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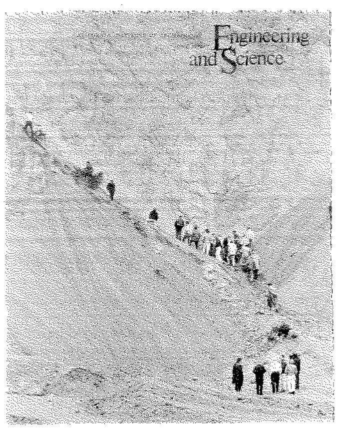

In this issue

Earthquake Research

On The Cover—Members of Caltech's Earthquake Research Affiliates climb up the side of a sheer cliff in a rock quarry near Carson City, Nevada, to get a close look at the controversial Genoa fault scarp. This was one of many stops made during a two-day ERA field trip last month through the eastern Sierra region. A pictorial record of the trip starts on page 12.

Genetics and Ethics

The ethics of genetic engineering is the source of considerable soul searching on the part of scientists, theologians, politicians and laymen. Caltech last month held a seminar on the subject, and in "The Impact of Genetic Engineering on Society," (page 2) Leroy E. Hood, faculty chairman of the conference and assistant professor of biology, discusses the goals and format of this seminar. "Genetic Engineering" (page 3) by Robert L. Sinsheimer, chairman of the division of biology, and "Ethical Issues in Genetic Engineering" (page 9) by Senator John V. Tunney are detailed examinations of the issues.

Search for Atlantis

The search for Atlantis has gone on for a long time, but an end is in sight. In "Atlantis: Cradle of Western Civilization?" (page 16) Nicholas Tschoegl, professor of chemical engineering, suggests a possible site for this legendary civilization.

STAFF: *Editor and Business Manager*—Edward Hutchings Jr.
Managing Editor—Jacquelyn Hershey
Associate Editor—Bernard Cole
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Photographer—Don Ivers

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The Impact of Genetic Engineering on Society

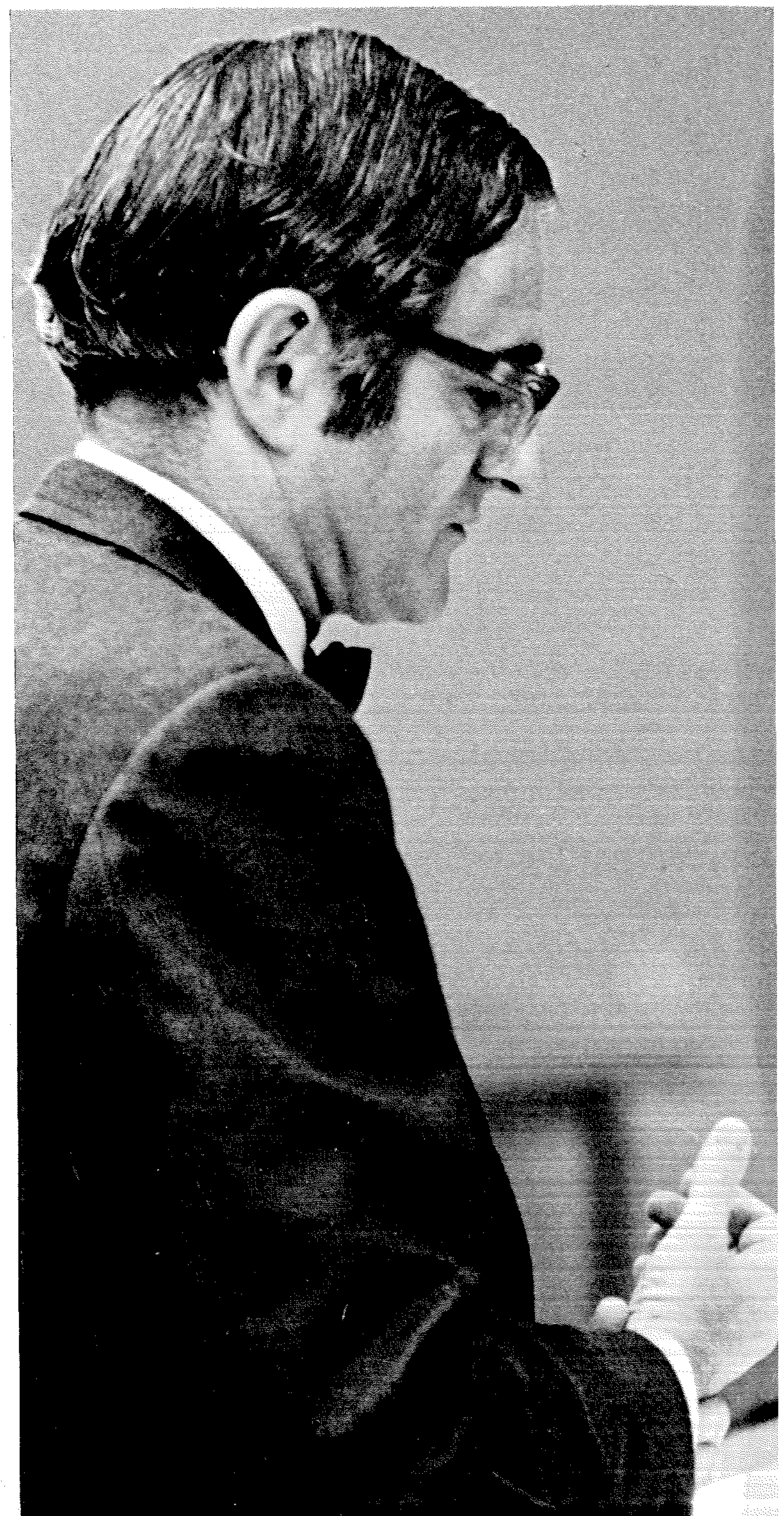
One of the profound challenges facing science today is to communicate its problems, its goals, and its achievements. A lack of understanding exists between scientists of distinct disciplines as well as between scientists and the public, and it is vital to remedy this lack, not only because of the need to justify the massive dollar expenditures required by modern science but also because science has and will continue to have profound effects on the life of each individual in our society.

With the goal of beginning to bridge this communication gap, on May 6 Caltech and the Caltech Y jointly sponsored an all-day conference on The Impact of Genetic Engineering on Society. The three-part conference included, first, speeches by Robert Sinsheimer, professor of biophysics and chairman of the division of biology, and by California's Senator John Tunney. These talks were designed to give information and to raise issues. Second, an open forum interchange between the speakers and the participants in the conference brought out further questions; and, third, small-group discussions of specific problems pinpointed some of the scientific, social, legal, and ethical intricacies of the potentials of genetic engineering.

This was the first in a series of similar conferences to be offered at Caltech, and while the format and subjects of future conferences will be different, the purpose will remain the same: to facilitate dialogue between members of all segments of the community—scientific and otherwise—on subjects of mutual interest and concern.

—Leroy E. Hood

Robert L. Sinsheimer



Genetic Engineering

by Robert L. Sinsheimer

The possibilities of genetic engineering derive from the great discoveries made in molecular and cellular biology in the past two decades, building, of course, upon the previous century of scientific advance in biology and genetics and in particular upon the profound understanding of the nature of matter provided by physics and chemistry in the first half of this century. These advances have included the comprehension of DNA as the basic substance of heredity; some grasp of the means by which this substance is reproduced—precisely, or with change as in mutation—of the means by which this substance directs the activities of the cells and thus the organs and thus the organisms; an understanding in outline, at least, of the way in which the DNA genes direct the synthesis of the complex proteins—the hemoglobins and hormones and enzymes that do the work of the body; a beginning knowledge of the detailed architecture of these complex proteins that enables us to see how they carry out their intricate molecular tasks—and also how they have evolved to their present state of efficiency—and more.

These are truly great intellectual triumphs. One might have thought that such great discoveries would provoke joy and zest for more in the pride of understanding. But these are troubled times on every front—times of intense self-doubt which corrode confidence and cripple resolve, and hence perhaps it is not surprising that these major scientific advances have also provoked fear and suspicion and troubled indecision.

Thus we read in an article by George Steiner: "It is as if the biochemical and bio-genetic facts and potentialities we are beginning to elucidate were waiting in ambush for man. It may prove to be that the dilemmas and possibilities of action they will pose are outside morality and beyond the ordinary grasp of the human intellect."

Or Sir McFarlane Burnet, the noted immunologist, has written: "Man, that dominant mammal, evolved in a middle-sized world: his curiosity has led him into two universes which are totally irrelevant to his evolution from mammal to man. The first, which concerns both the cosmic universe of the astrophysicists and the infinitely small world of the fundamental physical particles, is the process by which elements evolved in stars. The second is the chemical basis of life, the coded nucleic acid polymers that we call DNA and RNA. There is a third forbidden universe still to be effectively explored, the nature of what we call thought or consciousness and its relation to brain structure and function. It also is not relevant to human evolution, and its partial understanding may present us with greater perils than have come from our intrusion into the other two."

Do we face an ambush—or an epic opportunity? A forbidden universe—or the long-sought land, the goal toward which evolution has been striving for five billion years—to be in its product, aware of its origin and its essence, and thus to rise above the chance that has brought us to this time?

These are most certainly profound questions. We have over the past few centuries achieved a very considerable mastery over our physical world, and many are less than pleased with the results. We can now foresee—through our new insight into the bases of life—a growing mastery over our biological world—and that includes us—and many are terrified at the prospect.

They are not without reason. Much of the despair of our times stems from the realization that at last, after all the toil and all the invention, all the savagery and all the genius, the enemy is "us." Our deepest problems are now "made by man."

Now I should point out that genetic engineering is not only applicable to men. However, I expect that it is not the prospect of the application of the new knowledge to the biological world in general that frightens thoughtful

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Portions of "Genetic Engineering" were first used by Dr. Sinsheimer in a recent speech to a Conference on Ethical Issues in Genetic Counseling and the Use of Genetic Knowledge, sponsored by the Fogarty International Center of the National Institutes of Health. The proceedings of that conference will be published by Plenum Press.

men. If we can clone prize cattle to improve our food supply; if through designed genetic change we can produce more nutritious crops which make more effective use of sun and water; if we could, for instance, greatly expand the range of plants with the capacity to serve as hosts for nitrogen-fixing bacteria; if we can engineer viruses or microbes to curb pests or to destroy cancer; these innovations might produce ecological concern but not dire doubt. It is the possible application of genetic engineering to man that generates the shock wave. For this possibility, remote as it may yet be, illuminates from a new direction all that is encompassed in the word "human." Even the possibility of genetic engineering makes us ponder our understanding of the nature of man and thereby challenges traditional concepts in every area of human activity.

And much of the alarm is that we scientists, with our clever new tools, could crudely disrupt much of our social order—imperfect as it may be—with scant regard for its replacement. It has happened.

Out of the vast range of possibilities, I would like to discuss a small set which are, however, those which I think are most likely to be the more immediately feasible. I would like to emphasize that very little of what I am about to discuss is feasible today, but I can imagine that some components might become so within, say, the next two decades.

I want to discuss specifically, first, the detection of genetic defect and the related subjects of genetic counseling, amniocentesis, and the prospects for gene therapy. I would also consider the status of in vitro fertilization and the often-cited "test tube babies." Both these technologies also generate the possibilities of sex selection. A further development concerns the possibility of vegetative reproduction, or cloning, of human beings. And lastly we might briefly consider the issues posed by the ultimate possibility of a positive eugenics.

One consequence of our deepened understanding of inheritance and of the increased prominence accorded to this subject has been the surprised recognition that a very considerable number of our human ailments have genetic origins. This set of diseases has become particularly important as our ability to cope with the ailments of external origin—microbial disease and such—has increased. Over 2,000 different human disorders are now recognized to be the consequence of genetic defects. It is estimated that 25 percent of the hospital beds in the United States are occupied by sufferers from genetic disease. Because genetic disease often takes its toll early in life, the number of life-years lost per year due to genetic disease is far higher than the life-years lost due to the more widely known diseases such as cancer or heart ailments which more usually strike later in life.

This somewhat belated recognition of the importance of genetic disease has given rise to new activities designed to cope with it—to the profession of genetic counseling as a means for the prevention of genetic disease and to a search for possible means of genetic therapy.

Genetic counseling is a new profession based upon our increasing understanding of the genetic origin of human disorders and our increasing ability to recognize the genetic or chromosomal bases for these disorders—either in a prospective parent or in the developing fetus. The techniques for the discovery and analysis of single gene defects that obey Mendelian rules are well established; in an increasing number of these the biochemical defect is known and can be assayed, even in heterozygotes. Of course, the known existence of the defective gene in the parent only conveys a certain statistical probability of the appearance of the disorder in the fetus. The detection of such a defect in the fetal cells derived from amniotic fluid is more certain and is now possible in certain disorders by means of the new technology of amniocentesis. The detection of genetic disorders in fetal cells is presently limited to about 15 to 20 diseases, but it is plausible to suggest that means may be developed to permit the detection of a much wider range. The detection of such a defect in a fetus then permits the option of abortion.

The most urgent field for further advance in genetic counseling concerns those conditions which while subject to evident genetic influence cannot be attributed to simple single gene defects. In my view the evidence for a major genetic component in such widespread disorders as schizophrenia, diabetes, certain forms of cancer, susceptibility to heart disease, even rate of aging (if that is properly a disease) is unarguable. But we know as yet too little about the associated biochemistry even to know what to look for in the fetus.

One important possibility for further empirical advance in this field lies in the potential for more detailed chromosomal analysis. It is only within the past two years with the recent development of specific staining methods that it is possible to recognize uniquely each of the 23 human chromosome pairs. There is now clear evidence of the existence of marked differentiations along individual chromosomes and therewith the existence of previously unknown variations among the human population. It is possible that such variations may be correlated with some of these genetically complex disorders. (Parenthetically, it is an ironic commentary that one of the first uses to be made of this remarkable discovery has been to resolve cases of disputed parenthood.)

Further, it is at least possible that the differentiation along the individual chromosomes may by appropriate techniques be carried to much finer levels than are revealed by the light microscope. The visualization of submicroscopic differentiations along human chromosomes, if such exist, is certainly within our reach and is most worthy of exploration.

Of course the implications of such possible advances for genetic counseling are scientifically evident—and ethically confounding. For what conditions will one counsel genetic restraint—or abortion?

The genetic counselor already faces cruel and complex decisions. Suppose, for instance, he ascertains that a fetus or a newborn child has XYY chromosomal composition. He knows that this condition is associated, statistically but by no means invariably, with an increased tendency toward antisocial behavior. Should he, or is he required, to inform the parents of this condition?

