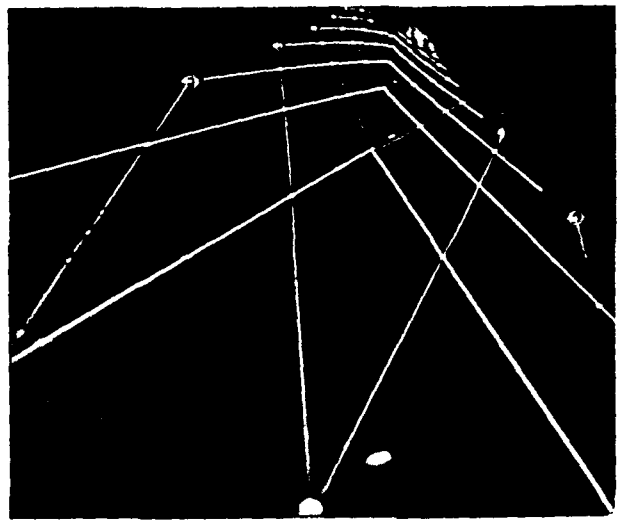
1973 Britannica Yearbook of Science and the Future

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Shaping Our Lives Through Science and Technology



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The world is cool, peaceful, green. Birds sing in the trees. They seem to answer man's call. For there, he is a friend. Man and his environment are in harmony. Nature fulfills his material needs and he does not abuse it. If man is unhappy, he does not know it or show it.

Those words might be said to describe the life of a society of just 25 people whose existence became known to us only in 1971. And if ignorance is bliss, is it folly to be wise? For perhaps centuries, their discoverers tell us, the Tasaday tribe has been isolated from the rest of the world in a dense rain forest in the Philippines. There, the Tasaday are still living in caves like our primitive ancestor, Stone Age man. Even the discovery in 1902 of a group of similar people in the Celebes does not equal the importance of the Tasaday in adding to man's knowledge of his distant past. (The Celebes group, called Toalas, had begun giving up caves 30 years before they became known to the outside world.)

As the description suggests, the Tasaday live a serene life. As far as we know, they have no natural enemies. They are food gatherers, rather than food growers, and apparently have to spend as little as three hours a day providing themselves with food that is in abundance and close by. The rest of the day the Tasaday is usually free to do as he pleases. He and his mate play with their children and teach them about the jungle. Or the Tasaday man may make music. Or swing on vines or climb trees. Or just sit and look contentedly into the valleys of his tropical rain forest.

The discovery of a unique people is of scientific significance, an event of exciting dimensions to anthropologists. The layman, too, must celebrate this find with the scientist. We here at Encyclopædia Britannica share in the concern felt all over the world for the ultimate fate of a Stone Age people suddenly exposed to our technological civilization.

I congratulate Philippine President Ferdinand Marcos, Imelda Marcos, his wife, herself a beloved figure among her people, and the PANAMIN Foundation, headed by Manuel Elizalde, Jr., for taking quick and decisive steps to assure that the Tasaday culture will not be destroyed. The Foundation, which assists all minority groups in the Philippines, is a good, indeed an excellent, example of government and the private sector working together for the greater good of the people. It has a simple guiding principle. As Elizalde told Britannica's editors, "We are for choice, the people's choice, not ours." Assistance to the minority peoples must be coupled with acceptance of their right to be different, says Elizalde. "The minorities themselves must retain the option of preserving their traditional way of life, or, if they so desire, changing it at the pace and in the direction they choose."

And this happily applies to the Tasaday. Already the Philippine government has set aside 46,299 acres of government land as a preserve for the Tasaday and their neighbors, the Manobo Blit. This will prevent encroachments by loggers, miners, and other industrial segments of society.

We are grateful to the Philippine government and to the PANAMIN Foundation for making the story about the Tasaday possible in this edition of the *Britannica Yearbook of Science and the Future.* The fascinating report that begins on page 50 was assembled by members of the PANAMIN staff, all of them anthropologists. As publisher of the Britannica, concerned about the future, I am grateful for the foresight shown by the government of the people of the Philippines in dealing so sensibly with such a challenging matter.

I suppose like most men of this rampaging society, I rather envy the Tasaday the choice they have to make. I wonder, if we all had it to do our-

John Nance from Magnum



This rare photograph shows members of the Tasaday tribe outside their caves

selves, to make the choice consciously, whether we would elect the tranquil existence of a Tasaday rain forest or exposure to the rest of the world that seems full of so much stress and tension.

Can't we on our part seek to use the power through our own science and technology to make our world into our own version of a tranquil rain forest, where the world is cool, peaceful, and green, where birds sing in the trees, answering man's call?

Every year in the Science Yearbook we see proof in developing science and technology that man has the skills to shape his life as he wants it. One can see that from the variety of things reported in this year's edition. We know, for example, that we are nearing the time when babies can be conceived in test tubes (page 398); that crimes can be solved scientifically (page 374). We are just beginning to learn about the scientific developments in the People's Republic of China and the progress of its 800,000,000 citizens, whose cultural, scientific, and technological advancements have largely been a matter of guesswork up to now (page 30). We are learning more and more about nuclear fusion as a possible new and endless source of power that will not pollute the environment (page 110). We know now that the presence of mercury, lead, and cadmium in our systems and our environment (page 360) is as much a danger to us as it is to the animals of the earth, including those especially that are in imminent danger of extinction (page 10).

It's all there, really, the ability, the knowledge, the technology that can make our present and our future a comparative paradise.

