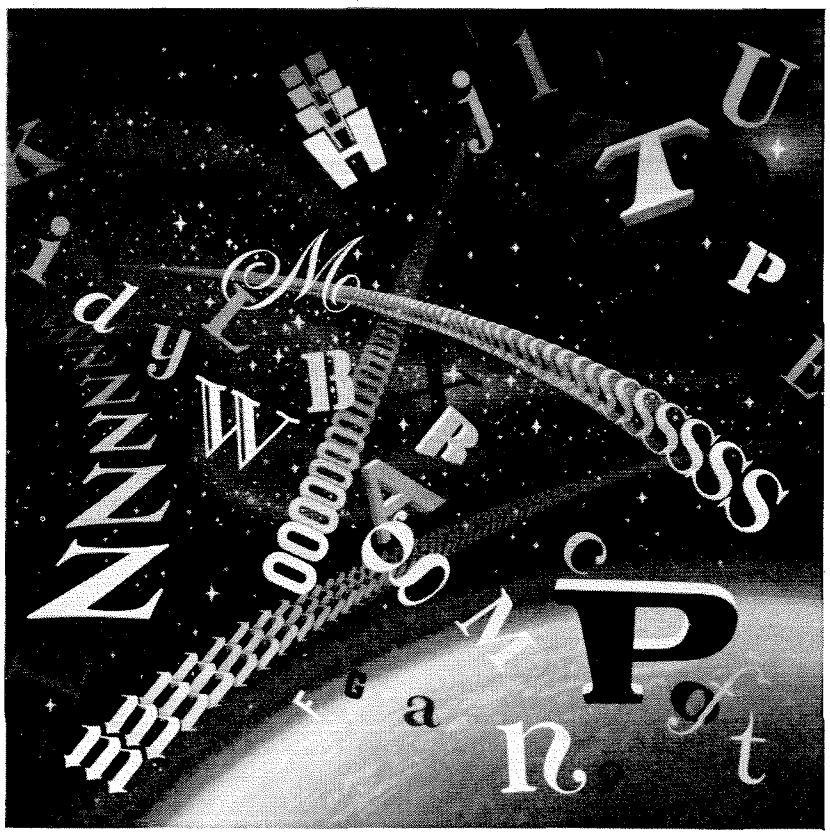
Published monthly, October through June, at the California Institute of Technology, 1201 East California Blvd., Pasadena, Calif. Annual subscription $4.50 domestic, $5.50 foreign, single copies 50 cents. Second class postage paid at Pasadena, Calif., under the Act of August 24, 1912.



COVER

The pattern of subatomic elementary particles shown on our cover was theoretically predicted by Caltech professor of theoretical physics Murray Gell-Mann in 1962, and concurrently advanced by Israel's Yuval Ne'eman. Two years later the theory was confirmed by the discovery of the omega-minus particle. Gell-Mann talks about these patterns and their origin in "The Elementary Particles of Nature" on pages 20-25 of this issue.

Engineers/Scientists



Is there hope for 26 of the world's most misunderstood characters?

Although graphic communications of all kinds is our business, making ideas matter is our main concern. Since this encompasses every alphabet, numerical system and other graphic means known to man, the possibilities are endless.

For example, LDX (Long Distance Xerography) has already begun to demonstrate its immense potential as a graphic way to put any idea across continents or oceans . . . in seconds and with great fidelity.

We think it likely that LDX will do for facsimile transmission and reproduction what our 914 copier did for office copying. Revolutionize it.

And, we expect that, as with the 914, the revolution will come quietly. Suddenly a world of people will have ready access to documents that can help bridge the communications gap. To press this revolution forward we are concentrating on exciting corollary concepts like 3-dimensional imaging, color xerography and the global transmission of images through computer systems.

But even as we extend ourselves to explore and develop the potentialities of LDX-type systems—such as may print the morning paper at your breakfast table some day—we're simultaneously giving a lot of thought to a range of related possibilities. Not least is the creation of potent, low cost educational concepts and techniques.

Your degree in Engineering, Science, Statistics or Mathematics can qualify you for some intriguing openings at Xerox, in fundamental and applied research, engineering, manufacturing, programming and marketing/sales.

See your Placement Director or write directly to Mr. Stephen G. Crawford, Xerox Corporation, P.O. Box 1540, Rochester, New York 14603. An Equal Opportunity Employer.

XEROX

In The Name of Science

by H. L. Nieburg
Quadrangle Books $7.95

Reviewed by Joel N. Franklin, professor of applied science

This book is a violent, opinionated, reckless diatribe against science, industry, and military research and development. Nieburg is an associate professor of political science at the University of Wisconsin. His book is full of grave charges —seldom new, but all sensational. I am reviewing this book because it has become famous and, therefore, dangerous. Representative Henry S. Reuss, chairman of the House Subcommittee on Research and Technical Programs, is quoted on the jacket of the book as follows: "These charges deserve most serious and earnest consideration by the Congress as well as the executive branch of the government."

Really, we at Caltech should not complain. Nieburg writes favorably of DuBridge, Pickering, Caltech, and JPL. Nieburg also praises Secretary McNamara and government laboratories and universities.

The villains in Nieburg's book are James Webb, the director of NASA, and industrialists like Simon Ramo. Among numerous atrocities of which Webb is accused is "the crippling of the Jet Propulsion Laboratory." Dr. Ramo is pilloried for having gotten rich by serving his country.

Not even Nieburg doubts the alertness, initiative, and competence of Simon Ramo and Dean Wooldridge. In the 1950's these two men did more than any other industrialists to protect the free world from the growing missile power of the Soviet Union. They and a few men like them have preserved our civilization and our lives. Should we honor them less because they did not make their fortunes selling cars or cigarettes?

Nieburg's section on, "The JPL Story," is full of colorful errors. With patience and restraint, Dr. Pickering explained to me that Webb has done much to facilitate the work of JPL. JPL has *not* been crippled, nor has it become a business office doing no technical work of its own. General Luedecke was *not* hired by Webb; he was hired by Pickering. There are many other errors, but the whole book is not about JPL.

According to Nieburg, prime contracting as administered by NASA is a racket. The prime contractors are pictured as being so carefully shielded by the government that they inevitably make unearned billions. This "big lie" is exposed by the present financial distress of the Douglas Aircraft Company, which holds many prime contracts for NASA. The fact is that the competition for prime contracts is "vicious," to use the word of JPL's Eberhardt Rechtin. He gave me as an example the intense competition for the Apollo contract.

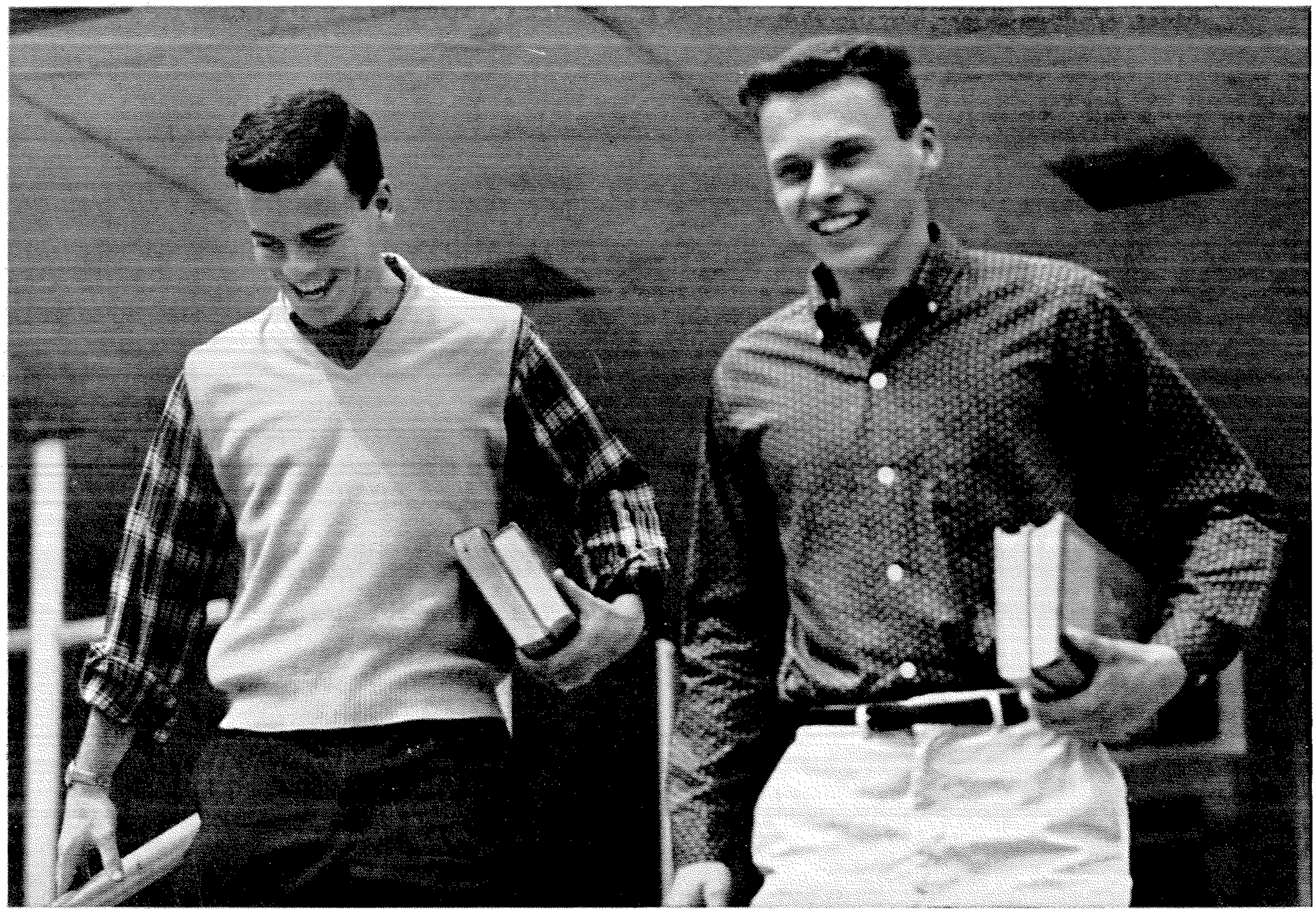
Nieburg speaks much ill of the Communications Satellite Corporation and of the supersonic transport project. His main criticism is that the government is spending too much money subsidizing private industry.

Not everything that Nieburg writes is misleading or false. It would be impossible to write a 431-page book that contained no truth. The research and development necessary for our defense comprise a big, complex, novel enterprise. Some mismanagement has been inevitable. Mismanagement of research and development should be investigated, and it *has* been investigated again and again by all three branches of the government. One should not criticize Nieburg's book because it contains unpleasant charges. But the charges are not new, and many of them are false.

Nieburg blames science for almost everything, including water pollution. On page 91 we read, "A honeymoon at Niagara Falls no longer evokes the lyricism of love but, with its unsightly sewage and noxious odors, the realities of married life." In a chapter inscrutably titled "Entropy and Pump-Priming" science is also blamed for air pollution. In fact, if our scientific knowledge were fully applied, we could greatly *reduce* air pollution.

One of Nieburg's main points is that more work should be done by government and university laboratories and less by private industry. Actually, more work should be done by both. We do not want a great government bureaucracy controlling production. Moreover, an advanced laboratory like JPL *does not* want to do production. After the laboratory has made new developments and after the laboratory and the government have decided policy, the laboratory is delighted to delegate the huge, vexing, mundane chores of production to private industry. Nor should private industry be prevented from doing research. Who has not marveled at the achievements of the Bell Telephone Laboratories? If the transistor is a result of "the economics of ambiguity," then we had better vote for ambiguity.

No brief review could fully catalog the delights and challenges of Nieburg's book. If you are a scientist, an engineer, or an executive, you should read it. As a group, they are said to be inarticulate. If we who understand science, engineering, or business firsthand decline to enter the great debates, we shall all be ruled by the Nieburgs in the end.



ENGINEERING
AND SCIENCE
January 1967, Vol. XXX, No. 4

WHERE IS BIOLOGY TAKING US?

by Robert S. Morison

We in the United States have always held institutionalized education in high respect and, second only to our Soviet friends, have looked to it to solve all manner of individual and social evils. As it becomes more and more capable of actually doing so, its prestige must necessarily increase concomitantly. What, then, are the probable consequences of the increased prestige of institutionalized education? No doubt there will be a considerable number, but I should like to look particularly at its effect on more traditional ways of transmitting accumulated experience to a new generation and to lay before you my reasons for believing that, as public recognition of formal education continues to rise, the prestige and influence of the family will continue to decline. As you will see, many, if not all, of the reasons have a strong biological cast. Whatever the reasons, if the conclusion is approximately correct, we would do well to try to predict and prepare for the consequences—some of which will be of biological and all of which will be of great psychological and sociological importance.

The principal reasons for expecting a decline in the prestige of the family may be briefly listed:

1. The family, which is a fine mechanism for transmitting conventional wisdom in a relatively static society, is relatively poor at assimilating and transmitting new knowledge essential to survival in a rapidly moving world.

2. Growing awareness of the population problem and of human genetics weakens the prestige of the family as the basic unit of reproduction.

3. Increasing knowledge of the plasticity of the human nervous system in early life will encourage further invasion of the home in the name of ensuring equality of opportunity.

Let us now explore the first of these propositions a little more fully: the inadequacy of the family as a transmitter of knowledge. Survival in the modern world depends on a rapid mastery of new knowledge. One of the clearest examples, and a nice biological one at that, is to be found in the production of food.