Or suppose he ascertains that an adult is the carrier of a translocation which would give a statistical chance of a defective child, and therefore suspects that other members of that family may likewise be carriers. Is it his responsibility to seek out and inform these relatives?

And if a fetus is discovered to have an invariably crippling condition, should the decision to abort or not be solely that of the parents? Or does society have a role to play, when we note in this regard that the abortion, if performed, is primarily for the parents' or society's benefit? To argue that it is for the child's benefit is tricky ground.

The possibility of gene therapy would, of course, markedly alter the fateful character of decisions such as these. This prospect—which we can foresee—of detailed genetic premonition has many philosophic implications, but practically, I think, it is very likely that we will for some generations to come be faced with a situation in which we have increasing knowledge of individual genetic predestination, with limited means and probably limited will to eradicate the less adequate genes from the population—and therefore with a rapidly increasing demand for some techniques of individual genetic therapy.

Varied approaches to this end can be envisioned dependent upon the particular condition and the stage in life at which therapy can or must be applied. If we consider a single gene defect, the most evident therapy would be to supply a valid copy of the defective gene, incrementally. That is, if we consider a disease such as galactosemia or phenylketonuria or sickle cell anemia in which the individual lacks a good copy of a gene known to provide a specific function, the simplest procedure might be to provide that individual with a good copy of that gene by addition—by adding it to his genetic complement.

How might we do this? Various possibilities can be imagined, but I would like to mention only one which I think may be the most likely—through the use of what might be termed beneficial viruses. We think of viruses in general as rather destructive, and most are. They invade a cell, release their nucleic acid, reproduce, kill the cell, make more virus, and move on to the next victim.

But there is another class of viruses which enters into a more symbiotic relationship with the host cell. Such viruses invade the cell and release their DNA, but this DNA now, instead of reproducing, integrates with the host DNA. It is reproduced each time the host DNA is reproduced, so all the descendants of the original cell contain a copy of the viral DNA. Some of the genes of this DNA can be expressed while it is in this integrated state—so in effect a small set of new genes has been added to the complement of host cell DNA for an indefinite time.

Suppose now that one of the genes this virus brought in was the gene that was defective in a person suffering from galactosemia. If this gene were expressed, were functional, it could substitute for the defective gene of that individual.

We can already do just this trick in bacteria, and while we do not know just how to do it in humans, I think we are not that far from the possibility. While there are many unknowns as yet, and while much preliminary and precautionary work must be done—we, for instance, would certainly not want to run any risk of inducing a cancer while attempting the genetic therapy—I think the potential of this approach is obvious.

Of course, such a therapy will not suffice for all instances. It could not compensate for an extra chromosome, nor could it alleviate a disease in which serious lesions had already been introduced prior to birth, but it could be a powerful aid for many serious defects.

A partial consequence of the explicit realization of our genetic constraints and inequalities may be an increased impetus toward a more active or more eugenic attitude toward our collective biological inheritance. The successful achievement of in vitro fertilization of selected human eggs by selected human sperm, followed by uterine implantation and development, would be a major step toward such a technology. It should be noted that this has already been accomplished in other mammals such as mice; that is, it is now possible in mice with better than a 25 percent success rate to extract an ovum, fertilize it in vitro with sperm activated in vitro, allow the fertilized egg to develop to the blastocyst stage in vitro, implant the blastocyst in the uterus of a prepared mouse, and have a healthy delivery a few weeks later.

Preliminary experiments, directly analogous, are being performed with human ova and sperm.

Obviously, once the blastocyst is available, it need not be reimplanted in the original mother and the possibility of foster motherhood, "of wombs for rent," becomes quite real.

Such a technology, of course, affords the *possibility* of the selection of eggs and sperm from donors chosen for whatever eugenic objectives one might advocate. Indeed, banks of frozen sperm are already being established: The donor might even be some distinguished person long deceased.

In this day of Women's Lib, banks of frozen ova cannot be far behind.

Unless the success rate can be raised to 100 percent, one would have to face here the painful problem of "rejects." Many would, of course, simply fail to develop but a few might succeed, albeit with serious abnormality.

Since the sex of the blastocyst can be readily determined, this technology would permit pre-selection of the sex of the unborn child. Indeed, one should point out that if sex is acceptable as a criterion for abortion, amniocentesis already provides the same option. It is conceivable that other methods may be developed which might, for instance, permit the physical separation of X-chromosome-bearing sperm from those bearing Y chromosomes.

In any event, the possibility of sex selection would remove this choice from the realm of chance—in which it has lain for so long—into the arena of human decision. How might we cope with this new option? How would we arrange for equal numbers of men and women? Or would we want this distribution? More subtle questions arise: Surveys suggest that most families would choose to have their first child a boy, their second a girl. There are well-recognized psychological consequences of being the first child in a family, and these are very different for the two sexes. What might be the social consequences if there were no women who have been the oldest child or no men who have been the youngest child? If all women had an older brother and realized they were, in effect, a second choice?

The prospect of true "test tube babies," infants carried through fetal development in artificial uteri, is still remote in terms of present techniques—although its ultimate achievement if desired would seem entirely feasible.

A technology that appears much closer to hand is that of vegetative human reproduction or cloning. Cloning in principle removes the element of chance from the game of heredity. It replaces the genetic lottery with selection—based however, it must be remembered, upon one initial phenotype. The technology of cloning is derived from the concept that the nuclei of all cells of an organism contain its entire genome. Different portions of the genome are used in the cells of different tissues. This being so, it should in principle be possible to reproduce the entire organism manyfold by use of the genetic information replicated manyfold in its many cellular nuclei.

Such cloning has in fact been accomplished by nuclear transplantation in amphibia. Nuclei extracted from cells of young amphibia can be transplanted into previously enucleated eggs of the same species. Such eggs then develop with a small but real percentage of success into mature amphibia. Obviously the process can be performed with a considerable number of nuclei and eggs to produce a clone of genetically identical individuals, and it can be carried on through successive generations.

Cloning by nuclear transplantation has not yet been accomplished in man. But as far as is known only technical problems intervene. Could a nucleus be successfully transferred into an activated egg cell, the remaining steps are virtually in hand, as we saw in the discussion of in vitro fertilization.

Cloning would in principle permit the preservation and perpetuation of the finest genotypes that arise in our species—just as the invention of writing has enabled us to preserve the fruits of their life's work.

But man is certainly not an amphibian nor even a mouse. The relation of phenotype—the basis of selection —to genotype, which is selected, may be much less direct. I think there are profound questions to be asked before one can advocate this seemingly attractive shortcut to human genetic improvement. The first cloned man, the new Adam (or Eve), would be an orphan in a new and potentially poignant sense. He would be truly a child of the race, selected and produced by its collective wisdom. But how will he fit into our on-going society? How will he be received by his genetic relations—by his fellow clonees? The special psychological problems of twins have been extensively studied.

Assuming the phenotype reproduced as hoped, how would this Adam be received by his professional colleagues—as a superior, but a fellow, or as an alien to be outcast?

And how would he react to his special status in the world? Would he accept and enjoy it, or would he be likely to rebel against his predestination?

I hope these questions will be given serious thought before cloning—which may well be soon upon us—is attempted in a casual manner. It may well be that some of these matters can only be resolved by the experiment, but if so I hope such experimentation can be confined at first to a very small scale.

The larger possibilities for basic genetic change of our species beyond anything now known are fine for speculation, but certainly beyond our present capabilities. However, this does not mean that I think such possibilities will never be feasible. On the contrary, I am convinced they will, as we acquire new knowledge and understanding.

And this will give rise to grave questions and grave dangers. For what purposes should we alter our genes and to whom should we give such powers?

Many are opposed even to discussion of this subject. They argue, not implausibly, that we lack the intellect and wisdom adequate to assume such responsibility.

They question our intellectual capacity to foresee the probable results and if we could, they question our moral ability to define and choose the better.

As implied by McFarlane Burnet this point of view would question whether anything in the evolutionary history of our species had prepared us for this God-like role.

In one sense the only candid answer must be negative. It is in my view a miracle that the neuronal circuitry developed to cope with predators and permit adaptation to climatic shifts should also be able to comprehend the universe, to unravel the secrets of life, and its own origin.

But here we are—at this juncture in *our* evolution. We have really only two choices: to proceed with all the wisdom we can develop, or to stagnate in fear and in doubt. There is a consequence to either choice.

Now it can be argued, and indeed demonstrated, that given the apparently wide diversity of the human gene pool we have not begun to exhaust the possible favorable combinations in human inheritance. And it is also undeniably true that we should foster and preserve human diversity. It is the interaction of different human talents and points of view that most stimulates human progress.

But nevertheless from an evolutionary point of view it seems certain that there are limits to human capability, both physical, which most will concede, and intellectual.

I might suggest as one starting point that the facts of genetics and ordinary observation compel us to recognize the large element of predestination in our lives. Yet our internal reflections, our very quandaries, inform us that we as men are not wholly pre-programmed. We are confined within the finite sphere of our vision—yet we know perplexity and choice.

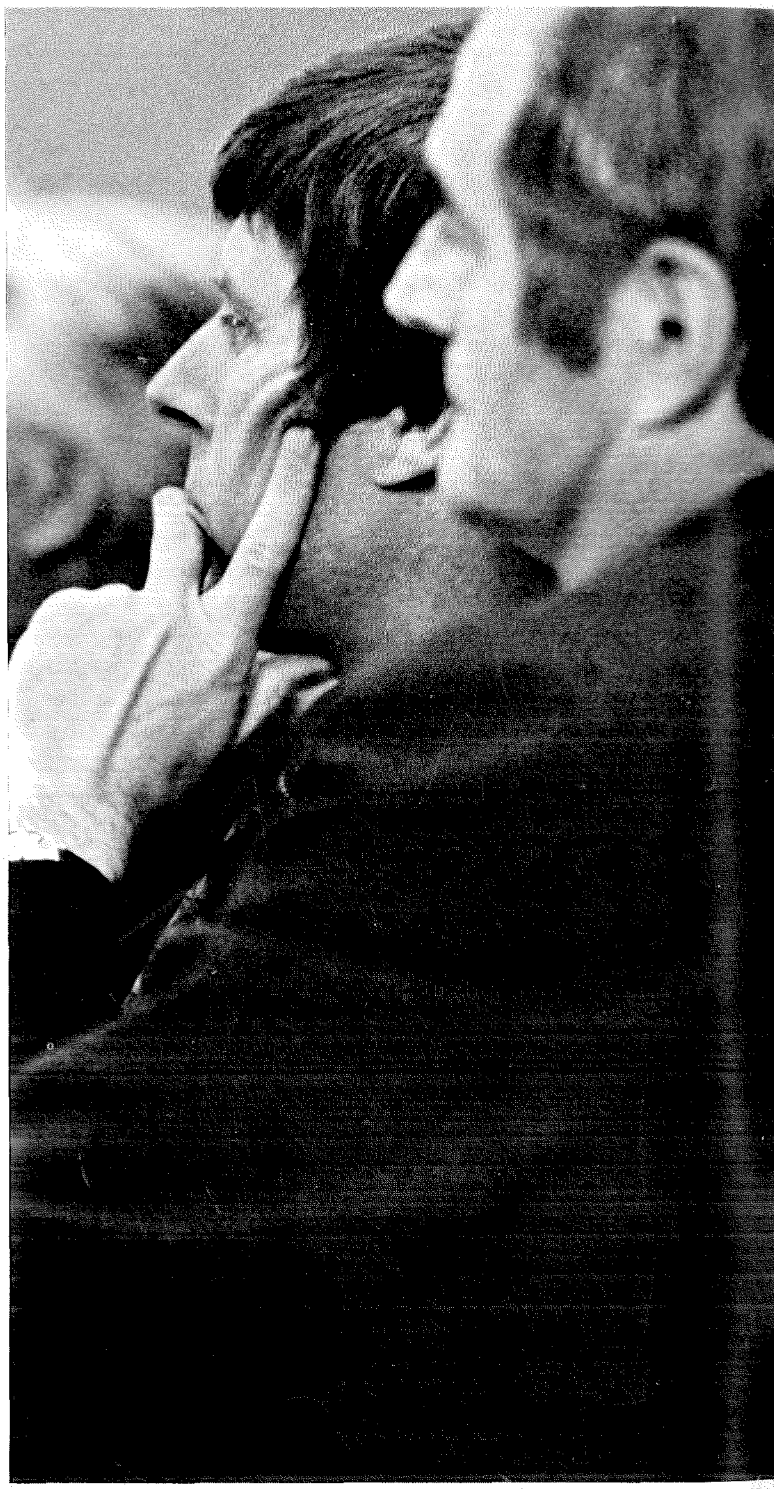
To me this element of reflection and self-reflection and choice is the core of humanity, and the object of any genetic engineering should be to enlarge our capacity for choice and to enhance our perception of consequence—to enlarge the sphere of our vision and to sharpen our tools for decision—and always to remember our finitude and thus our need for self-doubt and compassion.

More specifically, we might ask what in an evolutionary sense are the distinctive characteristics of the human species which—as we seize our destiny—we may wish to enhance? I would suggest a few, with no conceit that this is a complete list but rather with the intent to commence an inquiry:

1. Our self-awareness
2. Our perception of past, present, and future
3. Our capacities for hope, faith, charity, and love
4. Our enlarged ability to communicate and thereby to create a collective consciousness
5. Our ability to achieve a rational understanding of nature
6. Our drive to reduce the role of fate in human affairs
7. Our vision of man as unfinished

This is clearly a complex of characteristics; it is incomplete—and worse, for as of now we simply do not know to what extent these features of man are inherently coupled one to another, or maybe intrinsically hierarchical. I would hope that we might begin to explore these questions.

At the end of this discussion of issues sometimes sweeping and remote, sometimes immediate and anguished, we find we cannot escape the need to make the most crucial value judgments. Man *is* a social animal—the product of his culture as well as his genes. Inevitably there must be a progressive, developmental interaction between our social and our biological evolution. For what kind of a society shall we select genetic characteristics? To what kind of a society might the simple act of gene selection lead? Are some matters best left forever to the winds of chance? Or is that a failure of nerve and a denial of the human experience? Is it somehow inhuman to design a man?



Ethical Issues in Genetic Engineering

by John V. Tunney

Any science which has within its potential the alteration or the modification of human genes has awesome implications. The political impact of these possibilities, however, might be just as powerful as the scientific impact.

