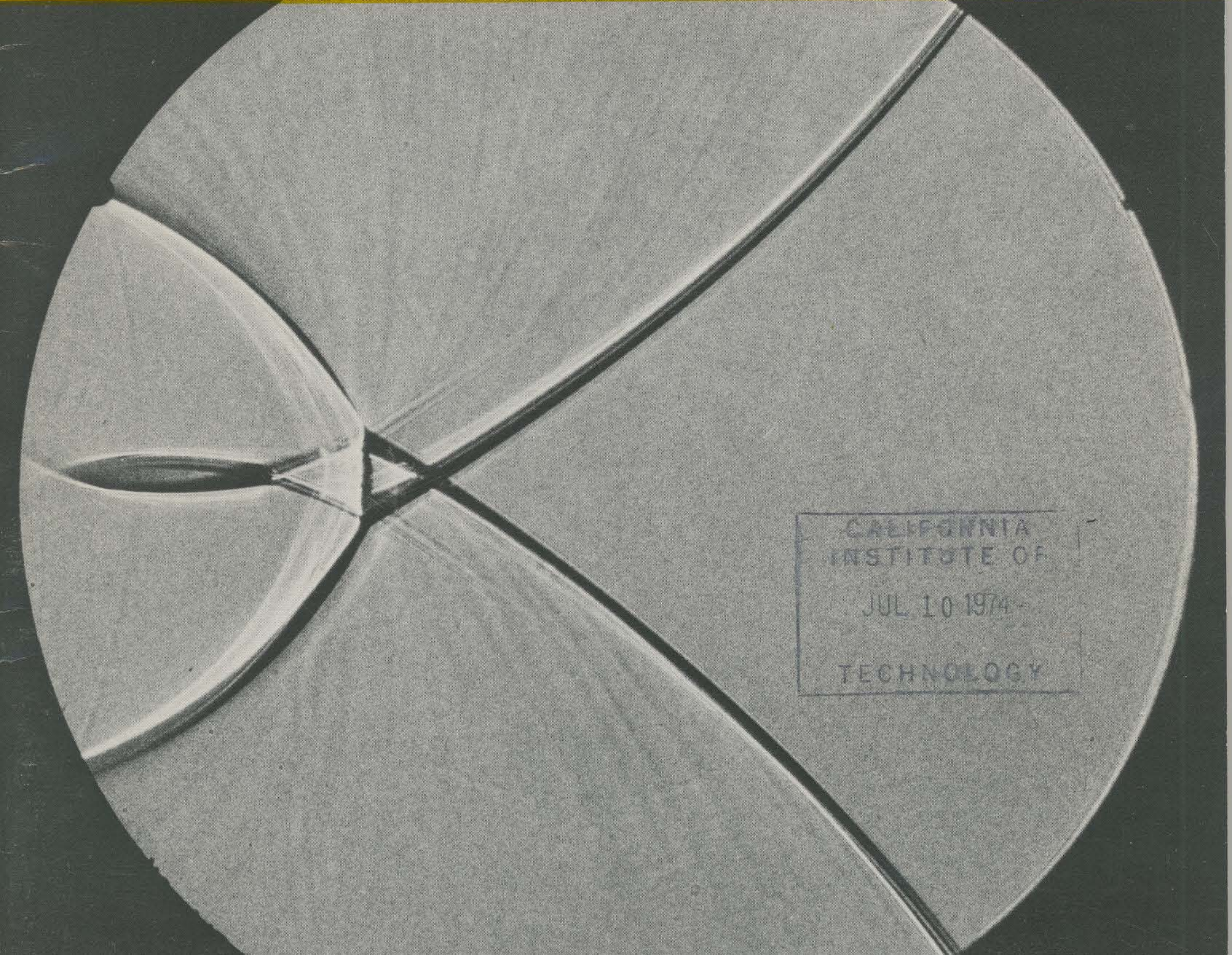
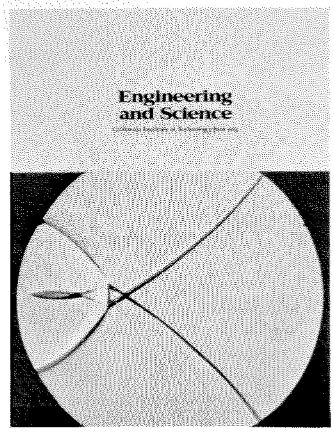
Engineering and Science

California Institute of Technology/June 1974



In This Issue



Grand Slam

On the cover—a portrait of a sonic boom. In this case a *focusing* sonic boom has been simulated in the 17-inch shock tube in Caltech's Graduate Aeronautical Laboratories. The shock wave has come in from the right, and has been reflected back from a curved wood surface. In this shadowgraph, the wave is 0.11 milliseconds old, and is shown coming out of the focus, leaving behind (at the left) a hot blob of gas that was heated at the focus. On page 14, more on this aeronautics research project in "Sonic Booms."

For further information about the articles and authors in this issue of *E&S*, please turn to the inside back cover.

TO OUR READERS

We are sorry to say that rising costs have forced us to change our publishing schedule, starting with the October 1974 issue. Instead of seven issues a year we will now publish quarterly–

October-November

December-January

February-March

April-May

Despite this schedule change, current subscriptions will continue through seven issues.

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Engineering and Science

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Medical Genetics and the Engineering of Man

Most technologies alter the conditions under which man lives—but biomedical technology can modify man himself

Recent advances in biology and medicine provide us with the power to modify and control the capacities and activities of men by direct intervention and manipulation of their minds and genes. Biologists and physicians disagree on the extent to which this "human engineering" is and will become a reality, but they agree that it is already beginning to have profound ethical and social consequences.

The impact these technologies will have on mankind is in part derived from the fact that they operate directly on man himself. The technologies of energy, transportation, communications, and food production admittedly alter the conditions under which man lives. In contrast, biomedical technology can modify the user himself; the engineer can for the first time engineer himself. The social and ethical questions thus created center about whether we should continue to develop and practice human engineering, what limitations we should impose, who should make these decisions, and what sets of values and other considerations should enter into them. The nature of these questions can be graphically illustrated by this case study:

A mongoloid with an intestinal obstruction was born to professional parents in Maryland. The parents refused permission for the surgery that would enable the infant to survive, deciding that it would be unfair to their two normal children to bring a mongoloid into the home. Doctors at Johns Hopkins Hospital in Baltimore sought help from the courts, which in Maryland have the power to appoint a guardian who will authorize necessary medical care for a child when parents refuse. A senior member of the judiciary advised the doctors that the courts would not force the parents—or society—to bear the burden of rearing such a child. Accordingly, the baby's bassinet was wheeled into a dark corner of the nursery where in 15 days the child became dehydrated enough to die a "natural" death.

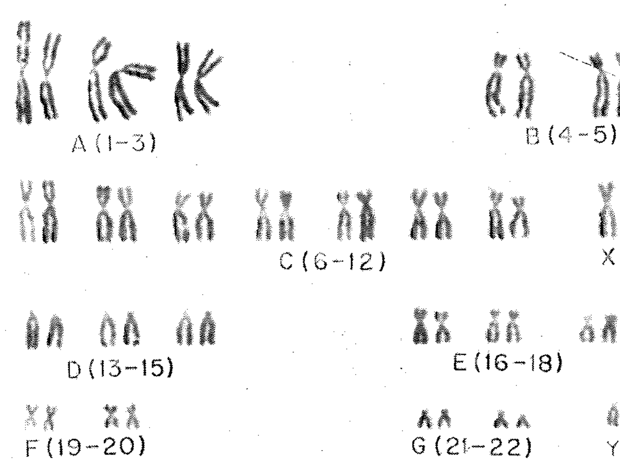
Modern medical technology has developed the life-saving operation for the removal of this intestinal obstruction in the last ten years. Prior to that time this infant would have died, and the life-or-death decision would not have arisen. Thus each advance in modern medical technology can present us with new and difficult social and ethical dilemmas.

This case and others like it raise a number of interrelated questions. Is the decision appropriate? Who should make these decisions? What is the process whereby these and similar decisions can be made?

Some aspects of modern medical genetics are of practical importance now (genetic counseling and genetic screening); others will gain importance in the future as new technologies are developed (*in vitro* fertilization and gene therapy). These technologies can alter the genetic fabric of society in two ways: First, certain constellations of favorable (or unfavorable) genes can be selectively expanded or deleted, thus altering the nature of the gene pool of the population as a whole. Second, in the future, man will develop the technology to alter his genes by direct modification. Either of these activities can have serious consequences for mankind and man's image of himself.

Human genetic disease

To appreciate the impact genetic technology can and will have on our lives, it is important to explain in general



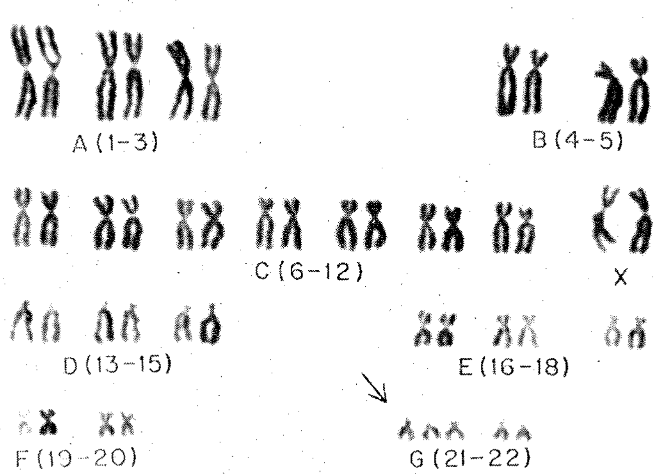
Normally, the 46 chromosomes of a human cell appear in random orientation in a microscopic slide, but in this display—called a karyotype analysis—they are organized into pairs numbered from 1 to 22, plus two single sex-determining chromosomes labeled X and Y. The pairs are collected into groups (lettered A through G) on the basis of size similarities. Because both an X and a Y chromosome are present, it is apparent that this karyotype is of a cell from a human male.

by LEROY E. HOOD and ROBERT J. MACKIN JR.

terms the nature of genetic disease, of which modern medicine has defined close to 2,000 different kinds—most of them quite rare. But there is a genetic component in the diseases of 25 percent of the children who are currently hospitalized.

To understand the nature of genetic disease we must first consider the 23 pairs of chromosomes that are the blueprint repositories for all of the information necessary to construct the human organism. One chromosome from each pair is derived from the father and the second from the mother. There are two sex chromosomes, X and Y. A female has two X chromosomes whereas a male has an X and a Y chromosome. The information in each chromosome is subdivided into smaller units that are called genes. Each gene codes one unit of information. Genetic disease can, accordingly, be of more than one type.

First, there may be abnormalities of the chromosomes themselves—extra chromosomes, missing chromosomes, or detectably altered chromosomes. (The mongoloid child discussed earlier is one example of a chromosomal abnormality which is caused by the presence of one extra copy of a small chromosome). Chromosomal abnormalities nearly always lead to serious physical and mental derangement.



This karyotype differs in two important respects from the previous one. First, it shows two X and no Y chromosomes, indicating that the cell is derived from a female. Second, the arrow points to an extra chromosome in the G group, an abnormality that is the most frequent cause of mongolism.

A second type of genetic disease is caused by defects (mutations) in individual genes. An example is sickle cell disease, wherein a gene that codes for a component of the oxygen-carrying blood protein, hemoglobin, is defective. As a result, low oxygen levels cause the hemoglobin molecule to change its shape and this in turn causes the red blood cells to change their shape (to sickle), which leads to blocking of the small blood vessels and the pathologic manifestations of sickle cell disease.

If the defective gene is present as a single copy (e.g., a defective gene is present on the paternal chromosome but a good gene is contributed by the maternal chromosome), usually the individual is clinically normal. He has what is termed a *recessive* genetic disease. For example, an individual with a single copy of the sickle cell gene leads a nearly normal life, in contrast to the individual with sickle cell disease who has two bad hemoglobin genes. It has been estimated that each of us carries from three to eight lethal recessive genes; these are genes that would kill us if both of our copies were defective. The increased probability of producing offspring with two identical defective genes is, of course, one reason why it is undesirable for closely related individuals to have children.

There are other classes of genetic disease or diseases with a genetic component. *Dominant* genetic disease—for example, Huntington's chorea—produces anomalies even when only one bad gene is present. Several other of mankind's most widespread diseases have a genetic component (cancer, arteriosclerosis) but also have other contributing factors.

Prenatal diagnosis

Some of the most striking social and ethical dilemmas presented by modern genetics come from new techniques that permit genetic disease to be diagnosed at a point in fetal development where abortion of the defective fetus is a possibility. These new diagnostic techniques combine the ability to withdraw amniotic fluid from the membrane sac surrounding the newly developing fetus (amniocentesis), the ability to grow fetal cells in tissue culture outside the living organism, and the ability to detect genetic defects through biochemical or chromosome analysis of the fetal cells.

Amniocentesis can be performed as early as 12-16 weeks of gestation, and it can yield enough cells for subsequent biochemical analysis of gene defects or karyotype analysis of chromosomal abnormalities. Once a particular diagnosis is made, the parents can decide whether or not to have the fetus aborted before 20 weeks of gestation.

Prenatal diagnosis can present parents and society with perplexing social and ethical dilemmas about whether or not to abort a genetically defective fetus. Gauge your reactions as a potential parent in the following cases which can be detected prenatally in adequate time for a safe abortion.

Would you abort these fetuses?

Case 1. Tay-Sachs disease is caused by a defective enzyme that leads to abnormal brain development. The child is born normal but quickly develops mental and physical abnormalities which rapidly progress and lead to the inevitable death of the child at 1 to 4 years of age. Obviously, the course of this disease is a traumatic experience from the viewpoint of a parent who sees an apparently healthy child deteriorate into a helpless vegetable, and finally die.

Case 2. Mongolism is a constellation of physical and mental abnormalities that is caused by the presence of an extra chromosome. Mongoloid children can have I.Q.'s that range from the low 20's up into the 70's. They are prone to a number of medical difficulties, such as repeated infections, and generally have a greatly shortened life span. Although many can learn simple tasks, mongoloids do not become independent members of society. These children generally have a happy disposition and are, some feel, quite loving.

Case 3. Another type of chromosomal abnormality consists of an extra male (Y) chromosome. The "XYY individual" has gained notoriety recently because certain studies on the inmates of penal-mental institutions have indicated their presence in such institutions at 50 times the frequency expected from their incidence in the general population. These statistics have led some investigators to infer that XYY individuals are prone to asocial behavior and as such are a destructive element in society. However, it must be stressed that this abnormality occurs at a frequency of about 1 per 1,000 births and, accordingly, there are many normal and functional members of society who are of this chromosomal constitution. Clearly the data on XYY individuals with regard to asocial behavior are very tentative and preliminary.

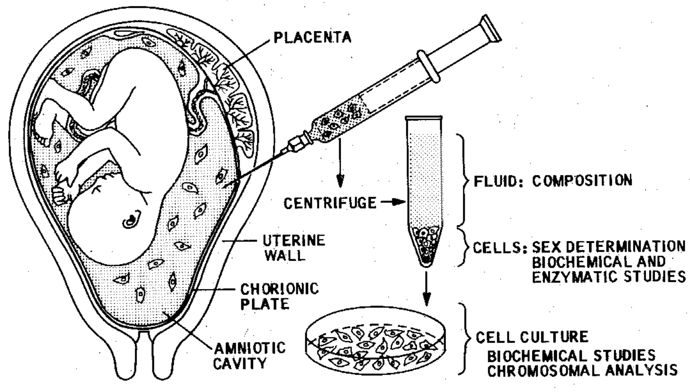
Case 4. Perhaps the most extreme possibility for abortion relates to the normal fetus that is aborted because of its sex. Suppose you are a parent with five girls and you want a boy. Prenatal diagnosis can establish the sex of a child in adequate time for a therapeutic abortion. Do you have the right to abort a normal female fetus in order to satisfy your desire for a boy?

The last two cases in particular illustrate the ever-present conflict between individual needs and societal needs. Should society protect itself against XYY individuals by detecting them at birth and providing them with special attention or treatment? Or does an XYY have the right to attempt to lead a normal life without the stigma of a mandatory chromosome analysis? Do parents have the right to opt for abortion if their child has such a defect? Is an XYY individual responsible for criminal behavior if this behavior is caused by a chromosomal abnormality that is beyond his control? Several such cases have appeared before the courts. In the other instance, should society tolerate a change in the sex ratio of infants just to accommodate the desires of individual parents?

These four cases raise very clearly the general nature and range of the personal moral and ethical dilemmas posed by prenatal genetic diagnosis. If you agree in any one of these cases that abortion is acceptable (and most individuals agree that abortion is desirable for Tay-Sachs disease), then a series of questions arise. What are the boundaries or limits of acceptable indications for abortion? Who makes these decisions? How? What information is to be given to other members of the family who may be carrying defective genes?

Genetic counseling

Three points should be made about genetic counseling and the current process of decision making as it relates to genetic disease. First, genetic counselors, even if they try, cannot transmit value-free facts to their patients because they are very much constrained by their own background and philosophy. Studies have established that the predispositions of genetic counselors greatly influence their patients' decisions, even when the counselors insist that they are not being directive. For example, one genetic



Amniocentesis is one type of prenatal diagnosis. A sample of fluid surrounding the fetus is taken by inserting a sterile needle into the amniotic cavity and withdrawing a small amount. This fluid, derived mostly from fetal urine and secretions, contains fetal cells, and the sample is centrifuged to separate the cells and fluid. A variety of tests can then be made. For genetic diagnosis, the optimum time for an amniotic tap is about the 16th week of gestation.

counselor may be very concerned about the potential contamination by defective genes of the gene pool in the population as a whole. Thus he may inadvertently counsel in such a fashion that his patients generally choose to abort defective fetuses. Another genetic counselor may be more concerned about the emotional and psychological strengths and needs of the family and counsel accordingly.

Second, the emotional trauma of having a defective child (or fetus) very often places the parents in such a state of emotional shock that education about the defect and subsequent rational decisions about a course of action are often impossible—sometimes for extended periods of time.