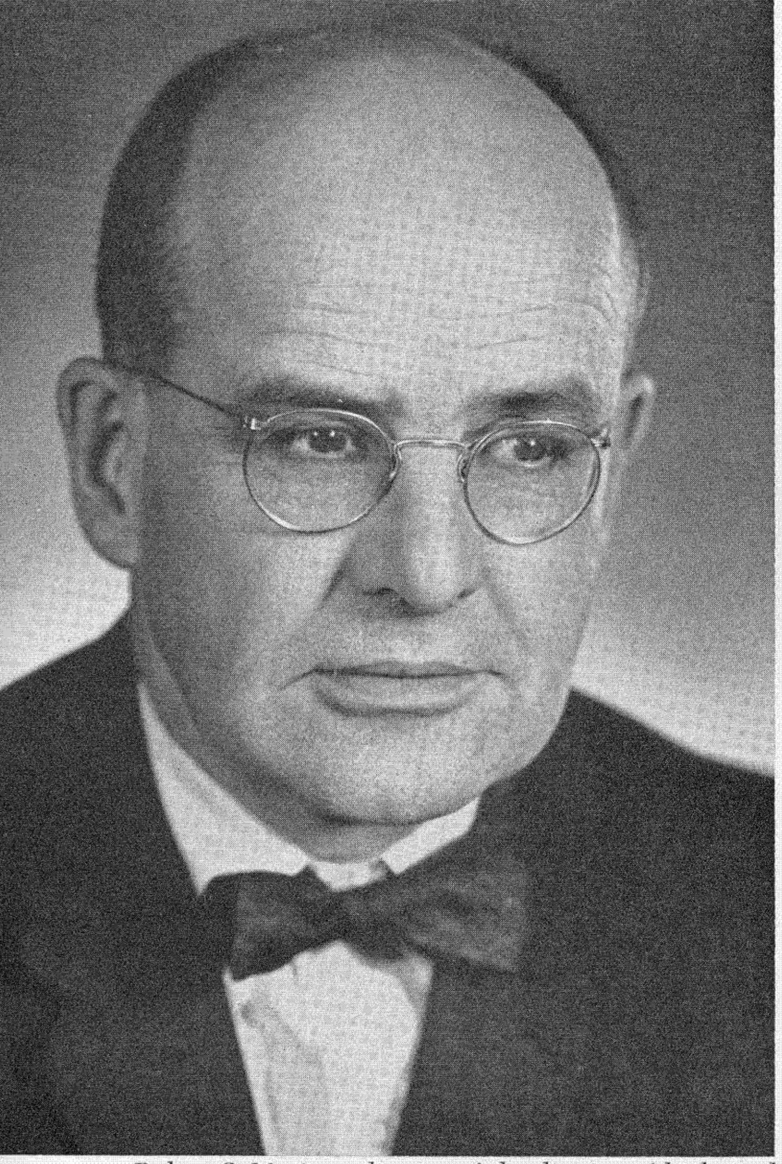
By and large, the most successful nations today are those that have conscientiously applied modern biological knowledge to the raising of food. The invention of the spinning jenny made such a difference in the social and economic life of Western Europe that, ever since, we have been taught to think of the Industrial Revolution in terms of the dark satanic mills of the 19th century, and the spotless, brightly lighted production lines of the 20th century. But none of this would have been possible if agriculture had not been made more productive at the same time. In recent years the rate of production per man-hour has been increasing more rapidly in agriculture than in conventional industry. Ironically enough, it appears that the continuing backwardness of most Communist countries, when measured in terms of standard of living, has been due primarily to a failure to assimilate modern agricultural practices—partly for doctrinal reasons and partly because of simple errors in planning.

When we shift our view from the survival of nations to the survival of the individual farmer, the principle is the same, but the poignancy of the situation becomes much clearer. The individual farmer who fails to keep up with the flow of new knowledge is out. In my own state of New York the dairy business illustrates the trend. In 1930 the number of individual dairy farms reached a peak of 70,000. In 1964 the number had fallen to 36,000 and is still declining rapidly. Milk production has nevertheless increased by nearly 50 percent. To be sure, individual farms are larger in terms of acres, but the number of men employed per farm has remained relatively constant—more constant in fact than anything else in the dairy business.

One obvious social consequence of this change has been the heartache of 35,000 farmers who have

---

"Where Is Biology Taking Us?" has been adapted from a talk given by Robert S. Morison at Caltech's 75th Anniversary Conference on October 26. Dr. Morison is director of the division of biological sciences at Cornell University and was formerly with the medical sciences division of the Rockefeller Foundation.



Robert S. Morison, director of the division of biological sciences at Cornell University.

had to admit defeat, suffer foreclosure, or sell out just ahead of the sheriff. Another has been the growing recognition of the importance of new knowledge and its rapid assimilation. Farming is highly competitive and operates on a very close margin. In recent years the production of broilers has declined very sharply in New York State simply because it cannot compete with states farther south in such matters as the cost of heating the chicken houses. In circumstances such as these, a farmer survives only if he keeps up to date with a mass of rapidly changing biological knowledge and the even more unpredictable shifts in economic trends. The source of such knowledge for most farmers is the land grant college or university and its network of extension agents. Consequently, the rural community in the United States has developed a healthy respect for scientific knowledge and the institutions which produce and promulgate it.

Inevitably, the prestige of more traditional repositories of knowledge and know-how has declined. Of these, the change in status of the family is perhaps the most important. The young boy or girl on the farm no longer looks to mother to learn about the setting of hens or to father about how to plow, fertilize, and harvest; instead he joins a 4-H club to learn about inbred and hybrid strains, antibiotics, hormones, and artificial insemination.

Farming provides but one example; expertise has replaced conventional wisdom in an ever-widening circle of human affairs. The trend began, of course, a long time ago and became particularly noticeable in this country at the height of the massive immigration from Europe. Observers of the social consequence of this movement have pointed out that the low estate of fathers in the United States can be traced in large part to the fact that the conventional wisdom of the immigrant European peasant was of little use to his children trying to adjust to a new world. By now, the inadequacy of fathers has spread from the immigrant to include almost all males over 35, since the new world is no longer a geographical but a chronological concept. A similar loss of status is found in the scientifically based professions, notably in medicine, where the senior member of the hospital staff is no longer the court of last resort simply because he has accumulated the most experience. In some ways the young man who has just finished his residency has the most, or at least the most relevant, experience because he has been the most fully trained in new and more penetrating methods of seeing, hearing, and smelling.

Particular interest attaches to the status of what might be called moral wisdom in this rapidly changing world In earlier times the repositories of knowledge, wisdom, and morals were inextricably intertwined. The high priests of the early river-oriented societies were the astronomers, the biologists, the philosophers, the lawyers, and the religious leaders all wrapped into one. To a large extent scientific and theological knowledge coincided. The rapid growth of scientific knowledge in our time has resulted in a greater and greater gulf between natural and theological knowledge and a considerable decline in interest in the latter. Ethics and morality occupy an uneasy position somewhere between.

Although it is customary in all ages to throw up one's hands in horror over declines in standards of behavior, the astonishing thing is that the decline in respect for fathers, mothers, and priests as repositories of expert scientific knowledge has not been accompanied by more of a decline in respect for their moral influences. Compared to our views on the nature of matter, the origin of the seasons, the control of the weather, and even on the creation and nature of man himself, our views on private property, murder, rape, and adultery have changed very little since the time of Moses.

We may now be approaching the end of this dualism. There are several reasons for believing that we can no longer keep our system of moral values and our system of scientific expertise in separate, watertight compartments. Perhaps most important is the fact that science, and especially biological science, has produced evidence to reinforce some ancient exhortations and weaken the hold of others and has invented, or at least called attention to, the significance of an entirely new range of good and bad behavior.

Take a perhaps morally trivial, but practically very important, example of my first point: The Surgeon General's report contains far more and far better reasons for not smoking than all the exhortations of the Epworth League put together. Admittedly, the statistics do not yet support the notion that appeals to scientific analysis will be any more effective as guides to right conduct than appeals to divine revelation or parental authority have been in the past. So far, unfortunately, it is easier to show how the progress of knowledge weakens the older sanctions than to demonstrate its ability to establish new ones.

Nevertheless, it seems reasonable to expect that, however slowly, we will increasingly look to careful evaluation of evidence on outcomes of alternative courses of action as a guide to right conduct. Insofar as the family is unable to assimilate and transmit such evidence, it will continue to lose its already dwindling influence in the area of morals and ethics.

"No longer can a mother and father take satisfaction in unrestricted reproduction as the straightforward fulfilling of God's injunction to go forth and multiply."

My second point concerns the impact of biological knowledge on the concept of the family as the unit of human reproduction. No longer can a mother and father take satisfaction in unrestricted reproduction as the straightforward fulfilling of God's injunction to go forth and multiply. The evidence is convincing that, beyond a certain point, reproduction is not a social good but an overwhelming social evil. The father of a large family must increasingly exchange the swelling pride of the *paterfamilias* for an embarrassed giggle over his carelessness or ineptitude.

Even if we admit in principle, as most of us do, that some families ought to have more children than others, it is not easy to specify the numbers in particular cases. For society as a whole it is not too difficult, perhaps, to arrive at some quantitative figure for the rate above which a population curve should not rise. For the individual, the problem is far more complicated, since before he can settle the quantitative question, he must involve himself in some very difficult qualitative questions or value judgments as well.

Even if a government decides that the average family should consist of 2.5 children, the ultimate social decisions must emerge as the sum of a very large number of individual decisions. The presumption is that families with "good genes," skill in raising children, and sufficient money to sustain a good standard of living (but not so much as to spoil or corrupt their children) should have more children than families that don't enjoy these advantages. But who is to say what are the good genes, or who has the most suitable childrearing practices, or who will dispense just the right amount of money? Even the purely biological considerations are not simple.

Perhaps the easiest cases are the clearly negative ones. For example, a known carrier of a more or less fully expressed dominant defect as disastrous as Huntington's chorea will probably have little difficulty electing to forgo the raising of natural offspring. But what about the unusually talented who also carry a recessive gene for something like pancreatic fibrosis or sickle cell anemia? If one of them marries another carrier, the chances are one in four that any children they have will exhibit the defect. How is this to be balanced against the chances of producing unusually capable offspring? If the carriers try to avoid the dilemma by identifying noncarriers as prospective mates (and the progress of science makes such identification increasingly possible), they will merely contribute to spreading the defect ever more widely through society, so that succeeding generations of carriers will find it ever more difficult to find suitable mates.

Considerations like these have led some very eminent geneticists to suggest abandoning the concept of the family as the unit of human reproduction in order to follow theoretically more suitable models derived from animal husbandry. Even more dramatic are the possibilities now being conjured up of eliminating defects and producing unimaginable virtues by tinkering with the genetic code itself.

Even though it seems unlikely that a substantial number of people will shortly abandon classical methods of reproduction for the models derived from animal husbandry or bacterial transformation, it is undeniable that the progress of science is bringing about a growing separation between the phenomena associated with sexual attraction and those involving reproduction per se. Much of the conventional moral apparatus of almost all societies has, however, been based on the assumption of an extremely close tie between the two. Clearly, we are in for some big changes, the social consequences of which are not easy to see.

Much attention has of course been given to presumed changes in the premarital habits of our adolescent and college populations, though there is relatively little real evidence as to how extensive these changes really are. Much more important, it seems to me, are the changes which may come in the institution of the family if sexual behavior and reproduction become completely separated from one another.

Many of us who have become impatient with the Roman Catholic church for the deliberate way in which it has approached the population problem must sympathize with the reasons for its reluctance. Although there is a tendency to play down the purely theological aspects of the situation, the problem for the church is still basically involved with abandoning the natural-law position that the point of sex is reproduction.

"All the evidence we have points to the importance for future development of influences brought to bear during the first five or six years of life."

Once the two are separated, society will have to struggle on the one hand with defining the nature of interpersonal relationships that have no long-term social point other than the satisfaction of the individuals concerned. On the other hand, it must seek new ways to ensure reasonable care for infants and children in an emotional atmosphere that lacks biological reinforcement through basic sexual and parental drives. Although there are plenty of examples of successful foster mothers and fathers, the application of the principle on a much wider scale than at present would seem to require a far higher degree of moral sophistication than the average person is likely to possess. It may, for example, be only the unusual husband who will feel very warmly about the children that result from the artificial insemination of his wife.

A third type of assault on the integrity and authority of the family is almost certain to grow out of our increasing knowledge of the biology and psychology of infancy and early childhood. Although relatively little is known in this area with any real certainty, all the evidence we have points to the importance for future development of influences brought to bear during the first five or six years of life. These are the years which the child ordinarily spends in the bosom of his family, and the evidence is accumulating that this fact is primarily responsible for the relative fixity of the socioeconomic class structure of a country like the United States.

Just as a wider appreciation of the science of genetics has made a pleasant 18th century fantasy of the stirring phrase "all men are created equal," growing knowledge of the plasticity of the human nervous system, of critical periods in development, of the phenomena of imprinting and releasing, as well as of conditioning and stimulus-response learning, have made it quite clear that it is idle to talk of a society of equal opportunity as long as that society abandons its newcomers solely to their families for their most impressionable years.

The institution of such programs as Head Start testifies to the growing awareness that society must in effect invade the sanctity, or at least usurp some prerogatives, of the home if it is to assure equal opportunity for all. As society itself becomes more complex and demands an even higher standard of emotional and intellectual competence from all its members, it seems increasingly unlikely that at any level it can rely exclusively on the haphazard educational procedures provided by home environments during the impressionable first six years of life.

Let me say here that I am not advocating that the family be abolished. I am merely pointing out that some of its functions have already been taken over by other social agencies and that more are likely to follow.

We have already accepted with only a minimum of protest the principle that children who don't get enough food at home should be properly fed at school, although it must be admitted that this social advance was facilitated by the fact that many normally Republican states were at the time producing excessive amounts of grain and dairy products.

There is still some difficulty in providing sex education in school for the children of parents too dogmatic or too squeamish to provide it at home, but the opposition is crumbling. Somewhat curiously, the major public opposition to invasion of the home by the State seems to center at present on the right of the parents to decide whether or not their children shall have dental caries.

As evidence accumulates that infants who have mobiles floating over their cribs develop hand-eye coordination faster and that those who have books at home learn to read earlier than those who don't have these amenities, it seems inevitable that society will see to it that aids to development are provided, just as it now provides vaccinations and school lunches.

"It is an induction from experience that the most educated people in a society are the least conformist and the most innovative."