Therefore, the issues raised by the biomedical sciences must be debated. The debate must begin now. If we postpone open discussion in this area, we might find irreversible trends not only in genetics but also in political freedoms. For, if the polity responds to the scientific community through fear and mistrust, it might delegate authority to a despot or a demogogue who appeals to the people with the promise of "curbing scientific abuses." If people are sufficiently frightened—if they feel they need to be rescued from a menace they do not understand—they are more likely to delegate freedoms and less likely to respond with restraint.

All segments of society should be involved in the debate which these new technologies demand. The techniques must be discussed and debated among lawyers, doctors, theologians, legislators, scientists, journalists, and all other segments of society. The issues raised require interdisciplinary attention.

The ethical questions raised by the possibilities implicit in genetic engineering are no less fundamental than the issues of free choice, the quality of life, the community of man, and the future of man himself. Let me posit a list of ten general considerations suggesting possible ethical distinctions:

First, if we are to engage in any eugenics, negative or positive, we must confront three vital questions which pervade this entire subject: (a) What traits are to be considered desirable? (b) Who is to make that determination? (c) When in the course of human development will the choice be made? These questions cannot be underestimated in their importance to the future of man, particularly when we are considering biological alternatives which might not be reversible.

Second, we must ask whether the genetic engineering or "improvement" of man would affect the degree of diversity among men. Does it presume a concept of "optimum" man? Is diversity important as a goal in itself? Does—or should—man seek an "optimum" or does he seek a "unique"? What would the quest for an "optimum" do for our sense of tolerance of the imperfect? Is "tolerance" a value to be cherished?

Third, we should consider whether it might be appropriate to delineate different biological times or moments—at least in humans—during which experimentation might occur. Do different ethical considerations apply if we attempt to distinguish between experimentation on (a) an unfertilized sperm or egg; (b) a fertilized sperm or egg; (c) a fetus; (d) an infant; (e) a child, perhaps until it becomes an adult; (f) an adult—or at any particular moment during any of these stages? Might the factors to be balanced in making a decision as to whether experimentation is proper vary at different stages of human development?

Fourth, is there a workable difference between "genetic therapy" (defined as therapy to correct genetic factors

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"Ethical Issues in Genetic Engineering" is abstracted from Senator Tunney's speech to the genetic engineering conference at Caltech on May 6. The full speech was read into the Congressional Record on May 23.

There are certain suggestions that I would offer in any debate on this subject: that among the values which man ought to protect most fully are those of freedom, of humility, of compassion, of diversity, and of skepticism; that any scientific or technical initiatives in one generation which would foreclose or eliminate the options of future generations smack of arrogance and should be avoided; that man should exercise the utmost caution in this sensitive field and that decisions which will be genetically irreversible might require a wisdom which we do not possess; that there is no reason why the ethics or morality of any one of us are better than those of another. Therefore, the issues raised by the biomedical sciences must be debated, and the debate must begin now.

known to cause disease) and "genetic engineering" (defined as techniques to alter man in terms of some parameters other than disease)? Is it appropriate to attempt such a distinction in definitions in this emotionally charged area? Might the term "genetic therapy" evoke less reaction than the term "genetic engineering"? Or are such distinctions unworkable?

Fifth, it would seem advisable to ask whether a particular technique is devised for the therapeutic treatment of an individual—or whether it is designed to have a broader societal impact. That potential distinction has a variety of ramifications. For example, should techniques developed for individual therapy automatically diffuse into the general public for purposes other than this therapy? Are physicians capable of restricting the use to one group, or does societal pressure make them semi-automatic dispensers of seemingly desirable technologies?

Sixth, doesn't any eugenics program—whether it is positive or negative, voluntary or compulsory—imply a certain attitude toward "normalcy"; toward a proper norm for human activity and behavior; and toward expectations with regard to the behavior of future generations of human beings?

Seventh, how are words such as "normal," "abnormal," "health," "disease," and "improvement" defined? Are they words which can be operationally used to determine what should be done?

Eighth, we must ask if the quest for genetic improvement would be continuous. Would it invariably make all children "superior" to their parents? What would be the societal consequences of this? Would it institutionalize generation gaps and isolate communities by generations as education may have done?

Ninth, will the quest for genetic improvement of man lead to his perception of himself as lacking any worth in the state in which he is? What does this do to the concept of the dignity of man in his or her own right, regardless of some "index of performance"?

Tenth, if we have a well-developed ability to perform genetic therapy and it is not available for all who have the affliction or who desire the "cure," how do we determine which patient will receive the cure? Are some people more worthy of treatment? How will the selection be made?

While these considerations by no means exhaust the ethical realm, they do suggest the enormity of the problems with which we are attempting to deal. Perhaps the attempt—however primitive—at ethical classification might also offer the lawyer some general guidance. Let us examine the manner in which the American legal system is likely to deal with the subject. The issues raised by the technology of genetic therapy or engineering affect constitutional, statutory, and common law principles.

At least three constitutional factors clearly emerge in considering the subject of genetic engineering. The first is the right to privacy. The fourth amendment to the Constitution declares that "the right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated . . . " This language has been interpreted to guarantee to the individual a constitutional right of privacy. This entire subject raises questions with regard to the extent and inviolability of that right.

Second, questions might be raised by the rights protected in the fifth and fourteenth amendments which guarantee that no person shall be deprived of life, liberty, or property, without due process of law.

Third, and perhaps the most important factor which the Constitution brings to bear upon genetic engineering is the approach of constitutional law—the method of analysis which courts have developed for dealing with constitutional issues. Apart from technicalities inherent in whether state action is or is not involved, constitutional law requires the government to show a more compelling governmental need when abridgement of fundamental freedoms is involved. Contrast, for example, a governmentally sponsored compulsory program of negative eugenics designed to eliminate a certain genetic disease with a compulsory government program of positive eugenics designed to control behavior. As both programs would be compulsory, both could infringe the fundamental freedoms of procreation and possibly marriage. But a more compelling state interest could arguably be demonstrated in eliminating a disease than in controlling behavior. Constitutional analysis of the two approaches would bring different factors into being—and might yield different results.

Moving from constitutional to statutory law, it should be noted that a variety of statutes in numerous American jurisdictions have attempted to impose eugenics controls (primarily prohibition of marriage to certain classes of persons: criminals, alcoholics, imbeciles, the feeble-minded, the insane, and persons with venereal disease). A number of more recent developments in the field of genetic engineering, however, go entirely unregulated. Sperm banks are an excellent example of an area in which statutes do not exist, an instance in which our third legal tier—common law—must be our guide. In the absence of constitutional and statutory guidance we must turn to common law for our standards. Here, again, the law is neither silent nor comprehensive. It falls somewhere in between. To the extent that current law is inadequate, legislation must be developed.

I do not believe that at this point in time it would be appropriate to suggest answers to the momentous issues that have been raised. But I do believe we know enough to undertake certain legislative initiatives. Let me suggest three.

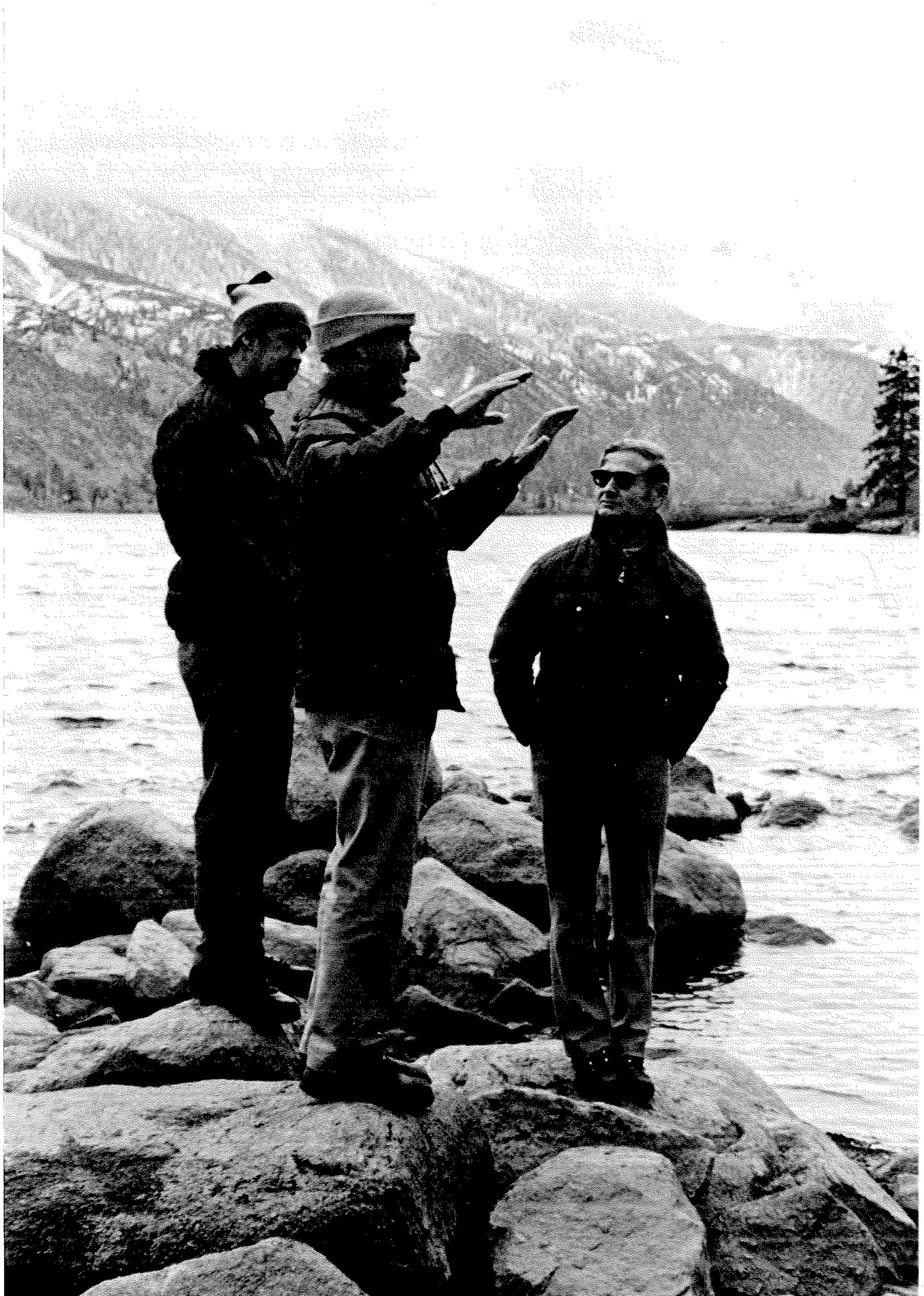
First, the Congress should enact the "Mondale Bill," providing for a study and evaluation of the ethical, social, and legal implications of advances in biomedical research and technology. This study could serve as a preliminary vehicle for educating the public into the foreseeable social consequences of biological advances.

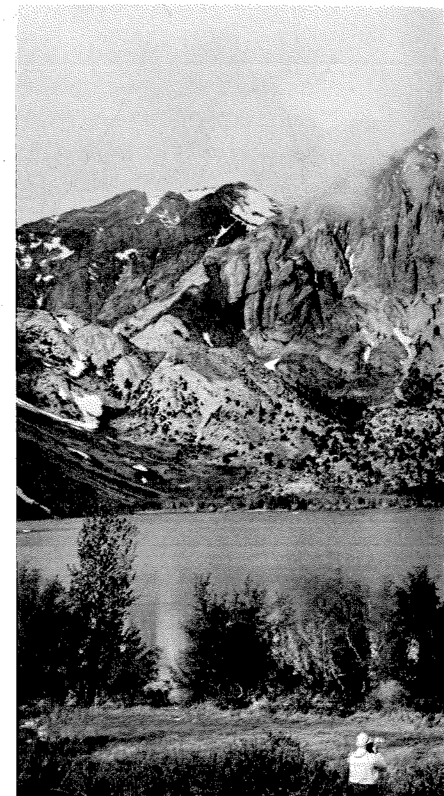
Second, we should initiate technology assessment in all institutions which disburse funds, direct research, or provide grants which are related to biomedical concerns.

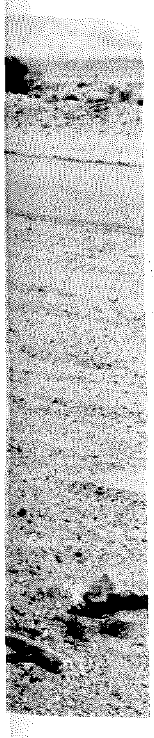
Third, it might be appropriate for the Congress to earmark a small portion of health research funds (say one-quarter or one-half of one percent) for research into the possible social consequences of biological technologies presently available or to be foreseen.

It should be evident that these potential legislative proposals include a common underlying thread—bringing science and society closer together. And this might be done in a variety of other ways as well.

In an area as fraught with subjectivity as this one, it is important that the issues raised be aired. It is important to recognize that we are dealing with an area in which there is no monopoly of expertise. We are dealing with a subject in which morality or one's own subjective sense of ethics is pervasive. We are, therefore, dealing with an area in which all persons have a right and a special claim to be heard.







Earthquake Researchers Hit the Road

Early last year preparations were under way for an Earthquake Research Affiliates field trip along the eastern flank of the Sierra Nevada to inspect evidences of recent seismic activity and geological events. But the February 9 earthquake in San Fernando Valley wiped out those plans about as thoroughly as it shook Sylmar. It wasn't until last month that the expedition finally took place.