Finally, the genetic counselor often consciously plays a major, if not determinative, role in this decision-making process. Many feel this is justified by the frequent inability of parents to cope rationally with the problem or by their desire to relieve parents of the guilt feelings the decision may produce.

Clearly, certain of these decisions should rest with well-informed and thoughtful individuals who are themselves directly affected, and not with a single group in society—such as the medical profession. The critical question is, of course, how to determine when social rights have precedence over individual rights or desires. These decisions will affect the very nature of the gene pool that is passed on to future generations. A great deal of thought must be given to the consequences of various alternative courses of action and to the process whereby these decisions are made.

It is important to stress that the prenatal diagnosis of genetic disease may be made even more routine and inexpensive in the future. Effective new techniques such as the staining of chromosomes with fluorescent dyes generate complex and characteristic banding patterns for each chromosome, which will permit a much more refined analysis of its structure. New devices are being developed—at Caltech's Jet Propulsion Laboratory and elsewhere—for the automatic and computer-aided analysis of large numbers of chromosomal karyotypes. And, finally, it may be possible that amniocentesis can some day be replaced by a simpler test of a small amount of the mother's blood. This possibility is based on the recent development of a device that can apparently separate a small number of fetal cells normally present in the maternal circulation from their maternal counterparts, for culturing and subsequent biochemical and karyotype analysis.

As these developments make prenatal genetic analysis increasingly simple and inexpensive, more and more widespread prenatal screening becomes a tempting option. New classes of questions emerge as screening programs begin to involve large segments of the population.

Genetic screening programs

Current genetic screening programs are designed to test large groups of individuals with special predilections for the presence of one (or two) defective copies of particular genes. The screening program for Tay-Sachs disease that has recently been carried out in the Baltimore area and is now being started in Los Angeles is an example of a useful application of this procedure. The defective gene for Tay-Sachs disease occurs ten times more frequently in certain Jewish populations (where 1 in 30 individuals carries the defective gene) than in other population groups. This defect can be detected in individuals with a single bad gene (carriers) by a simple biochemical test made on a small blood sample. It is useful to identify normal-appearing carriers of this disease because when two such individuals marry, the chances are one in four that an offspring will carry the two defective genes causing Tay-Sachs disease. Thus the pregnancies in any such marriage can be monitored by amniocentesis and afflicted fetuses aborted, if desired.

In contrast, the many recently initiated sickle cell screening programs are of questionable usefulness and, indeed, appear to invite some very dangerous consequences. This genetic disease occurs almost exclusively in one group, the blacks; there, one individual in ten carries a sickle cell gene. This sickle cell carrier (said to have "sickle cell trait") can readily be detected, once again, by a simple biochemical test of the blood. Although it is a matter of some current controversy, the carrier appears to be an essentially normal individual. The individual with sickle cell disease (two bad gene copies) is detected early in life through repeated sickle cell crises. This is an extremely debilitating disease, and afflicted individuals rarely live beyond their twenties.

Since sickle cell disease cannot be detected by prenatal diagnosis, and since there is currently no effective treatment for this disease, the usefulness of this screening program is not apparent. While it appears that few, if any, positive medical benefits accrue from this screening program (except for appropriate counseling regarding the marriage of two carriers), there are a number of dangerous side effects. Many states now require sickle cell screening to be carried out on all blacks by the time they are of school age, and this brings about two types of difficulties. First, it is hard to explain to the public at large the difference between sickle cell *disease* and sickle cell *trait*. Children with the trait, who can lead perfectly normal lives, are often categorized by parents and friends as sick, and these children rapidly become psychological cripples. Second, insurance companies and employers have on occasion obtained these genetic records and used them to the detriment of both those with sickle cell trait and those with sickle cell disease.

continued on page 30

Good Nutrition for the Good Life

by LINUS PAULING

It is possible by rather simple means, essentially nutritional, to increase the length of life expectancy and also the length of the period of well-being

I believe that it is possible by rather simple means, essentially nutritional, to increase the length of life expectancy for young people and middle-aged people (and to some extent, perhaps, old people too) by about 20 years. Not only can the life expectancy be increased, I believe, but also the length of the period of well-being can be increased by the same amount, or perhaps even a little longer; because it is likely that, as long as the process of aging goes on, the process of deterioration that culminates in death will proceed more rapidly at a late age than an earlier one.

The principal procedure to use is that of introducing nutrient substances into the human body in the optimum amounts. Take the vitamins, for example. We have in the United States a committee called the Food and Nutrition Board that is described as consisting of outstanding nutritional scientists, which makes recommendations to the people about the intake of vitamins and minerals. These recommendations are made for vitamins in the amounts that will prevent overt manifestations of avitaminosis for most people—95-99 percent of the people.

For example, for vitamin C, the studies that have been made with a rather small number of human subjects show that 10 milligrams a day is enough to prevent overt manifestations of scurvy from developing over a period of several months, or years even—the time it takes scurvy to develop for people on a scorbutic diet—and 45 milligrams might be enough for most adults, even taking into account their biochemical individuality. It is true that Roger J. Williams—who discovered one of the D vitamins, pantothenic acid—has suggested, on the basis of studies with guinea pigs, that the amount required for good health varies by a factor of 20, probably even among guinea pigs, and by even a greater factor among human beings, who are more heterogeneous genetically than the guinea pigs that he was using. There may well be some people who will become prescorbutic, with only 45 milligrams per day.

About 40 years ago, Albert Szent-Györgyi, who in 1928 made the first preparations of ascorbic acid, which turned out to be vitamin C, asked the question, What is the amount of vitamin C that would lead to the best of health for human beings—not just the amount that prevents them from dying of scurvy, but the amount that would lead to the best of health? He apparently decided that 1,000 milligrams a day might be a reasonable estimate, because he started taking 1,000 milligrams a day himself, and I think rather recently has increased his intake to 2,000.

This is a question that has been essentially ignored by the Food and Nutrition Board, not only for vitamin C but for all other vitamins too. It has been pretty much ignored by nutritional scientists as well; yet it is an important question. One way in which we might try to answer it is to ask, What amounts of various vitamins did human beings or their predecessors receive from the natural foods they were eating? It may be that at some time our predecessors were vegetarians rather than meat eaters, or catholic eaters—meat, vegetables, and so on. But in checking raw natural plant foods for the average amount of vitamin C in them, I found that for 110 foods the average amount in a day's ration of the various vitamins came out between two and five times the recommended daily allowance of vitamin A and thiamine and riboflavin and pyridoxine.

This, I think, suggests that the optimum intake of these vitamins might be two to five times the recommended daily allowances, but it is no more than a rough suggestion. On the other hand, for vitamin C the amount came out 55 times 45 milligrams, the currently recommended daily allowance. I think that this calculation is significant,

and it may well be that the daily recommended allowance of vitamin C should be much larger than the present value, and that the optimum intake is in the neighborhood of several grams a day, rather than a few tens of milligrams a day.

In 1949 G. B. Bourne, an English biochemist, was engaged in discussing the question of what the British recommended daily allowance of vitamin C should be—10 milligrams per day or 20 milligrams per day. Bourne pointed out that the bamboo shoots and other foods eaten by gorillas in the wild state contain about 5 grams of vitamin C, corresponding to something like 2 grams (2,000 milligrams per day) for a human being, taking the smaller body weight into consideration, and he asked the question, Should we not, instead of discussing whether 10 milligrams or 20 milligrams is the right amount to recommend, be discussing whether 1,000 or 2,000 milligrams is the right amount?

Irwin Stone, a biochemist from Staten Island, who now lives in Mountain View, California, collected information about vitamin C over the years and in 1965 and 1966 published four papers on "Hypoascorbemia, a Genetic Disease." He contended that the human race as a whole has been suffering from a deficiency in the intake of ascorbic acid and from a disease that he named hypoascorbemia, too small a concentration of ascorbic acid in the blood.

He gave several arguments to support his contention. For one thing, plants manufacture vitamin A, vitamin B_1 (thiamine), vitamin B_2, B_6, and other vitamins for themselves. Animals require these substances exogenously, and we can ask why. I think the answer is this: In the early days of the existence of animals, they had inherited from their plant ancestors the machinery for making these important substances. But they were eating plants, and the plants manufactured these substances, so they were getting a supply of them in their food. It may well be that the amount of vitamin A that animals were getting was just about as much as they needed—close to the optimum. Now if a mutant came along that had suffered a genetic deletion, losing the genes that are involved in producing the enzymes that catalyze the reactions leading to the synthesis of vitamin A, the mutant would still have vitamin A from his food, but he would be a streamlined animal, not burdened by the machinery for *making* vitamin A, and in the competition with a more slowly moving competitor who was handicapped by this machinery, he would win out. The situation would be the same with thiamine, riboflavin, pyridoxine, and other vitamins. I believe that this is what happened, and that this is why all animals require the vitamins.

But this didn't happen with vitamin C. The dog, the cat, the rat, the mouse, and other animals make their own vitamin C. Only human beings and their close relatives require exogenous vitamin C, and a few other animals such as guinea pigs. The reason, I would say, is that there isn't enough vitamin C in the plant food. For one thing, vitamin C is required for the synthesis of collagen, the connective tissue in animals. Plants don't synthesize collagen, so far as I am aware. They use cellulose for connective tissue. There's an extra need for ascorbic acid among animals. The fact is that these animals did not give up the power to make ascorbic acid—and I calculated 2,300 milligrams per day as the amount available in a diet for man of raw natural plant foods. This, I would say, surely means that the optimum intake for man is greater than 2,300 milligrams a day.

But human beings and anthropoids all require exogenous vitamin C. What happened? I think with little doubt that these are not separate mutations for human beings and gorillas and rhesus monkeys and other primates, but rather a single mutational loss—a common ancestor 25 million years ago, living in a tropical valley where the fruit foods were especially rich in vitamin C (providing 10 or 15 grams per day for a body weight of 70 kilograms), underwent a mutation. The mutant lost the machinery for making the vitamin C and was correspondingly streamlined and able to compete and as a result the mutant won out and we are all descended from this mutant, who suffered this unfortunate accident. As long as our ancestors stayed in this area they were getting enough vitamin C. When they moved into temperate and sub-arctic regions, the food available contained less vitamin C, and they began to suffer from scurvy.

One measure of good health is resistance to disease. There have been about a dozen carefully controlled studies carried out on a comparison of vitamin C tablets and placebo tablets in blind trials, with respect to the incidence and severity of the common cold. Every one of these studies carried out with people exposed to cold viruses by casual contact with other people has shown that vitamin C has protective value. There is no doubt about it. In fact, if, in addition to taking regular doses of vitamin C, you carry a supply with you and increase the intake at the first sign of a cold, or even other illness, taking 10 to 20 grams during the first day, and then tapering off, you can stop the cold. Many cold medicines make you feel better, but they don't prevent the cold from developing. Vitamin C will do this. Not only that, but vitamin C prevents other diseases.

In 1965 it was reported by Claus W. Jungeblut, working in the College of Physicians and Surgeons at Columbia University, that concentrations of vitamin C that you can produce in the blood plasma by taking the substance in good amounts will inactivate poliomyelitis virus, so that when this virus is exposed to the solution for half an hour and then injected into the brains of monkeys the monkeys do not become paralyzed, although monkeys treated with virus that has not been activated in this way get paralysis. Also, monkeys given large doses of vitamin C did not become paralyzed, and those receiving small amounts did. Jungeblut and others also reported that inactivation of other plant and animal viruses could be effected by treatment with vitamin C, and Japanese workers have published a half-dozen papers during the last three or four years on inactivation of bacterial viruses by vitamin C.

About a year ago Hume and Weyers in Scotland reported in the *Scottish Medical Journal* on the protection against bacterial diseases by vitamin C. It had been known for several decades that the white cells, leucocytes, are effective phagocytes (that is, with the ability to engulf bacteria) only if the leucocytes contain 20 micrograms per 100 million cells or more of vitamin C. Hume and Weyers found that people in Scotland eating an ordinary Scottish diet with perhaps 15 or 20 milligrams per day of vitamin C had an average of 20 micrograms in their white cells. When they caught cold, the value dropped in the first day to 10 micrograms and stayed that way for three days, and then began slowly to rise. That's below the limit at which the leucocytes have phagocytic activity. By giving extra vitamin C—1,000 milligrams per day, and 8 grams per day when the person caught cold—this effect was averted. The concentration was 30 micrograms per 100 million cells and it dropped to no less than 24, so that the phagocytic activity was retained. This explains why people who take vitamin C, even if they catch cold—a viral cold—do not get a secondary bacterial infection, in general.

Vitamin C seems to be valuable in many different ways. Constance Spittle, a pathologist in England, reported that she had been monitoring her own serum cholesterol,

A one-pack-a-day smoker has twice as much chance of dying of heart disease as a nonsmoker, and a two-pack-a-day smoker has four times as much chance

which ran about 210 milligrams per deciliter. Then she began taking about 1 gram a day of vitamin C and found that her serum cholesterol dropped to 130 micrograms per deciliter. She found a similar effect in over 50 subjects.

About 15 years ago I gave a Friday Evening Lecture at Caltech on aging and death. In this talk I mentioned the Englishman, Gumpertz, who 150 years ago showed that the age-specific death rate is a logarithmic function of chronological age. Take a population and determine the rate at which people are dying, and plot the logarithm of the death rate against the age. You get a straight line from about age 30 on. The slope of the line is such that there is a doubling of the death rate for every 8 years' increase in chronological age.

If you take two populations—for example, the population of nonsmokers in the U.S. and the population of one-pack-a-day cigarette smokers—you have a Gumpertz curve that has shifted by 8 years toward lower ages. (The two-pack-a-day curve shifts by 16 years toward lower ages.)

If you plot the death rate by coronary heart disease alone, for smokers and nonsmokers, you find a similar shift of 8 years, doubling the age-specific death rate by heart disease for one-pack-a-day smokers—that is, at a given age, such as 50, a one-pack-a-day smoker has twice as much chance of dying of heart disease as a nonsmoker, and a two-pack-a-day smoker has four times the chance of dying of heart disease as a nonsmoker. The same effect is also found for other diseases.

The incidence of disease—not just the death rate, but the morbidity, the number of cases of disease—as well as the mortality, is also twice as great at a given age for a one-pack-a-day smoker as for a nonsmoker. The average smoker is a one-pack-a-day smoker, and about half of the people in the U.S. smoke. If cigarette smoking were abolished, there would be a four-year average increase in longevity and a four-year average increase in the length of the period of well-being.

But about vitamin C—Edmé Régnier, a physician in Salem, Massachusetts, wrote some papers about vitamin C and the common cold and then got out a book, *You Can Cure the Common Cold*. In this book he describes the studies he carried out with his friends and patients. He decided some 15 years ago that vitamin C in proper doses had value against the common cold, and he gave tablets to his friends and patients, sometimes a vitamin C and sometimes a placebo, with instructions that they were to take a tablet every hour at the first sign of a cold and continue throughout that day and the next day. He reported that 90 percent of the colds were averted by the simple procedure of taking only a few grams of vitamin C per cold.

After five years Régnier had to give up his study because his telephone began ringing in the middle of the night and one of these people would be saying, "You gave me the wrong tablets," because the cold didn't go away as it had before.

I don't know why it is that there has been so much opposition by the establishment to vitamin C as a way of controlling the common cold and other diseases, but there has been. A couple of years ago I wrote a paper with Ewan Cameron on "Ascorbic Acid and the Glycosominoglycans: A Contribution to the Orthomolecular Treatment of Cancer." Cameron is a cancer surgeon in Scotland. We talked about where we would publish the paper, and I said, Why don't I send it to the *Proceedings of the National Academy of Sciences*? So I did, and it was turned down. The policy of the NAS had then been for 58 years, since it was started, that a member had the right to publish papers, but they decided to change the policy and turn this paper down.

When word of this leaked out—I didn't say anything, but an article was published in *Science* about it—I got a telegram from the editor of *Oncology*, saying that their policy was that papers were not accepted for *Oncology* until they had been refereed and examined thoroughly, but in this case they would accept the paper sight unseen. So it was published 14 months ago, and although many people have written for reprints, it hasn't caused any great stir so far as I am aware, and the dangers stated by the editorial board of the NAS that we would be raising false hopes in people haven't materialized.

I think there's no doubt that ascorbic acid is helpful in preventing and treating cancer, but there is still doubt as to how great its benefit is. There are good arguments. You know ascorbic acid is required for the synthesis of collagen; connective tissue contains collagen fibrils, and the tissues are strengthened by an increased intake. It's valuable for wound healing. There is little doubt that the proper intake of ascorbic acid strengthens the tissues enough to permit them to offer increased resistance to infiltration by a growing malignant tumor. There is also evidence that ascorbic acid works against the enzyme hyaluronidase, probably by facilitating the synthesis of hyaluronidase inhibitor. Many cancerous growths produce this enzyme, which attacks the hyaluronic acid in the intercellular cement of the surrounding tissues and weakens these tissues in such a way as to permit infiltration by the cancer.

When I spoke at the dedication of the Ben May Laboratory for Cancer Research at the University of Chicago in November 1971, I said that with the proper use of ascorbic acid the mortality from cancer could be reduced by about 10 percent. I am now willing to make

With the proper use of ascorbic acid the mortality from cancer might well be decreased by 50 percent

an estimate that the age-specific incidence of this disease might well be decreased by 50 percent. In fact, I think it may well be that with ascorbic acid alone, a proper intake —getting people back to the level of animals that manufacture their own ascorbic acid; perhaps we might say to the natural level—the age-specific morbidity and mortality in general can be decreased by 50 percent. This means an extension of the period of well-being by 8 years, and an extension of the life expectancy by 8 years.