With nature's surrender to man, with our ability to destroy everything on earth with the push of a button, we now face the necessity of conscious action. It is a time that T George Harris of *Psychology Today* has termed the "Age of Conscious Action." Those things that we have since the beginning of time left to nature, accident, tradition, now must be faced as conscious acts. Our society has finally reached the point that our own technology is forcing us to learn how to face up to the consequences of technology. Where are the teachers? We are prepared to be the taught. What are the next steps? Where do we go from here? This *1973 Britannica Yearbook of Science and the Future* contains some of the guideposts.



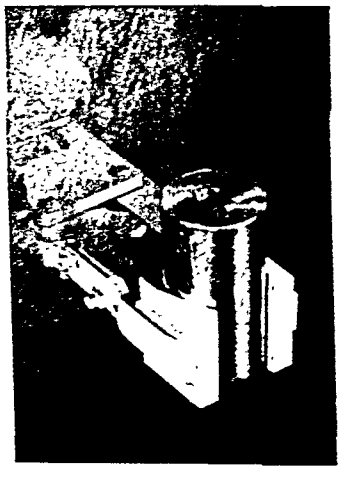
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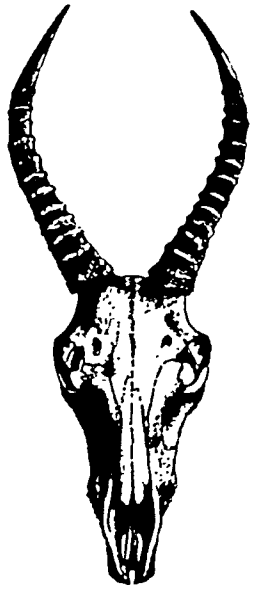
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A Pictorial Essay





Species in Peril

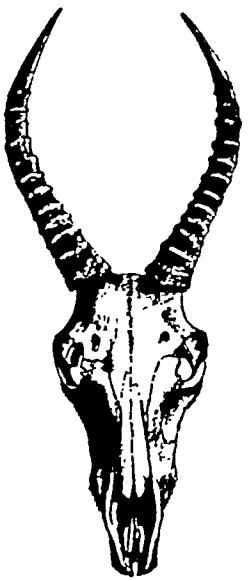
by William G. Conway

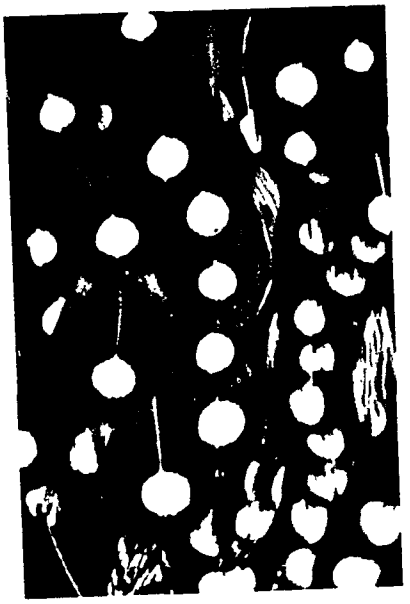
Man and his civilization have already caused many varieties of animals to become extinct. Unless preventive measures can be taken, other species also seem certain to disappear.