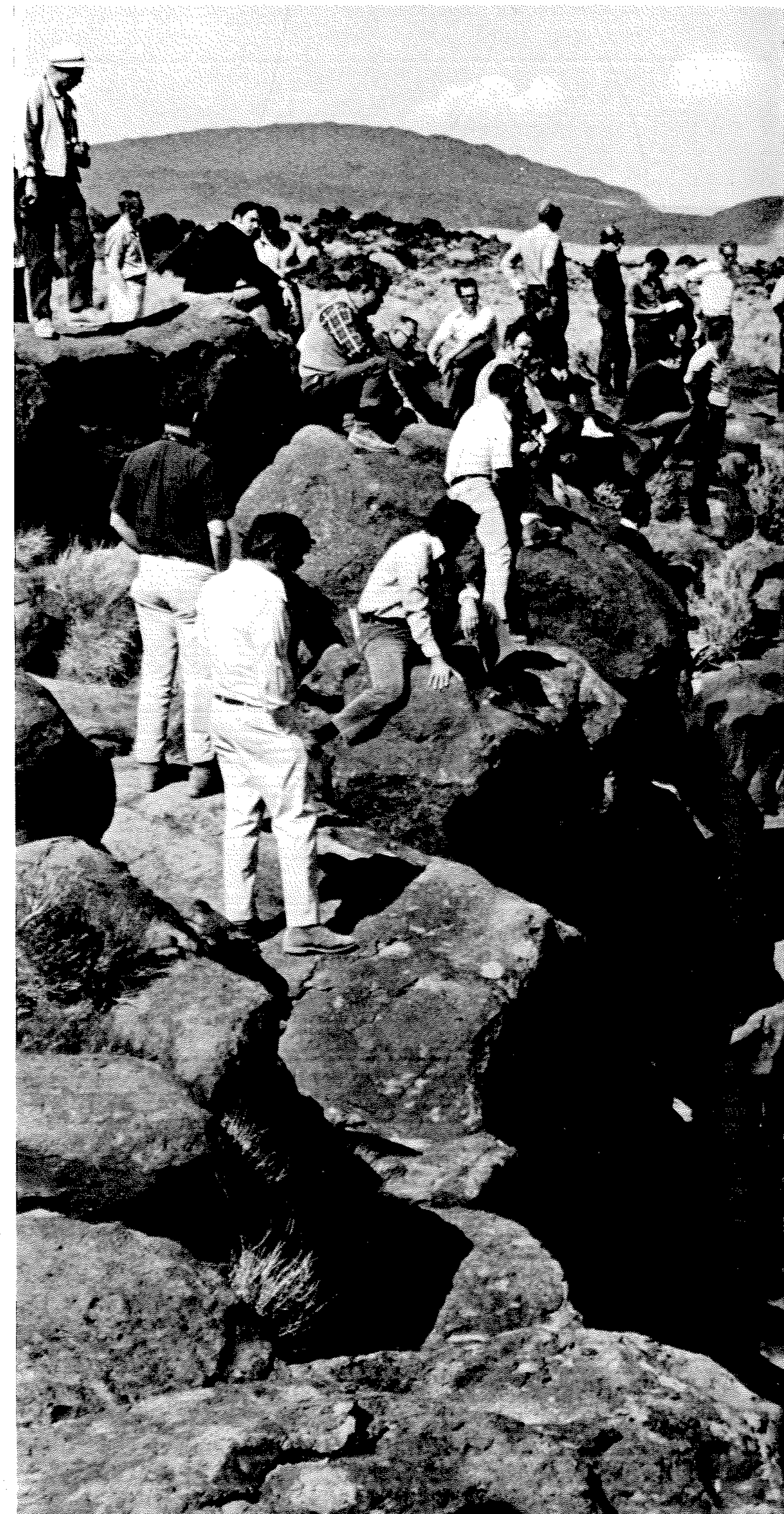
The Earthquake Research Affiliates represent organizations whose financial support assists earthquake research at Caltech. For 15 years officers and engineers from these companies have been participating in and learning from on-campus symposia and outdoor excursions. With Robert Sharp, professor of geology, and Clarence Allen, professor of geology and geophysics, as tour guides, this year's group—about 50 in all—boarded a bus in Reno, Nevada, for the two-day trip along the base of one of the world's most impressive fault-block mountain ranges.

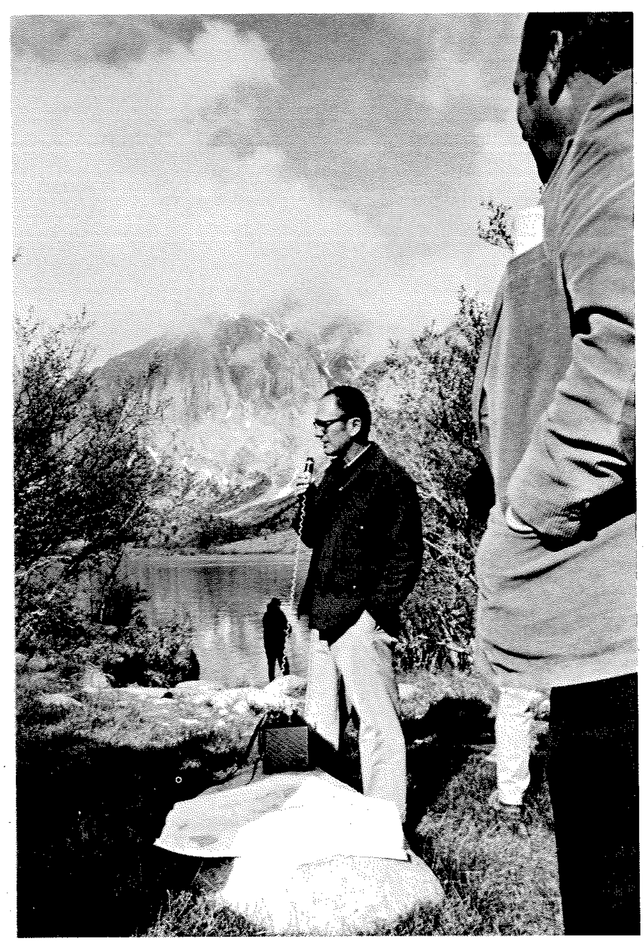
A heavy cloud bank over the range, plus intermittent rain, sleet, snow, and fog, turned the first day into a series of character-building forays from inside the bus into the elements. Compensations included the chance to look at the area between the Genoa fault scarp near Carson City, Nevada, and the Garlock fault northeast of Los Angeles through the eyes of Allen and Sharp. This section of Nevada and southern California accounts for 90 percent of the significant seismic activity in the United States.

Allen and Sharp pointed out and discussed the broad structure of the Sierra Nevada and of the White and Inyo mountain ranges; glacial features of the eastern

Sierra; evidences of recent volcanic activity in Mono Basin and Owens Valley; the fault structure of the Sierran escarpment and geologic features of the great 1872 Owens Valley earthquake. And mixed in with this geology was some of the human history of the area: Mark Twain anecdotes about the Washoe Lake Basin and Slide Mountain; the story of Sandy Bowers, one of the Comstock Lode's first millionaires and his wilderness mansion; a history of the Comstock Lode, Virginia City, Gold Hill, and Sutro's Tunnel; the saga of Convict Lake where four escaped prisoners from Carson City were cornered by a posse; nearby Mt. Morrison, which was named for a slain member of the posse; and an entertaining survey of the Alabama Hills near Lone Pine—an area dubbed "Movie Flats," because it has served as a scenic backdrop for many movies.

As the photographs on these pages attest, the trip was also an aesthetic experience.





ATLANTIS:

by Nicholas Tschoegl

Archeologists pieced together this delicate and vivid fresco of two boys in a playful boxing pose from hundreds of fragments found at the excavation of a Minoan town on Thera near the present village of Akrotiri. The fresco had been buried for over 3,400 years.

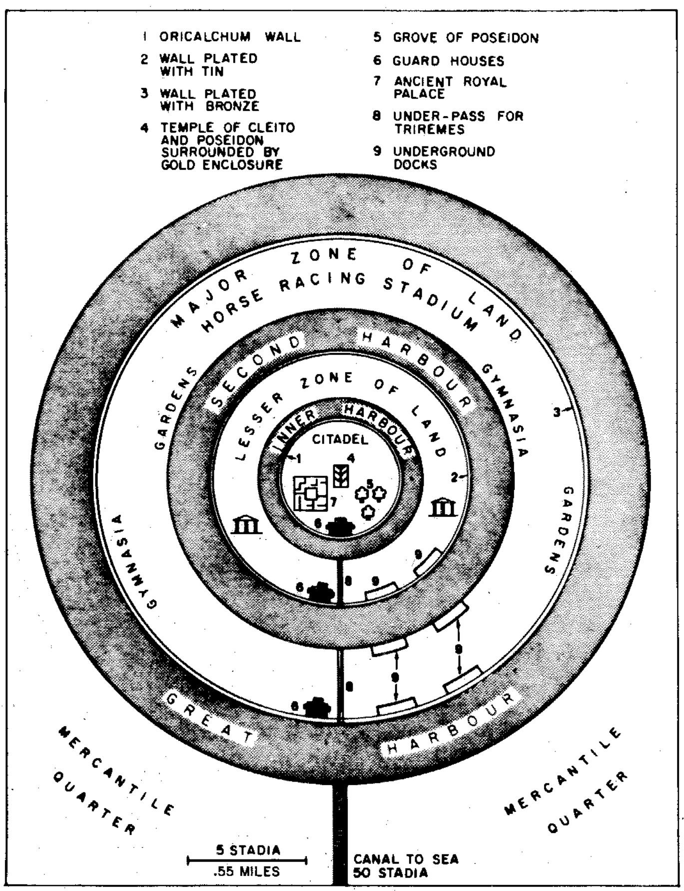
The idea of a rich and powerful island civilization that perished in a sudden cataclysm has held man's imagination ever since "Atlantis" was first mentioned in the writings of Plato. Accumulated scientific and archeological evidence now indicates that the "Lost Continent" may have been located on the islands of Crete and Thera, which were devastated by volcanic eruption in about 1450 B.C. Recent archeological discoveries on Thera, including surprisingly beautiful frescoes, add to the compelling evidence of a peaceful ancient civilization which corresponds in many striking respects to Plato's description of Atlantis.

Although the number of books that have been written about Atlantis could fill a small library, they are all based on a single literary source: The Platonic dialogues, *Timaeus* and *Critias*. Plato (427 to 347 B.C.) was related through his mother's family to Solon, the Athenean poet and socioeconomic reformer who became chief magistrate of Athens in 594 B.C. Solon had learned the story of Atlantis from a priest of Neith (the equivalent of the Greeks' Athena) while visiting Egypt, and it was passed down in the family of Plato. The *Timaeus* and *Critias* contain the essence of the Atlantis legend:

> Long before the classical Greek civilization of Solon's time, another civilization existed on the Greek mainland. This earlier civilization had a powerful rival in the great and wonderful island empire of Atlantis, an empire that was at first a veritable model of the ideal commonwealth. In time, however, it became corrupted, and endeavored to subjugate and enslave the rest of the world. The Greeks defeated the Atlanteans, but afterwards there were violent earthquakes and floods. In a single night and day of disaster, the island of Atlantis disappeared into the depths of the sea.
>
> According to the narrative, the main island of Atlantis was fashioned by the sea god Poseidon, also known as the "earth-shaker," whose cult was intimately associated with the bull. The island, clearly volcanic in origin, was shaped by Poseidon into alternating belts of sea and land. The Atlanteans bridged over the sea zones surrounding the Ancient Metropolis, making a road to and from the royal palace in the center. They bored a canal 300 feet wide, 100 feet deep, and 5½ miles long from the innermost circular channel to the open sea. Since the banks of the canal were a considerable distance above the water, the Atlanteans were able to cover over the channels and still leave room for ships to maneuver.

A schematic of the Ancient Metropolis prepared from the description in *Critias* is shown at the right. Its splendor, described by Plato in great detail, indicates that the Atlanteans were wealthy, probably from the proceeds of a lucrative maritime traffic. The rest of the country, the so-called Royal State, is said to have been a large, roughly rectangular plain, 2,000 by 3,000 stadia (about 340 by 230 miles). The exact geographical relationship between the Ancient Metropolis, or Royal City, and the Royal State is not clear in the narrative.

The empire is described as being ruled by a Royal House of princes, all descended from a common ancestry and bound never to take up arms against one another. Every fifth and sixth year alternately, the reigning members of the royal family left their cities on the plain and gathered in the Ancient Metropolis to deliberate on matters of common interest. These meetings were accompanied by an elaborate ritual comprising the sacrifice of a bull which had to be captured with the use of staves and nooses only. The sacred bulls were free to range the temple of Poseidon.



This schematic of what the Ancient Metropolis of the Atlantean empire may have looked like is based on a map conceived by J. V. Luce, a Greek classicist, after many years of close study of the sources of the Atlantis legend.

Is the Atlantis story fact or fancy? Both views have been argued with equal eloquence, ingenuity, and conviction for almost 2,500 years. Aristotle (384-322 B.C.) dismissed the Atlantis legend as pure fantasy. He believed that Plato made up the story because he found it useful in expounding his ideas on ideal government, and that—having created it—he made it disappear in a cataclysm so as not to have to account for its whereabouts. But there is no need to suppose that just because the tale served Plato's philosophical purposes it had been fabricated out of whole cloth. Indeed, it has been taken seriously by at least as many people as have rejected it.

The first strong hint that the tale might not be mere fabrication came with the spectacular exploits of Heinrich Schliemann (1822-1890), a German businessman who became one of the founders of modern, scientific field archeology. At an early age he became fascinated with the epics of Homer, which described a civilization of Greeks prior to that of Plato. At the time he read them, the *Iliad* and the *Odyssey* were mostly regarded as works of pure fiction. Schliemann became convinced that they really related historical events, and he resolved to prove it. In 1872 he found—or thought he did—ancient Troy, whose siege is the subject of the *Iliad*. In fact, in his impatience he had cut through Homer's city to a much earlier Troy.

In 1876 Schliemann began excavating at Mycenae in Greece and was immediately successful. The so-called shaft graves he found there yielded an enormous wealth of spectacular finds. He thought he had found the city and palace of Agamemnon, the "king of men" who was the leader of the Greek host that sailed against Troy. But again Schliemann had erred amid success. The graves were 300 to 400 years older than Agamemnon's could have been. Schliemann was followed by other archeologists, whose work revealed a highly advanced ancient civilization,

Why Atlantis?

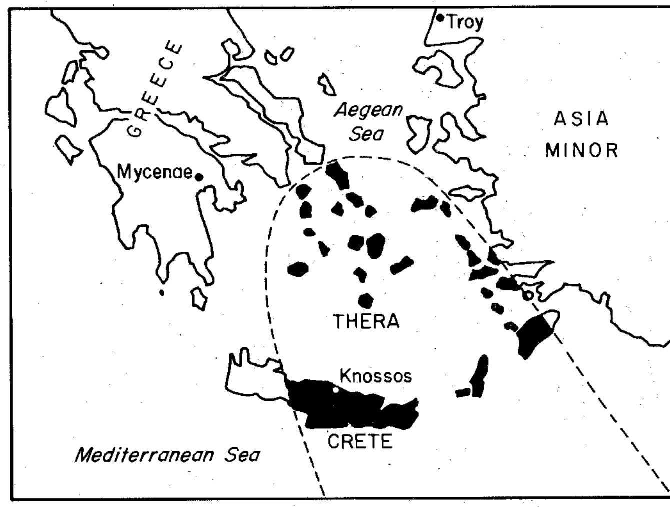
Nicholas Tschoegl, professor of chemical engineering, has—in addition to writing "Atlantis: Cradle of Western Civilization?"—spoken several times over the past year to students, alumni, and the general public about Atlantis. His talk at Beckman Auditorium last month drew more people than any other lecture ever given there, packed Ramo Auditorium for a piped-in version without the slides and graphics, and left hundreds of people outside.