I am now director of the Institute of Orthomolecular Medicine in Menlo Park, a new institution just across from the Stanford campus; the assistant director is a former Caltech student, Arthur B. Robinson, who received his BS in chemistry in 1963. I invented the word "orthomolecular" in 1968. It is from the Greek "ortho," meaning right or correct, as in "orthodox"; and "molecular," meaning molecular. "Orthomolecular" means the right molecules in the right amounts—having the right molecules in the right concentrations. The right molecules are those that are normally present in the human body. Many of them are required for life—such as the vitamins and essential amino acids. Orthomolecular medicine is the prevention and treatment of disease, the preservation of good health, by varying the concentration

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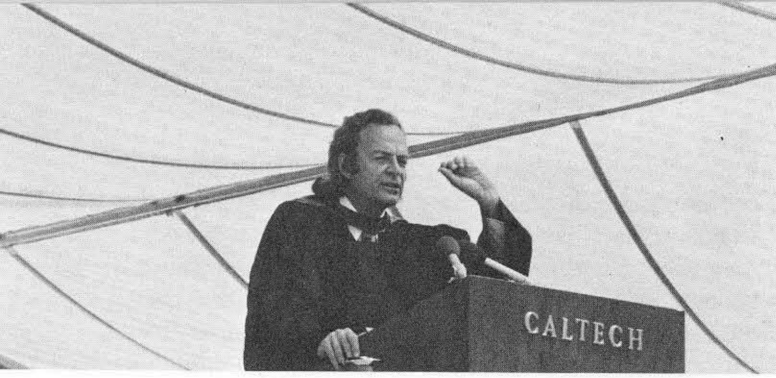
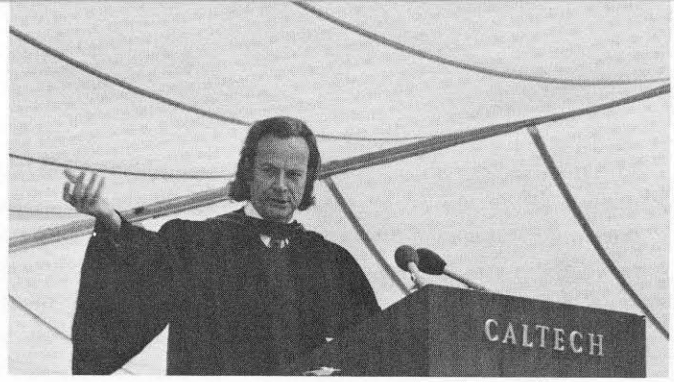




Cargo Cult Science

by RICHARD P. FEYNMAN

Some remarks on science, pseudoscience, and learning how to not fool yourself. Caltech's 1974 commencement address.

During the Middle Ages there were all kinds of crazy ideas, such as that a piece of rhinoceros horn would increase potency. (Another crazy idea of the Middle Ages is these hats we have on today—which is too loose in my case.) Then a method was discovered for separating the ideas—which was to try one to see if it worked, and if it didn't work, to eliminate it. This method became organized, of course, into science. And it developed very well, so that we are now in the scientific age. It is such a scientific age, in fact, that we have difficulty in understanding how witch doctors could *ever* have existed, when nothing that they proposed ever really worked—or very little of it did.

But even today I meet lots of people who sooner or later get me into a conversation about UFO's, or astrology, or some form of mysticism, expanded consciousness, new types of awareness, ESP, and so forth. And I've concluded that it's *not* a scientific world.

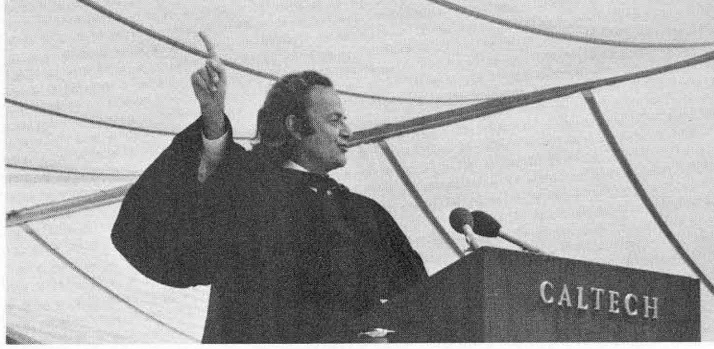
Most people believe so many wonderful things that I decided to investigate why they did. And what has been referred to as my curiosity for investigation has landed me in a difficulty where I found so much junk to talk about that I can't do it in this talk. I'm overwhelmed.
First I started out by investigating various ideas of mysticism, and mystic experiences. I went into isolation tanks (they're dark and quiet and you float in Epsom salts) and got many hours of hallucinations, so I know something about that. Then I went to Esalen, which is a hotbed of this kind of thought (it's a wonderful place; you should go visit there). Then I became overwhelmed. I didn't realize how *much* there was.

I was sitting, for example, in a hot bath and there's another guy and a girl in the bath. He says to the girl, "I'm learning massage and I wonder if I could practice on you?" She says OK, so she gets up on a table and he starts off on her foot—working on her big toe and pushing it around. Then he turns to what is apparently his instructor, and says, "I feel a kind of dent. Is that the pituitary?" And she says, "No, that's not the way it feels." I say, "You're a hell of a long way from the pituitary, man." And they both looked at me—I had blown my cover, you see—and she said, "It's reflexology." So I closed my eyes and appeared to be meditating.

That's just an example of the kind of things that overwhelm me. I also looked into extrasensory perception and PSI phenomena, and the latest craze there was Uri Geller, a man who is supposed to be able to bend keys by rubbing them with his finger. So I went to his hotel room, on his invitation, to see a demonstration of both mind reading and bending keys. He didn't do any mind reading that succeeded; nobody can read my mind, I guess. And my boy held a key and Geller rubbed it, and nothing happened. Then he told us it works better under water, and so you can picture all of us standing in the bathroom with the water turned on and the key under it, and him rubbing the key with his finger. Nothing happened. So I was unable to investigate that phenomenon.

But then I began to think,what else is there that we believe? (And I thought then about the witch doctors, and how easy it would have been to check on them by noticing that nothing really worked.) So I found things that even *more* people believe, such as that we have some knowledge of how to educate. There are big schools of reading methods and mathematics methods, and so forth, but if you notice, you'll see the reading scores keep going down—or hardly going up—in spite of the fact that we continually use these same people to improve the methods. *There's* a witch doctor remedy that doesn't work. It ought to be looked into; how do they know that their method should work? Another example is how to treat criminals. We obviously have made no progress—lots of theory, but no progress—in decreasing the amount of crime by the method that we use to handle criminals.

Yet these things are said to be scientific. We study them. And I think ordinary people with commonsense ideas are intimidated by this pseudoscience. A teacher who has some good idea of how to teach her children to read is forced by the school system to do it some other way—or is even fooled by the school system into thinking that her method is not necessarily a good one. Or a parent of bad



boys, after disciplining them in one way or another, feels guilty for the rest of her life because she didn't do "the right thing," according to the experts.

So we really ought to look into theories that don't work, and science that isn't science.

I tried to find a principle for discovering more of these kinds of things, and came up with the following system. Any time you find yourself in a conversation at a cocktail party in which you do not feel uncomfortable that the hostess might come around and say, "Why are you fellows talking shop?" or that your wife will come around and say, "Why are you flirting again?"—then you can be sure you are talking about something about which nobody knows anything.

Using this method, I discovered a few more topics that I had forgotten—among them the efficacy of various forms of psychotherapy. So I began to investigate through the library, and so on, and I have so much to tell you that I can't do it at all. I will have to limit myself to just a few little things. I'll concentrate on the things more people believe in. Maybe I will give a series of speeches next year on all these subjects. It will take a long time.

I think the educational and psychological studies I mentioned are examples of what I would like to call Cargo Cult Science. In the South Seas there is a Cargo Cult of people. During the war they saw airplanes land with lots of good materials, and they want the same thing to happen now. So they've arranged to make things like runways, to put fires along the sides of the runways, to make a wooden hut for a man to sit in, with two wooden pieces on his head like headphones and bars of bamboo sticking out like antennas—he's the controller—and they wait for the airplanes to land. They're doing everything right. The form is perfect. It looks exactly the way it looked before. But it doesn't work. No airplanes land. So I call these things Cargo Cult Science, because they follow all the apparent precepts and forms of scientific investigation, but they're missing something essential, because the planes don't land.

Now it behooves me, of course, to tell you what they're missing. But it would be just about as difficult to explain to the South Sea Islanders how they have to arrange things so that they get some wealth in their system. It is not something simple like telling them how to improve the shapes of the earphones. But there is *one* feature I notice that is generally missing in Cargo Cult Science. That is the idea that we all hope you have learned in studying science in school—we never explicitly say what this *is*, but just hope that you catch on by all the examples of scientific investigation. It is interesting, therefore, to bring it out now and speak of it explicitly. It's a kind of scientific integrity, a principle of scientific thought that corresponds to a kind of utter honesty—a kind of leaning over backwards. For example, if you're doing an experiment, you should report everything that you think might make it invalid—not only what you think is right about it: other causes that could possibly explain your results; and things you thought of that you've eliminated by some other experiment, and how they worked—to make sure the other fellow can tell they have been eliminated.

Details that could throw doubt on your interpretation must be given, if you know them. You must do the best you can—if you know anything at all wrong, or possibly wrong—to explain it. If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it. There is also a more subtle problem. When you have put a lot of ideas together to make an elaborate theory, you want to make sure, when explaining what it fits, that those things it fits are not just the things that gave you the idea for the theory; but that the finished theory makes something else come out right, in addition.

In summary, the idea is to try to give *all* of the information to help others to judge the value of your contribution; not just the information that leads to judgment in one particular direction or another.

The easiest way to explain this idea is to contrast it, for example, with advertising. Last night I heard that Wesson Oil doesn't soak through food. Well, that's true. It's not dishonest; but the thing I'm talking about is not just a matter of not being dishonest, it's a matter of scientific integrity, which is another level. The fact that should be added to that advertising statement is that *no* oils soak through food, if operated at a certain temperature. If operated at another temperature, they *all* will—including Wesson Oil. So it's the implication which has been conveyed, not the fact, which is true, and the difference is what we have to deal with.

We've learned from experience that the truth will out. Other experimenters will repeat your experiment and find out whether you were wrong or right. Nature's phenomena will agree or they'll disagree with your theory. And, although you may gain some temporary fame and excitement, you will not gain a good reputation as a scientist if you haven't tried to be very careful in this kind of work. And it's this type of integrity, this kind of care not to fool yourself, that is missing to a large extent in much of the research in Cargo Cult Science.

A great deal of their difficulty is, of course, the difficulty of the subject and the inapplicability of the scientific method to the subject. Nevertheless, it should be remarked that this is not the only difficulty. That's *why* the planes don't land—but they don't land.

We have learned a lot from experience about how to handle some of the ways we fool ourselves. One example: Millikan measured the charge on an electron by an experiment with falling oil drops and got an answer which we now know not to be quite right. It's a little bit off, because he had the incorrect value for the viscosity of air. It's interesting to look at the history of measurements of the charge of the electron, after Millikan. If you plot them as a function of time, you find that one is a little bigger than Millikan's, and the next one's a little bit bigger than that, and the next one's a little bit bigger than that, until finally they settle down to a number which is higher.

Why didn't they discover that the new number was higher right away? It's a thing that scientists are ashamed of—this history—because it's apparent that people did things like this: When they got a number that was too high above Millikan's, they thought something must be wrong—and they would look for and find a reason why something might be wrong. When they got a number closer to Millikan's value they didn't look so hard. And so they eliminated the numbers that were too far off, and did other things like that. We've learned those tricks nowadays, and now we don't have that kind of a disease.

But this long history of learning how to not fool ourselves —of having utter scientific integrity—is, I'm sorry to say, something that we haven't specifically included in any particular course that I know of. We just hope you've caught on by osmosis.

The first principle is that you must not fool yourself—and you are the easiest person to fool. So you have to be very careful about that. After you've not fooled yourself, it's easy not to fool other scientists. You just have to be honest in a conventional way after that.

I would like to add something that's not essential to the science, but something I kind of believe, which is that you should not fool the layman when you're talking as a scientist. I am not trying to tell you what to do about cheating on your wife, or fooling your girl friend, or something like that, when you're not trying to be a scientist, but just trying to be an ordinary human being. We'll leave those problems up to you and your rabbi. I'm talking about a specific, extra type of integrity that is not lying, but bending over backwards to show how you're maybe wrong, that you ought to do when acting as a scientist. And this is our responsibility as scientists, certainly to other scientists, and I think to laymen.

For example, I was a little surprised when I was talking to a friend who was going to go on the radio. He does work on cosmology and astronomy, and he wondered how he would explain what the applications of this work were. "Well," I said, "there aren't any." He said, "Yes, but then we won't get support for more research of this kind." *I* think that's kind of dishonest. If you're representing yourself as a scientist, then you should explain to the layman what you're doing—and if they don't want to support you under those circumstances, then that's their decision.

One example of the principle is this: If you've made up your mind to test a theory, or you want to explain some idea, you should always decide to publish it whichever way it comes out. If we only publish results of a certain kind, we can make the argument look good. We must publish *both* kinds of result. For example—let's take advertising again—suppose some particular cigarette has some particular property, like low nicotine. It's published widely by the company that this means it is good for you—they don't say, for instance, that the tars are a different proportion, or that something else is the matter with the cigarette. In other words, publication probability depends upon the answer. That should not be done.

I say that's also important in giving certain types of government advice. Supposing a senator asked you for advice about whether drilling a hole should be done in his state; and you decide it would be better in some other state. If you don't publish such a result, it seems to me you're not giving scientific advice. You're being used. If your answer happens to come out in the direction the government or the politicians like, they can use it as an argument in their favor; if it comes out the other way, they don't publish it at all. That's not giving scientific advice.

Other kinds of errors are more characteristic of poor science. When I was at Cornell, I often talked to the people in the psychology department. One of the students told me she wanted to do an experiment that went something like this—I don't remember it in detail, but it had been found by others that under certain circumstances, X, rats did something, A. She was curious as to whether, if she changed the circumstances to Y, they would still do A. So her proposal was to do the experiment under circumstances Y and see if they still did A.

I explained to her that it was necessary first to repeat in her laboratory the experiment of the other person—to do it under condition X to see if she could also get result A—and then change to Y and see if A changed. Then she would know that the real difference was the thing she thought she had under control.

She was very delighted with this new idea, and went to her professor. And his reply was, no, you cannot do that, because the experiment has already been done and you would be wasting time. This was in about 1935 or so, and it seems to have been the general policy then to not try to repeat psychological experiments, but only to change the conditions and see what happens.

Nowadays there's a certain danger of the same thing happening, even in the famous field of physics. I was shocked to hear of an experiment done at the big accelerator at the National Accelerator Laboratory, where a person used deuterium. In order to compare his heavy hydrogen results to what might happen with light hydrogen he had to use data from someone else's experiment on light hydrogen, which was done on different apparatus. When asked why, he said it was because he couldn't get time on the program (because there's so little time and it's such expensive apparatus) to do the experiment with light hydrogen on this apparatus because there wouldn't be any new result. And so the men in charge of programs at NAL are so anxious for new results, in order to get more money to keep the thing going for public relations purposes, they are destroying—possibly—the value of the experiments themselves, which is the whole purpose of the thing. It is often hard for the experimenters there to complete their work as their scientific integrity demands.

All experiments in psychology are not of this type, however. For example, there have been many experiments running rats through all kinds of mazes, and so on—with little clear result. But in 1937 a man named Young did a very interesting one. He had a long corridor with doors all along one side where the rats came in, and doors along the other side where the food was. He wanted to see if he could train the rats to go in at the third door down from wherever he started them off. No. The rats went immediately to the door where the food had been the time before.

The question was, how did the rats know, because the corridor was so beautifully built and so uniform, that this was the same door as before? Obviously there was something about the door that was different from the other doors. So he painted the doors very carefully, arranging the textures on the faces of the doors exactly the same. Still the rats could tell. Then he thought maybe the rats were smelling the food, so he used chemicals to change the smell after each run. Still the rats could tell. Then he realized the rats might be able to tell by seeing the lights and the arrangement in the laboratory like any commonsense person. So he covered the corridor, and still the rats could tell.

He finally found that they could tell by the way the floor sounded when they ran over it. And he could only fix that by putting his corridor in sand. So he covered one after another of all possible clues and finally was able to fool the rats so that they had to learn to go in the third door. If he relaxed any of his conditions, the rats could tell.

Now, from a scientific standpoint, that is an A-Number-1 experiment. That is the experiment that makes rat-running experiments sensible, because it uncovers the clues that the rat is really using—not what you think it's using. And that is the experiment that tells exactly what conditions you have to use in order to be careful and control everything in an experiment with rat-running.

I looked into the subsequent history of this research. The next experiment, and the one after that, never referred to Mr. Young. They never used any of his criteria of putting the corridor on sand, or being very careful. They just went right on running rats in the same old way, and paid no attention to the great discoveries of Mr. Young, and his papers are not referred to, because he didn't discover anything about the rats. In fact, he discovered *all* the things you have to do to discover something about rats. But not paying attention to experiments like that is a characteristic of Cargo Cult Science.

Another example is the ESP experiments of Mr. Rhine, and other people. As various people have made criticisms—and they themselves have made criticisms of their own experiments—they improve the techniques so that the effects are smaller, and smaller, and smaller until they gradually disappear. All the parapsychologists are looking for some experiment that can be repeated—that you can do again and get the same effect—statistically, even. They run a million rats—no, it's people this time—they do a lot of things and get a certain statistical effect. Next time they try it they don't get it any more. And now you find a man saying that it is an irrelevant demand to expect a repeatable experiment. This is *science*?

This man also speaks about a new institution, in a talk in which he was resigning as Director of the Institute of Parapsychology. And, in telling people what to do next, he says that one of the things they have to do is be sure they only train students who have shown their ability to get PSI results to an acceptable extent—not to waste their time on those ambitious and interested students who get only chance results. It is very dangerous to have such a policy in teaching—to teach students only how to get certain results, rather than how to do an experiment with scientific integrity.