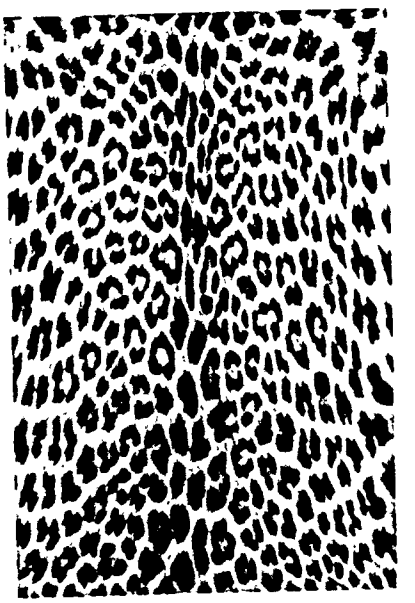


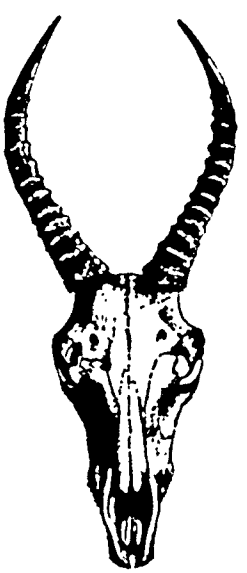


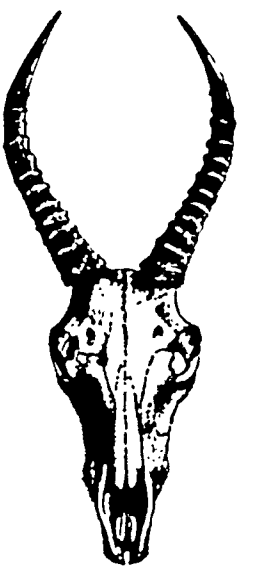


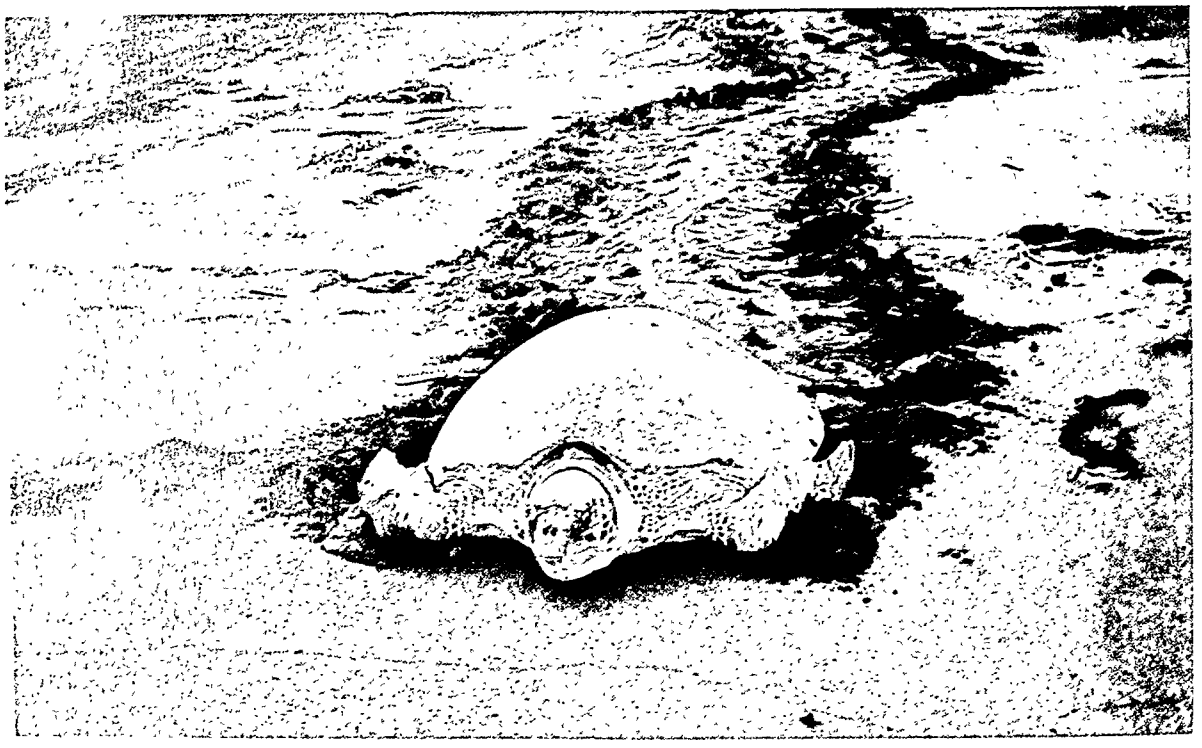









Jo Conner



The green sea turtle of Central America (above) is gradually vanishing. It is being killed for its meat and skin, and its eggs are dug up for the market. The monk seal (opposite), long hunted for its oil, is nearly extinct.

Within the past 400 years more than 220 mammals, birds, and reptiles have become extinct, the majority through the activities of man. Many other animal species are now declining. Among the endangered are such common animals as the grizzly bear, the polar bear, the giant panda, the wolf, several of the big cats (the cheetah, the jaguar, the ocelot), the rhinoceros, the great apes, many of the large birds of prey, the stork, the crane, the crocodile family, the large sea turtle, and the larger whales—as well as a host of the more exotic, lesser known species such as the thylacine, the gaur, the tuntong, the Philippine monkey-eating eagle, and the Komodo Island monitor, the world's largest lizard.

Until the coming of civilized man, the extinction of wild animals and the evolution of new ones proceeded surely but almost imperceptibly on a continuum of loss and renewal stretching back more than 3,000,000,000 years. A species' span on earth was not measured in centuries but in millennia—a particular animal's species might be traced back at least through several hundred thousand years.

Today this continuum of loss and renewal in forms of animal life is gravely threatened. In recent years man has sharply accelerated the pace of wildlife extinction at the same time that he has reduced the opportunities for the adaptation and evolution of new forms, especially of larger and higher animals. He has done this directly, by catching or killing animals—mainly for food, sport, pets, commercial use, or because the animals compete with him in some way—and indirectly, by displacement or by the despoliation of animal habitats.

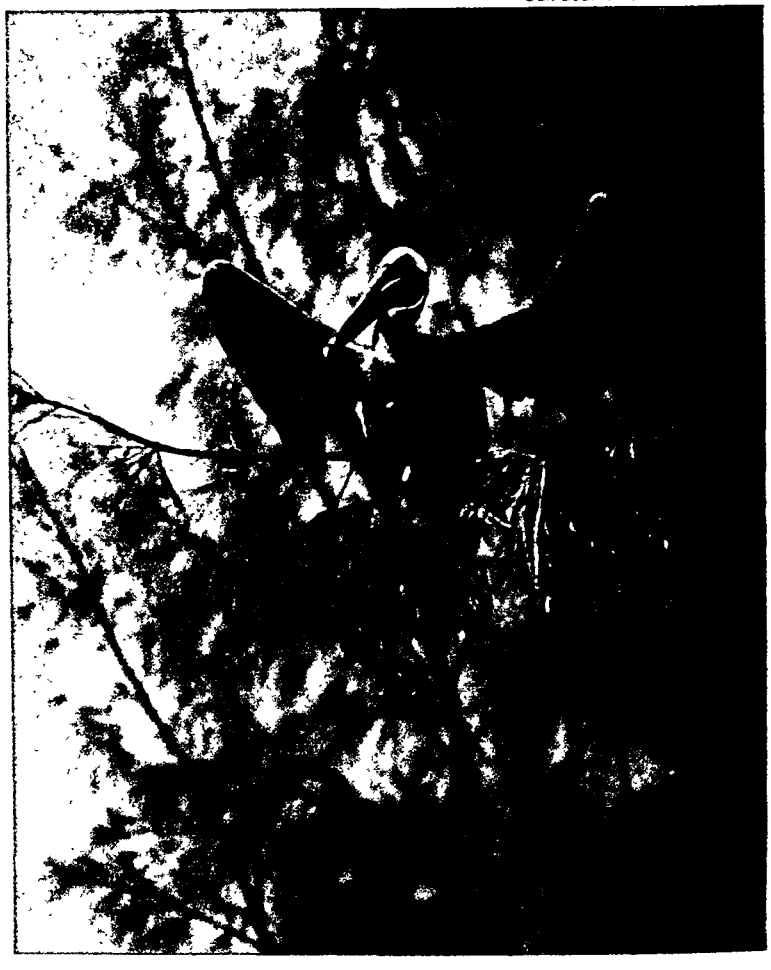
***WILLIAM G. CONWAY** is general director of the New York Zoological Society and the Center for Field Biology and Conservation.*