This phenomenon gives rise to a number of questions: Why is the subject of Atlantis so interesting to so many people? In fact, why is Tschoegl interested, and why did he decide to give the lectures? How, as a chemical engineer and scientist, does he feel qualified to lecture and write about something so far removed from his particular specialty—the study of synthetic materials, in particular synthetic rubber?

Tschoegl believes that the lure of Atlantis is partly a general fascination with the mysterious and partly a desire on the part of some people to find simple answers to the complex problems facing us.

"For some, Atlantis is in the same category as UFO's [unidentified flying objects]," he says. "Both go back to the same common root—the feeling that perhaps at some earlier age we had the secret of living together peacefully, and somehow that secret got lost. By rediscovering Atlan-

Nicholas Tschoegl



The disappearance of the richly cultured Minoan civilization on Crete and of its outposts on many of the islands in the Aegean Sea is believed to have been the result of a tremendous volcanic explosion at Thera in about 1450 B.C. The area within the dotted line, plotted from deep-sea core samples of volcanic ash fallout, indicates the area of worst devastation.

dubbed Mycenaean from its chief archeological site. Just before the outbreak of World War II, numerous clay tablets written in the "Linear B" script were found at the excavation of the palace of King Nestor, near Messenia in Greece. The deciphering of the script in 1953 showed that the Mycenaeans were Greek. The civilization that this archeological work uncovered is in all essential details identical with that of Homer's Greece.

Thus, at least the Greek part of the Atlantis legend has been vindicated: Long before the Greek classical period, there was indeed another practically forgotten period of high civilization in Greek history.

What about the location of Atlantis? Plato unmistakeably put it in the Atlantic Ocean. But what we now know about the topography of the Atlantic makes it virtually impossible to believe that an island empire could have existed in this ocean in anything like historic times. In addition, because of the unbelievable logistics of conducting a war over such vast distances, it would make much more sense to seek Atlantis rather closer to the Greek homeland.

One possibility is Crete. Its relation to the Greek mainland and the nearby island of Thera is illustrated above. At the beginning of this century, archeologists—foremost among them Arthur Evans (1851-1941), excavator of the palace of Minos at Knossos—unearthed on Crete what appeared to be another highly advanced civilization, somewhat older and artistically more refined and more original than the Mycenaean. An example of some of the delicately executed art of this civilization is illustrated to the right.

Evans called this civilization, which was destroyed around 1450 B.C., Minoan. Evidences of Minoan outposts have since been discovered on many Aegean islands and

In contrast to much of the art of the time—Egyptian, for example—Minoan art of 1500 B.C. emphasized the natural rather than the ritualistic. This portion of the "Harvester Vase" shows smiling workers returning home from the fields. The vase was found at the palace of Phaistos, near Hagia Triada in Crete.

as far away as Sicily and perhaps Spain.

But the notion that Atlantis just had to have been in the Atlantic Ocean was so firmly rooted in the minds of so many people that the establishment of a connection between Atlantis and the Minoan culture was surprisingly slow in coming. Another reason for the lag was that for a long time remains of the Minoan civilization were found essentially only on Crete—and Crete was still there. It certainly had not disappeared into the sea.

In 1913, the British archeologist K. T. Frost published a paper identifying the Minoan civilization and Crete with Atlantis. But although he argued convincingly and compellingly, his thesis was ignored by archeologists. Still unexplained remained the causes for the sudden decline of Minoan civilization, which had been noted by Evans, and its replacement by the Mycenaean.

In 1939, while excavating Amnissos, the ancient harbor of Knossos, the Greek archeologist Spyridon Marinatos became convinced that he had found the clue to the sudden catastrophe that befell the Minoan civilization. He believed it was a consequence of a gigantic eruption of the volcano on the island of Thera, about 70 miles northeast of Crete. At that time archeologists generally believed that the Minoan civilization was destroyed by conquest from the mainland.

Marinatos published his revolutionary ideas in the respected British journal *Antiquity*, but the outbreak of World War II and the subsequent civil strife in Greece prevented any further work. When archeological and scientific work was resumed in about 1955, startling results were obtained in quick succession. In particular, the Greek seismologist A. G. Galanopoulos connected the Minoan civilization with Atlantis, and Marinatos had also come to the same conclusion.

Why Atlantis . . . *continued*

tis, many people believe, we will find the secret again. In the same way, some believe a race of beings in some far galaxy has the secret and will deliver it to us someday."

But for Tschoegl the fascination has a much more rational and factual basis. "The theories and evidence that seem to connect the mythical Atlantis with the historical Minoan civilization are appealing to me because they order my personal universe a little more. Something that was hitherto incomprehensible now finds its proper niche in the scheme of things."

One reason he decided to give the Beckman lecture was his desire to clear away some of the mysticism about Atlantis. "Another reason," he says, "has to do with the purpose of the Beckman lectures, which has always been to present Caltech and its faculty to the general public—not only through discussions of their work, but through the personalities of the scientists as human beings."

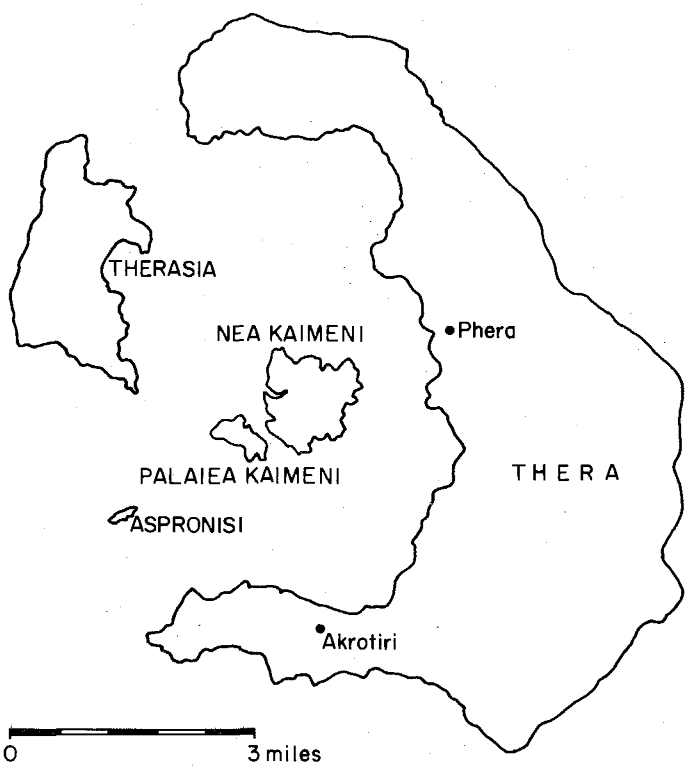
He believes the image that needs to be projected is the real one of men with interests and social concerns that go beyond their narrow specialties rather than the distorted—but all too prevalent—one of a bunch of mad scientists huddled in their laboratories plotting how either to save or to destroy mankind.

Tschoegl is a good example of the scientist who is both a specialist and a generalist. He knows a good deal about chemical engineering because "that is the way I earn my living." But science and engineering are only two of his many activities and interests. Archeology, linguistics, and the art and history of foreign cultures are others. This variety is perhaps a result of his classical European education. In the high school he attended in Hungary, science was no more important than any other subject. And much emphasis was given to languages, history, and literature.

"I was about 14 years old when I came across a book that showed a color plate of the palace of Minos at Knossos on the island of Crete. The palace was going up in flames. I wanted to understand the fate of that strange and exciting culture that created so many beautiful things. I wanted to know why such beauty was destroyed; knowing the reason, I thought, would put things right for me somehow. So when I saw an exhibit on the Thera excavations in Athens last summer, I realized I might have found an answer."

Although he admits to no qualifications on this subject other than an extensive amount of reading, Tschoegl resolved then and there to present a Beckman lecture on the archeological work being done on Crete and Thera.

One result of his lectures is interest on the part of some Caltech chemists and geologists in contributing their skills to the determining of whether the Atlantis-Crete-Thera theory is true. Meanwhile, Tschoegl is thinking about presenting another lecture at some future date—this time on a topic that combines his interest in cultural anthropology and his specialty in chemical engineering. The proposed title is "A Cultural History of Rubber."



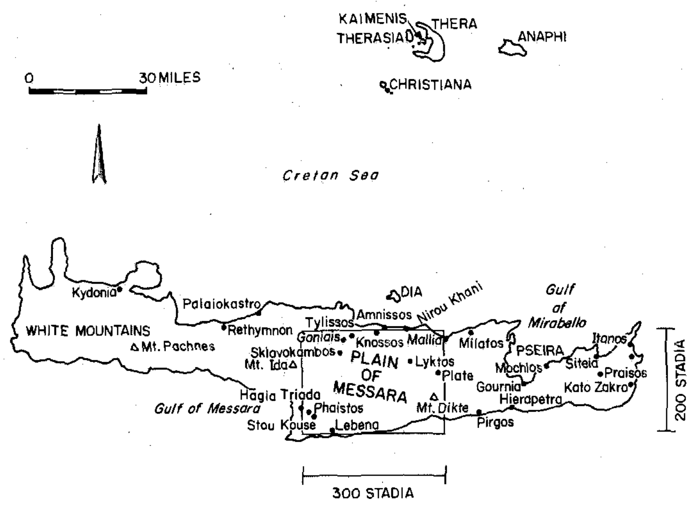
The key to the obliterated Atlantean and Minoan civilizations is the volcanic island of Thera, about 75 miles north of Crete.

Since Thera appears to be an important clue to the whole mystery, let us have a closer look at it. Thera, illustrated above, is a small volcanic island group about five miles in diameter—one of the Cyclades islands in the southern part of the Aegean Sea. The volcano on Thera is active, a minor eruption having occurred as recently as 1956. The work of volcanologists—Reck in Germany, and Heezen and Nincovich of Columbia University's Lamont Geological Observatory in this country—has shown that the island volcano underwent major eruptions in about 25,000 B.C. and again about 1450 B.C., when Minoan civilization was at its height. Volcanic ash thrown up during the later eruption was as much as 1,000 feet deep on Thera, and in lesser amounts was scattered over a wide geographic area of the Aegean. The eruption of 1450 B.C. is estimated to have been four to five times as powerful as the well-documented eruption of Krakatoa in the Indian Ocean in 1883. The sound of Krakatoa's explosion was heard as far away as 3,000 miles; ash fall was recorded over distances of 2,000 miles; and particulate matter from the eruption circled the earth for many years.

The map on page 18 indicates the approximate area over which the Thera blast was felt. This truly gigantic explosion, several times more powerful than that of the largest nuclear bomb ever exploded, surely affected the entire Aegean world. The accompanying earthquakes and tidal waves, and the ensuing conflagrations, destroyed Minoan palaces and cities all over the island. Many of the inhabitants, and the animals on which their livelihood depended, were killed. Crete must have been covered with ash, smothering vegetation, rendering wells useless, and blocking irrigation canals. For many years Crete must have been a shambles—the Minoan civilization destroyed at its base.

Life soon reasserted itself, however; Mycenaean Greeks moved into the power vacuum. Linear B tablets, written in Mycenaean Greek, have been found in Knossos. The Homeric epics, dealing with events about 200 years after the eruption—about 1200 B.C.—describe Crete as again rich and powerful. The Mycenaean ruler of Crete, Idameneos, is listed by Homer as one of the most powerful among the Greek kings who fought at Troy. About 100 years after the Trojan War (1000 B.C.), a Dark-Ages period that lasted several hundred years descended upon the Aegean world. The reasons for this decline are not clear; it may have been due to a long-lasting climatic change. But classical Greek civilization began to emerge about 700 B.C.

Since nothing was known to either Solon's or Plato's Greek contemporaries about either Mycenaean or Minoan culture, they could not imagine that the events the Egyptian priest described could have happened so close to home. Plato reports the priest as saying that Atlantis was destroyed 9,000 years before Solon's time—about 12,000 years ago. This is plainly impossible, for no trace has ever been found of any advanced civilization that flourished that long ago. Galanopoulos, the Greek seismologist who has made a special study of the Atlantean problem in relation to volcanic activity in the Aegean, has pointed out that whenever Plato mentions figures involving the number 1,000 they do not make any sense. They appear too large by a factor of 10. The conjecture is that somewhere in the transmission of the record to Plato the numeral for 1,000 became confused with that for 100. Thus, the Atlantean host is given as numbering 1,200,000. One-tenth of this—120,000—is still large, but it seems a more reasonable number when we consider that the entire population of the Mediterranean region at that time was scarcely more than that of New York City now.



A possible site of the "Royal State" of Atlantis, a flat region bordered by mountains, is the Plain of Messara on Crete.

If the destruction of Atlantis is, accordingly, taken to have occurred 900—and not 9,000—years before Solon, the date of the catastrophe becomes 1500 B.C. It is difficult to be exact about when the Thera eruption took place, but that it was about 1450 B.C. is currently accepted.

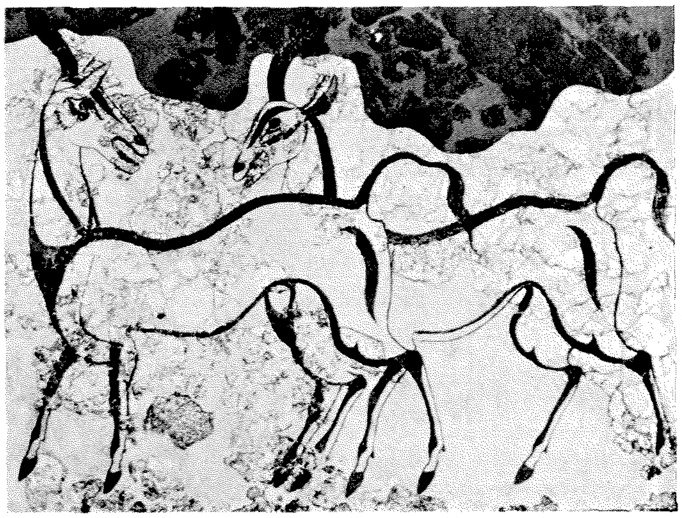
The correction immediately makes sense with respect to the size of the Royal State. If this is reduced from 2,000 by 3,000 stadia—roughly the size of California—to 200 by 300, the dimensions almost perfectly fit that part of Crete, the Plain of Messara, where Minoan sites have been excavated. This is illustrated above.