So I wish to you—I have no more time, so I have just one wish for you—the good luck to be somewhere where you are free to maintain the kind of integrity I have described, and where you do not feel forced by a need to maintain your position in the organization, or financial support, or so on, to lose your integrity. May you have that freedom. May I also give you one last bit of advice: Never say that you'll give a talk unless you know clearly what you're going to talk about and more or less what you're going to say. ☐

Research Notes

Astronomical Association

After four years' observing, J. B. Oke and James Gunn, professors of astronomy and staff members of the Hale Observatories, recently provided a direct answer to a key astronomical question: Are quasars a separate class of object or can they be associated with ordinary galaxies? With the aid of an optical trick and a very sensitive spectrometer mounted on the 200-inch Hale Telescope, they were able to prove that the circle of fainter light around a brilliant quasar-like object named BL Lacertae is really a galaxy of ordinary stars.

For 50 years BL Lacertae has been listed in astronomical catalogs as a variable star. (In fact, "BL" signifies a variable star.) It is located in the Constellation of Lacerta (the Lizard) in the northern sky. But attempts to determine its distance have been unsuccessful by the usual methods of sorting out its light into the spectroscopic code, which describes its chemical and magnetic properties and, according to most astronomers, its distance from the earth—if it is beyond our own Milky Way.

The light from BL Lacertae did not show spectral lines even when observed with the 200-inch and the very sensitive 32-channel spectrometer designed by Oke. But at this point the optical trick changed the picture. Earle Emery, a research engineer, designed and built a tiny disk that could be mounted in a round aperture. With the disk in place in the telescope, BL Lacertae's central bright object was blocked out, and the Oke spectrometer recorded spectra of the stars that make up the outer ring.

The spectra show that the object is about a billion light years away and that its stars are typical of the older stars found in giant spherical galaxies. Indeed, the object surrounding the very bright central source has all the appearance of a normal spherical galaxy. Thus, BL Lacertae proves not to be a variable star in the Milky Way Galaxy but evidently is much further away and is itself a large galaxy with a quasar in it.

Like many quasars, BL Lacertae varies rapidly in brightness, sometimes from night to night. Flickers only two minutes in duration have been reported. The light varies eight to ten times in brightness—roughly from 13th to 16th magnitude. The variations come from the central quasar.

The rapid variability of the light (along with some direct measurements by radio telescopes) indicates that the diameter of the quasar is less than one light year. This is very small compared to the diameter of its surrounding galaxy, which is more than 100,000 light years.

In spite of being a billion light years away from earth, BL Lacertae is the nearest known quasar. In fact, if it weren't so near, and if the central quasar had not been dimmer than usual, it might not have been possible to obtain the spectra even using the disk to block out light from the central object. The quasar's brilliance might have swamped the dimmer light from its stars.

Sonic Booms

Caltech aeronautical engineers are now studying sonic booms—in the laboratory. They have an ideal tool for these studies in the 17-inch shock tube in the Graduate Aeronautical Laboratories.

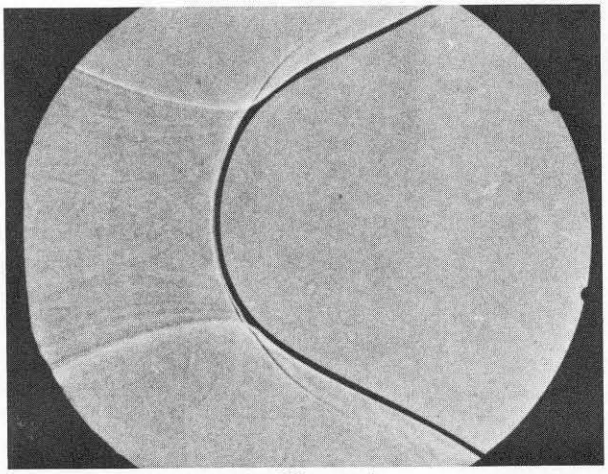
Measurements of sonic booms have been made in the field for some time, of course. The Air Force has flown airplanes at supersonic speeds over Oklahoma City, for example, measuring the sonic booms they create, and studying the effects of the boom; and the French government has sponsored a program in which airplanes were maneuvered so the sonic booms tended to concentrate or focus. But the Caltech studies of focused sonic booms are the first to be made in the laboratory, under controlled conditions.

When sonic booms are focused, they can cause plenty of damage. Abnormally strong and damaging sonic booms are occasionally experienced after the overflight of supersonic aircraft—due perhaps to focusing caused by such aircraft maneuvers as accelerations, dives, or turns, or perhaps due to certain atmospheric effects. One spectacular sonic boom, caused by a jet plane flying in formation over the Air Force Academy in Colorado Springs in 1968, blew out more than 2,000 windows.

This kind of accident has encouraged researchers to study ways of predicting the pressure that a focused sonic boom, called a "super boom," would create.

In Caltech's 17-inch shock tube, Bradford Sturtevant, professor of aeronautics, and Vijay Kulkarny, research assistant, are able to create an idealized situation similar to a sonic boom coming into a valley. As the boom, or shock wave, moves down the 80-foot tube, it meets a parabolic reflector. As with light waves, the reflector—or mirror—focuses the sound waves. The Caltech researchers want to know what happens to the sound waves near this focal point—and, in the process, perhaps find out just how strong a sonic boom can get.

Photographing a Sonic Boom



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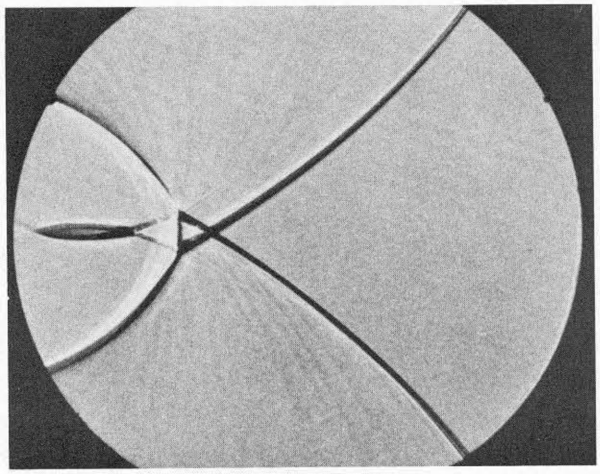

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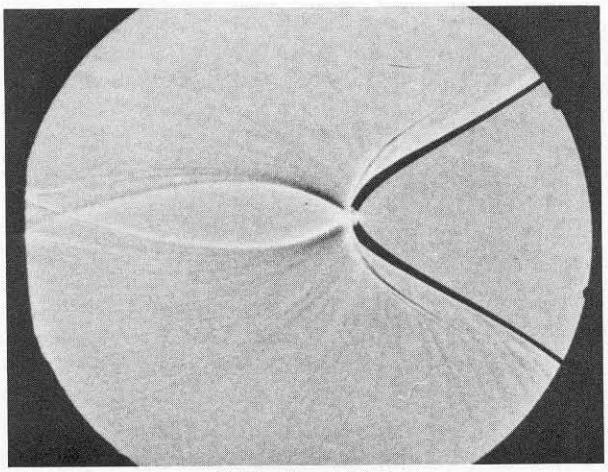

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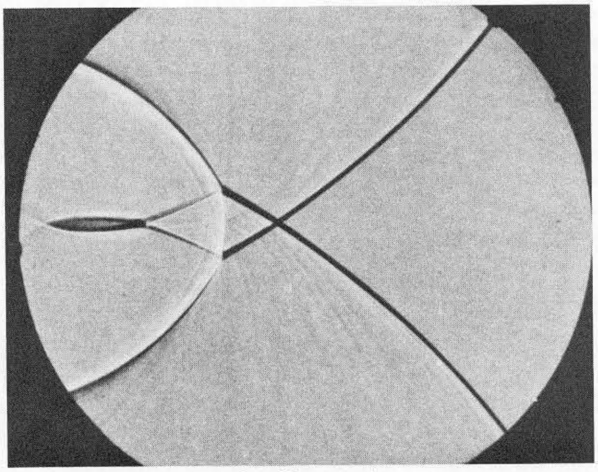

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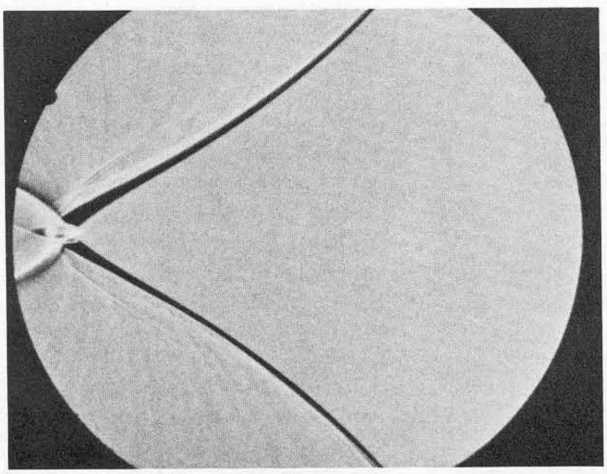

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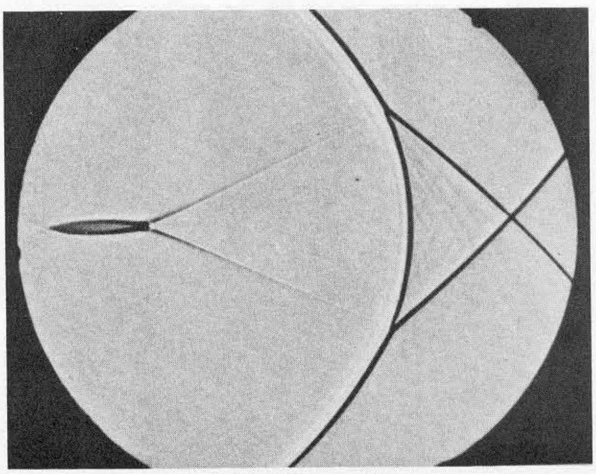

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0.0 milliseconds—In the shock tube in Caltech's Graduate Aeronautical Laboratories, a shock wave comes in from the right, meets a curved wood surface, and is reflected back (black lines). The white lines at the left, behind the reflected wave, are diffracted waves; the upper one is traveling downward, the lower one is traveling upward.

0.05 ms—The shock wave is closer to the focus. The diffracted waves have crossed each other so that the one that started at the top is now on the bottom.

0.08 ms—The shock wave is at the focus. A hot blob of gas has begun to appear at the left.

0.11 ms, 0.12 ms, 0.19 ms—The shock wave is coming out of the focus, leaving the gas that was heated at the focus behind.

Riddle of the Rings

The bright rings around the planet Saturn may be made of ice, or even ice-coated chunks of iron. This is the tentative report of two Caltech radio astronomers, Duane Muhleman, professor of planetary science, and Glenn Berge, senior research fellow in planetary science and radio astronomy.

The combined information they get from radio signals, radar echoes, and infrared light observations suggests that whatever these chunks are in Saturn's rings, they at least have a layer of ice on them. So it's a strong possibility that the rings are made up of water ice.

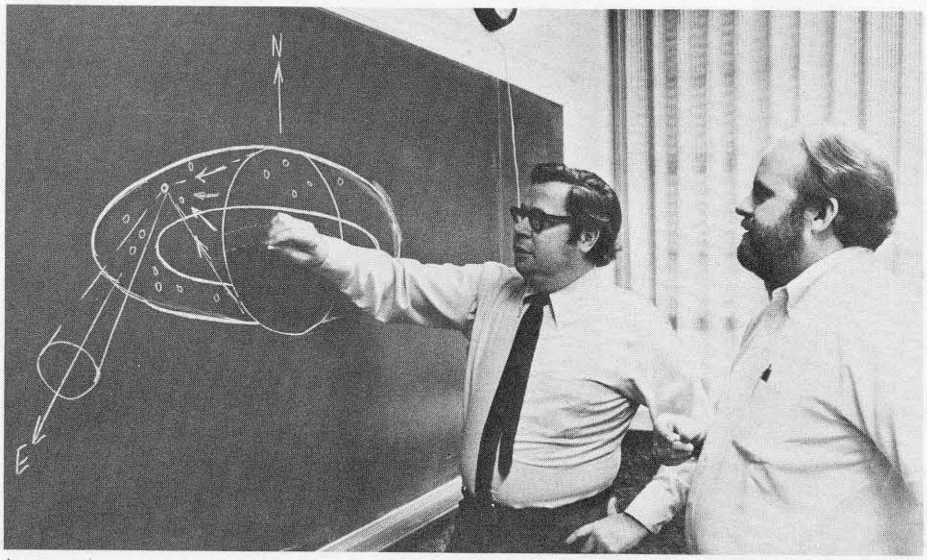
It's also possible—but much less likely—that the rings consist of small bits of iron, covered with frost.

The Muhleman-Berge team has been studying radio signals from Saturn since 1965, using the big dishes at Caltech's Owens Valley Radio Observatory near Bishop, California. Similar work done by F. H. Briggs of Cornell University tends to strengthen the ice conclusions. Briggs did his observing with radio instruments at the National Radio Astronomy Observatory in Green Bank, West Virginia.

Right now the scientists have a massive amount of data which may tell them—when it's all processed—something about where in the rings the radio flux is coming from.

If the rings of Saturn were just thin, tenuous layers of gas, even thousands of kilometers thick, scientists wouldn't expect to see radio emissions. Early measurements of Saturn's radio noise indicated that at least 90 percent of the emission came from the planet itself, with the remaining 10 percent or less coming from the rings.

As the experiments progressed over the years the men also began to find that there are no radiation belts around Saturn like those found at Jupiter. This means one of two things. Either the planet has no significant magnetic field, or there are no high-energy particles there. One or the other is apparently missing. A radiation belt around a planet—such as those found first around the Earth, then around Jupiter—is made up of high-energy particles such as electrons and protons that are trapped in the magnetic field of the planet. It seems likely that Saturn does have a magnetic field, however, because it is a huge planet that is similar in most important ways to Jupiter.



Interpreting masses of data from nearly ten years of observing and analyzing radio signals from Saturn is no easy task, but Duane Muhleman and Glenn Berge think they can conclude that the rings around the planet may be made up of chunks of ice that do not emit radiation themselves but bounce off signals emitted from the planet.

As for the high-energy particles, the scientists think the rings of Saturn probably soak them all up. In later observations there was definite evidence that about 5 percent of the radiation was coming from the rings.

Radar observations of Saturn and its rings have also been carried out by Richard Goldstein of Caltech's Jet Propulsion Laboratory, who is a research associate in planetary science on the campus. Goldstein did his work with JPL's big dish antenna at Goldstone, California, and got strong radar echoes back that have to come from the rings of Saturn, Muhleman believes. At the same time the radio response of the planet itself is peculiar. Saturn doesn't give the usual response of a circular, uniformly bright planet.

Putting their observations together with Goldstein's, Muhleman and Berge decided that a large fraction of the particles in the rings must be at least five centimeters in diameter to yield the radar echoes. This means that the ring particles are of sufficient size and number to block the planet's disk—to cast a shadow across the radiation we see coming from Saturn. This would explain the planet's peculiar radio response.

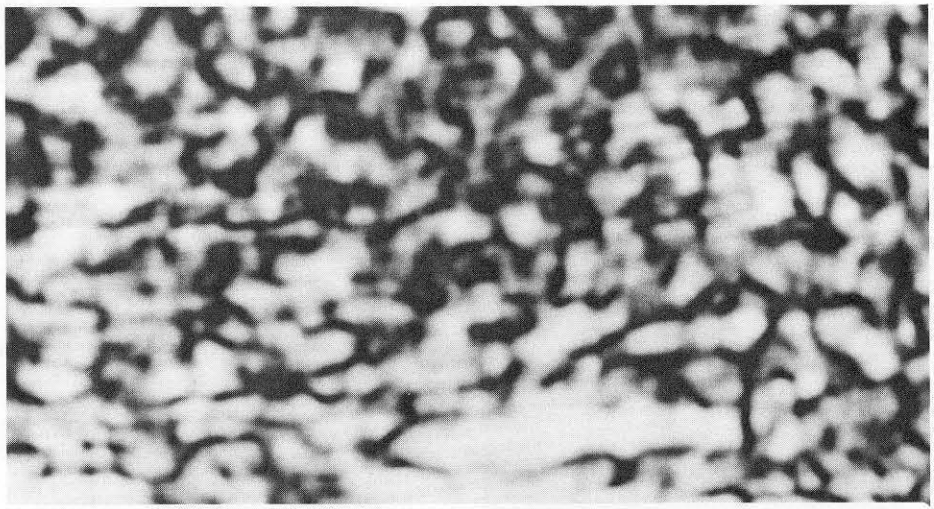
If the particles are big enough and plentiful enough to block emission from the planet, then we should be seeing scattered Saturn radio emission from everywhere around the rings—and this is what Muhleman and Berge think they do see.

The radiation being recorded from the rings, amounting to about 5 percent of the total, is scattered radiation; that is, the signals are emitted by the planet but bounced off the particles in the rings. But it is not clear yet whether the researchers are seeing the whole ring or some sort of internal structure. Their interpretation is that there's probably no radio emission from the rings themselves, just radiation that bounces off the ring materials.

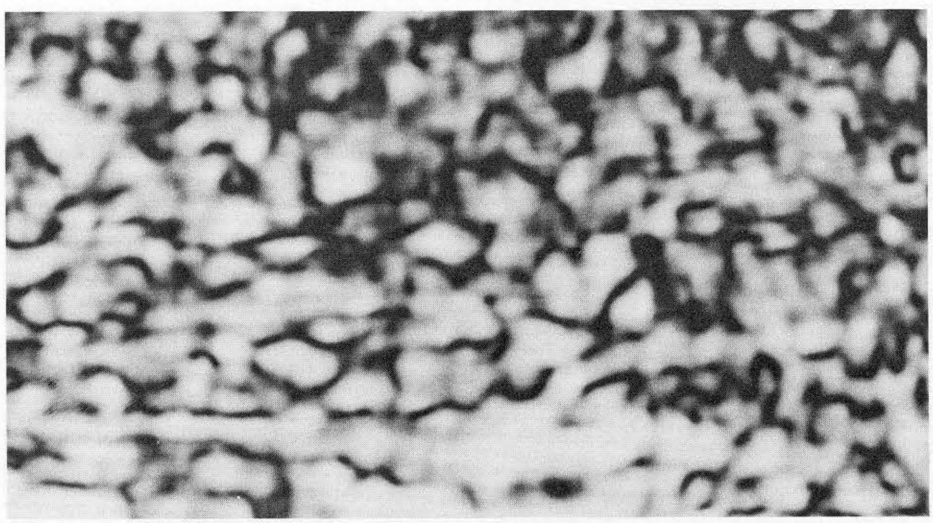
Since the size of the particle tends to govern what kinds of radiation will be seen, this conclusion says a lot about the particles in the rings. If the ice in the rings is in chunks bigger than about three and a half meters in diameter, there should be radiation at radio wavelengths—but there isn't. This means that a size boundary can be put on the ice particles—bigger than five centimeters but smaller than four meters.