It is not very hard to believe that on balance the expected erosion of parental responsibility in certain areas will be good for the child. It is less easy to be sure of the effect on the parents. The principal fear of those who would keep society, or the even more frightening State, out of the home is that too much control of growth and development will reduce the freedom of the individual and in the long run produce a colorless, conformist society. I have relatively few worries on this score. Education has never been successful in turning out the exact product that the educators had in mind, and I am reasonably confident that it never will. To use a phrase taught me by L. J. Henderson, "it is an induction from experience" that the most educated people in a society are the least conformist and most innovative. The Reformation was sparked by highly trained monks like Luther and Calvin, and in our own time the leaders of the Russian Revolution were drawn from the educated intelligentsia of the old regime. Conversely, those who worry about the conformity of the organization man should reflect that the greatest conformist of all history has been the unlettered peasant, whose ways are much the same on every continent and have scarcely changed in 4,000 years.

The real point of bringing education into the home at the earliest possible age is not to induce conformity but to cultivate the plasticity, the almost infinite adaptability of the human nervous system. Deprived of appropriate sensory inputs at an early age, it may never realize more than a fraction of its capacity. Stereotyped behavior is not the result of training, but of deprivation. It is hard to see how enriching the environment and increasing the contacts of young children can do other than increase their capacity for intelligent choices later in life and thus free them from both external and internal constraints that normally limit personal freedom.

The difficulties that are likely to arise are of quite a different sort and would, in the first instance, be visible in the parents. Insofar as parents are relieved of responsibility for their children and the importance of the family becomes diffused throughout society at large, the parents are likely to feel less significant in the scheme of things in general. It is now commonplace to notice that it is in the so-called advanced countries, where the problems of immediate survival have largely been solved, that men are least convinced that life has any real point. Lacking the spur of hazards to their own lives, many people find a feeling of significance in their role as parents. For example, I have not felt seriously anxious in an airplane since my children reached the age at which they could quite obviously take care of themselves. One way of interpreting this phenomenon is to say that life means somewhat less to me now that I recognize that my continued existence is less important to my children.

If we are right in predicting that in the future almost everyone will have fewer children, that for sound genetic reasons an increasing number will have no children at all, and that society will take a larger share of responsibility for the welfare of the children who manage to get born, it seems inevitable that larger and larger numbers of people will be deprived of the pride of parenthood; and by so much will their sense of worthiness in general be diminished.

If all this is even approximately right, it would seem essential to set about devising substitutes or sublimations. Somehow people must be made to expand their sense of loyalty and responsibility to include a larger share of the human race.

Such an expansion of responsibility is pressingly important on other grounds, for the advance of biological knowledge has created new misdemeanors if not induced new sins. It is no longer sufficient to assess our behavior in terms of its results on those immediately around us. Much of what we do has

"Somehow people must be made to expand their sense of loyalty and responsibilty to include a larger share of the human race."

some sort of numerical probability of injuring someone else we have never seen, on another continent perhaps, or even in a generation yet unborn. As we sum the increasing probabilities of these adversities, we find life growing intolerable for a large share of the human race. We are thus becoming statistically responsible for the purity of the air we breathe, the water we drink, and the safety of the highways we drive on; but, so far, it is hard for us to feel a statistic. And, without the proper feeling, few of us can be moved to change our behavior. Perhaps the most important social consequence to be hoped for from our increase in biological knowledge is the development of the ability to feel statistical meaning keenly enough to make us modify our actions in adaptive directions.

Maybe it will take some drastic biological mutation, but when it comes, we will give up smoking when we read the Surgeon General's report, feel as pleased with ourselves for not having children as we now do for having them, and be delighted to get together with our fellows to fluoridate our water or to cease and desist from pouring incompletely burned hydrocarbons into our atmosphere.

What can we do short of the proposed drastic mutation, which in any case will come too late? Clearly, we must turn to the more rapid way of changing human behavior and rely on cultural rather than biological evolution. Here we find that one of the very real difficulties in reaching a general solution to the human predicament lies in the inescapable biological paradox: we experience life as individuals while in the long run we survive as members of society.

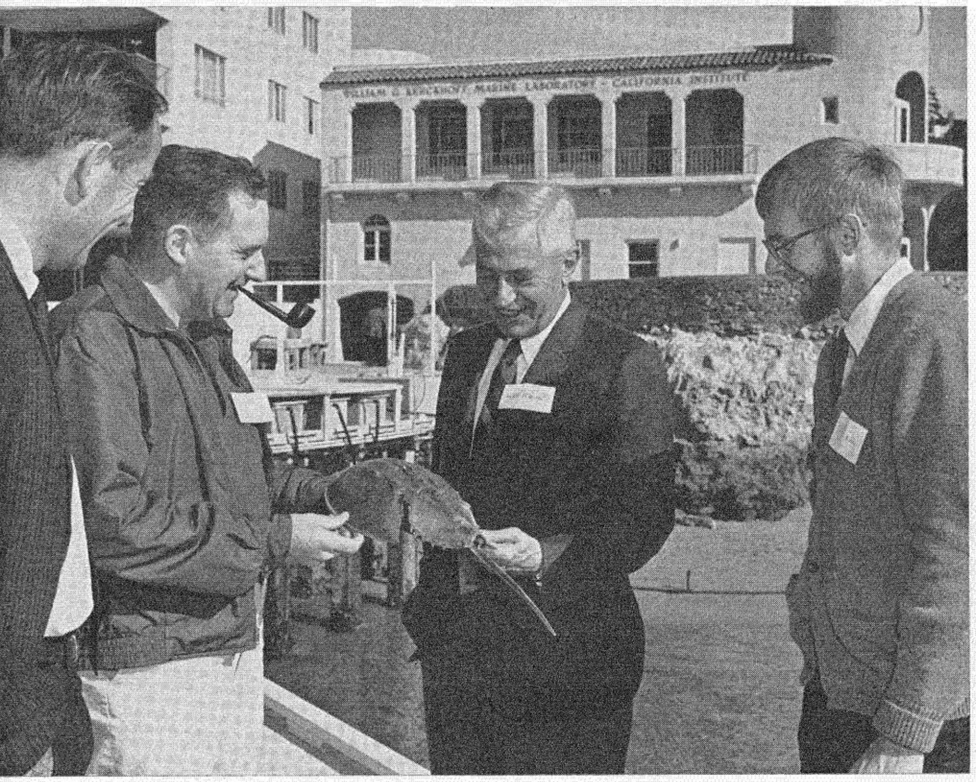
Our homeostatic apparatus, which has come down to us from a former generation, is geared to producing intensely personal sensations of hunger, pain, fear, and rage whenever our existence as individuals is threatened. Our dependence on a social context is less clearly defined in immediate consciousness. At the level of social organization represented by the family, for example, certain basic attractions and responsibilities are built into our biological structure in the form of sexual and maternal love and a somewhat more uncertain and ambivalent sense of filial dependence. As we go up from there through the village, the tribe, and the State to the comity of nations, the ties that bind derive less and less from instinctive patterns or immediate conscious sensations and more and more by inference and abstraction.

Society has therefore had to invent ways of coupling its needs to the emotional apparatus of the individual. Religion and art were two of the most important of such inventions. In an earlier time a large proportion of artistic production served a patriotic or religious and, in consequence, a social and moral purpose, by making the individual feel in his bones the importance of dying for his country or, at a higher and more abstract level, the mystical unity of the brotherhood of men as children of God.

Now we seem to face unprecedented demands for mobilizing all possible aids to help the individual perceive the needs of society at large and identify himself with these. Not only have the social and economic developments of the last few centuries made everyone far more dependent on everyone else for the means of subsistence, but the responsibility for development of the individual personality even at very early stages is shifting from the family to society at large. Conversely, an increasing number of individuals must seek emotional security and a sense of significance in roles which greatly transcend the classic limits of family or village.

In view of these obvious and pressing needs it is certainly curious and probably rather terrifying that so large a proportion of the artistic and literary community has opted out of society and elected instead to stand aside like a Greek chorus chanting over and over again, "See the unhappy man who can do nothing other than endure the existential suffering forced on him by a hostile and malformed society."

These are not merely the thoughts of an unfeeling biologist striking out at random against another culture. A far more penetrating analysis of the state of modern literature and its impact on the university and intellectual world generally may be found in the recently published essays and lectures of one of the finest humanist critics of our time, Lionel Trilling. The principal message of these papers is quite explicitly that modern letters are oriented against society—not, as used to be the case, against a particular society or a particular outmoded social norm, but against the very idea of society, in other words, of any society at all. As a biologist, I find the biological consequences of such an attitude terrifying.



OPEN HOUSE

Caltech's President Lee A. DuBridge tours the Institute's newly renovated marine laboratory in Corona Del Mar at an open house held on January 7. Accompanying him on the tour are Wheeler North, associate professor of environmental health engineering (left); Ray Owen, chairman of the division of biology; and Charles Brokaw, associate professor of biology.

THE MONTH AT CALTECH

NEW ASTRONOMY INSTITUTE

Fred Hoyle, distinguished British cosmologist, Cambridge professor, and science fiction writer, has just completed a six weeks stay on the Caltech campus as visiting associate in physics. He returns to England to continue his responsibilities as director of the newly established Institute of Theoretical Astronomy at Cambridge.

For many years Professor Hoyle has worked almost singlehandedly to get the support and financial backing to establish such a study center. The building, now under construction, is scheduled for completion in June, and the staff is beginning to assemble. The group will eventually number about 50. Approximately half will be permanent, with the rest short-term visiting scientists; half will be from England and the others from foreign countries.

Both Hoyle and Caltech expect there will be intermittent crossing of the Atlantic by Caltech physics and astronomy personnel to participate in programs of the Cambridge Institute.

HUMANITIES GRANT

Caltech's division of the humanities and social sciences has received a grant of $200,000 from the Rockefeller Foundation to study the impact of science and technology on society. The grant will finance the first two years of an eight-year program. Initial emphasis will be on developing a substantial program in political science. The division's staff will be strengthened by appointments this year in political science and, subsequently, in economics and the study of human behavior.

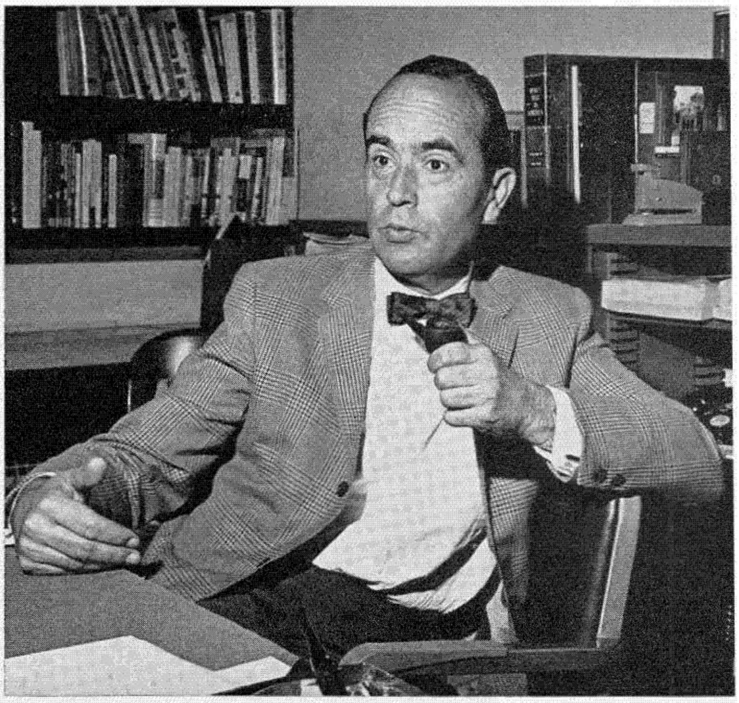
To provide direct experience in the study of governmental operations, the program will include faculty visits to Washington D.C. and other capitals, facilities for interested students to spend at least one summer working in a Washington office, and an expanded program to bring men with current or recent governmental experience to the Caltech campus. Ultimately, as the program and staff develop, an undergraduate major in political science is expected to be offered.

HUMANITIES EXECUTIVE OFFICER

David Elliot, Caltech professor of history, has been appointed executive officer of the division of the humanities and social sciences. In his new position Dr. Elliot will assist division chairman Hallett D. Smith in the regular operation of the division and will be especially responsible for the division's increased emphasis on the social sciences—particularly the relationship between science and government and the effect of technology on human beings.

The creation of the new post marks a significant shift in emphasis for the Institute, as it expands its commitment to students from the areas of pure science and technology to include greater emphasis in the social sciences.

"Dr. Elliot is an extremely able administrator and is well known in the fields of international affairs and science and government," says Hallett Smith. "His direction of Caltech's 75th Anniversary Convocation and Conference demonstrated his fine grasp of the fields in which we are most interested. His new position will greatly strengthen our position of growth in the social science area."



David Elliot, professor of history.

RARE BOOK

Caltech professor of history Rodman Paul has written a new book that is already so rare a single de luxe copy is worth $85 on the rare book market. A fire at the bindery is just one of the reasons.

Last spring 1,100 volumes were printed of Dr. Paul's manuscript, *The California Gold Discovery*—100 de luxe, numbered, autographed copies (costing $25 each) and 1,000 regular trade copies (selling for $10). All but 300 were shipped to bookstores and libraries, and both sales and reviews were rewarding. Just when reorders were accumulating, a night fire at a Sacramento bindery consumed the remaining 300 volumes. And, further curtailing the supply, the printer unwisely had broken down the type. A photo-offset edition is now being printed, but in the meantime 800 book owners have in their possession a very limited edition of Dr. Paul's 237-page account of the discovery of gold in California.

ROSEMARY PARK, LEADER OF AMERICA

The distinguished woman educator Rosemary Park, president of Barnard College, who will officially assume the position of vice chancellor for educational planning and programs at UCLA in June, will be at Caltech February 22nd through the 24th as the second Leader of America in the YMCA's 1966-67 series. During her three-day stay on campus Dr. Park will give an evening lecture in Beckman Auditorium, will speak to the California Institute Associates, and will meet informally with student and faculty groups.