Collecting wild animals alive

Perhaps the least important drain on wildlife caused by man is by live collecting for pets, zoos, and biomedical research. However, this drain alone is enormous. In 1970, according to the U.S. Department of the Interior, the United States imported alive 83,867,029 fish, 572,670 amphibians, 2,109,571 reptiles, 687,901 birds, and 101,302 mammals. The great majority of fishes were destined for pet shops. No one has any real idea of the effect of this vast trade upon fish stocks in nature. Most imported amphibians were frogs intended for laboratory studies and human pregnancy tests. The reptiles, which varied from crocodiles to pythons, were sold primarily as pets. Surprisingly, the huge bird importation figure did not even include canaries or such psittacine birds

Don Budnik from Woodfin Camp



Joe Bilboo from Photo Researchers



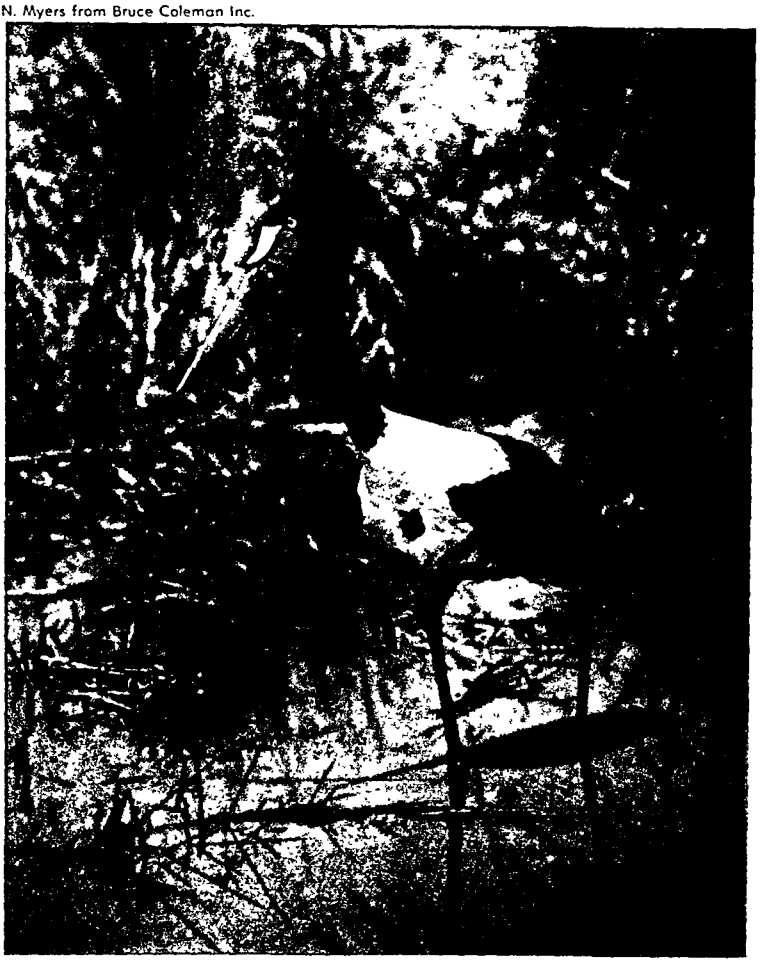
Destruction of their natural environments, through pesticide pollution and encroaching human habitation, threatens (left to right) the American bald eagle, brown pelican, saddle-billed stork, and Galápagos flightless cormorant.

as parrots or parakeets, but this trade too went almost entirely for pets. Of the 101,302 wild mammals that were imported in 1970, some 85,000 were monkeys captured mostly for biomedical research. Although consumption of wild monkeys in 1970 may seem high, it was modest compared to the importations during the height of the production of poliomyelitis vaccine in 1958–60, which tallied 634,000.

The demand by zoos for wildlife is relatively modest. All of the world's zoos together contain fewer than 600,000 mammals, birds, reptiles, and amphibians, many of which were bred in captivity. Nevertheless, zoo importations occasionally affect species of exceptional rarity.

Unfortunately, U.S. wildlife import figures give only an approximate idea of the drain on wild animal populations created by the live trade. Most nations do not keep such records. Thus the real number of animals taken from the wild is much higher. And for every animal imported alive, several may have died during the stress of collecting and shipping processes. Moreover, large numbers of mammals, birds, and reptiles are consumed in their countries of origin by local demands for pets.

N. Myers from Bruce Coleman Inc.



Peterson from Photo Researchers



Hunting for sport

For many wildlife populations, sport hunting is a far more important drain than live collecting. Nevertheless, such hunting in developed countries like the United States, which assiduously assesses and manages its "game crop," usually does not occasion extinction and may even provide funds and support for wildlife preserves. Sport hunting can be a more serious threat in developing nations that cannot afford the costs of highly trained game biologists and the constant research their work entails to determine the numbers of animals that may be annually killed without endangering the breeding base of the species.