This doesn't mean that there are *no* large chunks, but if there are big ones, they are not doing the job of radiating the signals.

Work at the Massachusetts Institute of Technology indicates through infrared observations that water ice is present in the rings, which suggests that, whatever these chunks are, they must have at least a layer of ice on them. The possibility of iron particles cannot be dismissed since they would also be excellent scatterers and very poor radio emitters.



A pattern of bright spots appears about the direct beam of a laser that is passed through a vial of large spheres suspended in water. This pattern of continually moving, twinkling spots is produced by the Brownian motion of the spheres.



A photograph taken just a few seconds later shows a changed pattern. The twinkling time of the areas of light is related to the diffusion coefficient of the spheres. The same principle applies to liquids and liquid mixtures and has been used to study diffusivities.

Light-Mixing Spectroscopy

Because the structure of liquids is so complex, coming to an understanding of their properties and predicting their reactions has been a notoriously unreliable, laborious, expensive, and time-consuming process. Methods in current use often require large quantities of material and weeks of experimentation.

Recently, however, C. J. Pings, professor of chemical engineering and chemical physics, and two of his graduate students, Ronald Brown and Erdogan Gulari, have developed a new method of determining two properties of liquids —the rate at which they mix (the diffusion coefficient) and the rate at which heat flows through pure liquids (the thermal diffusivity). This new technique, which is known as light-mixing spectroscopy, has several advantages over older methods. It is more accurate, it uses very small quantities of liquids, and it produces precise values in as little as 15 minutes to two hours.

Light-mixing spectroscopy is based on the fact that when a beam of light shines through a liquid some of the light will be scattered. Localized differences in temperatures and composition (due to the random thermal motion of the molecules in the liquid) slightly alter the frequency—that is, the color—of the scattered light. In time, these localized inhomogeneities dissipate by diffusion, and this gradual loss is detectable by light-mixing spectroscopy. The size and shape of the resulting distributed spectra are directly related to the liquid's transport properties.

The frequency shifts predicted by scattering theory are less than one part in one hundred trillion—a ratio that made it necessary for Brown and Gulari, under the supervision of Pings, to design and build a spectrometer a million times more sensitive than conventional ones. The system achieves this enhanced sensitivity by comparing the spectral curve of the light beam with that of a beam that has not penetrated the liquid. The new spectrometer is made up of an argon ion laser, a transparent cell that holds about four ounces of whatever liquid is being checked, and a photomultiplier tube plus instruments that analyze the current from it. The highly directional, monochromatic laser light beam is directed through the cell containing the sample fluid. The phototube then detects the light that is scattered by the sample. The resultant current from the phototube mirrors and amplifies the nature of the scattered light. This current is then analyzed by either a wave analyzer or a correlator, which are instruments designed to extract information from the photocurrent by generating the distributed spectra.

The technique can be used to study the motions of molecules by observing slight changes in the color of laser light passing through a fluid. Brown is currently using it to study the dynamics of closed, circular DNA in solution. In this case the scattered light yields information on the conformation and internal motion of the molecule, information that has been inaccessible by standard biophysical techniques.

Among the immediate practical applications of the new technique are the continuous monitoring and control of the stability of processes in chemical plants. It can also be used for such tasks as automatically changing heater settings and altering flow rates.

A few years ago chemical and petroleum companies built their plants sequentially. An experimental discovery in the laboratory would be followed by construction of a pilot plant to determine the feasibility of production. The next step might be a small demonstration plant with limited output. And usually it was only after this amount of trial-and-error effort that a full-scale plant was set up.

Building several generations of trial plants is, however, expensive in both time and money. Today, industry attempts to bypass these preliminary steps by having computers design large chemical processing plants on the basis of engineering measurements. For their design to be good, computers must be given very precise numbers, and that is exactly what light-mixing spectroscopy can do.

A Superconducting Alloy

New alloys are not unexpected in Pol Duwez' laboratory. In a special research project sponsored by the Atomic Energy Commission, he and his colleagues have been creating them one after another since 1960 (*E&S*, January 1966, May 1973). The most recent one, discovered by two of Duwez' students, may require extension of the theory of superconductivity.

Superconductivity, which is beginning to play a major role in the production and transmission of electric power, is a property of more than a score of metals and many alloys. At very low temperatures they lose all their electrical resistance, so that currents induced in them seem to flow indefinitely without loss of power. However, to date, this behavior has been observed in bulk metals and alloys only when the constituent atoms are arranged in precise crystalline lattice patterns. Now, William L. Johnson, a graduate student in applied physics, and Siu Joe Poon, a senior in electrical engineering, have demonstrated that a special alloy—made up of 20 percent gold and 80 percent lanthanum with their atoms in an amorphous state (jumbled randomly together)—can become superconducting.

Johnson and Poon melted the two metals together, and a drop of the resulting alloy was spilled from the crucible. An electronic eye observed the drop and triggered a pneumatic hammer that slammed the drop onto a heat-absorbing copper "anvil." There it spread out and was frozen almost instantly into a thin foil. The speed of the freezing is critical, because it doesn't give the atoms time to align themselves into a characteristic crystal pattern. With the atoms in an amorphous state, the alloy demonstrates new chemical bonding properties.

This alloy is not expected to be useful for engineering applications or superconducting materials, first because it can be obtained only in thin foils about two-thousandths of an inch thick. Second, the temperature at which the alloy becomes superconducting is very low—about 4 degrees Kelvin. It is not difficult to achieve this low temperature, but it is not practical economically to do so, since some alloys become superconducting near 20 degrees Kelvin.

"For ten years we have been looking for an amorphous alloy that is superconducting," says Duwez. "We wanted to prove that a superconductor doesn't have to have a crystal structure, and now we've done it. At this point it is of purely scientific interest, but we hope it will lead to a better understanding of one of the most fascinating properties of the metallic state." □

Speaking Of...

Scientists and Romanticists

Ray Bradbury tells us in poems and prose that behind every scientist is a romantic. (This is probably widely true, except perhaps at Caltech, where romanticism must be either stamped out or overlain with cynicism.) The 21st century may regard Bradbury as the man who *really* understood why we left the Earth.

—*William K. Hartmann, in a book review of* Mars and the Mind of Man *in* Science, *May 10*

Peace

You remember Robert Oppenheimer's analogy, when he spoke of the Soviet Union and the United States as being like two scorpions in a bottle. There we are in a bottle, and if either of us stings, the other one stings—and we'll both be dead! So, it looks like a pretty hopeless situation for the two scorpions.

Now this is a view of the scorpions in a bottle as seen by one looking down from outside. From the scorpions' point of view, the implicit conclusion of the outside observer is quite unacceptable. We happen to be *involved*, and being involved, we have to proceed on the assumption that something useful *can* and *will* be done.

In the first place it is very disagreeable not to make that assumption, and in the second place it is literally true that we cannot resign from the human race.

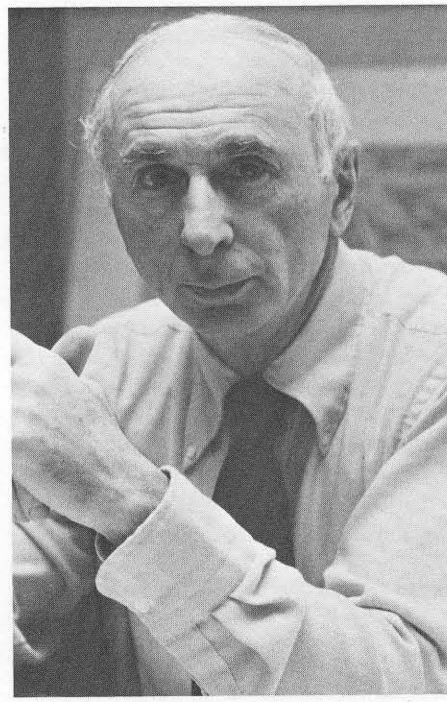
I think things *can* be done, and I don't see any need to give way to a gospel of despair. It comes down to a question of what are the available lines of action.

Here I would remind you that some good things have happened in the last 20 years. We have made progress with China. We are making progress of a kind with the Soviet Union—for example, there has been in the past a very real apprehension of direct military attack by the Soviet Union on Europe or on the United States; but this is not something that we now feel to be an imminent threat.

Let's see what we ought to do now; and then let's see whether there's any reason to assume we can't. First, I turn to the home front. It's of the very nature of the foreign relations of the United States that the United States is always at least half of any foreign relationship we have. The home front is of the essence; to use the words of the old fable, it is the goose that lays the golden eggs. The *internal* vitality, cohesiveness, and morale of the United States is the single most important factor that must be constantly taken into account in the conduct of foreign affairs. It is the *central* problem *now*, and nothing is more important than for us to deal with it. I will put this bluntly—we have to restore relations of trust and confidence between the people of the United States and their government.

There are times when I am tempted to put this need in the technical language of the foreign service: We must at least restore diplomatic relations between the American people and their government. At the moment it is hard to say that there are relations of trust and confidence—or even cordial diplomatic relations—between Congress and the presidency, or between the judiciary and the presidency, or between many of the regular departments of government and the White House, or between the Democratic party or indeed the regular Republican party and the White House.

Along with that restoration—here I will not hesitate to use old-fashioned language—there has to go a sense of moral cleansing, and a sense that we can count on the elementary decencies in our government.



Milton Katz

With China, I think we should continue the way we are going, which is, be sensible, don't be rambunctious, recognize that there is no serious conflict of interest, certainly not the kind which warrants shooting.

When I turn to the Soviet Union, I see two things to keep in the forefront of attention. First, we must continue to work on control of nuclear weaponry not only because it is directly related to the risk of a holocaust and because, for both of us, it is enormously expensive in dollar terms (a precipitating factor to continuing inflation), but also because it is enormously expensive in terms of materials and energy. It is one of the great and rapid consumers of the raw materials and energy about which we are now troubled.

Second, it seems to me manageable for the Russians and us to arrive at a point where we could agree to stay *out* of local conflicts. I don't know what significant interest the Soviet Union had in southeast Asia, but it has been my view ever since I first had the honor and opportunity to express my opinions to President Eisenhower in 1954 that there have been no vital interests of the United States engaged in Indochina. And to fight wars where no *vital* interest is involved—and not even any *major* interest—is stupid in the extreme. It's also immoral, even for people who are not pacifists but believe that war can on occasion properly be used as an instrument of policy. It's immoral because that kind of killing can never be justified unless it's necessary to maintain vital purposes and interests.

We are managing now, at least in the military sense and for the time being, to keep American and Russian forces out of the Middle East. If we and the Russians could at least agree to stay out of there militarily, and stay out in fact, then we could work with them on arms control.

With regard to Europe and Japan, it's clear that we have to reestablish far more mutually constructive relationships than we have. This does not mean we close our eyes to the facts of conflicting interests. But it means that we identify our elements of common interest and build on them, and identify our conflicts of interest and find ways of reducing the friction to a practical minimum.

I recognize the psychological difficulties. When we developed the relationships with Europe and with Japan through the fifties, we were the only one that was vital and really able to function. Both Europe and Japan needed our military protection, and we gave it; they needed our economic support, and we gave it; they wanted and welcomed our leadership in many respects, and we gave it.

Today Europe is again an immensely vital area in the basic intellectual and political sense and in the economic sense; and Japan is a thriving and enormously vigorous economy. If Europe and Japan seem to have difficulty in accepting the responsibilities that go with their present strength, we on our part seem to have difficulties in accepting the fact that they no longer will readily do everything that we ask them to do.

I don't think we can reconstruct NATO as it was or reconstruct the kind of relationship that formerly existed. What we *can* do is reconstruct a working relationship that's mutually useful and constructive, that takes account of present realities, and in which all of us adjust ourselves to changed circumstances.

I think the United Nations, given its changed character, can be used effectively for certain things. It could be the institutional mechanism, above all institutional mechanisms, where the advanced industrial societies (meaning, essentially, Europe, North America, and Japan in the non-Communist world, and the Soviet Union and East European countries like Czechoslovakia and Poland on the Communist side) could deal with the so-called L.D.C.'s (the "Less-Developed Countries," which means essentially the nations of Latin America, South Asia, and Africa) as a group. The dealings could relate to trade and exchange; and to the apparent attempts of the L.D.C.'s to organize intergovernmental cartels to raise the prices of raw materials.

Through the U.N., it may also be practicable to find somebody—not the United States, not the Soviet Union, but somebody with our support and the Soviet Union's support—to work on local conflicts between or among L.D.C.'s in an endeavor to bring them to some kind of adjustment.

These are the lines of effort I would suggest. In regard to all of them I would again stress the primacy of our internal situation. It is the central and outstanding factor in the contemporary foreign policy of the U. S.

Some years ago, in the late fifties, Hugh Gaitskell, who was then the chairman of the Labor Party in Britain and heir apparent to the Prime Ministry, was in this country. In a discussion of certain economic difficulties of Britain and of Europe, someone asked Gaitskell: "What is it you want the U.S. to do?" He replied: "The principal thing I want you to do is to have a vigorous internal economy *here*, because if your economy goes down, there will be little hope for the rest of us."

Unless we recover our basic resources —and I here refer to the primary moral, psychological, and social sources of our strength, which have been our strength since the days of the founding fathers—I don't think we're going to be able to conduct a very useful or intelligent or far-sighted policy.

—Milton Katz,
Sherman Fairchild Distinguished Scholar, in an Athenaeum Lecture, "The Question of Peace—Reexamined after Twenty Years," March 14.

Energy

The shortages are temporary. There are enough resources in the earth's surface for the whole population of the world, even if it rose to ten billion, to live at the level of Americans for literally millions of years, provided that you go the route of using the lowest grade of all resources, which is the common rock of the earth's crust. This contains everything that is needed to run a high-energy, high-technology society.

The thing is that, because we have allowed ourselves the luxury of napping, we are now caught in a bind of

James Bonner

having to do the research and development work that will enable us to get those low-grade resources.

Copper ore was once considered worthless unless it contained over 30 percent copper, but today ore containing .3 percent copper is being mined. Thus by improved technology it may be possible to mine the minute quantities of various minerals from ordinary rock—granite, for example.

I believe it will take tens of years to develop this kind of technology, and I predict that the biggest changes in life-styles will occur in these development decades.

—James Bonner,
professor of biology, in a newspaper interview, February 15

Faith and Reason

Since the beginnings of civilization, man has attempted to predict his future. He has sought to foretell his destiny from the intricate patterns of the star-filled heavens, the entrails of sacrificed chickens, the residue of tea leaves in cups, the turn of tarot cards, and thousands of other signs, symbols, and omens.

Wise men, shamans, gurus, oracles, and yes—even priests, professors, and politicians—are looked to for their visions and foresight. How do we divine the future? What forces shape our behavior and thus, in effect, create the future reality? I see today, as never before, an intense and polarizing struggle for man's mind between the forces of faith and mysticism and science and reason.

Look about us. We live in a bumper-sticker world. In the few letters that can be scrawled and pasted upon the outer limits of automobiles, we see calls for religious dogma and for radical-political action, statements for and against guns, demands for wilderness areas and at the same time for more ski lifts. Our lives and times are motivated by slogans, 30-second commercials, headlines, and the instant mass culture of superficiality.

And yet, this is the very moment when the fundamental problems of man have a base in science and technology and cannot be solved without them. On the other hand, how long have we been lulled into a sense of false security by our scientists and technologists? They continually reach out for more moneys for their research projects, holding forth promises of everlasting health and life, smog-free cities, supersonic transportation, and Elysian fields of a labor-free life—none of which are delivered.

One of the major factors contributing to our schizoid dilemma between mysticism and reason is the apparent crisis we face in handling the enormous amount of information which is generated, transmitted, and received throughout the world. Each of us continually feels inadequate to come to grips with this superabundance of information—to understand it, to digest it, and to utilize it. We must have a "fluency" with language which enables us to express our complex ideas both in quantitative and qualitative terms.

We must also develop conceptual structures within which the language, both verbal and numerical, can be utilized. Scientists have too often neglected their social responsibility to communicate and explain their ideas and discoveries in language and in concepts which can be understood by interested citizens. Those of us who work in the areas of science and technology must recognize the necessity not only to share our knowledge, but also to point out the diverse social consequences of applying this knowledge. Scientists and technologists must always recognize and identify where their "knowing" is scientific and where it is a function of personal value judgments.

I believe that our feeling of intellectual impotence may be built into our approach to education. We have long been geared to the notion that education should impart facts and data, literally fill up the biological data banks of our brains.

Rarely do we come to grips with developing the skills of mathematics and language, the ability to see fundamental relations and explanations within the data and the facts, and above all, the methods by which to seek and find new knowledge and new relationships. At a time when computers can store far more information for instant recall than can the human brain, it seems a shame not to use the intricacies of the human brain in a more creative and functional fashion.

Furthermore, within the process of education at all levels from preschool through postgraduate, we readily succumb to the fragmentation of knowledge as described in C. P. Snow's *The Two Cultures*. We fail to commit ourselves to the notion of an education for one culture in which the disciplines of science, the social sciences, the humanities, and the arts interrelate and integrate.

Mysticism and reason need not be polarizing forces.

In all of our thoughts and actions these modes of perception are functioning together. How few scientists and technologists recognize and are willing to admit the acts of faith that underlie the very scientific methods that they employ. Conversely, some of the most basic contextual aspects of art, poetry, philosophy, and music are closely related to concepts that are operational in science.