What about the Royal City, or Ancient Metropolis? Galanopoulos has advanced the bold idea that the Ancient Metropolis has to be sought not in Crete but in Thera. According to this idea, the island group including Thera was the real center of the Minoan—or Atlantean—empire. The Ancient Metropolis thus becomes completely destroyed in the eruption.

The theory has gained even more credence as a result of the recent excavation by Marinatos and others of a Minoan town on Thera with a level of sophistication similar to that of the civilization on Crete. An intact city of two- and three-story houses is still standing under the volcanic ash. Thus, another Pompeii, some 1,500 years older than its Italian counterpart, is emerging on this Aegean island. To make their buildings elastic and earthquake resistant, the Therans—or Atlanteans—set wooden pins in the corner points of the stones. They cultivated the olive and produced pottery similar to that found in Knossos. But by far the most amazing creations of the ancient islanders were their frescoes, such as the one below. Beyond any doubt they surpass all contemporary art found so far in the Mediterranean region. The frescoes at Knossos, for example, are less delicate, free-flowing, and rhythmical than these. These show Bronze Age civilization at its peak. Such exquisite art could have been executed only by professional artists, who could only have been sustained by a rather high level of civilization.

These discoveries are exciting because of what they tell us about the possible origin of western civilization. Our North American culture has its roots in European culture. The civilization of Europe is founded on the classical Greek culture of Plato, Socrates, and Aristotle, which in turn has its roots in the preceding Mycenaean culture. And the Mycenaeans are intertwined with the Minoan culture.

If it is proven that the Minoan and Atlantean civilizations are one and the same, then Thera—the site of the Royal City of Atlantis—may have been the true birthplace of our own civilization.



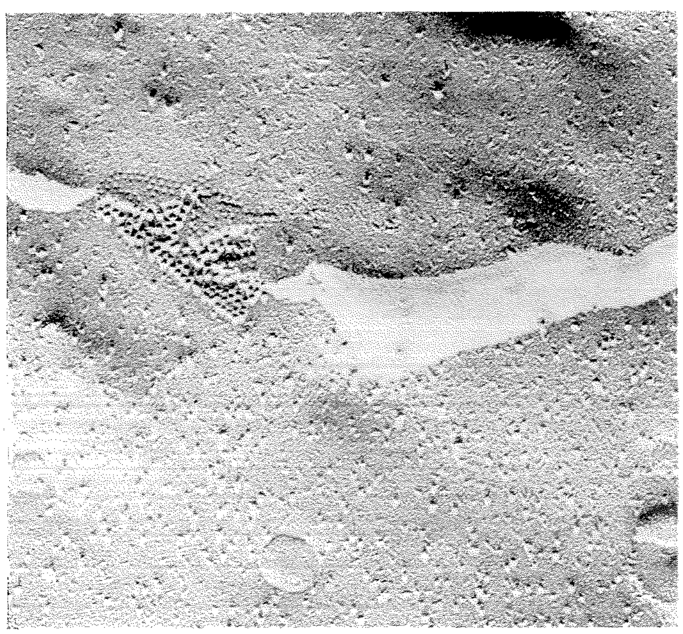
Fresco of "Two Antelopes" found on Thera makes similar finds at Minoan excavations on Crete seem provincial by comparison.

Research Notes

Bridging the Gap Junction

It is well known that specialized kinds of cells in the human body—brain, nerve, and muscle cells, for example—have sophisticated and well-defined systems of interaction and communication. However, scientists now believe there is another cell interaction that occurs in most, if not all, tissues regardless of their function—a generalized interaction that takes place in the excitable tissues of the heart, smooth muscle, and nervous system, as well as in the non-excitable tissues of the rest of the body.

Research by Jean-Paul Revel, professor of biology, indicates that this cell interaction (called "electrotonic coupling") may be associated with special intercellular contacts called "gap junctions." These junctions are about 20 Angstrom units wide (80 billionths of an inch).



This electron micrograph of a portion of two baby hamster cells and the space between them (light band across the center) is magnified about 150,000 times. The narrowing of intercellular space at the left—and the pits and particles associated with it—is a "gap junction."

Revel has found what appears to be an array of small pits or closely packed particles bridging the gap between two cells. While it has not been proved conclusively, there is a high degree of circumstantial evidence linking the particular shape and internal structure of the gap junctions to electrotonic coupling and possibly to other forms of intercellular communication as well.

The purpose of the contacts, or gap junctions, seems to be to pass ions between cells. The ions vary in molecular weight from 39 to about 10,000 as a rule, but in some cases ions with molecular weights of as much as 50,000 have been passed.

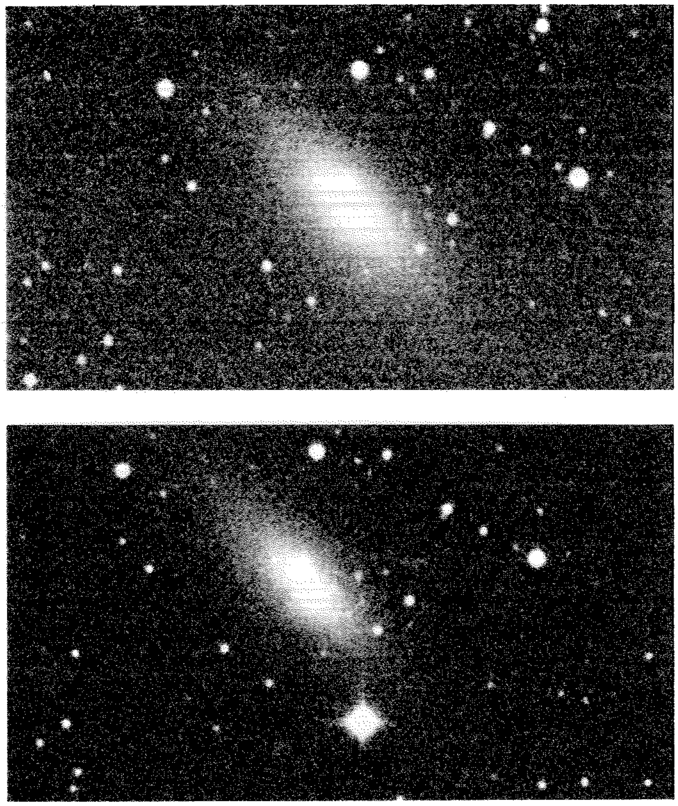
What the roles of electrotonic coupling and the gap junction are in the body is not yet clear, but it is surmised that they may play an important part in the control of cell growth. If this is so, it would give scientists some clues about cell differentiation and development in multicellular organisms—why cells from the same ancestor diversify to form the various specialized organs and tissues.

Cosmic Explosion

On the night of May 13 the 18-inch Schmidt telescope at Palomar Observatory was set to scan an area of the sky in the Constellation of Centaurus when its camera caught a star in another galaxy in the act of exploding. This exploding star, called a supernova, is the brightest one seen in 35 years. In fact, it is brighter than the entire galaxy in which it resides.

The supernova was discovered by Charles Kowal, a member of the staff of Caltech's Robinson Laboratory, who apparently photographed the explosion near its peak. Of magnitude 8.5, it was not quite bright enough to be seen with the unaided eye, and it is fading away rapidly, though it will be visible in small telescopes through July.

Stars at least four times as massive as the sun are believed to end their cosmic lives in supernova explosions after they have exhausted their hydrogen and helium fuels. They collapse, and this results in a titanic explosion. Normally, the maximum brightness of a supernova lasts a couple of weeks. Then it loses its brilliance and may collapse into a pulsar—a class of fast-spinning stars



Comparison of two photographs of stars in the Constellation of Centaurus reveals a supernova occurring in the tenuous spiral arm of the galaxy NGC 5253 (just below center). Of magnitude 8.5, it is the brightest recorded in 35 years.

that emit rapid radio pulses. (Smaller, sun-size stars are thought to shrink into white dwarfs.) Astronomers are interested in the explosion phenomenon because it marks the end of the evolutionary life of a larger star and because supernovae offer the possibility—through their brightness and red shifts—of becoming a yardstick to measure the universe.

Kowal discovered the supernova while examining photographs of a large spiral galaxy (NGC 5236) which has had four supernovae since 1923. The small galaxy (NGC 5253) in which this supernova was found is near the large one and had a supernova in 1895 of magnitude 8.

Kowal spends six nights a month at Palomar surveying the sky for supernovae in a research program directed by W.L.W. Sargent and Leonard Searle, staff members of the Hale Observatories. Aided by a grant from the National Science Foundation, they oversee the supernovae search that was started in the 1930's by Fritz Zwicky, professor emeritus of astrophysics. The Palomar search has resulted in the discovery of 200 of the 300 supernovae that have been recorded—most of which are only about one-thousandth as bright as the one Kowal just discovered.

New Data on Ground Shaking

The San Fernando earthquake, already more than a year in the past, is still providing engineers with a gold mine of information—and some knotty problems as well. Evaluation of the data by Paul Jennings, professor of applied mechanics; Ronald Scott, professor of civil engineering; and Donald Hudson, professor of mechanical enginering and applied mechanics, has led them to question a number of longstanding assumptions about the nature of earthquake motions.

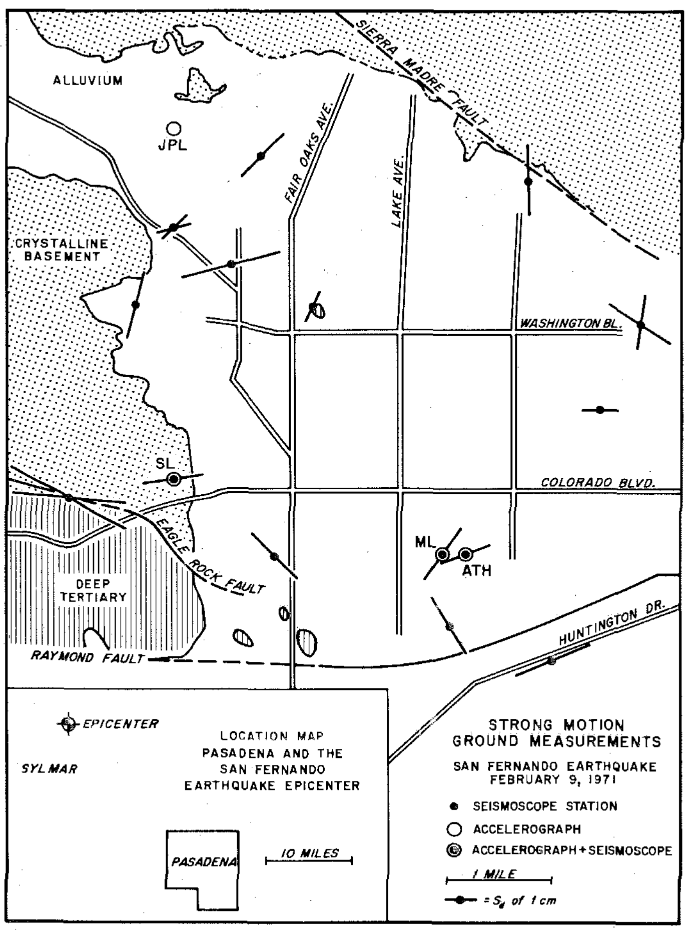
The general picture that emerges from a study of the distribution of accelerograph and seismoscope readings is one of considerable complexity. In general, recorded accelerations for this quake were very similar whether the strong-motion instruments were located on rock or on alluvium. At some stations located on rock—Caltech's Seismological Laboratory, for example—the instrumental response was relatively large; some stations on alluvium showed small response. On the campus, where the alluvium is about 900 feet deep, the seismoscope readings for Millikan Library and the Athenaeum show significantly different values—and these two buildings are less than three-tenths of a mile apart.

The instrument data do not support the assumption that the firmer the ground on which a structure is built, the less an earthquake will shake it. The general character of the motions recorded appears to be unrelated to the firmness of the ground over a wide range of conditions. It may be that the soils in this area are not sufficiently soft to show the sort of effects that have occurred on the very soft deposits of Mexico City, for example. Perhaps the soils here are so firm that any soil effects are much smaller than the fluctuations in motion from other causes, such as the travel paths of the seismic waves and the nature of the motion at the source of the earthquake.

Instrument readings of the quake indicate that its motions varied more than the scientists expected in three ways:

First, the assumption that the farther a site is from a quake epicenter, the less intense the shaking it receives still holds true generally, but it is not borne out consistently. There was a lot more scatter than expected. At one point 40 miles from the epicenter, the peak acceleration was only .08 of the force of gravity, but at another place, also 40 miles from the epicenter, it was .24g.

Second, the motion varied more widely at points near each other than anyone had previously considered likely. An example of this is the variation in shaking at the Millikan Library and at the Athenaeum. Although the general character of the shaking was the same, the shaking at the library was somewhat greater. Why this should be is not clear. The explanation that occurs first is that the difference is due to the different character of the buildings. But even though Millikan is eight stories high and the Athenaeum only two, present theories of building dynamics do not explain why the first was shaken more violently than the second.



Unexpectedly complex records of the San Fernando earthquake made in Pasadena contradict some longstanding assumptions.

The third variation from expected motion was the differences in the strength of shaking in different directions at the same point. At Millikan and the Athenaeum, there was very little difference between the east-west and north-south components of motion. However, at the Seismological Laboratory the east-west motion was two to three times stronger than the north-south. Possible explanations for this include modification of the earthquake waves by local geology along the travel path, and the type of motion generated at the earthquake source.

One conclusion that can be drawn thus far from the studies of the San Fernando earthquake is that predictions of ground shaking based on measurements at a number of sites of many small earthquakes may not correspond very well to what actually occurs during a damaging earthquake. Up to the present, calculations have been based on what scientists believe to be the "average" conditions of ground shaking that a particular location can expect. But long-term average conditions are of small comfort to an engineer whose structures are destroyed by an earthquake that happens to depart from the average.

The significance of average conditions becomes vague when it is considered that most structures will probably be exposed to only one damaging earthquake during their lifetime. By the time the local distributions of a number of large earthquakes are superimposed, the average conditions will be considerably smoothed out, and the seismic zoning map may approach a one-zone pattern. Considerable caution must thus be used in the preparation of detailed local seismic risk maps.

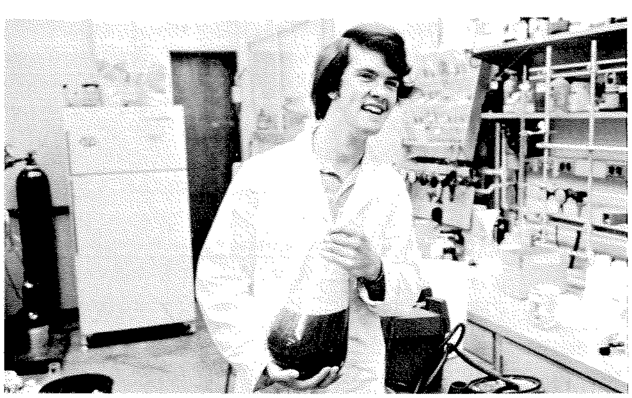
All these variations in strong earthquake motion will make the job of structural engineers harder. The variations in ground motion are too large to be ignored, and it does not appear possible to describe the strength of shaking consistently by means of simple rules or calculations.