In the United States, annual sport kills of waterfowl have ranged from 9 million to 15 million in recent years, deer kills about 2 million, and black bear more than 20,000. It is estimated that U.S. hunters shot 41.9 million mourning doves in 1965–66! The lesson in this is that some wildlife populations are enormously productive and produce enough individuals so that many may be killed without serious threat of extinction *if* they are provided with the proper habitat and protected from overhunting.

Jerry L. Hout from Photo Researchers





Erwin A. Bauer

Hunting for food

The hunting of wild animals for daily food is an integral part of the livelihood of millions of people in the developing nations. The United Nations Food and Agriculture Organization recently reported, for example, that more than 80% of all fresh meat consumed in Ghana comes from game, and more than 50% in Zaire (formerly Congo [Kinshasa]). There is no doubt that the drain on wildlife populations from food hunting far outweighs that from live collecting and sport hunting. Many species are endangered by it. It was commercial hunting for food that destroyed the Eskimo curlew and passenger pigeon populations in the United States, not sport hunting.

In the fishing industry, overfishing has long been a problem affecting certain species. One indication of the seriousness of this drain on fish stocks is the fact that the 1969 world fish catch (published in 1971) showed an overall drop of about 2% from the previous year.

The hide and fur, meat, and animal oil trades

The number of animal lives sacrificed to the hide and skin trades dwarfs all other drains on those species it affects. The big cats, the otters, the fur seals, and the crocodilians are the primary victims. Before New York's recent conservation legislation (now being followed by other states), thousands of these animals were killed for the U.S. trade alone. For example, in 1968 and 1969, U.S. furriers imported 3,168 raw cheetah skins, 17,490 leopard skins, 23,347 jaguar skins, 262,030 ocelot skins, and 99,002 otter skins. These figures do not include the animal deaths represented by the finished products imported from furriers in other countries. In 1969 alone, the United States was shipped 275,000 skins from the capybara (the world's largest rodent) and 436,000 deer skins from Brazil.

Commercial exploitation of wild animals for meat and oil affects such disparate creatures as sea turtles, kangaroos, and whales. The decline of whale stocks in the face of almost unregulated slaughter and modern technology is a well-known international disgrace. Today the trade is primarily in the hands of Soviet and Japanese whalers who appear bent upon converting the last whales into dog food, lipstick, soap, paint, transmission oil, and, to a certain extent, food for human consumption. Unhappily, few species in international waters have ever been satisfactorily protected by reasonable hunting regulations.

It is depressing to note that not one essential commercial product is made from the entire traffic in wild animal hides and furs or from whale oil for which there are not adequate substitutes.

The destruction of predators

Animals whose homes and food supply have been usurped by man and who must therefore compete with him for the crops he plants or the domesticated animals he rears are regarded by man as predators. In the United States, studies have shown that the majority of wild predators make only limited inroads on livestock but do offer real values in

Animals of the polar regions—the emperor penguin (below), musk-ox (opposite, top), and walrus (opposite, bottom)—are endangered by man's activities. Pesticide pollution has been detected in Antarctica, home of the penguin, while the walrus and musk-ox of the Arctic suffer from overhunting.



Tom Myers

Mondadoripress from Pictorial Parade



the control of other competing wildlife, particularly rodents. Broad nonspecific predator control programs can rarely be justified on economic grounds. Nevertheless, shooting, trapping, and poisoning campaigns have long been conducted against wolves, foxes, coyotes, and against the large birds of prey.

However, it is unrealistic to ignore the problems of those who must live next door to tigers and crocodiles. Predators such as these must have large enough areas within parks and refuges to permit them to avoid man if they are to survive at all. In fast-growing over-crowded countries, there appears small chance that the people will decide to set aside such lands until it is too late for the great predators.

Environmental destruction

The most serious menace to current wild animal populations comes from man indirectly, not through guns or traps. The continuing increase of human population—with its supporting technology and seemingly inevitable habitat despoliation, environmental poisoning, and pollution —dwarfs all other threats to the survival of wild creatures in the importance and finality of its effects.

Man's population increased by more than 70 million annually in the early 1970s and was expected to rise by a greater amount in succeeding years. As a consequence, more land is continually being settled and made unsuitable for wild creatures. When a marsh is drained, an estuary filled, a forest cut, a savanna plowed, a stream dammed, or a river channelized, animal habitats are eliminated. There is usually no wish to destroy wild animals in this process but it is the inevitable result. When animals are hunted directly, usually not all are killed; their homelands remain where remnants of the population can find food and shelter in which to rebuild their numbers. But when land or water is

Tom Myers



Les D. Line



Reptiles under pressure include the giant monitor of Indonesia (opposite), the banded gecko (above, left), and the alligator (above). Collectors have depleted the supply of monitors, while the gecko suffers from its use as a pet. Alligators, long hunted for their skins, are now under protection and are making a comeback.

made uninhabitable to wildlife, those populations it supported must then be considered extinct, whether the species dwells elsewhere or not. Canvasback ducks cannot feed and nest in wheat fields, orangutans cannot rear their families in lumber mills, and bison cannot graze on parking lots.

Pesticides and pollution are the most subtle threats to wildlife. In North America the chlorinated hydrocarbons, the best known of which is DDT, have been shown to affect the physiology of many animals, particularly birds. Pesticides applied to control insects on crops eventually wash into watercourses and the sea, where they are ingested by microorganisms which are themselves eaten by fish and other animals. These latter are, in turn, eaten by the birds. At each step in this food chain, the pesticide is further concentrated. One result of such concentrations is that affected birds produce eggs with shells so deficient in calcium that they are crushed in incubation. Because of this process, brown pelicans, cormorants, peregrines, bald eagles, and many other birds of prey are already extinct in various localities.