There are three underlying assumptions of faith that every scientist must hold whether he knows it or not. These are:

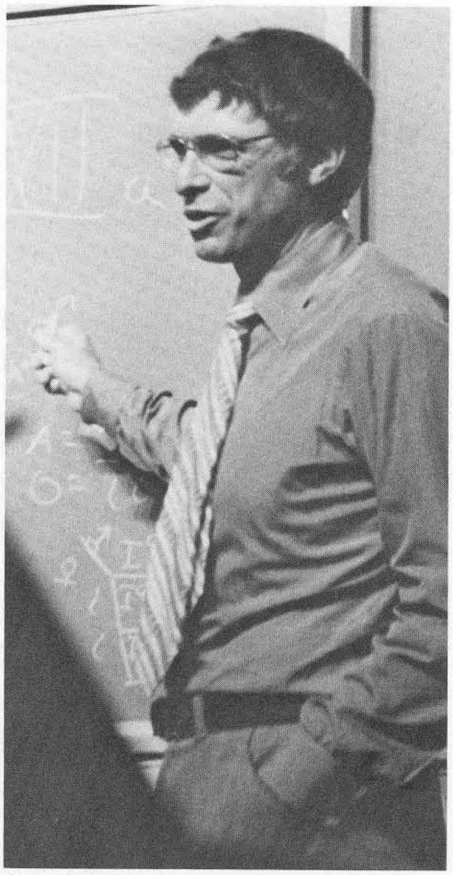
(1) There is order in the universe.

(2) Man can understand that order.

(3) It is good to understand that order.

Indeed, it is the quest to understand meaningful relationships in the universe that drives all of us who practice science to continue searching.

My concern as a scientist, as a teacher, as a citizen, and perhaps above all as a human being is to live and act in accord with the notion of the one culture of man. Science is only one way of perceiving the universe through its questioning, proposing hypotheses, experimenting and verifying the hypotheses, and ultimately extrapolating from present understanding to new questions and new ideas and new relationships. I think we should bring this same sort of perception into everything we think about and do.



Paul Saltman

At the same time, we must see that the fundamental issues of the future of man are not solely based on facts or data, but rather lie in the human and social values that we place upon our interpretations of these facts.

Jacques Monod, the French Nobel Prize winner and biochemist, spoke most eloquently when he said: "Man finally knows that he is alone in the indifferent immensity of the universe. No more than his destiny is his duty anywhere preordained. It is up to him to choose between the kingdom and the shadows."

What is to be man's choice? On what rational or mystical individual and collective premises shall it be made? For me, the answer lies in our commitment to knowing and understanding, our concern for self and others, our sensitivities to our own and our society's needs, and our belief in individual and collective man's ability to change and evolve.

Many years ago, I appeared on a panel program with a delightful and brilliant Canadian author, June Callwood. At that time, we were discussing our value judgments and concerns, and I referred to the biblical credo which has influenced greatly some aspects of my own life, "I am my brother's keeper."

On reflection, June Callwood asked me to reconsider that motto, slightly changed but far more powerful, "I am my brother." If each of us can recognize the reality of this paradoxical and dynamic interaction of existential self and societal others, and at the same time bring into dynamic equilibrium the forces of faith and reason, I believe that the future of man and the societies and nations of this earth will be better. We can and must make it so.

—Paul Saltman (BS '49, PhD '53), from "I Am My Brother" in Courses by Newspaper, *a copyrighted series of lectures. (Reprinted by permission.)*

Getting Started

I remembered a remark which Professor Richard Tolman had once made to one of his classes: "When you have conceived a new experiment, don't think about all of its possible difficulties too long or you will never attempt it!"

—Jesse W. M. DuMond, professor of physics emeritus, in Autobiography of a Physicist

Retiring This Year

Four Caltech faculty members will receive emeritus status in July—H. Frederic Bohnenblust, professor of mathematics; Edward W. Hughes, senior research associate in chemistry; Anthonie Van Harreveld, professor of physiology; and Vito A. Vanoni, professor of hydraulics.

At a faculty dinner at the Athenaeum on May 22, Robert P. Dilworth, professor of mathematics and chairman of the faculty, reviewed the distinguished careers of the four men. We quote from his remarks:

H. F. Bohnenblust

H. F. Bohnenblust, born in Switzerland, came to this country to do graduate work in mathematics at Princeton University in 1928. He completed his doctoral work in 1931 and was a member of the mathematics faculty at Princeton until 1945. Following a year at Indiana University, he joined the Caltech faculty in 1946.

Boni's administrative ability and fine judgment were quickly recognized, and he promptly became head of the mathematics faculty—serving in that capacity for 20 years. From 1956 to 1970 he was also dean of graduate studies, and his administrative contributions extended far beyond the campus. He has been president of the Association of Graduate Schools in the American Association of Universities, was a vice president of the American Mathematical Society, and is a member of several professional societies. He was co-editor of the "Annals of Mathematics" for 10 years.

Boni's research interests have been mainly concerned with that area of mathematical analysis known as functional analysis. This subject was just blossoming into a full-fledged research field when he began his mathematical career. Because of his enthusiasm and clear insight, his ideas had broad impact on the development of the field. The fact that this field is still one of the major research areas of mathematics is strong evidence that his ideas were indeed sound. Appropriately, one of the basic

H. F. Bohnenblust

results in the subject is the Bohnenblust-Sobczyk Theorem which is still quoted frequently by workers in the field. (It would probably be quoted even more frequently except for a certain understandable pronunciation problem.)

Although he established a solid reputation through his mathematical work, Boni has become even better known as a teacher of mathematics. He has, in an unusual way, the ability to make his subject matter superbly clear to students. He is one of the few members of the Caltech community to have had his picture on the cover of *Time*—as one of the ten outstanding teachers in the nation.

There is one aspect to the teaching of mathematics that has always been a source of frustration to Boni. Many of the situations in the real world to which mathematical analysis applies are in a constant state of change. Parameters and the corresponding solutions are changing, but the diagrams drawn on the blackboards are static. They can be changed only by drawing a new diagram. With the advent of the high-speed computer and the CRT tube, Boni realized that here were tools which could overcome many of the deficiencies of blackboard and chalk. For the past several years he has been busy exploring the use of these new tools for this purpose. He is just getting well into this project, so it is clear that he will be busy for some time to come.

Edward Hughes

Edward W. Hughes

Edward W. Hughes came to Caltech in 1938, after getting his PhD at Cornell and spending three more years at Cornell as Resident Doctor. At Caltech he quickly assumed the post of Resident Bachelor. However, in 1951 he quietly went off to England for a year and to the astonishment of his colleagues returned with a wife.

Eddie has also been in the forefront of science. He introduced the techniques of the method of least squares into his professional field, crystallography; today, with high-speed computers having replaced the slide rule, least squares is the universally accepted method for handling the large amounts of data used in crystallography.

Eddie has acted as the official "greeter" for the chemistry division for many years, both in an official capacity as host for the divisional seminars and in an unofficial capacity as liaison for his wife, Ruth, who has provided housing, furniture, and solace to innumerable bewildered visitors and graduate students. The second instruction normally given to a newcomer to the division was to check in with the faculty office; the first, to check in with Ruth Hughes.

Eddie has long served as official photographer for the chemistry division, and his collection runs the complete gamut of campus life. He has also been the unofficial photographer for the American Crystallographic Association, which he served as president and as national committeeman, and for the Wildflowers and Trailblazers' Societies.

Anthonie Van Harreveld

Anthonie Van Harreveld was born and educated in Holland, completing his doctoral work at Amsterdam University in 1931. He began his professional career at the University of Utrecht and then came to Caltech in 1934.

He has served the biology teaching program well as a lecturer in Biology I, maintaining the tradition established by Thomas Hunt Morgan of having senior members of the staff teach this basic course. But first of all he is a research scientist. His work involves the nervous system, including the structure and interactions of neurons, the effects of chemicals in the nervous system, the effects of asphyxiation of the spinal cord on the spinal reflexes, and the creation of memory traces in the brain.

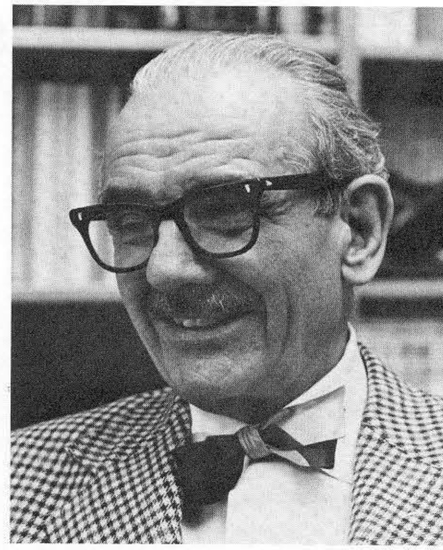
Van Harreveld has devoted his major research efforts to the study of the distribution of water in the brain. It is this work which has brought him world-wide recognition and fame.


Anthonie Van Harreveld

The studies of brain tissue by the electron microscopists had convinced them (and most brain physiologists) that the cells of the brain were solid against one another. From his study of what happens to the brain in asphyxia and spreading depression, Van H came to quite the opposite conclusion—namely, that in the normal brain there is substantial space filled with water that runs between the cells, and that furthermore this water can move in a mad rush from outside the cells to their insides, swelling them and making them butt against one another.

In order to show that this hypothesis was correct, it was necessary to design experiments which would detect the extracellular water. This was far from easy, since the standard detection techniques simply caused the water to disappear into the cells. With great ingenuity, and persistence, Van H designed a series of experiments that demonstrated the existence and stability of the extracellular water. He then went on to discover some of the chemical mechanisms which control the stability of the brain's water. Recently he has shown that a chemical released during spreading depression that brings the cell boundaries close together plays a role in the changes which occur in memory formation.

Vito Vanoni


Vito Vanoni

Vito Vanoni made his first appearance on the Caltech campus 52 years ago when he enrolled as an undergraduate student. He then went on to earn his BS (1926), MS (1932), and PhD (1940) degrees in civil engineering, and began his official academic career at the Institute in 1942, when he was appointed assistant professor of hydraulics—having spent the intervening years in a mixture of studies, work, and research.

Though he has been on the Caltech faculty for 32 years, he has taught his specialty—sedimentation—to more foreign students than Americans. What's more, he's done it mostly in Spanish. In 1959 he took part in a U.S. government-funded AID project to upgrade the education of practicing Chilean engineers. The project seemed so worthwhile—both to Vanoni and to the Chileans—that he did it again in 1962. His Chilean students indicated their appreciation by translating his lectures (given in English at that time) into Spanish and publishing them as a text. News of such a practical and successful idea has a way of crossing national borders, and in 1967 he was invited by the Venezuelan government to lecture at the University of Venezuela, an invitation he was able to accept and carry out in Spanish. He did so again in 1971, '72, and '73, and will be off to Caracas again this summer.

Vito is internationally known as a consultant on water projects and problems, but his very special interest for many years has been the movement of water in its natural state, in rivers and floods (*aqua motus naturalis*). Like a river, Vito himself has meandered over the globe in pursuit of his studies. Having a special interest in sediment transport by rivers, he collected samples of sand from the Amazon, the Orinoco, and the Parana, the Nile (which he pursued to its source in Lake Victoria), the Yukon (from which he panned gold dust), the Volga, the Sepic River in New Guinea, the Skang River in Malaysia, the Colorado River, and the River Jordan. In addition to his academic research, Vito has also carried out applied research on the stability of water in harbors, and on wave action, and numerous engineering projects have profited from this work. □

The Month at Caltech

New Chairman

R. Stanton Avery has been elected chairman of Caltech's Board of Trustees. He succeeds Arnold O. Beckman, who becomes chairman emeritus and a life trustee.

Mr. Avery, who has been a trustee since 1971, is founder and chief executive officer of Avery Products Corporation. He started the company in 1932, three years after he graduated from Pomona College, and it has become the world's leading producer of self-adhesive products.

A leader in southern California academic and cultural affairs, Mr. Avery is chairman of the Board of Trustees of the Huntington Library and Art Gallery, and a member of the boards of the Performing Arts Council of the Los Angeles Music Center and of the Los Angeles County Museum of Art. From 1965 to 1973 he served as chairman of the Board of Fellows of the Claremont Colleges.

Caltech Loves Albert

Watch a man laying a new cement sidewalk. Watch how skillfully he smooths the fresh, wet cement. Watch what happens to the smooth, new cement as soon as the workman departs. Somebody finds it absolutely necessary to record on it, for posterity, the fact of his existence, such as:

FRANK ALBANESE

or the state of his emotions:

FRANKIE LOVES ANGELA

or even a four-letter Anglo-Saxon exhortation:

(EXPLETIVE DELETED)

This is the way it goes, almost anywhere in the world. But not—as so often happens—at Caltech. For a few short weeks (before it was destroyed during the renovation of the Throop Hall site), a pristine strip of new sidewalk at the southeast corner of Dabney Hall bore a single inscription:

$$\Sigma g_{\mu\nu}\, dx_\mu\, dx_\nu$$

—which, Frank Albanese would be surprised to learn, is Einstein's tensor equation for gravity.

It's for Keeps

The history of the Institute is in safe hands—Judith R. Goodstein's. She has been Caltech's archivist since 1968.

Judy came to Caltech, looking for a teaching job, after she got her PhD in the history of science from the University of Washington in 1968. Though there wasn't any opening in that field, the Institute *was* looking for an archivist—a position that had been created because Caltech, after a long period of litigation with the Air Force, had finally been awarded custody of the voluminous Theodore von Karman papers.

When Judy took over, the only collections in the archives, aside from the von Karman papers, were those of two of Caltech's founders—George Ellery Hale and Robert A. Millikan. There are 30 collections in the archives today, housed along with Judy and her assistant, Ruth Gordon, in the basement of Millikan Library. ("Collection," incidentally, includes everything from notebooks and committee reports to personal and professional correspondence, scientific journals, and preprints.)

The archives now house the papers of Earnest C. Watson, Richard P. Feynman (including his high school notebooks), Max Delbrück, and Edward C. Barrett. Barrett served as secretary (and later also as treasurer and comptroller) of the Institute from 1911 to 1952, and his papers offer a challenge to cryptographers. For many years, Barrett compiled detailed information about the workings and activities of the Institute for eventual use in a history of Caltech. But all the notes are in a shorthand devised by Ned Barrett himself—and, unfortunately, no one has even come close to breaking his code.

E. T. Bell, one of Caltech's great mathematicians, destroyed *all* his scientific material before he died. (This is not at all uncommon, according to Judy—for reasons ranging from privacy to modesty.) The only papers he kept were his correspondence with editors of science fiction magazines, for whom he wrote regularly under the pen name of John Taine.

When Judy Goodstein got wind of the fact that all of this correspondence was still extant, she wrote at once to Bell's widow—unaware of the fact that she had died many years before. The letter was passed on to the banker who was in the midst of settling the estate of a deceased student of Bell's who had been working on a biography of Bell for the National Academy of Sciences. The student's house on Seventeen-Mile-Drive in Carmel was about to be auctioned off, together with all its contents. Since the bank felt that the science-fiction papers were of no particular value for estate purposes, the Caltech archives got a real windfall.

The archives now contain about 300,000 documents and a growing collection of tapes, including those of the original lectures of R. P. Feynman, which were transcribed and edited into the famous *Lectures on Physics*. The tapes of the Monday evening Watson Lectures given in Beckman Auditorium are also preserved there.

The Month at Caltech . . . *continued*

Judy has also been collecting more general information such as old accounting ledgers of the Institute, which she found in a warehouse, and some division records. The biology division's papers from 1928 until 1957 include the minutes of all biology division faculty meetings and even the names of undergraduate advisors. These papers were compiled for the most part while George Beadle was division chairman. Comparable documents from astronomy have also been promised, and these will be greatly augmented by the papers of Jesse L. Greenstein, Lee A. DuBridge Professor of Astrophysics, who has agreed to start transmitting some of his material to the archives in the fall.

The most recent acquisition is the collected papers of physicists Charles C. Lauritsen and Thomas Lauritsen, which were given to the Institute by the Lauritsen family.

Another recent acquisition of special interest is the scientific and personal correspondence of the mathematician Tullio Levi-Civita, who maintained a correspondence between the years 1896 and 1941 with more than 900 people throughout the world, including many Caltech scientists. About 4,000 letters, postcards, reports, and miscellaneous documents were written during that time, and Judy has just completed the enormous task of cataloging them. Because of this work, she was invited by the Accademia Nazionale dei Lincei (Italy's national academy) to take part in the 100th birthday celebration for Levi-Civita in Rome last winter.

The Caltech archives is one of the very few anywhere to be devoted exclusively to science, and it is the first of its kind on the West Coast. Scientific historians from all over the country consult its collections. "And we get a lot of calls," says Judy, "from Harvard, Johns Hopkins, the Smithsonian, and UC Berkeley." Freelance writers also

Judy Goodstein

use the collections, and the Institute administration uses archival materials for determining names, dates, details of publications, and personnel information. CBS's "60 Minutes" news program on the Chinese Nuclear Development program came to the archives for information on Hsue-Shen Tsien—a student of Von Karman's, and now director of the nuclear development program to the People's Republic of China. One of the most obscure requests, Judy recalls, was from a student doing research on the group of row houses in Chicago where Robert Millikan once lived.

What would she like to have for the archives more than anything else in the world? Judy's eyes take on a faraway expression, and then she smiles. "The Linus Pauling papers," she says.

—*Joy Hays*

In Memoriam

John G. McLean

John G. McLean, a member of the Board of Trustees since 1971, died May 20 in Greenwich, Connecticut. He was 56.

Mr. McLean, who was chairman and chief executive officer of Continental Oil Company, graduated from Caltech in 1938 with a BS in applied physics, and was recipient of the Institute's Distinguished Alumni Award in 1970. He received his master's and doctor's degrees from Harvard Business School and served on its faculty for 14 years before joining Continental in 1954.

Herbert G. Nash

Herbert G. Nash died in Pasadena on May 10 at the age of 79. At the time of his retirement in 1964, he had served Caltech longer than any administrative nonacademic employee—42 years.