The Bean Freaks

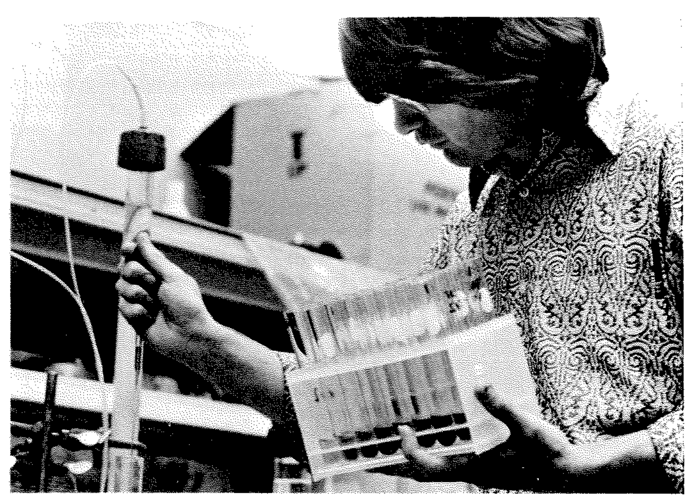
Harry Gray's "bean freaks" now know that scientific research sometimes requires more than just mental effort. The graduate students under Gray, professor of chemistry—they are formally known as the bio-inorganic chemistry group—are studying the metalloproteins involved in photosynthesis, the process by which light energy is transformed into chlorophyll and chemical energy in plants. One student, Don Fensom from the University of Sydney in Australia, is studying the metalloprotein *plastocyanin*. To complete his work this spring he needed about five grams of the purified substance. This meant Fensom and his friends had to pull up about a quarter of an acre of green bean plants by their roots at the Jeffrey Ranch of the Western Marketing Company near Irvine, load about a ton (907,000 grams) of plants onto a truck, and drive them back to Caltech. At the Institute they spent three days stripping half a ton of leaves from the plants, stuffing them into 50-pound-capacity bags, and storing them in a freezer to prevent decomposition.

For their leaf-stripping efforts, the bean freaks—including Barry Donher, John Robbins, Jill Rawlings, Bob Holwerda, and Leslie Hodges—received a rich bonus: a 50-pound feast of fresh green beans.

Each bag of leaves was reduced to a green liquid mush in a blender. The fibrous residue was filtered out by pouring the mixture through a porous plastic material.



Barry Donher holds the results of a day's filtering—several quarts of dark brown juice. The next step is to add various chemical agents to precipitate out most of the plant material except for plastocyanin and a few other metalloproteins.



Fensom processes the liquid several times through a series of filtration columns to separate the proteins on the basis of electric properties and molecular weight. The resulting liquid, now dark blue, is pure copper protein—plastocyanin.

Telescopes with Television

For almost 100 years photographic plates at the focal point of a telescope have been the major means of recording astronomical images. Useful as this technique is—and will remain in many areas of astronomy—some of the world's largest telescopes, including those of the Hale Observatories, are being switched to the use of sophisticated television systems to record the details of planetary atmospheres, faint galaxies, and quasi-stellar objects.

One such system, the image intensifier tube, has been used since the 1950's and simply brightens the image. Another older type of device, the photomultiplier tube, produces an electrical signal that is a measure of light intensity. It registers light from a single undifferentiated element but cannot map an entire image. A third device, called an image dissector, functions like a single photomultiplier tube with directional capabilities and is able to scan an entire image in successive elements.

A successor to this is a device developed at Princeton University and used on the 200-inch Hale telescope to obtain details of gaseous cloud banks apparently associated with a quasar that may be the second most distant object known.

The device is called a vidicon, and it differs from earlier systems in that it has a memory. It can build up images on a target for an exposure as long as six hours. Working by converting a visible image into a pattern on a target, vidicons for astronomy are designed for very slow scan rates in order to achieve better sensitivity to all wavelengths of light, especially the infrared and ultraviolet.

One adaptation, the modified SEC (secondary electron conductivity) vidicon, has been used by Maarten Schmidt, professor of astronomy and a staff member of both the Hale Observatories and the Owens Valley Radio Observatory; J. Beverley Oke, professor of astronomy and associate director of the Hale Observatories; and Donald Morton of Princeton to delineate six specific layers—and several other possible ones—between earth and the quasar PHL-957, which is about nine billion light years away.

In related research, James A. Westphal, associate professor of planetary science, and Thomas McCord, associate professor of earth and planetary sciences at MIT and director of MIT's Wallace Astrophysical Observatory, have adapted the vidicon for use as a photometer. The heart of the system is a silicon diode vidicon tube. Incoming photons (packets of light) are collected by the telescope and focused onto the tube's wafer of silicon, which is two-fifths of an inch square. In the diode the photons are transformed into electrical charges. A microscopic electron beam scans the wafer, extracts the information, and stores it on a computer tape.

This system will give telescopes ten times keener vision at great distances than the traditional methods. The photometer will be used by Westphal and McCord to observe the recently discovered neighboring galaxies, Maffei I and II (*E&S*, February 1971). These two galaxies are difficult to see optically from the earth because they lie on the other side of the disk of the Milky Way Galaxy, with much interstellar dust intervening. The photometer will be used to observe them in the infrared, which penetrates the dust.

In its initial testing stages, the photometer was used by McCord and Westphal at the Cerro Tololo Inter-American Observatory in Chile to measure the reflected light (albedo) of Mars and Jupiter, and they have begun using one on the 100-inch telescope at Mt. Wilson for taking spectra of cosmic objects.

In addition to sensing stars, quasars, and planets, vidicon systems have been used to steer large telescopes more efficiently. It is now possible to use stars fainter than those the eye can see to guide telescopes, and this results in saving a great deal of observing time that would otherwise be wasted in sighting and checking. Also, an astronomer can oversee all the details from a warm, lighted room instead of spending the night bundled up in a small cage at the end of the telescope—the astronomers' usual lot.

The Month at Caltech

Coming Up— A New Behavioral Biology Building

The hole in the ground was already sizeable (approximately 300 feet long, 100 feet wide, and 20 feet deep), and some of the reinforcing steel had begun to rise. So, it was indeed too late to call the May 8 ceremony in behalf of Caltech's new behavioral biology building a "ground-breaking." It was even stretching a point to consider it as marking the beginning of construction, though that is what the function was called officially.

President Harold Brown presided for the gathering of trustees, faculty members, students, and other guests. Speakers included Arnold Beckman, chairman of the board of trustees, alumnus, and chief donor with Mrs. Beckman of funds to construct the new building; Nobel laureate George Beadle, trustee and former chairman of the division of biology; and the current chairman of the biology division, Robert Sinsheimer, who spoke of the hopes and plans for activities in the new building. "We will seek to couple the mind to natural science: behavior to currents, thoughts to circuits, emotions to molecules. We will seek to explain perception and memory, logical analysis and emotional impulse, the roots of motivation and the springs of action. In good time we may even learn to ask intelligent questions as to how the brain turns currents into will, as to how noiseless currents can become sound, and invisible impulses become sight and color."

Sinsheimer also presented Beckman and three of Caltech's pioneers in behavioral biology—C. A. G. Wiersma, professor of biology; Anthonie van Harreveld, professor of physiology; and Roger Sperry, Hixon Professor of Psychobiology—with souvenirs of the occasion. These were plastic replicas of the human brain elegantly mounted in polished wood boxes—gifts that elicited the quick quip from Brown that everyone present had, of course, an original version.

President Brown closed the ceremonies by presenting the Beckmans with a watercolor by Hunt Lewis of the Court of Man as it will look when it is completed, with Beckman Auditorium on the north, the Donald E. Baxter, M.D., Hall of Humanities and Social Sciences on the east, and the behavioral biology building —a virtual mirror image of Baxter— along the west side of Beckman Mall.

The new building, designed by architect Robert Alexander and scheduled for completion in the summer of 1973, will have three floors above ground and one below. It will provide offices, laboratories, and other facilities for 9 professors, 30 postdoctoral fellows, 30 graduate students, and several technicians. There will also be an instrument room, animal quarters, stockroom, and an electron microscope facility.

Arnold Beckman, chairman of the board of trustees, was honored at special ceremonies marking the beginning of construction of the behavioral biology building. He received a plastic reproduction of the human brain.

Public Lobbying Conference

John Gardner was the keynote speaker on May 6 for the "Design for Public Lobbying" conference held at Beckman Auditorium, a conference jointly sponsored by the Caltech Y and the Planning and Conservation League (a California-wide lobbying organization for environmental protection).

Gardner is a familiar and much appreciated speaker for special occasions at Caltech. In 1966, when he was secretary of the Department of Health, Education and Welfare, Gardner was convocation speaker for Caltech's 75th Anniversary celebration; in 1968 he was the first recipient of the Institute's Robert Andrews Millikan Award, which is presented to outstanding citizens who have made great contributions to human welfare. Since 1970 he has been chairman of Common Cause, an organization that attempts to link the tradition of citizen action in this country with the skills of professional lobbying.

John Gardner

The theme of Gardner's recent address was that as a nation, as a species, and as inhabitants of this planet we are dealing with a series of interlocking revolutions —in transportation, communications, sources of energy, computers, and biology, for example—and they have put an almost unbearable strain on our social institutions. Yet those institutions resist change, or disintegrate rather than change, or change only under the impact of violence.

"I am not one of those who lust after institutional change for its own sake," Gardner said, "but I am interested in it to the extent that it will help us in solving the problems that history has handed us. Anyone who shares that interest must give primary attention to our political and governmental institutions."

The panel discussions during the rest of the conference featured state legislators and environmentalists analyzing prospects for legislation to protect the California coastline, the wild rivers of northern California, the Santa Monica Mountains as open space, and air quality.

MCA Award

Harry B. Gray, professor of chemistry, has been named one of four notable college chemistry teachers in the United States. The award, given by the Manufacturing Chemists Association, carries an honorarium of $1,000 and is considered one of the most important citations in the field of chemistry.

Gray is widely known as an educational innovator. At Caltech he has made major contributions to restructuring the chemistry curriculum, and his own teaching activities range from instructing freshmen to working with PhD candidates in his research area—the study of metalloproteins. He is the author of 135 papers and has written or collaborated in writing eight chemistry textbooks.

Two years ago Gray won the prestigious American Chemical Society Award in Pure Chemistry, and he recently received a Guggenheim Fellowship Award for 1972.

Rodman Paul

Harkness Professorship

Rodman W. Paul has been appointed Edward S. Harkness Professor of History. Paul is an alumnus of Harvard University, and taught both at Harvard and at Yale before coming to Caltech as an associate professor of history in 1947.

A native of Philadelphia who was raised near Boston, he has nevertheless turned out to be someone who takes the West and its history seriously. His research covers the Far West and the Great Plains in the period between the Civil War and World War I, with particular emphasis on the sociological importance of mining. His books include *California Gold, Mining Frontiers of the Far West,* and *The California Gold Discovery.*

Paul is the third Caltech historian to be named to the Harkness professorship. William Bennett Munro held the chair from 1940 until 1945, and J. E. Wallace Sterling from 1945 to 1948.

Hammond Appointed Vice Chancellor at UC Santa Cruz

George Hammond, Arthur Amos Noyes Professor of Chemistry and chairman of the division of chemistry and chemical engineering, is leaving Caltech on July 1 to become vice chancellor of natural sciences at UC Santa Cruz. In his new job, Hammond will oversee the operation of one of the three main areas of the UCSC program—the other two being humanities and social sciences.

The natural sciences division at Santa Cruz is responsible for undergraduate major programs in biology, chemistry, earth sciences, information and computer sciences, mathematics, and physics. It provides PhD programs in astronomy and astrophysics, biology, chemistry, earth sciences, mathematics, and physics. In addition, the facilities and support for the advanced research conducted by the science faculty are administered by the division. The vice chancellors at Santa Cruz play a key role in working out the unusual relationships that arise as a consequence of the dual organization of the faculty who are both fellows of the individual colleges and members of the university boards of study.

Hammond's notable scientific achievements and growing interest and participation in the educational process give him impeccable credentials for just such a job and just such an opportunity. He has made distinguished contributions to scientific knowledge through his research in photochemistry. His work on the transfer of electronic excitation energy from one molecule to another, where light is absorbed by one species and the chemistry is done by another, has led to his being called the "father of modern photochemistry." In 1968 he received the American Chemical Society's James Flack Norris Award in Physical Organic Chemistry for his research on the mechanisms of photochemical reactions.

Through public lectures, writing, and restructuring of both individual courses and entire undergraduate curricula, he has made a considerable impact on the education of thousands of students in the United States and abroad. Last fall the Danforth Foundation awarded him the 1971-72 E. Harris Harbison Award for Gifted Teaching.