The joint student-faculty committee that selects the Leaders chose Dr. Park not only because of her outstanding performance as an educational administrator but because of her special position as head of a women's college associated with a men's school and the breadth of her understanding of the essential ingredients involved in undergraduate education today.

The first Leader in the current series, writer and social critic Paul Goodman, visited the Institute in October.

CHEMISTRY GRANT

The Institute has received a $63,000 grant in support of its program in chemistry and chemical engineering from E. I. duPont de Nemours and Company. Of this amount, $50,000 is designated for the renovation of the Gates and Crellin Laboratories of Chemistry. Work on the buildings will begin following the completion next fall of the new Arthur Amos Noyes Laboratory of Chemical Physics, now under construction. The remainder of the grant includes $10,000 for fundamental and graduate study and $3,000 for a teaching assistant award.

PSYCHOBIOLOGY GRANT

A Caltech research program headed by Roger W. Sperry, professor of psychobiology, has received a $1,157,615 grant from the National Institute of Mental Health. The funds renew and extend support for seven years of work on the functions and circuitry of the brain.

Dr. Sperry explains that the ultimate aim of the field of psychobiology is to understand the cerebral mechanisms underlying mental activity like perception, learning, and memory.

A large part of the Caltech research program involves delicate surgery on monkeys and cats, which severs the connection between the right and left hemispheres of the brain. Tests show that each disconnected hemisphere can function independently of the other. This work, combined with various other brain research techniques, has opened promising new possibilities for detailed experimental analysis of cerebral organization.

Another major area of investigation concerns the developmental pattern of nerve networks and how they relate to behavior. Still another phase includes the search for the locus and nature of memory traces and the actual physiological basis of memory.

WHODUNIT

Was it a construction worker's horrible mistake? Or just another in a long line of Student Pranks? In any case, it was all too clear that someone, over the New Year's weekend, had placed the cornerstone of the new Millikan Library *upside down* (right).

Apprised of the situation, construction workers were properly aghast. Students were even aghaster. Finally, under the strain of interrogation, the workers confessed. Having been harassed by Student Pranks all during the construction of the Millikan Library building, they had purposely turned the cornerstone over in the hope that the students would get the blame. This feat, it turned out, was neither as difficult, nor as final, as it appeared to be. The "cornerstone" can easily be moved in and out of place until the formal dedication of the library next fall. Here the matter rests, unless there is something to the rumor that the students have immediate concrete plans for the cornerstone.

Dennison Rusinow, AUFS man from Yugoslavia, speaks at seminar on Political Geography of Developing Countries conducted by Professor Edwin Munger (right).

AUFS ON CAMPUS

Dennison I. Rusinow, the first of four American Universities Field Staff representatives scheduled to visit the campus this year, arrived at Caltech on January 10 for ten days of lectures and informal talks with the students and faculty on the subject of Yugoslavia.

The second AUFS visitor, Victor D. DuBois, specialist in West African affairs, will be at Caltech from January 24 to February 2; Willard A. Hanna, authority on Indonesia and Malaysia, from February 7 to 16; and Kalman H. Silvert, whose assignment is South America, April 3 to 12.

The AUFS, sponsored by Caltech and 11 other universities, supports scholars of international affairs who study and live in the areas of their special assignments and report regularly, both editorially and in person, to the supporting institutions.

NEWS for 1966 1967 ENGINEERING GRADUATES

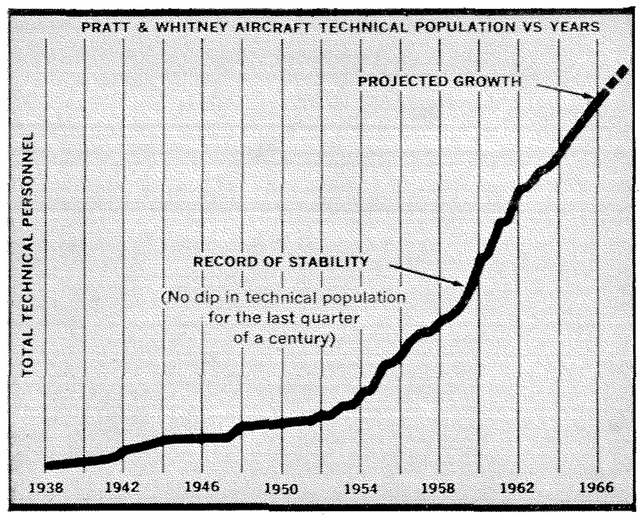
Continued expansion of our military and commercial business provides openings for virtually every technical talent.

As you contemplate one of the most important decisions of your life, we suggest you consider career opportunities at Pratt & Whitney Aircraft. Like most everyone else, we offer all of the usual "fringe" benefits, including our Corporation-financed Graduate Education Program. But, far more important to you and your future, is the wide-open opportunity for professional growth with a company that enjoys an enviable record of stability in the dynamic atmosphere of aerospace technology.

And make no mistake about it . . . you'll get a solid feeling of satisfaction from your contribution to our nation's economic growth and to its national defense as well.

Your degree can be a B.S., M.S. or Ph.D. in: **MECHANICAL, AERONAUTICAL, CHEMICAL, CIVIL (structures oriented), ELECTRICAL, MARINE, and METALLURGICAL ENGINEERING • ENGINEERING MECHANICS, APPLIED MATHEMATICS, CERAMICS, PHYSICS and ENGINEERING PHYSICS.**

For further information concerning a career with Pratt & Whitney Aircraft, consult your college placement officer—or write Mr. William L. Stoner, Engineering Department, Pratt & Whitney Aircraft, East Hartford, Connecticut 06108.



Take a look at the above chart; then a good long look at Pratt & Whitney Aircraft—where technical careers offer exciting growth, continuing challenge, and lasting stability—where engineers and scientists are recognized as the major reason for the Company's continued success.

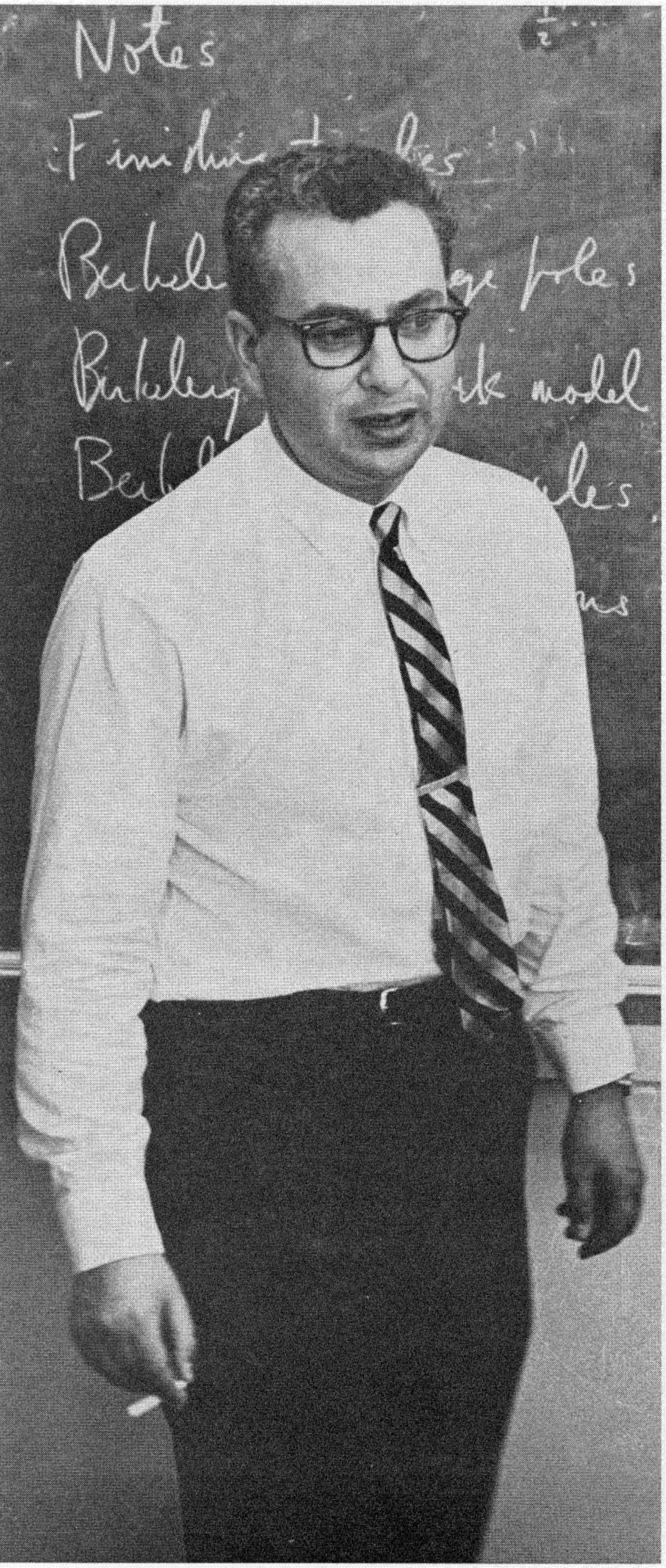
SPECIALISTS IN POWER . . . POWER FOR PROPULSION—POWER FOR AUXILIARY SYSTEMS. CURRENT UTILIZATIONS INCLUDE MILITARY AND COMMERCIAL AIRCRAFT, MISSILES, SPACE VEHICLES, MARINE AND INDUSTRIAL APPLICATIONS.

Pratt & Whitney Aircraft

DIVISION OF UNITED AIRCRAFT CORP.

CONNECTICUT OPERATIONS EAST HARTFORD, CONNECTICUT
FLORIDA OPERATIONS WEST PALM BEACH, FLORIDA

An Equal Opportunity Employer



THE ELEMENTARY PARTICLES OF MATTER

by Murray Gell-Mann

All matter everywhere is composed of particles, each of which has identical properties throughout the known universe. As far as we can tell from the light from the most distant galaxies, electrons there obey the same laws that they do in our laboratories on the earth. So, presumably, do the other particles. The laws of these elementary particles, supplemented by the laws of the cosmos, underlie all the laws of natural science—first those of physics, then those of chemistry, geology, biology, astronomy, and all the others. We humans are made up of these same particles. One would like to find a simple and unified description of these elementary building blocks, but so far that unification has eluded us. For the moment we must still divide the subject of elementary particles into a few pieces which we investigate separately.

One way to divide the subject is to discuss four kinds of force, which are presumably responsible for all natural processes. Two of them have been familiar for a long time—gravitation and electromagnetism. Gravitation, understood first by Newton and then in an improved way by Einstein, is a long-range force of *very* small strength. To express its strength in natural units, we would have to write a fraction—one divided by a number written as 1 followed by 40 zeros (10^{-40}). Electromagnetism is also well understood and also a long-range force. Its

---

MURRAY GELL-MANN, *Caltech professor of theoretical physics, this month becomes the first Robert Andrews Millikan Professor of Physics. This new chair has been established by the board of trustees and is named in honor of the noted physicist and chairman of the executive council of the Institute from 1921 to 1945. "The Elementary Particles of Nature" has been adapted from an address Gell-Mann delivered at the Institute's 75th Anniversary Conference on October 25.*

strength is very much greater than that of gravity and can be described by a dimensionless parameter of about 1/100.

Then there are the two forces or interactions discovered in the 20th century that are responsible for subnuclear processes—the weak interaction, which leads to certain kinds of radioactive decay; and the strong interaction, which is responsible for the binding of the atomic nuclei. These are both very short-range forces with a range less than or equal to the size of an atomic nucleus—i.e., 10^{-13} centimeters, which is very much smaller than the size of an atom. At distances beyond that, these forces die away to almost nothing. The strong interaction, as its name indicates, is very strong indeed; on the scale of strength we are using, its strength is 1. The weak interaction is much weaker. An exact description of its parameter of weakness is not so easy to give, but a rough value is 1/10,000,000.

Microscopic physics is described by a magnificent and confusing discipline called quantum theory. Although none of us has fully understood it, quantum theory has been perfectly successful up to the present time. According to quantum theory, forces in general are expected to be transmitted between the objects they affect by means of a particle that serves as a carrier. The photon is the carrier, or quantum, of electromagnetism. This has been known for a long time. In the case of gravity, we theorists believe there must be a similar carrier called the "graviton," but no one can figure out any way, with present technology, of doing an experiment to find it. Thus the graviton remains a hypothetical particle.

In the case of the weak interaction, we are not sure whether there has to be a carrier or not, because the force might be of zero range, making the idea of a carrier particle unnecessary. However, people continue to look for such a carrier or quantum of the weak interactions (sometimes called X), although they have not yet been successful. In the case of the strong interaction, the subject of a carrier is more complicated, and to introduce that topic let me first briefly discuss the other interactions.

There are some particles that are unfortunate enough not to participate in the strong (or nuclear) interaction. One group of these particles consists of the "leptons," including the electron and neutrino. The electrons in an atom, particularly a heavy atom, spend a great deal of their time inside the atomic nucleus. But while they are there, they do not feel the nuclear force, whereas the nuclear particles feel it very strongly. The electrons pass right through and feel only the electrical force of the nucleus.

The neutrinos do not even have electrical interactions. The electron e- has an electric charge, but the neutrino is electrically neutral and has neither strong nor electromagnetic interactions—only the weak interactions. In "An Explanatory Statement on Elementary Particle Physics," in *American Scientist,* M. A. Ruderman and A. H. Rosenfeld wrote: "Every second, hundreds of billions of these neutrinos pass through each square inch of our bodies, coming from above during the day and from below at night, when the sun is shining on the other side of the earth." This inspired John Updike to write:

COSMIC GALL

Neutrinos, they are very small.
They have no charge and have no mass
And scarcely* interact at all.
The earth is just a silly ball
To them, through which they simply pass,
Like dustmaids down a drafty hall
Or photons through a sheet of glass.
They snub the most exquisite gas,
Ignore the most substantial wall,
Cold-shoulder steel and sounding brass,
Insult the stallion in his stall,
And, scorning barriers of class,
Infiltrate you and me! Like tall
And painless guillotines, they fall
Down through our heads into the grass.
At night, they enter at Nepal
And pierce the lover and his lass
From underneath the bed—you call
It wonderful; I call it crass.**

**The original reads "And do not interact at all." This change is made by scientific license.*

Among the leptons we encounter a fundamental principle of relativistic quantum mechanics confirmed by all experiments up to the present time: that there is a symmetry of nature between particles and anti-particles. And so the leptons have their corresponding anti-leptons, e.g., the anti-neutrino and the positron. (The positron was discovered by Caltech's Carl Anderson some 34 years ago.)