The threat to other animals posed by DDT is increasing. DDT or its breakdown products is now being found even in remote Antarctic populations of seals and penguins.

And there are other pervasive pollutants. Recently, PCBs (polychlorobiphenyls), the organic compounds used frequently in making plastics, have been implicated in birth defects of seabirds off the coasts of Connecticut and New York. There has also been an increase of heavy metals, particularly mercury, in lakes and rivers as a result of sewage from plants using this element in manufacturing processes. As a result, U.S. government agencies have been forced to declare certain food fish unfit to eat. (*See* Feature Article: THE NOTORIOUS TRIO: MERCURY, LEAD, AND CADMIUM.)

Fred Bruemmer



Baby seals like the one shown above with its mother are hunted extensively for their white fur. The orangutan (opposite) has suffered greatly from the destruction of its natural habitat and from collecting for laboratories, museums, and zoos.

Pollution of the air and waters is emerging as an increasingly serious threat to wildlife as well as to man. Secondary habitat despoliation is the most readily observable result. Various types of conifers near the sprawling urban complex of Los Angeles are dying, and the epiphytic Spanish moss, pride of many cities in the southeastern United States, also appears to be on the decline—the result of air pollution. These losses should be viewed as the forerunners of future losses in the wildlife community that will inevitably follow the changes in habitat.

Water pollution from sewage and industrial wastes has also had grave consequences for wildlife. The life of Lake Erie has been seriously depleted, and fishes and other aquatic life have disappeared from many of the streams and rivers in the United States and Europe. The effects of pollution can grow at an increasing rate as the demands imposed by bacteria breaking down sewage cause a decline of oxygen in surface waters and pathogenic bacteria reach concentrations sufficient to spread disease to man as well as wildlife. Wildlife is also threatened by rising industrial activity with the resulting increases in industrial accidents, such as oil spills. A serious oil spill off the coast of an island where a restricted colony of mammals or birds exists might eliminate a species. Finally, almost all polluting materials dumped on the surface of the earth or sprayed within its atmosphere ultimately come to rest within the oceans. Although fish are harder to count than some land creatures, there is no reason to believe that they are any less threatened.

Co Rentmeester, LIFE Magazine © Time Inc



Animals added and subtracted

The introduction of exotic wild or domestic animals is still another way in which man has endangered species. Countless cases have been recorded where the introduction of birds, pigs, goats, cats, mongooses, dogs, rabbits, and rats have pressed animals with small populations or those confined upon islands to the verge of extinction. At the same time, the introduced have often become serious pests. Introduced animals usually compete with native forms for food and even destroy food supplies. Some simply eat the native animals.

The removal of a native animal may also have unexpected results for other species in the same area. The American alligator, for example, now recovering under protection, has been shown to be necessary to the survival of other wildlife in the Everglades during a drought. Its deeply dug den, or "well," may be the only remaining water when the glades dry up. Seed stocks of fish and amphibians survive in the well to repopulate the glades when the waters return.

The removal of a predator may result in such increases of its prey that their demands for food wreak havoc upon the vegetation of the area and thus the habitat's ability to support them. Thus populations of deer in some rural areas of the United States have expanded to such an extent, with the elimination of the wolf and puma, that they have destroyed forest understory vegetation and even barked trees in some years. Ecological interrelationships like these call for careful study and research before wildlife is killed or habitats altered.

G. B. Schaller from Bruce Coleman Inc.



Large African mammals are among the endangered species, even though Africa has sought vigorously to preserve its wildlife. The gorilla (above) is menaced by the destruction of the rain forests in which it lives, while the pygmy hippopotamus (opposite, top) is hunted for food. The rhinoceros (opposite, bottom) is being depleted by both habitat destruction and hunting for its horns.

The effort to save vanishing species

The status and probable rates of decline of wild animals vary in different parts of the world. Although our knowledge is incomplete, what is clear is that the scope of the problem is immense. Unhappily, those who would protect wild lands and animals, at best, can fight only a holding battle. They can preserve a particular forest or a rare creature only until ignorance or self-interest impels yet another challenge to its existence through further exploitation.

The hard facts faced by conservationists are that man's utilization of wild lands and parks must remain modest if the plant and animal life they support is to survive; that much of the world's most fascinating wildlife is in the developing countries, which have high rates of population growth and tremendous economic needs that might well override preservation; that preservation of wildlife may not offer immediate local economic incentives; that the profit motive in commercial exploitation of wildlife is hard to combat; and that wild creatures whose life cycles regularly take them over national boundaries or into international waters are particularly difficult to protect.

Nevertheless, strong park and conservation departments have developed in many nations, and hundreds of nonprofit organizations have taken up the conservation challenge. These organizations mainly work through public education by producing publications, holding conferences, giving lectures, and generating funds. They muster support for conservation legislation and for the establishment of parks and reserves, and they conduct research on wildlife problems. Clearly, the establishment and maintenance of parks and reserves that include appropriate habitats is the most important step that can be taken to insure the survival of most threatened species. In a few cases, wild animals have been saved or aided by captive propagation.