Bert Nash was a native of London, England. In 1922 he came to the Institute from Winnipeg, Canada, as chief accountant. He was made assistant secretary of the Board of Trustees in 1935, and in 1952 he became its secretary. At the time of his retirement he was also assistant secretary and assistant treasurer of The Associates. Mr. Nash served as a member of several key administrative committees, and he administered the insurance programs for the Institute and JPL. He is survived by his wife, Josephine, and three children.

Jeanne Augé

Jeanne Augé died on May 30 after a long illness. She came to the Institute in 1935 to be an assistant to the graduate dean, Richard Tolman, and for the next 30 years she worked with a succession of them, including Roscoe Dickinson, William Houston, William Lacey, Sterling Emerson, and H. F. Bohnenblust.

By the time of her retirement in 1966, Mrs. Augé had earned the gratitude of a multitude of graduate students, as she helped them to adjust to their new environment. After leaving the campus, she continued an active interest in Caltech affairs, and she never failed to attend Commencement—taking pride in noting "her" Caltech-PhD faculty members in the procession and after the exercises congratulating the new degree holders.

In 1972 she moved to Kentucky to be near her son Roger. She is survived by him, four grandchildren, and three great grandchildren.

NAS Addenda

Last month *E&S* reported on the election of faculty members Roy Gould and Leon Silver to membership in the National Academy of Sciences. Now, we add the names of six alumni who received the same honor: Horace W. Davenport (BS '35, PhD '39), Dan L. Lindsley Jr. (PhD '52), Allen E. Puckett (PhD '49), William R. Sears (PhD '38), Howard M. Temin (PhD '60), and John S. Waugh (PhD '53).

NAS has also tapped William A. Fowler, Institute Professor of Physics, for a three-year term on its 17-member governing council. John R. Pierce, professor of engineering, has just completed a stint as a councilor.

And George Hammond, former Arthur Amos Noyes Professor of Chemistry and chairman of the Division of Chemistry and Chemical Engineering at Caltech, has been elected NAS foreign secretary for a four-year term. He succeeds Harrison Brown, professor of geochemistry and of science and government, who has held that position since 1962.

More Faculty Honors

Clarence R. Allen, professor of geology and geophysics, has been elected to the American Academy of Arts and Sciences.

Harrison Schmitt (BS '57), astronaut and Sherman Fairchild Distinguished Scholar at Caltech, has been appointed assistant administrator for energy programs in the National Aeronautics and Space Administration headquarters in Washington, D.C.

John D. Roberts, Institute Professor of Chemistry; and Roger W. Sperry, Hixon Professor of Psychobiology, have been elected to membership in the American Philosophical Society. □

Letters

Chuck Bures

EDITOR:

Charles Bures is no longer here.

At a time and place where success is measured in units of dollars and politically manipulatable awards, true giants may come and go unnoticed by the scientific lot.

I first met Professor Bures in '65 when I attended his Psychology classes; I am still a student of his, still learning from his example.

When I first enrolled in his class, it was out of a desire to maintain my sanity and humanity in a small world of largely unidimensional pseudoscientists who composed the "mutual admiration society of Pasadena." It became immediately apparent that I had met a Master, in the true Oriental sense.

Professor Bures had a more analytic mind than most of the self-proclaimed analytic types who thrived there. More than that, he had realized that the linear one-at-a-time approach of conventional science was a self-imposed blindfold; real-life problems don't behave in a linear one-at-a-time fashion, and it takes a unique ability to perceive them in their complexity. Professor Bures had that ability.

He understood life and what makes it worthwhile. He was quick-witted, and careful at the same time to be compassionate. Given the usual choice between prolific publications for their own sake and teaching Caltech's youth, he chose the latter. And I am forever thankful to him for that.

MICHAEL A. CALOYANNIDES
(BS '67, MS '68, PhD '72)

No Glee

EDITOR:

I am writing to you about a feature that appeared in the May 1974 issue of *Engineering and Science* magazine, namely "An Outburst of Music." As the official student representative of the Men's Glee Club I have a few complaints about this feature.

First, it is supposedly a "smorgasbord of musical activities." However, I think it could have been more representative and inclusive. No pictures of the Madrigal Singers, Varsity Quartet, or Men's Glee Club appeared, although these groups are as active as any others on campus and form a "main course" of the smorgasbord. The Men's Glee Club is mentioned and the reader is referred back to a previous issue. However, the article referred to (*E&S*—October 1973) was about vocal instruction, not the Men's Glee Club, Madrigals, or Quartet. True, it gave us coverage, but the issue here is representation not coverage. I am wondering what sort of impression readers, specifically alumni, will get when they see "An Outburst of Music." Will they think we have ceased being a vital force while we still in actuality have the largest student involvement of any club on campus?

Secondly, I take issue with the statement that the Women's Glee Club and the Chamber Singers are "moving in" on the Men's organizations. This is somewhat illogical, since the men in the Chamber Singers are from the Men's Glee Club. Also, it is simply not true. Our groups work in cooperation, not in competition. I would like to know just what prompted that statement to be written.

Finally, the pictures seem to imply a larger numerical contribution by women. While this may be true on a percentage basis, it is certainly not accurate as far as actual figures go, and not to the extent presented in the article.

It seems obvious that no attempt was made to present a reasonable representation of musical activities with regard to effort, time, or numbers involved. If there was a reason for this I would like to know why. But I believe it presents an inaccurate picture to your readers and this is unfortunate.

Sincerely,
JEFF ERIKSEN
President
Men's Glee Club

P. S. By the way, the reference was wrong—it was *November* 1973!

Right: We were wrong. The three-page picture story on the Glee Club ran in our November-December 1973 issue.

Good Nutrition for the Good Life

... continued from page 9

of these molecules in the human body. The powerful drugs that are used by doctors, who treat crises with these crisis drugs, do the job, but they usually have serious side effects and you have to be careful about them. In particular they shouldn't be taken day after day, whereas the vitamins can be taken day after day for the rest of your life.

The paper in which I introduced the word orthomolecular had the title "Orthomolecular Psychiatry." In 1954 I began work here at Caltech with the support of a grant from the Ford Foundation and later from the National Institute of Mental Health on the molecular basis of mental disease. After some time I learned about the work of Drs. A. Hoffer and D. Osmond in Saskatoon, Saskatchewan. Hoffer had observed that large doses of one of the B vitamins, the antipellagra vitamin nicotinic acid, niacin, seemed to be beneficial to schizophrenic patients. Hoffer and Osmond carried out the first double blind test done in psychiatry, and they concluded from the results of this test that, taken in amounts of several hundred times the amount that will prevent pellagra, the substance did have value for many schizophrenic patients—especially young, acute schizophrenics who were hospitalized for the first time.

I wrote a paper in 1968 in which I presented a number of arguments about why megavitamin therapy should be especially valuable for mental disease. This argument appealed to people who were using this therapy to such an extent that there is now a journal named *Orthomolecular Psychiatry* and an International Academy of Orthomolecular Psychiatry, and a book, *Orthomolecular Psychiatry*, published a year ago—of which a psychiatrist, David Hawkins from Long Island, and I are co-editors—about the basis of megavitamin orthomolecular treatment.

I believe there's no doubt that the statements made by the orthomolecular psychiatrists are right. The ordinary treatment with the use of phenothiazines mainly for acute schizophrenics leads to about 35 to 45 percent success. This means that 35 or 45 percent of these acute schizophrenics are released from the hospital and do not suffer a second hospitalization. But if they also receive orthomolecular treatment in addition to the phenothiazine and whatever else the psychiatrist wants to give them, it is said that 80 percent of them are released and not hospitalized a second time. They are to continue the vitamins the rest of their lives. The phenothiazine they stop taking quickly.

In my paper, I pointed out that the brain is probably the most sensitive of all organs to its molecular composition, and that it is not surprising that the megavitamin therapy should have been developed first of all for mental disease. But it is valuable also for physical disease.

The amounts given these schizophrenic patients vary—they are not the same for individual patients, but they usually run about 6 grams a day—4-8 grams of ascorbic acid, about 8-20 grams a day of niacin or niacinamide, and about 400-800 milligrams of pyrodoxine and sometimes 400-800 units of vitamin E and thiamine. These all vary, but usually with emphasis on ascorbic acid and niacinamide.

Vitamin E is an important substance. The Food and Nutrition Board brought out a few months ago a statement to the effect that they have reduced the daily recommended dosages of vitamin E from 30 milligrams to 15 units. It's hard to know why they have reduced it, but I believe it would have been wiser to increase it. Perhaps one reason for reducing it is that the big food companies have begun stripping the cooking fats, the oils, of their vitamin E so that the fats you eat don't contain as much vitamin E as they used to. Then they sell the vitamin E, and it's rather high priced—nearly $100 per kilogram. (Vitamin C can be be purchased for $7.50 per kilogram as pure crystals, and it is cheapest this way.)

Well, about vitamin E—in the Food and Nutrition Board report they said that there is no evidence that any disease, except one rare disease among infants, is benefited by taking large doses of vitamin E. So I wrote to Jean Mayer, professor of nutrition at Harvard, who has a newspaper column in which I first saw this reported, and asked him why he made the statement (he is a member of the committee) in light of the report by Knut Haeger of Sweden about peripheral occlusive arterial disease, and the other reports on this disease. And he replied by a letter in which he said that he was asking the Food and Nutrition Board to send me a copy of the statement, and that was all. The statement arrived, and it was just as he had quoted it. So I wrote to the chairman of the Food and Nutrition Board three months ago asking why they made this statement in the light of Haeger's results, and I haven't gotten an answer from them.

Knut Haeger published a paper in 1968 about a seven-year study he had made of patients with peripheral occlusive arterial disease. He had 220 patients under observation—people perhaps with diabetes or prediabetic conditions who have hardening of the peripheral arteries with a decreased flow of blood to the extremities; sometimes they get gangrene in the foot. He gave half of them 300 units a day of vitamin E and the other half a placebo. They were age-matched so that the average ages were the same in these two groups. During the seven years of the study, one of the vitamin E patients had to have a leg amputated because of gangrene, and 11 of the control group had to have legs amputated; this difference has high statistical significance. It's not a statistical fluctuation—one chance in a thousand of that. Nine of the vitamin E patients died during the seven years, and 19 of the control patients. This difference has borderline statistical significance—about 10 percent chance of its being a statistical fluctuation.

These people have what is called intermittent claudication—that's a highbrow name for limping occasionally. They can start out walking at a good rate; after they have walked a while, they develop angina in the calves of the legs. The work of the muscles uses up the oxygen so that they have to stop walking because of the pain caused by anoxia. It takes about six months for them to get in a stable state. After about six months, though, the vitamin E subjects could walk on average about twice as far as the control subjects before they developed claudication, and this is statistically significant too—the standard deviations are such that the difference is statistically significant. There are a number of other studies that report essentially the same thing.

Haeger asked the question, Who is it who believes that angina in the calves of the legs is different from angina in the heart muscle caused by anoxia? There have been no good double blind studies made of vitamin E in relation to heart disease. But Wilfred and Evan Schute in Canada treated 30,000 heart patients by giving them large doses of vitamin E, and they report that there is no doubt they are benefited. For example, a Dr. George wrote them about himself. He had diabetes and had a leg amputated because of gangrene—poor circulation—and then after that he heard of the work the Schutes were doing and he started taking vitamin E. He was scheduled to have the other leg amputated, but it healed when he took the vitamin.

And yet the medical profession as a whole has rejected this evidence in the same way that they have rejected the evidence about the value of vitamin C for the common cold and other diseases.

Now I don't know just what the optimum intake of vitamins is. I take 1,200 units of Vitamin E per day, which gives an indication of what I judge to be the sensible thing to do. And I take super-B vitamins every day which contain 50 milligrams (that's about 25-30 times the recommended daily allowance) of thiamine, and 50 milligrams of riboflavin and 50 milligrams of pyridoxine, and 100 milligrams of nicinamide (though I usually take 300-400 milligrams of nicotinic acid separately too) and a multivitamin tablet that gives me 4,000 units of vitamin A plus other vitamins and minerals, and sometimes I take 25,000 units of vitamin A. I am trying to see if I can discover what the optimum intake of vitamin A is. But this is a hard problem. I think there should be hundreds of millions of dollars expended on finding out what the optimum nutrition is for a human being.

Avoid sucrose, take a fair amount of vitamins, stop smoking cigarettes, and you'll have a longer and happier life

I think that vitamin E has great value, and that these other vitamins have value, and I'm willing to estimate that the morbidity and mortality of various diseases and the rate of aging can be decreased by another factor of two in this way.

There's one more nutritional orthomolecular treatment that I'll mention. This is a negative one involving sugar—sucrose. John Yudkin was professor of biochemistry and nutrition at the University of London 15 years ago, and he published a paper on his research on sucrose in relation to heart disease. He studied the incidence of heart disease as a function of the amount of sugar ingested, and he concluded that people who take 120 lbs of sugar per year have six times the chance at a given age of coming down with coronary heart disease as people who take 60 lbs per year or less. Those who take 150 lbs or more a year have 15 times the chance at a given age of developing coronary heart disease as those who take 60 lbs or less.

Two hundred years ago practically no one got any sugar. And the intake—you get small amounts in fruit and honey—measured up to 15-20 lbs per year. The average in the U.S. is now over 100 lbs per year. It's 110-120 lbs in England, and Holland, and some other countries. This is an unnatural situation, to ingest so much sucrose—and it is harmful. A study was made by Milton Winitz, a biochemist, in the state correctional institution at Vacaville. He got 18 volunteers in a locked ward and fed them a small-molecule diet consisting of 17 amino acids, a small amount of essential fat, all of the vitamins in the recommended daily amounts, and all of the essential minerals, and glucose as the only carbohydrate. He measured 26 clinical characteristics and found that they all stayed the same when the prisoners went from the prison diet over to this chemically determined diet—except one. The serum cholesterol dropped from 207 milligrams per deciliter average to 155 average within a month. Within a week it was down half way. After a few months the patients complained about the taste of the food, so Winetz replaced a quarter of the glucose with sucrose—with everything else the same—and the serum cholesterol went back up to the original level. It's the sucrose—not the carbohydrate—that's the culprit.

I believe that if people were to avoid sucrose—hardly ever spoon out a spoonful of sugar from the sugar bowl onto anything, avoid sweet desserts except when you're a guest somewhere, avoid buying foods that say "sugar" as one of the contents—they could cut down on the incidence of disease and increase life expectancy. Take a fair amount of vitamins. Stop smoking cigarettes. And you'll have a longer and happier life—more vim and vigor and a better time altogether. □

Medical Genetics and the Engineering of Man

. . . continued from page 5

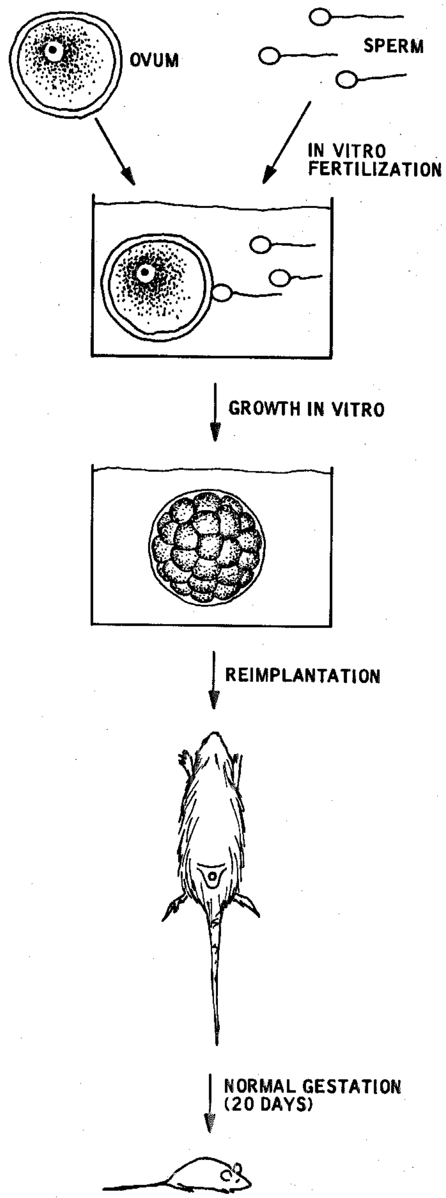
Thorny questions arise concerning any genetic screening program. Should a screening program be carried out if there is neither treatment for the disease nor any possibility of prenatal diagnosis? If the screening program is desirable for medical reasons, how should the information be stored and who should have access to it? Insurance companies? Employees? Interested private individuals?

In the future two other techniques now in the developmental stages will also afford man opportunities to manipulate his gene pool (*in vitro* or test tube fertilization and reimplantation) or to alter his own genes directly (gene therapy).

Test Tube fertilization

It is now possible to combine mouse sperm and ovum outside the mother's body to produce a normal fertilized zygote which can be grown in tissue culture to the 16- or 32-cell stage (blastocyst stage). At this stage of development, if the zygote is implanted in the uterus of an appropriately prepared female, in more than 50 percent of the cases normal infant mice will be produced after an appropriate gestational period. *In vitro* fertilization has also been accomplished with human sperm and ova. Reimplantation of the fertilized zygote in female humans should be possible within a very few years. These procedures could permit many thousands of couples who are infertile due to blockage of the uterine tubes to have their own children.

Obviously this procedure raises its own interesting questions. Can one be assured that the offspring from such a procedure will be normal infants? (In mice the abnormal offspring appear to abort early, and most of the fetuses surviving through to birth appear perfectly normal.) The procedure of ovum extraction from the mother generally yields multiple ova. If only a single ovum is necessary for fertilization, how will the remaining ova be used? The fertilized egg can be transplanted into any female uterus. Could a single set of parents hire wombs (i.e., "wombs for rent") to produce many of their own progeny? Artificial wombs seem to be a very distant possibility at this time, and Aldous Huxley's test-tube factory for babies appears remote.



Manipulating the gene pool in mice is now possible with *in vitro* fertilization and reimplantation. Ova and sperm from mice can be mixed in a test tube to yield a fertilized egg (zygote). After the egg grows in the test tube to the blastocyst stage, it can then be reimplanted in an appropriately prepared female. After a normal gestation period, normal mice are born.