The strongly interacting particles also have anti-particles, which in most cases are different from the particles themselves. In any case, there is a perfect particle-anti-particle symmetry—provided, of course, that you make the anti-particles run backwards in space and time when you are performing the symmetry operation.

The so-called "hadrons" (which include mesons and baryons) are the particles (unlike leptons) that *do* possess the nuclear or strong interaction. Very familiar hadrons are the neutron and proton, which are popularly described as the building blocks of atomic nuclei. Their anti-particles, the anti-neutron and anti-proton, have been discovered in the laboratory recently. If you replace protons by anti-protons, neutrons by anti-neutrons, and electrons by positrons in ordinary matter, you can build up so-called anti-matter. For every object you can make a corresponding anti-object. Such anti-objects behave in very much the same way, in an environment of other anti-matter, as ordinary objects do with respect to their normal background of matter. However, if the object and the anti-object are brought into contact with each other, they annihilate with a burst of energy. This has given rise to another poem, by the physicist Harold P. Furth.

PERILS OF MODERN LIVING

A kind of matter directly opposed to the matter known on earth exists somewhere else in the universe, Dr. Edward Teller has said . . . He said there may be anti-stars and anti-galaxies entirely composed of such anti-matter. Teller did not describe the properties of anti-matter except to say there is none of it on earth, and that it would explode on contact with ordinary matter. —*San Francisco Chronicle*

Well up beyond the tropostrata
There is a region stark and stellar
Where, on a streak of anti-matter,
Lived Dr. Edward Anti-Teller.

Remote from Fusion's origin,
He lived unguessed and unawares
With all his antikith and kin,
And kept macassars on his chairs.

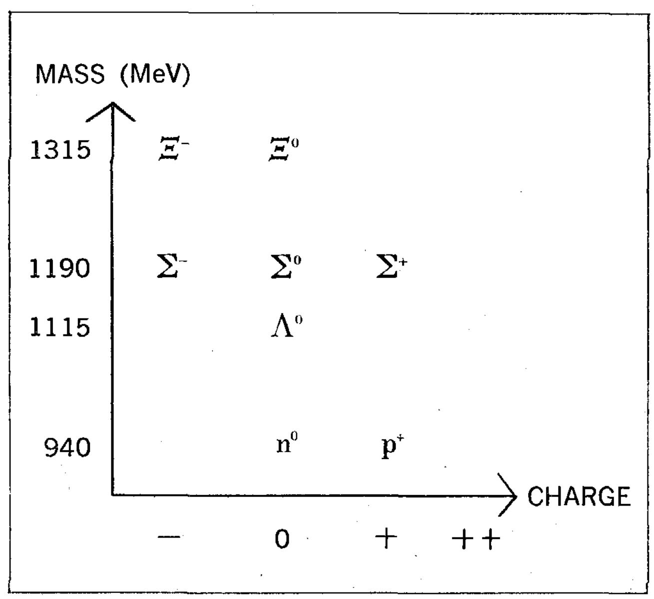
One morning, idling by the sea,
He spied a tin of monstrous girth
That bore three letters: A.E.C.
Out stepped a visitor from Earth.

Then, shouting gladly o'er the sands,
Met two who in their alien ways
Were like as lentils. Their right hands
Clasped, and the rest was gamma rays.*

Having presented this vivid picture of the distinction between matter and anti-matter, we can look at all the hadrons and try to arrange them by the value of a number A, which in elementary physics is called the atomic mass number. In elementary particle work it is often called the baryon number. The bookkeeping of A in nature seems to be very strict. As far as we know, the total A must agree exactly on both sides of any reaction. We can assign numbers A to the various nuclei: For example, the famous U^{235} and its excited states have an A of 235. The deuteron, or heavy hydrogen nucleus, usually pictured as consisting of a neutron and proton, is assigned $A = 2$. The neutron, proton, and all other so-called baryons, such as the particles Λ, Σ, Ξ, are assigned $A = 1$. Likewise, there are the anti-baryons: anti-neutron, anti-proton, anti-lambda, which have $A = {}^{-}1$. The anti-deuteron, which has actually been produced in the laboratory, has $A = {}^{-}2$. And correspondingly, we could, given enough time and energy, make anti-U^{235} with $A = {}^{-}235$. In the middle position, we have particles called mesons which have $A = 0$. The anti-particles of mesons are also mesons, and in some cases a particular meson is its own anti-particle.

Of all these hadrons, or strongly interacting particles, that participate in the nuclear force, which are the basic building blocks? What are they all made of? Virtually nobody in the business believes the popular tale that neutrons and protons are elementary building blocks, although this legend persists in textbooks. It does not appear that there is anything particularly elementary about the neutron and proton. They are simply the lowest energy states of an enormous set of baryon levels, of which some hundred are now known. There is no reason to believe that any one of these is any more fundamental than the others. The neutron and proton, because they are the lowest and most stable states, are the most conspicuous ones in our experience.

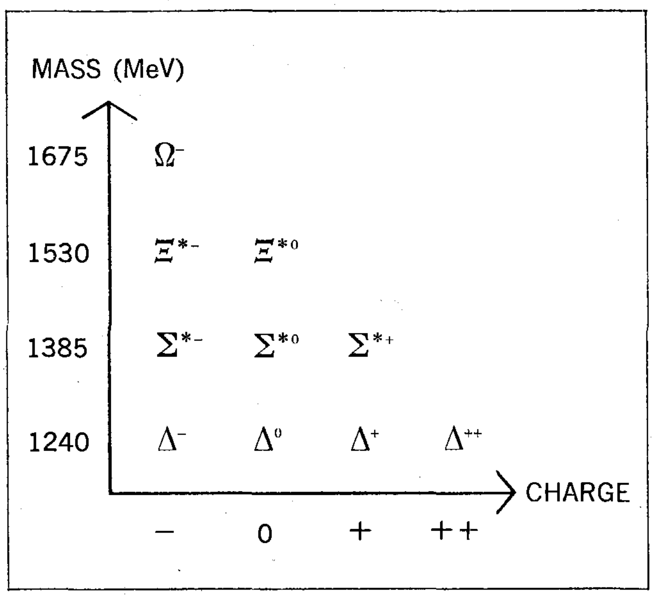
The baryon states, including the neutron and proton, come in families and super-families, with a beautiful and simple structure. For example, we now know that the neutron and proton are two members of a super-family of eight particles, illustrated below. Here each particle is represented by



BARYON OCTET, $J = 1/2^{+}$

a point on a graph which has electric charge as its horizontal axis and the mass of the particle in units of MeV as its vertical axis. Each of these particles has the same angular momentum, one-half of the unit of angular momentum ($J = 1/2$). Each of them is also characterized by the value of a certain peculiar number called parity, which is either plus or minus and which, for these baryons, is plus. Within the super-family of eight are smaller families, for example, the neutron and proton at practically the same energy, 940 MeV. Their energies differ by only about 1 MeV, and they form what is called a doublet. Higher, there is the Λ—a neutral baryon at 1115 MeV; then a triplet—the three Σ's at about 1190 MeV, differing among themselves by a few MeV; then the Ξ doublet at 1315 MeV. But all of these together form the super-family, with its very large mass separation of a few hundred MeV. Within the super-family, the masses of the families obey a certain simple relation.

In another super-family, shown below, the mass

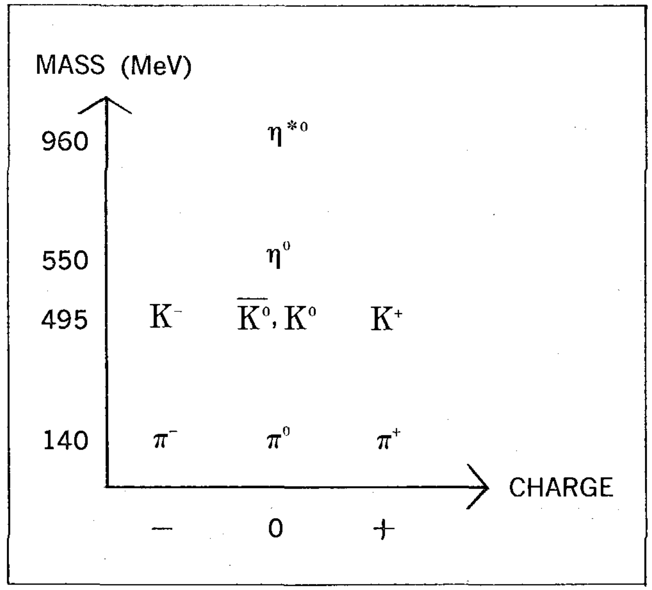


BARYON DECIMET, $J = 3/2^+$

relation is even simpler. This set of baryons has 3/2 units of angular momentum ($J = 3/2$) and again parity plus. The members of the quartet at the bottom have about the same mass of 1240 MeV and electrical charges ranging from $^{-}1$ to $^{+}2$. Just above is another set of sigmas, in this case, excited sigmas, Σ^*, forming a triplet with charges $^{-}1$, 0, and $^{+}1$. Higher up, there is a Ξ^* doublet with charges $^{-}1$ and 0. Still higher is a singlet, Ω^-, with a negative charge.

The mass relation here is extremely simple. The mass spacings are all the same—about 145 MeV between each family and the next. As the number in the family goes down from 4 to 3 to 2 to 1, the masses go up in steps of 145 MeV. Both these patterns—the eightfold pattern above and the tenfold pattern here—were actually predicted by a theoretical method called approximate symmetry. We succeeded in predicting that the families in the decimet would be equally spaced; so when the first two were found, it was possible to predict the next two—the Ξ^* and the Ω^-. The Ξ^* was found at once, but the Ω^- has some very peculiar properties, and people doubted that it would, in fact, exist. After a long, expensive, and agonizing search, it finally turned up at the Brookhaven National Laboratory with exactly the predicted properties.

The mesons, likewise, fall into families. The lowest set (below) is a bunch of mesons with zero



MESON OCTET AND SINGLET $J = 0^-$

units of angular momentum and negative parity. The fairly familiar pions, π, are at the bottom, a triplet at 140 MeV. Above are two doublets, K^+, K^0, and their anti-particles, at 495 MeV. Above these are a singlet and another singlet. The whole pattern forms two super-families, an octet and a singlet, made up in turn of families: a triplet, two doublets, a singlet, and another singlet. Here the charges range from $^{-}1$ to $^{+}1$. As we see, the familiar π mesons are once again just three members of a much bigger set. And, as with the baryons, our super-family of eight plus one is accompanied by many other super-families lying higher in mass and with different values of the angular momentum and parity. Hundreds of meson and baryon levels are now known. The neutron and proton are simply the lowest of the baryon levels, and the pions are simply the lowest of the meson levels. So when you read in the newspapers that some very clever experimentalist has discovered 12 more elementary particles, you will know what he means. Now, having agreed that there is nothing special about the neutron and proton, we are left with the question, "What are these hadrons in fact made of?"

There are two current theoretical hypotheses—

which are not necessarily contradictory. One idea, and it seems a very promising one, is the so-called bootstrap hypothesis: that the hadrons are made up out of each other, so that none of them is particularly fundamental. Here we have a so-called democratic theory of hadron structure; every hadron level is as good as any other hadron level. I can give a crude description of how this situation comes about. If you take a baryon and an anti-baryon and you allow them, in the sense of quantum mechanics, to exchange a meson, then the meson acts as the carrier of the strong interaction in the same way that the photon acts as the carrier of electromagnetism. In that way, a force is generated between the baryon and the anti-baryon—the baryon and the anti-baryon attract each other, forming bound systems. And the bound systems are just mesons—the same mesons that generated the force responsible for the binding. The meson, then, is both the carrier and the bound state. It makes itself, and we see the bootstrap mechanism at work.

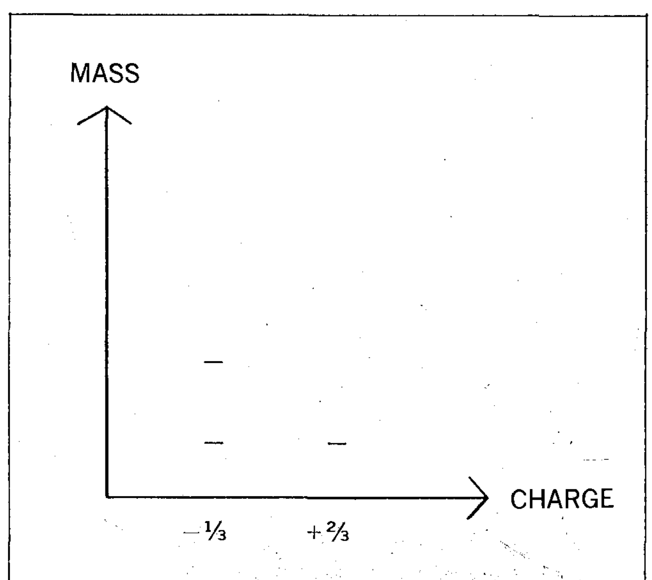
In the same way, the baryon is made of itself and a meson, exchanging a baryon to make the force. Now, in fact, if you try to consider the picture more accurately, you find that *all* hadrons are exchanged—that they make forces among all hadrons, that all hadrons bind to all other hadrons to make, as their bound states, all the hadrons. That is the bootstrap idea. It seems very promising, but it is rather difficult to use for detailed calculations. So far most of the calculations have given qualitative results; that is, they have shown that things might work more or less this way. They have not given a clear picture of exactly how things come out numerically.