One thing is clear. There is no reason whatsoever for optimism about the future of wild animals. It remains an open question whether man the destroyer can become man the preserver in time to prevent many more species from becoming extinct.

uss Kinne from Photo Researchers



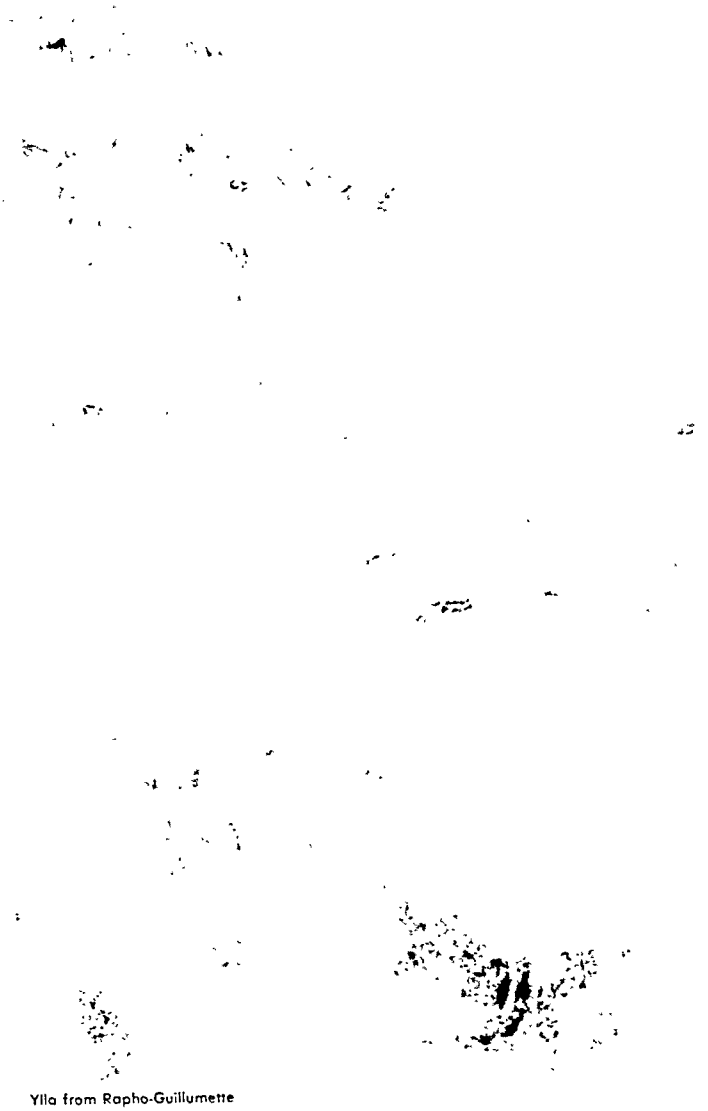


Eliot Elisofon, LIFE Magazine © Time Inc.

Shelly Grossman from Woodfin Camp

Richard Keane





Ylla from Rapho-Guillumette

White pelicans have decreased considerably because of the effect of pesticides on their calcium metabolism, causing their eggshells to break before the young are hatched. Leopards are hunted for their skins, while the pressure of increasing human population on their habitats has caused the tiger to decline in numbers from 30,000 to 2,500 in 35 years.

S. Gillsater from Bruce Coleman Inc.





Bruce Coleman from Bruce Coleman Inc.

N. Myres from Bruce Coleman Inc.





George Holton from Photo Researchers

Endangered large mammals include the polar bear (opposite, top), which suffers from excessive hunting, and the giant panda (opposite, bottom), a species of small numbers that lives only in western China. African hoofed mammals that are threatened include the oryx (above), hunted extensively for food, and the already rare okapi (left).

Monkeys are threatened both by human encroachment on their habitats and by hunting. In 1970 approximately 85,000 monkeys were imported into the United States, mainly for biomedical research. On the opposite page two endangered animals, the cheetah and open-billed stork, enjoy the protection of a game refuge in Kenya.

Carlo Bavagnoli, LIFE Magazine © Time Inc.



Bill N. Kleeman from Tom Stack & Associates



Science in China

by C. H. Geoffrey Oldham

According to Mao, science should serve the people. After almost 25 years of Communist rule, what methods have been evolved to reach this goal and how close is it to realization?

Almost 25 years have passed since Mao Tse-tung established the People's Republic of China and committed that country along a path toward his concept of a Communist utopia. Throughout these 25 years the cornerstone of China's science policy has been that "science must serve the people." Most of the Chinese investments in science and technology have been governed by this dictum and, hence, any assessment of the current status of science and technology in China must be measured against Mao's own objectives.

Had this article been written 20 years ago it would have been much more difficult to develop this viewpoint. Then a nation's scientific prestige was measured almost entirely by its ability to produce new knowledge and, to a lesser extent, to use knowledge in producing sophisticated weapons and generating wealth. In the 1970s policymakers in almost all countries are much more concerned with the utilization of science and technology to achieve a whole gamut of objectives, frequently summed up in the phrase "improvement in the quality of life." That "science should serve the people" has now become the cornerstone of science policy in the United States and Europe and, indeed, in most countries of the world.