These studies also set the stage for advances in yet another area which, for human beings, is currently placed in the realm of science fiction—cloning. Frogs and carrots, however, have been successfully cloned. In the case of a frog, a nucleus is removed from one of the cells that line the intestinal wall, and it is reimplanted in an ovum that has had its own nucleus removed. This "manufactured" zygote (i.e., fertilized egg) apparently initiates the normal developmental programs, which thereby induce the growth of a normal frog with a genetic constitution identical to the parent from whom the intestinal nucleus was removed (i.e., a clone).

Two major difficulties arise in carrying out such a procedure in mammals. First, mammalian ova are extremely small and, accordingly, difficult to manipulate with the microsurgical techniques required for the transplantation of a new nucleus. Second, mammalian eggs, unlike their amphibian counterparts, develop in the mother's body rather than in pond water. In theory the first difficulty can be circumvented by an important new technique of cell biology—cell fusion, which makes it possible to fuse together any two cells (even those from different species). Using this technique, it should be possible to destroy the nucleus in a human ovum (with a laser beam, for example) and then to fuse this enucleated egg to a normal human cell from the same or a different individual. Presumably this egg with a single nucleus could be induced to start the normal developmental program, and at an appropriate stage the "clone" could be implanted in the uterus of a surrogate mother.

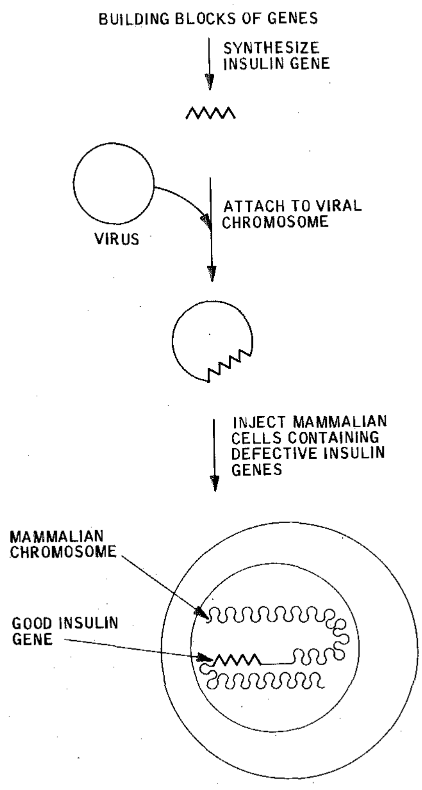
Most of the theoretical barriers to cloning have been circumvented by various techniques of modern science. A number of technical details have yet to be mastered, but within 10 to 15 years cloning is likely to be a reality. Then, of course, another host of questions will be raised. Should only individuals with unusual traits or abilities (such as music, mathematics, art) be cloned, or should any individual who can afford the procedure be permitted to generate copies of himself?

The potential use (or abuse) of cloning will be limited by the necessity of providing a surrogate mother for each clone. Thus a single individual could be cloned only to the extent that surrogate mothers could be found. When and if Aldous Huxley's vision of fetal development in an artificial womb becomes a reality, a new dimension of cloning possibilities will arise.

Gene therapy

Gene therapy, or "genetic engineering" as it is often called, might take many forms. Perhaps the simplest to envision is the use of modified viruses to replace defective genes. For example, certain simple genes have already been synthesized in the test tube, and in theory, the gene coding for the hormone insulin could be synthesized. This gene could then be attached to the chromosome of an appropriate virus. Certain viruses have the ability to insert or attach their chromosomes into those of their mammalian hosts. Thus, in principle, an individual with a defective insulin gene could be infected with a virus carrying a good insulin gene, which in turn could lead to the integration of a good insulin gene into one (or more) of the human chromosomes in the defective cells. Presumably the good gene could then supply the missing hormone and thus correct the genetic defect.

It must be stressed that many theoretical and practical difficulties remain before this form of gene therapy, or any other for that matter, becomes a reality. How can the defective gene be identified and isolated for chemical analysis? Must the gene be inserted into a single correct position in a particular mammalian chromosome? Will the complex control systems for the genes of mammals operate appropriately on such an inserted gene? Can we be assured that the virus vector will not cause cancer in the host? These are only a few of the questions that render the possibility of gene therapy unlikely for many years—but the eventuality will come to pass, perhaps much sooner than the always conservative estimates of medical scientists.



Theoretically, gene therapy could be accomplished by replacing defective genes with modified viruses. For example, a human insulin gene could be synthesized and attached to a viral chromosome. The modified virus could then be used to infect human cells that have a defective insulin gene by integrating the good insulin gene into one or more human chromosomes. The good gene could supply the insulin that defective cells are otherwise unable to synthesize.

Two points should be made with regard to gene therapy. First, it will be utilized for treating single-gene defects. Most of the human qualities that we attribute to man, such as intelligence, emotions, and physical appearance, are controlled by many different genes in the human chromosomes—that is, they are polygenic traits. It appears unlikely that man will soon be able to alter polygenic traits because this would require an understanding of complex multigenic interactions as well as the actual identification of all of the genes involved. Thus gene therapy will be directed at *diseases that are caused by single defective* genes (such as phenylketonuria and galactosemia). Second, genetic engineering will provide man with the opportunity to alter either the genes in the organs and tissues that constitute most of his own body (somatic cells) or those in his sex cells. In the first case the gene correction will be confined to the individual himself and will not be passed on to his progeny. In the second case, man will alter the genes to be passed on to future generations and in doing so will start to play an active role in guiding, consciously or unconsciously, the evolution of the human race.

In summary, medical genetics has given (or will give) man the opportunity to engineer his own genes, either by expansion or elimination of selected genotypes or individuals through genetic counseling, genetic screening, and *in vitro* fertilization followed by reimplantation, or by direct alteration of his genes through gene therapy. Critical questions arise with regard to determining how these techniques should be applied, who should make these decisions, and how they should be enforced. These questions are, of course, made even more pressing because they raise issues concerning the nature and essence of man himself, which he can and probably will change. We are dealing with an intensely personal dilemma. How will the decisions be made?

continued on page 32

Medical Genetics and the Engineering of Man

... *continued from page 31*

Why not stop research in medical genetics?

One conceptual solution to many of these dilemmas is to stop all genetic research, but this appears unlikely. On the one hand, many of these genetic studies are important to areas of medicine other than "human engineering." Cell fusion studies, for example, may lead to important clues about the nature of cancer, as may studies on the insertion of viral chromosomes into mammalian chromosomes. In addition, studies in all areas of medical genetics are being carried on everywhere. A moratorium on genetic studies in any one country would probably have only a modest effect on the rate at which these various genetic techniques are being developed elsewhere. Accordingly, any solutions to the social and ethical dilemmas of modern genetics must be approached from an international point of view.

Two legitimate points, however, should be raised with regard to a consideration of controls over genetic research. First, society's resources are finite and priorities must be assigned for their deployment. How should we balance efforts in biology and medicine against efforts to eliminate poverty, pollution, urban decay, discrimination, and poor education? What are the social consequences of seducing many of our brightest young people into spending their lives in science while other more immediate and possibly more serious problems go begging? Second, are the biomedical sciences justified because they are directed toward the "betterment of mankind"? Perhaps it is time to explore what we mean by this phrase. What ends should these new technologies serve? What values should guide society's adjustments? Man must assess his goals, his values, and his needs.

The public's role

It is clear that an informed and thoughtful public should play a decisive role in formulating these decisions. The critical point is how to inform the lay public of the present and future possibilities of genetics and of their social and ethical implications. The mass media have so far not accomplished these ends in that their programs on medical genetics, even when carefully done, have focused mainly upon the medical advances themselves and not on the resulting social and ethical dilemmas. Scientists and physicians have done little better—partly out of indifference, sometimes from the erroneous belief that science is too complex to transmit to the public, or indeed, from the conviction that the moral and ethical implications of medical research should not be aired for fear of jeopardizing the funding of medical research itself.

At this pivotal point, our future directions should reflect the applied wisdom of the many–not of a few

Perhaps the most difficult aspect of the social and ethical dilemmas of modern genetics to convey to the public is the realization that the solutions are not single-valued; that is, different people will arrive at different, but equally valid, solutions to these dilemmas. For some families a mongoloid child could be a devastating experience; for others it could be inspirational. To account for the vast spectrum of different value systems, legislation resulting from public consideration of these matters must be appropriately flexible. The social and ethical implications of medical genetics are a paradigm for those presented by many other areas of medical science.

Future directions

If man can develop effective processes for dealing with the dilemmas of medical genetics, there is hope that these processes can provide a model for similarly coping with new developments in other areas of biology and medicine.

First, the armamentarium of modern medicine and its ability to maintain the human organism after the loss of varying degrees of brain function has raised thorny questions about euthanasia.

Second, B. F. Skinner, a behavioral psychologist at Harvard, has developed effective means of changing man's behavior without his conscious knowledge of what is happening. These methods are being employed experimentally in some penal and mental institutes throughout the country as well as in a variety of institutions that deal with ordinary individuals.

Third, effective drugs and chemicals are being developed for altering man's moods. These agents are already widely used in the treatment of certain mental diseases.

Finally, psychosurgery involves techniques which will alter certain types of behavior, presumably in an irreversible fashion. It has been advocated that these techniques be used to control socially undesirable behavior such as violence.

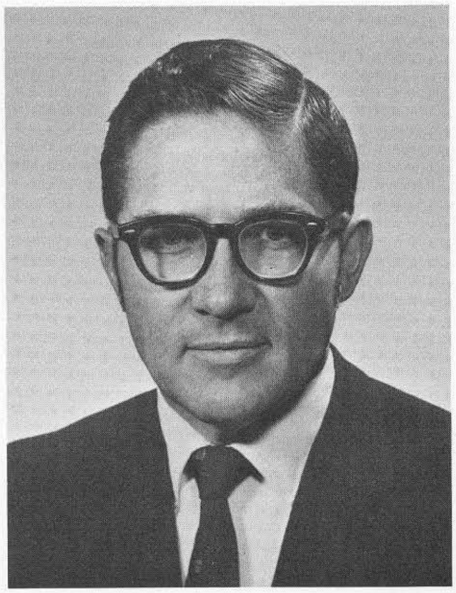
Each of these developments gives rise to a parallel set of questions. When, if ever, should these techniques be applied? Who should decide, and how should the decisions be enforced? In each case these techniques can be used for mankind's benefit or to his detriment. We have before us one glaring example of man's failure to deal with a problem posing comparable ethical and social dilemmas—the development of atomic weapons. Decisions will be made on these critical issues, whether or not the lay public contributes in an informed and thoughtful fashion. We stand at a pivotal point in man's history. Let us hope that our future directions will reflect the applied wisdom of the many, and not of a few. □

In This Issue *. . . continued*

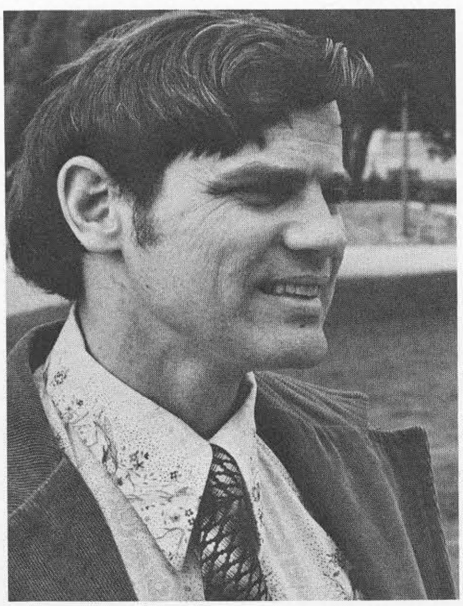
Fiat Lux

Many scientists are concerned about keeping the public informed of scientific findings that affect it. One way in which that concern has been demonstrated at Caltech recently is with a series of open conferences on the ethical questions of science. These conferences have been jointly sponsored by the Caltech Y and the Institute. The first, "The Impact of Genetic Engineering on Society," was held in May 1972. A second was held a year later on "The Impact of Behavioral Engineering on Society."

With partial funding by the Norton Simon, Inc. Foundation for Education, the third of these conferences, "The Impact of Modern Biological Research on the Ethics of Society," was held on the campus on April 20. One of the principal speakers was Leroy Hood, MD, associate professor of biology, and Caltech alumnus (BS '60, PhD '68). "Medical Genetics and the Engineering of Man" (page 2), by Hood and Robert J. Mackin Jr., is in part adapted from Hood's talk on that occasion and in part drawn from discussions held the following day to consider how these issues might be communicated to the general public. This workshop, also sponsored by the Simon Foundation, was attended by about a dozen scientists, physicians, ethicists, and representatives from the television industry.



Robert Mackin



Leroy Hood

Caltech alumnus Mackin (MS '51, PhD '53), who collaborated with Hood on this article, is also concerned about the public's need to know what scientists are doing. He is manager of Caltech-JPL Medical Sciences Laboratory Planning and of the JPL Space Sciences Division.

Food for Thought

Caltech's Linus Pauling, professor of chemistry emeritus, two-time Nobel Prize winner, and perennial generator and explorer of ideas—from the nature of the chemical bond, through outlawing war, to the value of vitamins, for example—came back to the campus recently as a guest of the Caltech Y's Leaders in America program. As always, he brought out standing-room-only crowds. One of the largest groups turned up at Ramo Auditorium on April 4 for his talk on nutrition. "Good Nutrition for the Good Life" (page 6) is adapted from that speech.

By Request

Richard P. Feynman, who is Richard Chace Tolman Professor of Theoretical Physics at Caltech, was Caltech's commencement speaker this year—by popular demand.

The faculty convocations committee, which arranges the Institute's commencement ceremony every year, had just about decided to do away with the custom of having a formal commencement speaker at Caltech's 80th Annual Commencement on June 14, when the graduating senior class not only begged them to change their minds, but presented them with a list of speakers the seniors would like them to invite. And Feynman's name led all the rest. (The rest, incidentally, included Elliot Richardson, Isaac Asimov, Eric Sevareid, and Woody Allen—a very catholic selection.)

As Feynman began to cast about for a subject for his talk, he decided that it would at least have something to do with his recent investigations into such *un*-scientific matters as ESP, Esalen, astrology, and expanded consciousness. It was at this point, of course, that he had to produce a title for the talk, because the commencement program was going to press. He settled on "Unscientific Evidence." Not until he began to put the actual talk together did he realize ("like the woman who expects to have a red-headed son and names him Rufus—then has a black-haired daughter") that his title no longer fit his talk.

So, on page 10, the transcript of Feynman's commencement speech, "Unscientific Evidence," appears with a new name—"Cargo Cult Science."

Development and Design. Is this the kind of engineering for you?

Trying to figure out the exact kind of engineering work you should go into can be pretty tough.

One minute you're studying a general area like mechanical or electrical engineering. The next you're faced with a maze of job functions you don't fully understand. And that often are called different names by different companies.

General Electric employs quite a few engineers. So we thought a series of ads explaining the work they do might come in handy. After all, it's better to understand the various job functions before a job interview than waste your interview time trying to learn about them.

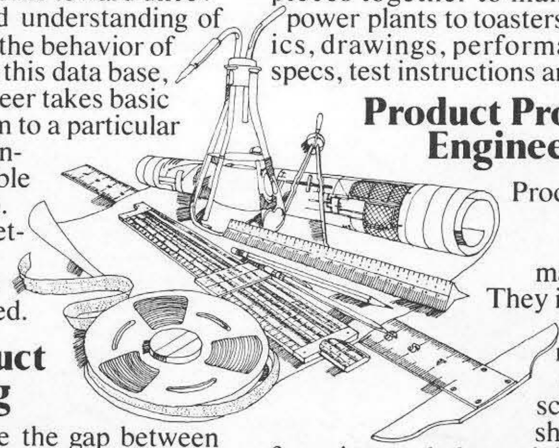
Basically, engineering at GE (and many other companies) can be divided into three areas. Developing and designing products and systems. Manufacturing products. Selling and servicing products.

This ad outlines the types of work found in the Development and Design area at GE. Other ads in this series will cover the two remaining areas.

We also have a handy guide that explains all three areas. For a free copy, just write: General Electric, Dept. AK-1, 570 Lexington Avenue, New York, New York 10022.

Basic/Applied Research Engineering

Motivated by a curiosity about nature, the basic research engineer works toward uncovering new knowledge and understanding of physical phenomena (like the behavior of magnetic materials). From this data base, the applied research engineer takes basic principles and applies them to a particular need or problem (such as increasing the energy available from a permanent magnet). Output is aimed at a marketable item. Both work in laboratories and advanced degrees are usually required.



Advance Product Engineering

Advance engineers bridge the gap between science and application. Their job is to understand the latest advances in materials, processes, etc., in a product area, then use this knowledge to think up ideas for new or improved products or to solve technical problems. They must also prove the technical feasibility of their ideas through laboratory testing and models. Requires a highly creative, analytical mind. A pioneering spirit. And a high level of technical expertise. Output is often a functional model.

Product Design Engineering

Design engineers at GE pick up where the advance engineer leaves off. They take the product idea and transform it into a product design that meets given specs and can be manufactured. Usually, they are responsible for taking their designs through initial production to prove they can be manufactured within cost. Requires a generalist who can work with many experts, then put all the pieces together to make a product. From power plants to toasters. Output is schematics, drawings, performance and materials specs, test instructions and results, etc.

Product Production Engineering

Production engineers interface between the design engineer and manufacturing people. They interpret the product design intent to manufacturing. They maintain production scheduling by trouble-shooting during manufacturing and determining deviations from specs. When necessary, they help design adaptations of the product design to improve quality or lower cost without changing the essential product features. Requires intimate familiarity with production facilities.

Engineering Management

For people interested in both engineering work and management. Engineering managers plan and coordinate the work of other engineers. They might oversee product development, design, production, testing or other functions in marketing and manufacturing. Requires a strong technical base gained through successful engineering work. Sensitivity to business factors such as cost and efficiency. Plus the ability to work with people.

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