Another and far crazier picture, however, gives fairly accurate numerical results and predicts those patterns of hadron families that we showed before. This is the notion that hadrons are made of "quarks" and "anti-quarks." But what *is* a quark? A quark is a very peculiar particle with an A or atomic mass numer of 1/3 and a charge of $^{+}2/3$ or $^{-}1/3$ (in the same units that we were using before). There are three kinds of quarks: one with charge $^{+}2/3$ and two with charge $^{-}1/3$. (One possible derivation of the name—scholars are already disputing this, some assuming it comes from the German word for rotten cottage cheese—is from the heading of a page in *Finnegan's Wake* where Humphrey Chimpden Earwicker rolls over in his sleep to hear a clock strike and the text says, "Three quarks for Muster Mark.")

As we see at the right, a doublet and a singlet are put together to make a system of three quarks. Of course, there are equally hypothetical anti-quarks with the opposite pattern of charges—a $^{-}2/3$ and $^{+}1/3$ doublet and then a singlet with $^{+}1/3$. It turns out, strangely enough, that if you put such quarks together, the combinations look very much like the pattern of observed baryons and mesons. Here is the recipe for doing so: you make the meson states by putting together one quark and one anti-quark, and you make the baryon states by putting together three quarks. We can illustrate, without going into mathematical detail, a little bit of how this works.

Suppose we look back, for example, at the baryon decimet. Remember that the hypothetical quarks are charged like this: $^{+}2/3$, $^{-}1/3$, and $^{-}1/3$. If we put together three of them, we expect the charges of the combinations to range from $^{+}2$ to $^{-}1$. And indeed this is what the baryons do.

Another point is that the quark singlet is higher in its mass than the doublet by a certain amount. So we expect that as we move from the larger charge multiplets, whose charges extend far to the right, to the smaller charge multiplets, the mass of the multiplets should increase regularly by this difference. And that is exactly what happens. For example, the low-lying quartet of baryons is made of three of the lighter quarks. The baryon triplet is made of two of the light quarks and one of the heavy quarks, while the baryon doublet is made of one light and two heavy quarks. Finally, the baryon singlet is made of three of the heavy quarks. The heavy quark has a charge of $^{-}1/3$, so three of them gives us a charge of $^{-}1$ in agreement with the heaviest baryon, Ω^{-}. This is just one illustration of the many simple properties of the meson and baryon systems that we get from studying the quarks. One completely crazy prediction, for example, which not even I believed at first, is that because the baryon is made up of three quarks and the meson is made up of a quark and an anti-quark



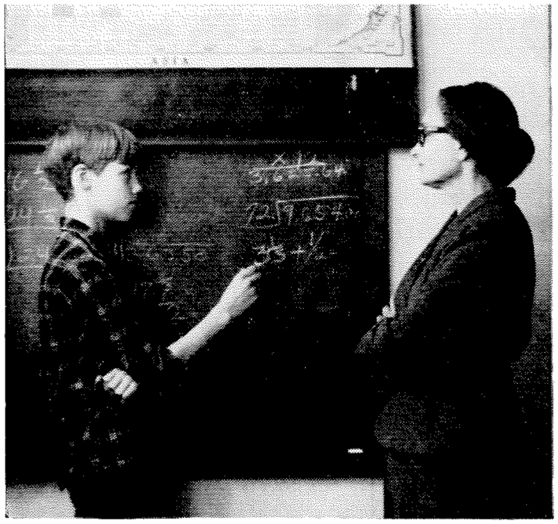
HYPOTHETICAL QUARKS, q

(that is, essentially 2), the ratio of baryon-baryon to meson-baryon scattering probabilities at very high energy ought to be 3 : 2. And, in fact, it is approximately 3 : 2. In many ways the quark structure seems to explain in detail the properties of the baryon and the meson systems of levels.

Are quarks actually real objects? My experimental friends are making a search for them in all sorts of places—in high-energy cosmic-ray reactions and elsewhere. A quark, being fractionally charged, cannot decay into anything but a fractionally charged object because of the conservation law of electric charge. Finally, you get to the lowest state that is fractionally charged, and it can't decay. So if real quarks exist, there is an absolutely stable quark. Therefore, if any were ever made, some are lying around on the earth. One atomic spectroscopist friend of mine calls me up, sometimes at midnight, to report his progress in a search for quarks in sea water. He has electrolyzed a huge amount of sea water to look for characteristic atomic levels of quark atoms. He thought he found one once, but it turned out to be an unknown line of tungsten. Since then he has decided that the chemical properties of real quark atoms—if they exist—would be very strange indeed. And since most things with curious chemical behavior in the ocean eventually are eaten by oysters, he is grinding up oysters and looking for quarks in them. He has not yet seen any, nor have any been found at very high energies in cosmic rays. So we must face the likelihood that quarks are not real.

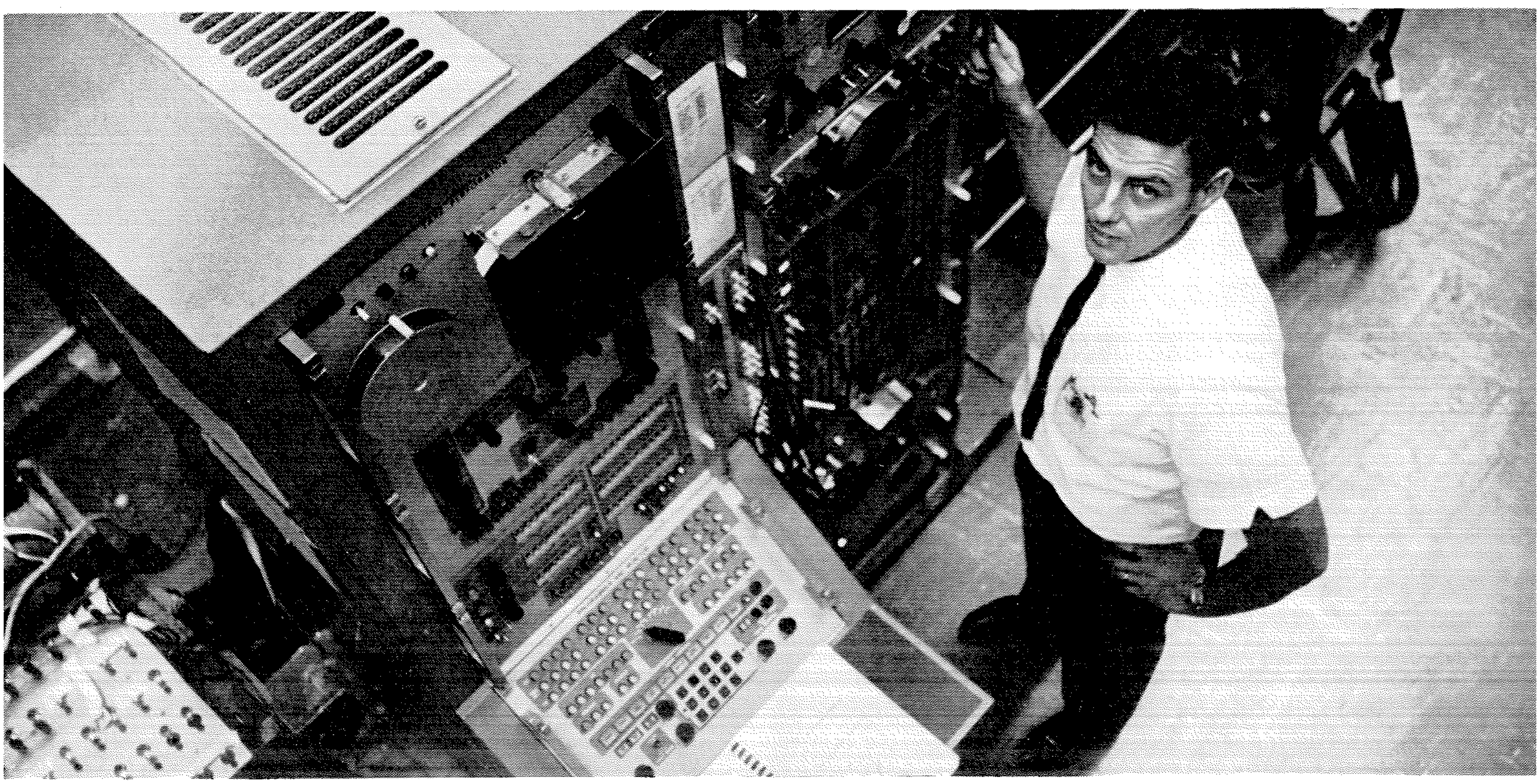
Actually that is just as well; mathematical quarks are even easier to work with than real ones, because certain restrictions imposed by the reality of the particles can be dispensed with. And working with mathematical quarks, we can begin to make a fairly satisfactory theory of the detailed properties of meson and baryon levels.

If the quarks turn out, in fact, to be mathematical, then there is nothing to prevent the quark hypothesis from being equivalent to the bootstrap hypothesis. In other words, it is possible that the hadrons actually make up one another, according to the bootstrap mechanism, with forces coming from the exchange of hadrons—but when you work out in detail the properties of hadrons so formed, they will turn out to look as if they are made of quarks. At the present time, this seems a very likely state of affairs—both hypotheses right and equivalent. It is also possible, of course, that they are equivalent and both wrong—or inequivalent and both wrong. However, if it turns out that they are equivalent and one is right and the other one is wrong, we will probably be in trouble.



A science-fiction buff with straight "A" in math...

now Blair Tyson plots a course to the moon.



From simple addition to analytical geometry, math was a snap for Blair Tyson. He was not only a whiz kid at mathematics, but he had an absorbing interest in any and all types of science fiction.

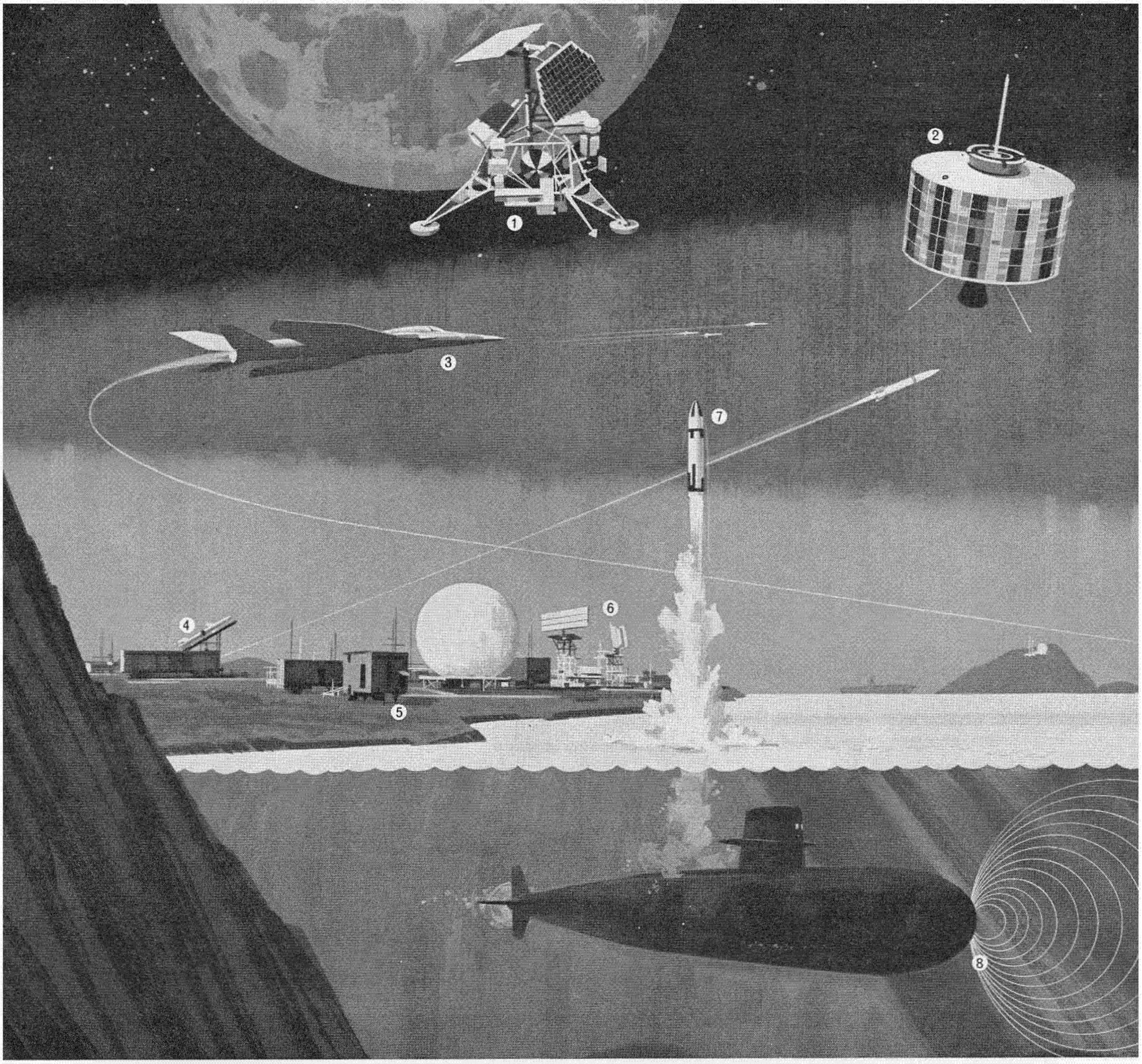
Graduating from the Milwaukee School of Engineering in 1958, Blair began working with computers for an electronics company. Here is where his background in science fiction and his aptitude for mathematics merged and were given direction. This combination of interests led him one way . . . to the AC Electronics Division of General Motors in Milwaukee.

Now he works on airborne digital computers. It is AC's job to integrate these computers into the guidance systems for space project, Apollo.

The goal is the moon, and GM's Blair Tyson helps chart the way.

General Motors is people making better things for you.