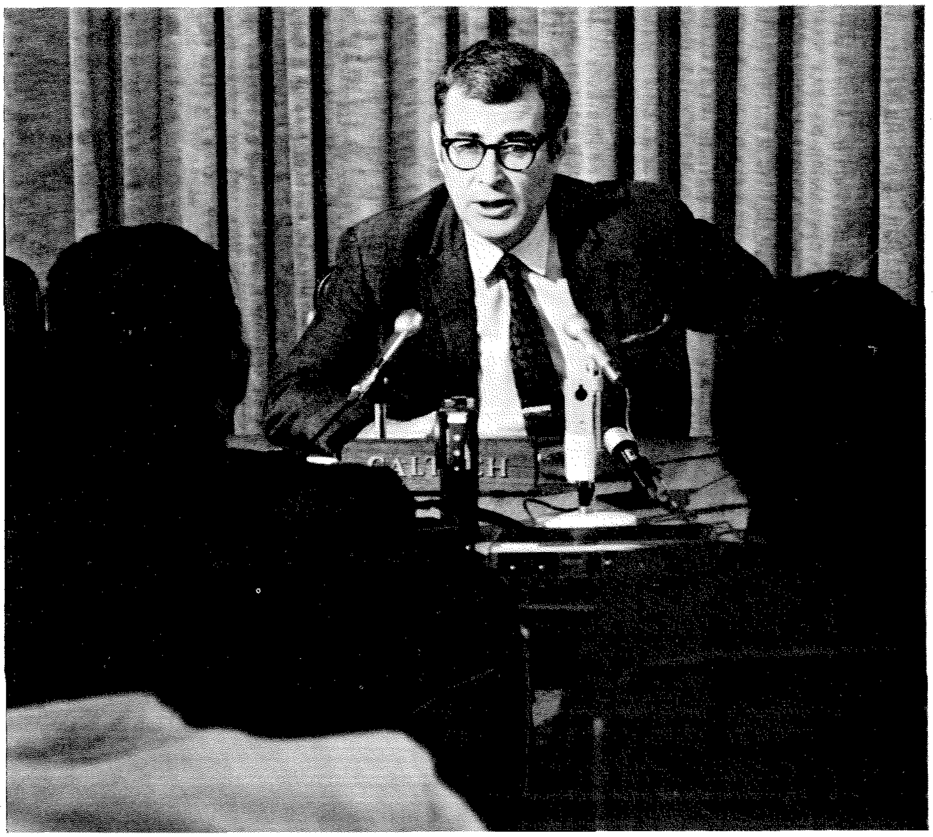
A consultant to textbook publishers and on the editorial boards of several scientific publications, Hammond is also author or co-author of five books and more than 200 articles, talks, and papers. He writes and speaks not only about the educational process but also about the problems of "future shock" in science, where acceleration in the rate of growth of knowledge creates a demand for painfully rapid change in styles and goals for scientific research.

George Hammond

Among the abilities that are likely to stand him in good stead at UCSC are his talent for looking in new ways at old problems and for communicating with his students both personally and professionally. On May 3 he demonstrated these skills to more than 200 high school science teachers and students at Baxter Lecture Hall. He concluded his talk—"A Scientist's Thoughts About Science"—by saying: "In summary, I find science intensely interesting, and the core of it is what goes on in the minds of people as they think about the way the world behaves. They construct mental models and study their behavior, either in their minds or with the aid of mathematical analysis. They do experiments—both wisely and unwisely chosen and, ordinarily, biased—and they exert judgment about the results. Their interpretations are not final but personal—and that's what science is.

"Now, I think that some people feel that if you level with students and tell them that this is what science is all about and this is how it works, they'll reject it. I don't think this is true at all; the students I know are usually relieved to learn about the very deep human element that goes into all of the scientific operation.

"It seems to me that this is a very thrilling and exciting thing about science: to realize that in scientific practice there is—as a regular part of the routine—a very personal and very human kind of activity. Of course there are uncertainties in the operation every step of the way. So, why not face them and enjoy the fact that science goes on in the minds of men? That concept should put to rest the creeping image of science in our society that makes science sound like a monster mechanical intellect in which people are simply cogs making technical contributions."



Brown on SALT

As president of Caltech since 1969, Harold Brown has had an exacting enough job even without the one he has also been carrying for most of that time as chief technical adviser of the U.S. delegation to the Strategic Arms Limitation Talks (SALT). But all that commuting between Pasadena and Helsinki and Vienna paid off handsomely when the signing of a nuclear arms limitation pact was announced in Moscow on May 26. Brown met with the news media at Caltech the next day and commented on the pact as a very important first step in the stabilization of the "balance of terrors" between the two nuclear powers. The agreement places a qualitative limit on the numbers of offensive and defensive missiles each side can have. "By doing this," he said, "and by enhancing communications between the American and Soviet governments, President Nixon and the Russian leaders have reduced the risk of turning this planet into a thermonuclear inferno. I consider this agreement to be one of the most rewarding things I have ever been involved in."

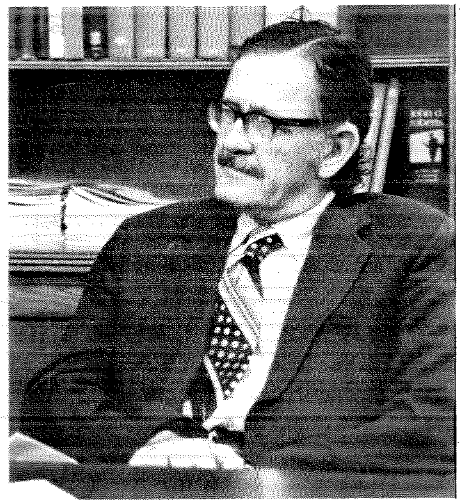
Awards to Sperry

Roger Sperry, Hixon Professor of Psychobiology, has spent a pleasant part of May and June receiving awards for his notable scientific achievements. In May he received the California Scientist of the Year Award from the California Museum of Science and Industry. He was cited for "his research into the functional organization of the mammalian brain where cerebral surgery, accident, or congenital conditions have eliminated communication between the left and right hemispheres. He has shown that each of the surgically separated hemispheres has a distinct mind of its own, and in man, each its own specialized mode of thinking and perceiving. His findings have advanced our understanding of the relationship of conscious awareness to brain activity."

Sperry, the sixth Caltech faculty member to receive this award in the 15 years since it was established, is a graduate of Oberlin College. He received his PhD from the University of Chicago in 1941, and held positions at Harvard, the Yerkes Laboratory of Primate Biology, the University of Chicago, and the National Institutes of Health before coming to Caltech in 1954.

Early this month Sperry received an honorary degree of Doctor of Science *honoris causa* from Cambridge University in England.

The National Paraplegia Foundation is also honoring Sperry this month. He is co-winner (with William F. Windle, professor of biology at Denison University) of the first William Thomson Wakeman Basic Research Award for work that may contribute toward an eventual successful treatment for paraplegia. Of particular interest in this context is Sperry's research on factors responsible for functional regeneration in the central nervous system and his development of concepts of chemical selectivity in nerve growth and connection.



John Roberts

A Second Institute Professor

John D. Roberts, professor of organic chemistry, has been singled out for distinction twice recently, and in each case he was the second member of the Caltech faculty to be so honored. Last month he was appointed the second Institute Professor. (Physicist William A. Fowler became the first Institute Professor in 1970.) In March Roberts received the William H. Nichols Medal of the American Chemical Society—32 years after Linus Pauling, professor emeritus of chemistry, received it.

Roberts is known for his study of reaction mechanisms, that part of chemical dynamics devoted to understanding the ways the atoms in molecules reorganize during chemical change. He has been a pioneer in the use of nuclear magnetic resonance to determine the structures of complex molecules and very fast molecular reactions. Although he is primarily an experimentalist, he has been active in bringing theory within the reach of chemists through a series of small books dealing with molecular quantum mechanics and theories of nuclear resonance. He also is the principal co-author of a widely used textbook of organic chemistry, and has published more than 300 technical papers.

A member of the National Academy of Sciences, the American Chemical Society, and the American Academy of Arts and Sciences, Roberts received the ACS Award in Pure Chemistry in 1954 and the 1967 Roger Adams Medal and Award in Organic Chemistry. He came to Caltech from MIT in 1953, and served as chairman of the Institute's division of chemistry and chemical engineering from 1963 to 1967.

Haagen-Smit Reaps Rewards

A. J. Haagen-Smit, professor of bio-organic chemistry emeritus, continues to receive awards even in retirement. A recent one is the first Frederick Gardner Cottrell Award for Environmental Quality. The Cottrell Award—a cash prize of $5,000—was presented to Haagen-Smit in April at the annual meeting of the National Academy of Sciences in recognition of his "highly innovative studies on the formation of smog and . . . untiring efforts to shape the air pollution control policies of the nation."

The Cottrell Award was recently established in the National Academy of Sciences by Research Corporation—a foundation for the advancement of science. Frederick Gardner Cottrell was the inventor of the first practical electrostatic gas-cleaning process and founder of Research Corporation. The award will be presented annually.

Another recent award to Haagen-Smit was the Honor Scroll of the American Institute of Chemists, given for his work on plant hormones, essential oils of plants, and atmospheric chemistry. And on June 24, he was named "Man of the Year" by the Achievement Rewards for College Scientists group.

Morale Builders

David Smith, Caltech's master of student houses, has been diverting the undergraduates this year by importing occasional live entertainers to perform on the Olive Walk. The last offering of the year, during finals week, consisted of fifteen belly dancers who drew a large and joyous crowd. A record number of seniors graduated with honors.

Letters

That Hughes Steam Car Keeps on Rolling Along

Yucca Valley

EDITOR:

Professor Daugherty's summary of the Burns and Lewis attempt to develop a steam car for Howard Hughes (*E&S*, March-April) is pretty darned good, considering that he wasn't directly involved and this all happened over 40 years ago. Since I *was* directly involved, I would like to add a few details.

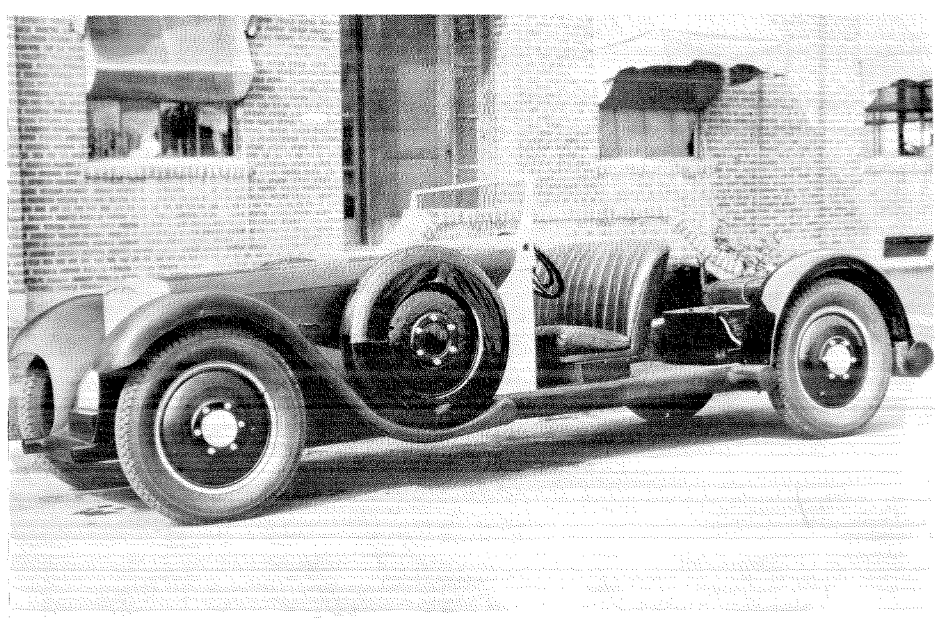
The first full year on the project, 1926, actually was spent in Houston. The first year in Hollywood, 1927, was under the name "Burns and Lewis" (the Hughes passion for secrecy). Dun and Bradstreet broke that down; their clients demanded to know how these two young squirts could afford to buy all that machinery! The name was changed to Hughes Tool Company, but that led to confusion with the Los Angeles branch of the parent company. Finally, Hughes Development Company was chosen. Lewis was manager, Burns chief engineer, and Mrs. Burns acted as part-time secretary.

When Lewis was assigned to Multicolor, he took Mrs. Burns with him. Burns continued to run the Development Company, building most of the film-processing equipment for Multicolor. After the Multicolor plant went into operation, Burns was brought in as research director.

In November 1931 Hughes brought in some Hollywood film laboratory people, and Lewis and Burns were swept out into a full-fledged depression. Mrs. Burns was kept on as purchasing agent and secretary to the new president and new general manager to show them what should be done. A few months later, Hughes let the whole operation go into receivership.

As for the steam car, the finished product was not satisfactory. We attempted to meet Howard's reported requirements, and we failed. There are people today who have spent ten times as much as we did and had to give up. No discredit to them either. The immutability of nature's laws remains intact; the goals were impossible.

BRUCE BURNS, '19



Bruce Burns, '19, and Howard Lewis, '23, completed this version of the Hughes Steamer in late 1929. Contrary to published reports, the car is not "one big radiator" with condenser tubes through everything, including the doors. On this version, driven by Hughes, there were no doors and the entire power plant was forward of the firewall.

Los Angeles

GENTLEMEN:

I think your readers are entitled to have my version of the Howard Hughes steam car. It is all in my book *Howard, The Amazing Mr. Hughes* and I can substantiate every statement I made.

Dr. Milikan may not have known Burns and Lewis, but it was through his good offices that they were put in contact with Hughes. Daugherty, in his article in your March-April 1972 issue doesn't deny that Dr. Milikan was the president of Caltech in 1925 or that Hughes was in contact with him. The initial call was from Howard to Dr. Milikan and I was present when he made the call.

Howard acquired both the Stanley Steamer and a Doble after his father's death in 1924. He did not lose interest in the Burns & Lewis project until the prototype was completed. It was built on the chassis of a French car with individual wheel suspension and a tubular frame. Hughes and I inspected the completed car just as I described it in my book. Burns & Lewis were both there and Burns can verify this.

Burns & Lewis were not "switched to work on the thief proof lock" as Daugherty indicated. They were transferred to the film coloring process at Multicolor, Ltd. Contrary to Daugherty, the manager was not Lewis but A. A. MacDonald who was transferred from Hughes Tool Co. When Multicolor went into bankruptcy Burns and Lewis both left Hughes' employ. They did not "jump from project to project" in the Hughes empire. During the period they worked on the steam car they also worked on a wire recording system but not after the car was junked.

NOAH DIETRICH

HOW CAN A SHEET OF SILICONE RUBBER HELP TURN A TEN-YEAR-OLD INVALID INTO A TEN-YEAR-OLD ATHLETE?

A few years ago, General Electric engineers developed a silicone copolymer rubber with some remarkable properties.

It's a membrane that permits the rapid exchange of oxygen and carbon-dioxide molecules.

So it's made a revolutionary new artificial lung possible. The GE Peirce lung™ oxygenates blood in much the same way the human lung does.

That's a major engineering accomplishment. But that's not the reason it's important.

The GE Peirce lung works with a minimum of disturbance to blood cells. So it can be used safely much longer than conventional lung machines. Days instead of hours.

That extra time may be what a doctor needs to repair the defective heart of a child. To open the clogged arteries of an adult. Or to save the life of an accident victim whose lungs give out.

That extra time may be all it takes to help put thousands of those invalids back on their feet.

It's a pretty clear example of how a technological innovation can help solve a social problem. A lot of times, the effect of technology on society is rather direct.

That's why at General Electric, we judge innovations more by the impact they'll have on people's lives than by their sheer technical wizardry.

Maybe that's a standard you should apply to the work you'll be doing. Whether or not you ever work at General Electric.

Because, as our engineers will tell you, it's not so much what you do that counts. It's what it means.

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