GM
MARK OF EXCELLENCE



Opportunities at Hughes for EE's—Physicists—Scientists:

from the ocean floor to the moon...and beyond

Hughes sphere of activity extends from the far reaches of outer space to the bottom of the sea . . . includes advanced studies, research, design, development and production on projects such as: ① SURVEYOR — unmanned, soft-landing lunar spacecraft for chemical and visual analysis of the moon's surface; ② SYNCOM (Synchronous-orbit Communications Satellite)—provides world-wide communications with only three satellites; ③ F-111B PHOENIX Missile System—an advanced weapon system designed to radically extend the defensive strike capability of supersonic aircraft; ④ Anti-ICBM Defense Systems—designed to locate, intercept and destroy attacking enemy ballistic missiles in flight; ⑤ Air Defense Control Systems — border-to-border control of air defenses from a single command center — combines 3D radar, real-time computer technology and display systems within a flexible communications network; ⑥ 3D Radar—ground and ship-based systems give simultaneous height, range and bearing data—now in service on the nuclear-powered U.S.S. Enterprise; ⑦ POLARIS Guidance System — guidance components for the long-range POLARIS missile; ⑧ Hydrospace — advanced sonar and other anti-submarine warfare systems.

Other responsible assignments include: ATS (advanced technological satellites), TOW (wire-guided, anti-tank missile system), VATE (automatic checkout equipment), advanced infrared systems, electronic signal processing, space communications, parametric amplifiers, airborne radar systems, reconnaissance systems, aerospace vehicle development, missile/spacecraft power & propulsion systems...and others.

B.S., M.S. and Ph.D. Candidates

CAMPUS INTERVIEWS

February 16 and 17 1967

Learn more about opportunities at Hughes, our educational programs, and the extra benefits Southern California living offers. **For additional information and literature, consult your College Placement Director.** *Or write:*

Mr. W. K. Walker
Research Laboratories
Hughes Aircraft Company
Malibu, Calif. 90265

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

U. S. CITIZENSHIP REQUIRED

An equal opportunity employer.

RESEARCH NOTES

Psychobiologist Evelyn Lee-Teng offers a simulated seed to a baby chick as part of her study of memory processes.

MEMORY CONSOLIDATION

Thirty seconds seems to be the minimum time required by the brain to form a permanent record of something that it needs to remember. Evelyn Lee-Teng, Caltech researcher in psychobiology, has determined this time span precisely in a study involving more than 2,000 baby chicks. This large number of subjects made it possible to define the time accurately. Other investigators have tried to measure the time span using rats and humans as subjects.

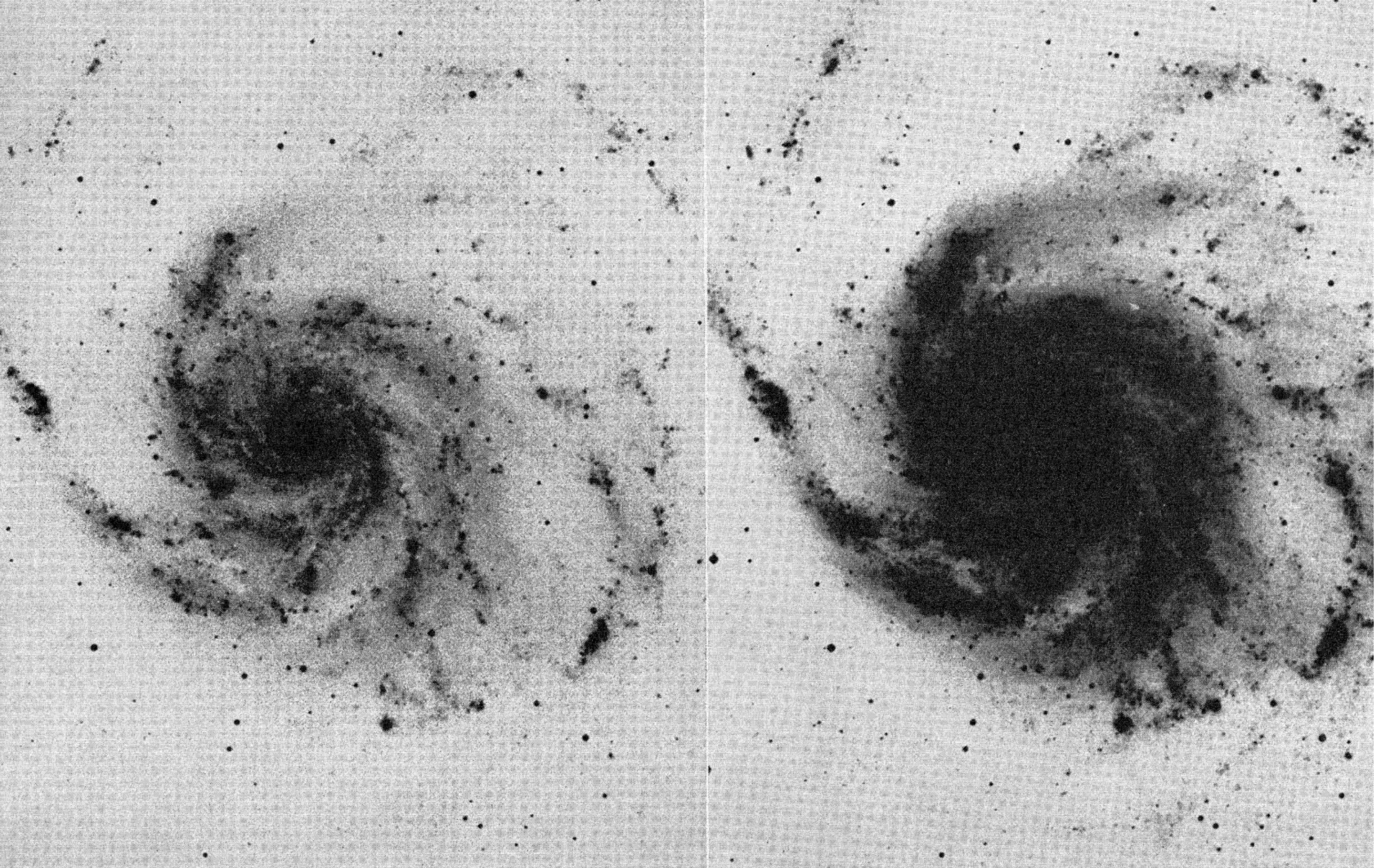
"Many experiments suggest the presence of a basic elemental process in the formation of memory traces that is common to all vertebrate brains --chicken and man alike," commented Roger W. Sperry, Hixon professor of psychobiology. "Dr. Lee-Teng's precise determination of the time required by the brain to lay down a permanent record in memory in the simple, basic form described in these experiments gives an important clue to the nature of the unknown memory processes."

Little is known about how memory works, although it is generally believed there are at least two underlying processes, one short-term and the other long-term. The short-term memory is perhaps electrical and may persist for a few seconds or minutes; the long-term memory is probably chemical and may also involve structural changes.

The research involved electroshock, similar to that used as a treatment for humans undergoing psychotherapy. It was employed in this case because the electric current sweeping through the brain wipes out those consolidation processes under way at the time the treatment is administered, without affecting established memory.

The research grew out of earlier investigations in which attempts were made to use quick-acting anesthetics, rather than electroshock, to interrupt the consolidation of the memory trace. Dr. Lee-Teng's collaborator in that work was Dr. Arthur Cherkin, a chemist. In the present work her associate was S. Murray Sherman, now a graduate student at the University of Pennsylvania. The research is supported by the National Institute of Mental Health.

The investigators took advantage of a strong instinct in chicks to peck at anything resembling a seed. They presented a shiny, seed-sized metal ball



CALTECH ASTRONOMERS *can now record celestial objects three times fainter than before with a new photographic emulsion developed by Eastman Kodak. The new material emphasizes very faint objects against the glow of the night sky. The difference between the old (left) and new emulsion is shown here in increased detail in the outer spiral arms of galaxy Messier 101, photographed with the 48-inch Schmidt telescope.*

to the chicks after it had been dipped in a highly unpalatable substance. Having tried it once, chicks ordinarily would not peck at it again. Each chick was given the chance to peck the ball once. Then its memory was allowed to gel for a certain measured period of time before electroshock was applied. The shock apparently wiped out the memory if it had not had sufficient time to become fixed in the brain.

The results, which were consistent in repeated tests, indicated that the brain began laying down the memory trace right after the original peck but that the trace was not finally "cemented in" until 30 seconds had elapsed.

Dr. Lee-Teng stressed that it is reasonable to expect that the time period will vary with the complexity of the learning tasks and with different forms of disruptive treatment. Comparing results from different experiments may lead to a better understanding of memory mechanism.

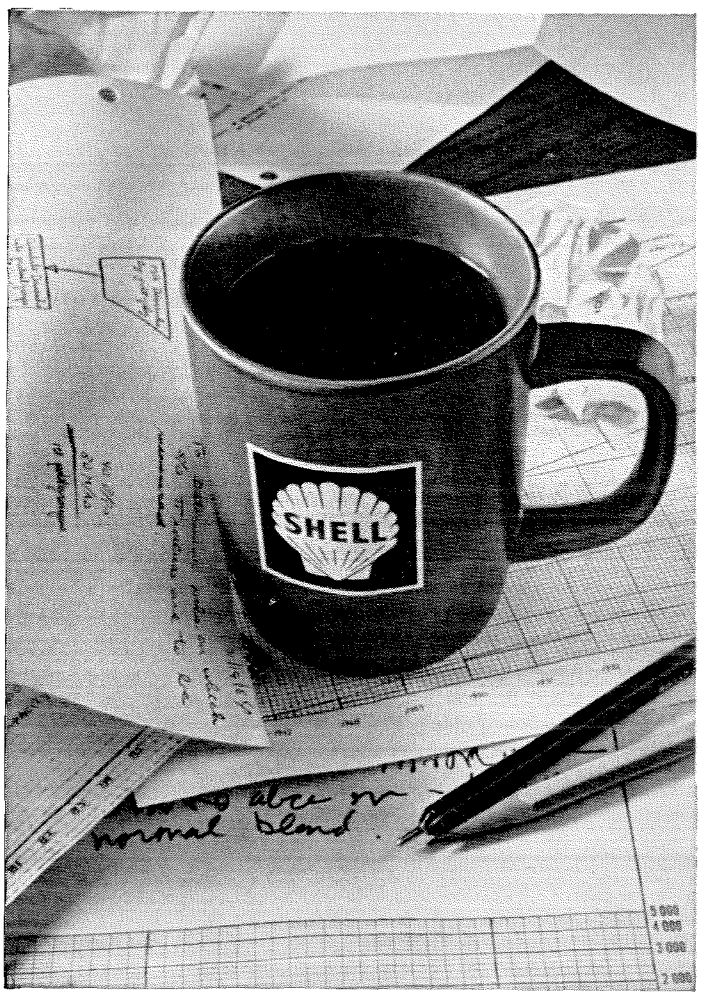
ANCIENT MOUNTAINS

The remnants of a mountain range 1.65 billion years old have been found in southern California. These mountains are by far the oldest known on the west coast of North or South America. The peaks of the range, which once extended eastward at least into Colorado, were eroded long ago. All that remain now are altered residuals of the granitic roots, which have been lifted to the surface of the very young San Gabriel Mountains by vertical movements along the San Andreas fault and other faults associated with it.

Leon Silver, Caltech professor of geology, made the discovery in the course of his continuing study of the origins of continents. In 1961 he and his colleagues found remains—also in the San Gabriel Mountains—of another mountain chain, formed 1.2 billion years ago, that may have extended across the entire continent.

The age of the mountains was determined by isotopic analysis of minute zircon crystals in rock samples. Dr. Silver measured the ratios of radioactive uranium and thorium isotopes to their decay products, lead isotopes. The amount of lead relative to its parent indicates how long ago the minerals first crystallized in molten granite emplaced during the mountain-forming episode.

IF YOU WORK WITH US YOU'LL WORK HARDER THAN YOU'VE EVER WORKED IN YOUR LIFE.



WHY? Because applying your knowledge and stretching your imagination are the hardest—but most satisfying—kinds of work there are.

And we have a whole grab-bag of problems that will challenge your abilities and stimulate your professional growth.

...For example, we designed and built an automated drilling vessel that allows us to drill for oil and gas in water up to 4,000 feet deep.

...Our research has given us a new synthetic elastomer—with the resiliency of rubber and the manufacturing versatility of plastic—which does not require vulcanization.

...We've developed a new hydrocracking process for vastly increasing the gasoline yield from a barrel of crude oil.

We've solved these problems.

But we've got many others.

Would you like to consider helping us solve them?

If so, talk with the Shell representative who will be on your campus soon. Or send a résumé to Manager, Recruitment Division, The Shell Companies, Department E, 50 West 50th Street, New York, N.Y. 10020.

THE SHELL COMPANIES • Shell Oil Company Shell Chemical Company • Shell Development Company • Shell Pipe Line Corporation

An Equal Opportunity Employer

1923

HAROLD ENDICOTT, who retired recently after 43 years with the General Electric Company, has moved with his wife and two sons from Devon, Pa., to Claremont, Calif. The Endicotts lived in Pittsfield, Mass., for 30 years but had been in Devon for the past five years.

1924

WILLIAM L. HOLLADAY has resigned as president and has been reelected chairman of the board of Holladay, Eggett & Horn, an architectural-engineering firm with offices in Los Angeles and Vietnam.

1925

LAWRENCE P. HENDERSON was married last summer to Margaret Seares Groat, widow of Edmund T. Groat '22. The Hendersons, who are retired and living in Berkeley, have ten children and ten grandchildren between them.

1927

HALLAM E. MENDENHALL, PhD, who retired in 1965 after 36 years with the Bell System, is in Walla Walla, Washington, in the office of financial development of Whitman College.

1928

STRATFORD B. BIDDLE JR. has been appointed editor of a new technical journal to be published by the Leeds & Northrup Company of Philadelphia. He has been with the company since 1930 and has most recently served as district manager of the Los Angeles office.

ROBLEY D. EVANS, MS '29, PhD '32, professor of physics at MIT, was recently elected president of the 1,200-member Radiation Research Society. Evans, who for 30 years has been studying the effects of radium on humans and who taught the world's first graduate course in nuclear physics in 1934, also has been awarded the Silvanus Thompson Medal of the British Institute of Radiology for his contributions in the field of radiation protection.

1930

NATHAN D. WHITMAN JR, MS '32, died on December 14 at St. Luke's Hospital in Pasadena. He was 57. As president of Whitman, Atkinson & Associates, consulting structural engineers in Pasadena, he was a widely recognized authority on the design of hydraulic structures and was identified with many major engineering projects in southern California. He began his career with the State of California Division of Highways, where he did structural design on the San Francisco-Oakland Bay Bridge. From 1936 to 1942 he worked for Leeds, Hill & Jewett, Inc. of Los Angeles. During the war he did structural design and testing for the aircraft industry. In 1945 he established his own consulting practice, and then in 1962 he merged with Thomas Atkinson of San Diego to form the present firm. Whitman is survived by a son, a daughter, and three grandchildren.

1934

MILTON U. CLAUSER, MS '35, PhD '37, has been appointed professor of aeronautical engineering and director of the Lincoln Laboratory at MIT. He has been director of the research and engineering division of the Institute for Defense Analyses in Washington, D.C. Clauser's son, MILTON JOHN, received his PhD from Caltech last June.

A. E. THOMPSON, formerly manager of Mobil Oil Corporation's refinery in Augusta, Ga., has been appointed manager of the company's refinery in Mersin, Turkey. He has been with the company since 1934. Thompson and his wife, Marion, have two sons and a daughter.

1941

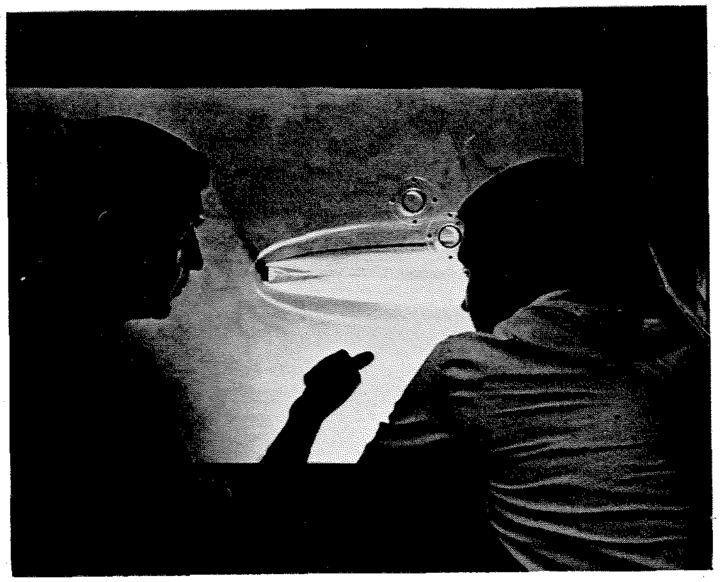
JOSEPH W. LEWIS JR. has been named president and chief executive officer of Poly Industries Inc. of Pacoima, Wash. He has been vice president and division manager of Beckman Instruments, Inc.

1942

WARREN A. HALL is director of the Dry Lands Research Institute at the University of California at Riverside. He has been serving as director of the Water Resources Center at UCLA.

continued on page 34

CALTECH IS RESEARCH



"In all the scientific and engineering departments of the Institute, research shall be made a large part of the work, not only because of the importance of contributing to the advancement of science and thus to the intellectual and material welfare of mankind, but also because without research the educational work of a higher institution of learning lacks vitality and fails to develop originality and creativeness in its students."

—ARTHUR AMOS NOYES
Policies and Procedures of the California Institute of Technology—November 29, 1921

Support your 1966-67 Caltech Alumni Fund

Personals . . . *continued*

1949

JAMES D. YOUNG, professor of English at the Georgia Institute of Technology, has been appointed Fulbright Lecturer in American Literature at the University of Vienna for 1967-68. Young, who first taught at Georgia Tech in 1956, recently received the school's first $1,000 Union-Camp Award for Teaching Excellence.

DAVID S. HOGNESS, PhD '53, professor of biochemistry at the Stanford University School of Medicine, has been awarded the $1,000, 1966 Newcomb Cleveland Prize for his contribution to the understanding of gene function in viruses and bacteria. Hogness and his wife, Judith, and their two sons live on campus.

1953

IRVING RAPPAPORT, PhD, has been appointed acting chairman of the department of microbiology of New York Medical College.

ARNOLD A. STRASSENBURG, MS, PhD '55, is director of the education and manpower division of the American Institute of Physics in New York City. He will continue as professor physics at the State University of New York at Stony Brook.

1955

ALLEN E. FUHS, MS, PhD '58, recently became professor of aeronautics at the U.S. Naval Postgraduate School in Monterey, Calif. He had been doing plasma research at the Aerospace Corporation in Los Angeles since 1960.

1961

DOUGLAS W. SHAKEL, a captain in the U.S. Air Force, writes that he has orders for release in January and plans to enter the University of Arizona in Tucson.

1964

ALAN LIMPO has been named recipient of the 1965 Richard West Temple prize for outstanding research in psychology at the University of Chicago. He is currently on leave to the department of psychology at the University of California, San Diego.

DAVID HOLTZ, a doctoral candidate at the University of California, Berkeley, has been given the annual Eastman Award for outstanding contributions in chemistry.

1965

MICHAEL J. GILLIOM, MS, first lieutenant in the U.S. Air Force was awarded his silver pilot wings at Williams AFB in Arizona and has been assigned to George AFB in California as an F-4C Phantom II pilot in the Tactical Air Command.

Come with us and enjoy the good life.

We'll give you a king-size ash tray. The kind you need for king-size thinking.

Why are we so generous? We know fresh new ideas don't come easily. And we're prepared.

Prepared to give you enough time to breathe. And experiment.

Researcher. Manufacturer. Marketer. It makes no difference.

New approaches to old problems can be used anywhere. And they will be used. Here. Whether they come from a ten-year veteran or a brand new recruit.

Pensions, insurance, stock, hospitalization—these you can get anywhere (including here).

But king-size ash trays?

That's the good life.

AMERICAN OIL COMPANY AMERICAN

An equal opportunity employer

Write and find out more from Harry L. Sheehy, Recruiting Coordinator, Dept. 19-B, American Oil Company, 910 S. Michigan Ave., Chicago, Ill.

ALUMNI ASSIST UNDERGRADUATES

A new award by the Alumni Association provides financial help for students

Four Caltech upperclassmen will become this year the first recipients of the newly established $250 Donald S. Clark Alumni Awards made possible by income from the $25,000 given in honor of Dr. Clark by Caltech alumni last year.

These grants are the most recent in the Alumni Association's long history of participation in programs to provide financial aid for Caltech undergraduates. Soon after its founding in 1915, the Association established an alumni scholarship, and the awardee was chosen directly by the Association. A later plan established loan funds, also administered by the alumni. Then, in 1953 the Association began a drive for scholarship funds that netted $100,000 and now provides four, four-year, full-tuition scholarships.

The four new Donald S. Clark Alumni Awards will be made to two sophomores and two juniors, preferably students in the engineering option, in recognition of demonstrated academic performance and potential leadership.

Financial need of the students will not be a condition. The selections, which will be announced every year in January, will be made by a committee headed by the chairman of the division of engineering and applied science and including the dean of students, dean of freshmen, and a professor of chemical engineering.

ANNUAL ALUMNI SEMINAR

It is early this year!

Save the date

Saturday APRIL 22

PLACEMENT ASSISTANCE TO CALTECH ALUMNI

The Placement Service may be of assistance to you in one of the following ways:

(1) Help you when you become unemployed or need to change employment.

(2) Inform you of possible opportunities from time to time.

This service is provided to Alumni by the Institute. A fee or charge is not involved.
If you wish to avail yourself of this service, fill in and mail the following form:

To: Caltech Alumni Placement Service
California Institute of Technology
Pasadena, California 91109

Please send me: (Check one)

☐ An Application for Placement Assistance

☐ A form indicating a desire to keep watch of opportunities although I am not contemplating a change.

Name .... Degree (s) ....

Address .... Year (s) ....

....

ALUMNI ASSOCIATION OFFICERS AND DIRECTORS

PRESIDENT
Sidney K. Gally, '41

VICE PRESIDENT
Frederic T. Selleck, '49

SECRETARY
Donald S. Clark, '29

TREASURER
John R. Fee, '51

Theodore C. Combs, '27
Donald D. Davidson, '38
Manfred Eimer, '47
Craig T. Elliott, '58
Robert W. Lynam, '54
Paul D. Saltman, '49
Richard P. Schuster, Jr., '46

ALUMNI CHAPTER OFFICERS

NEW YORK CHAPTER

President — Bruno H. Pilorz, '44, 75 Echo Lane, Larchmont, N.Y.

Vice-President — Willis A. Bussard, '44, Appleby Drive, RFD 1, Box 78B, Bedford, N.Y. 10506

Secretary-Treasurer — Harry J. Moore, Jr., '48, Old Orchard Road, Armonk, N Y. 10504

BOSTON CHAPTER

President — Francis Morse, '40, 16 Reservoir Rd., Wayland, Mass

Vice-President — Theodore G. Johnson, '57, Blueberry Hill Rd., Sudbury, Mass.

Secretary-Treasurer — Thomas C. Stockebrand, '53, 55 Summer St., West Acton, Mass. 01780

WASHINGTON, D.C. CHAPTER

Chairman — Willard H. Hanger, '43, 4720 Sedgwick St., N.W., Washington, D.C.

CHICAGO CHAPTER

President — Laurence H. Nobles, '49, Dept. of Geology, Northwestern Univ., Evanston, Ill.

Vice-President — Philip E. Smith, '39, Eastman Kodak Co., 1712 Prairie Ave., Chicago, Ill.

SAN FRANCISCO CHAPTER

President — G. Neal Huntley, '54, 3136 Padre St., Lafayette, Calif.

Vice-President — William N. Harris, '49, 1350 Cotton St., Menlo Park, Calif

Secretary-Treasurer — Harrison W. Sigworth, '44, 10 Casa Vieja, Orinda, Calif.

Meetings: 15th Floor, Engineers' Club, 206 Sansome St., San Francisco
Informal luncheons every Thursday at 11:45 A.M.
Contact Mr. Farrar, EX 9-5277, on Thursday morning for reservations.

SACRAMENTO CHAPTER

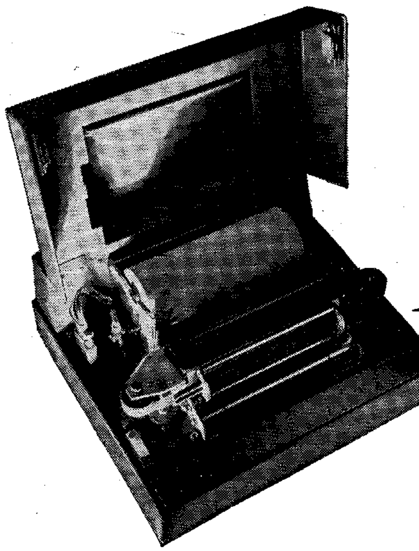
President — William D. Pyle, '49, 3920 Dunster Way, Sacramento, Calif. 95825

Vice-President — Paul J. Jurach, '46, 2824 Aurora Way, Sacramento, Calif. 95821

Secretary-Treasurer — Kenneth M. Fenwick, '28, 2954 26th Street, Sacramento, Calif. 95818

Meetings: University Club, 1319 "K" St.
Luncheon first Friday of each month at noon
Visiting alumni cordially invited—no reservation.

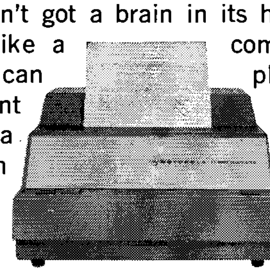
CONSUMER PRODUCTS ★ COMMUNICATIONS ★ SEMICONDUCTOR PRODUCTS ★ GOVERNMENT ELECTRONICS ★ AUTOMOTIVE PRODUCTS ★ CONTROL SYSTEMS



THIS MACHINE CAN DO ABSOLUTELY NOTHING...

ALONE. But plug it into a data processing system . . . and duck!

Motorola calls it a teleprinter—the TP-4000. It can spew out three-and-a-half feet of lettersize copy in just 60 seconds. That's probably as much as 50 secretaries could handle—a neat clip of some 3000 words a minute—or 300 characters **a second.**



The teleprinter hasn't got a brain in its head—but lash it up with a mind — like a computer's core storage memory bank and it can play back data at **real time,** virtually instant recall. For example, it can give you a copy readout of the entire payroll from Denver headquarters while you're running a plant in Vermont. Instantly. Or tell you precisely how much fuel you have, now, in your Texas storage tanks while you're in Albany signing a contract. Airlines can use them, banks, railroads, or even hospitals for just about anything from data retrieval to inventory count and traffic control.

Uncle Sam, too. For a machine with no mind of its own, the mighty teleprinter can immediately verify the computer programmed signal sent to a space craft. And give a visual analysis before the signal has a chance to be executed — an instant check for accuracy. It will be used, for instance, at far flung tracking stations as a precautionary check factor during the Apollo moon mission.

Dumb-Dumb machine? Maybe. Or maybe just lonesome. But once it gets together with a system . . . look out!

TRUST THIS EMBLEM WHEREVER YOU FIND IT

MOTOROLA

General Electric engineers and scientists are helping to satisfy the needs of society...

Like rapid transportation

Your technical career at General Electric can cover a wide range of engineering innovation. Take today's rapid transit problem for example. Inquisitive minds in research and design at G.E. have developed circuitry, radar controls and propulsion systems that can run and guide a 150 mph transit train. Manufacturing engineers have developed methods and machines to produce these transit systems as efficiently as possible. And technical marketing specialists are working with cities and government, planning their transportation networks. Good reasons why at General Electric innovations start and finish with the technical man.

For more information on career starting points available to you with G.E. (in research, development and design; manufacturing, or technical marketing) write: D. E. Irwin, Section 699-19, Schenectady, New York 12305.

GENERAL ELECTRIC

An Equal Opportunity Employer