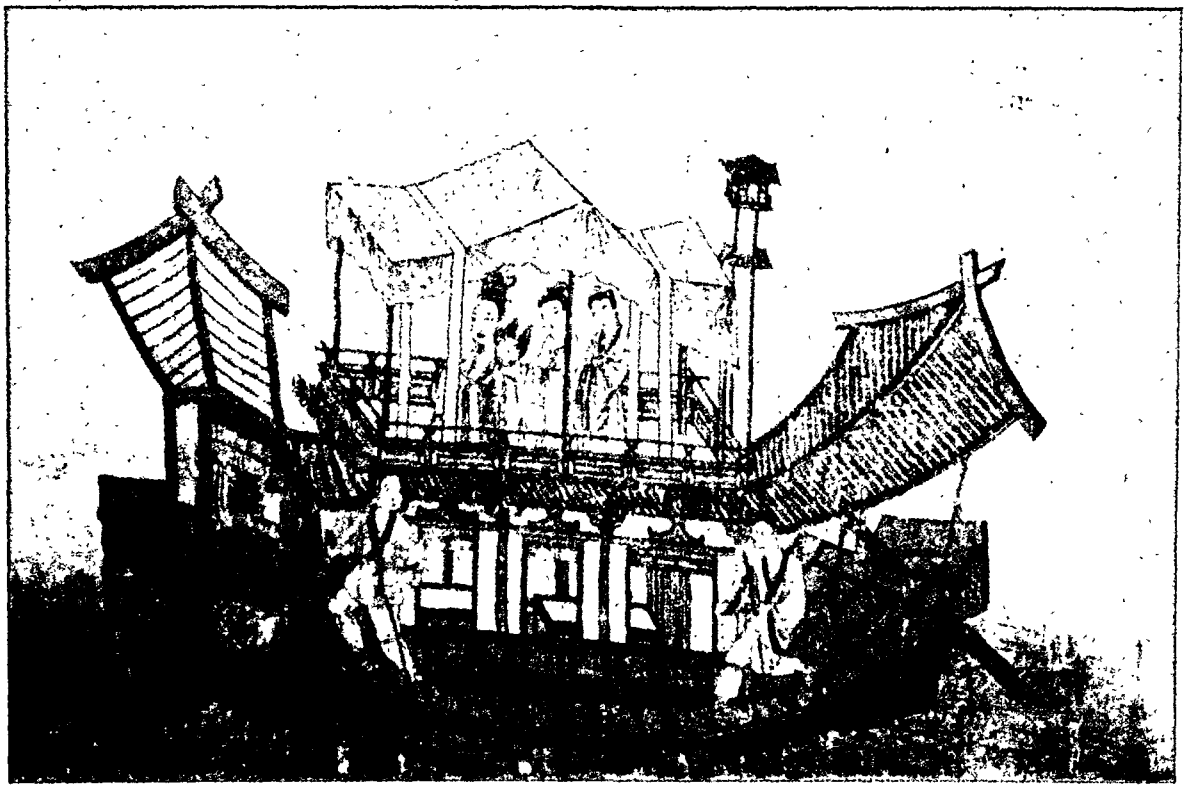
Although Chinese thinking about science has been dominated by a utilitarian viewpoint, the precise ways in which science should serve the people have been the subject of heated debate. The specific policies have changed frequently and sometimes dramatically. Indeed, it is these changes and the Chinese willingness to experiment with novel approaches that make a study of Chinese science and technology so interesting and yet so tantalizing. It is interesting not only because of the inherent interest of China's social experiment but because of the possible relevance of the Chinese experience to other developing countries. It is tantalizing because, although it is possible to form a reasonably good idea of Chinese policies from the Chinese press, it is extraordinarily difficult to obtain a clear picture of their success or failure in achieving the desired goals.

This article will attempt to reflect both the interest and the frustrations of a study of Chinese science and technology. It will attempt to summarize the changing Chinese policies on science and technology and, in a concluding section, it will speculate on the reasons behind Mao's strategy.

Throughout the article reference will be made to the major issues that are the subject of debate among those concerned with how less developed countries can best use science and technology as tools to aid their development. It is essential to recognize that China is the world's largest developing country in both area and population, and that it exists in a world where 98% of expenditure on research and experimental development takes place in the industrialized countries. This maldistribution of world research endeavor has profound implications for the less developed countries. Not only is much of the world's research irrelevant to the needs of poor countries, especially in the tropics, but some of it, such as research on the development of syn-

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Courtesy, Smithsonian Institution, Freer Gallery of Art, Washington D C



China's knowledge of the rudder more than 1,000 years before it appeared in Europe, suggested by the painting (above) copied in the 11th or 12th century A D from a 4th-century design, was confirmed in 1958 by archaeological evidence Civilization in China has been traced back many thousands of years The excavations in Sian (below) date from the Stone Age





Jurgen Bisch from Black Star

thetics, is positively harmful to their prospects for trade in raw materials. It is against this background that the Chinese priorities and experience must be viewed.

Historical background

Although China's commitment to modern science is relatively new, it has a long history of scientific discovery and technological invention. As Joseph Needham of Cambridge University has documented so well in his *Science and Civilisation in China,* China can lay claim to more technological firsts than almost any other civilization. It was the Chinese who invented the seismograph in the 2nd century A.D. The magnetic compass, gunpowder, and the printing press with movable type are further examples of technologies first developed in China and rediscovered in the Western world many years later. However, for some as yet unknown reason, the scientific revolution took place in Western Europe rather than in China. And following the scientific revolution came the industrial revolution and the growth in material wealth of Europe and then the United States. Meanwhile, China and the rest of what we now call the developing world changed only slowly.

Chinese industrial policy appears to give equal emphasis to small-scale, local factories and to heavy industry. The steel mill (below) is in Anshan in Manchuria. Automobile plants include those in Shanghai (opposite page, left) and Changchun.

Apart from a few early contacts with missionaries such as Matteo Ricci, China remained isolated from the changes that were sweeping through Europe until its defeat at the hands of the British during the Opium Wars in the 19th century. From that point the slow, painful process of modernization took on a new dimension as some Chinese reformers urged that China begin to adopt what they thought of as

Western science and Western technology. Their voices had but little effect, and it was not until after the Manchu dynasty was overthrown in 1911 that the efforts to transplant modern science onto Chinese soil produced any significant results.

Even then it was not until the 1920s that the major intellectual break with Confucianism was made and the politicians committed themselves to the building of a new China based on modern science and technology. By the mid-1930s the Nationalists had begun to institutionalize science and had established several research institutes and universities. Although this scientific effort was severely disrupted during the Japanese and civil wars, there still existed in China in 1949 a nucleus of competent scientists and engineers, and a start had been made toward building an indigenous scientific system.

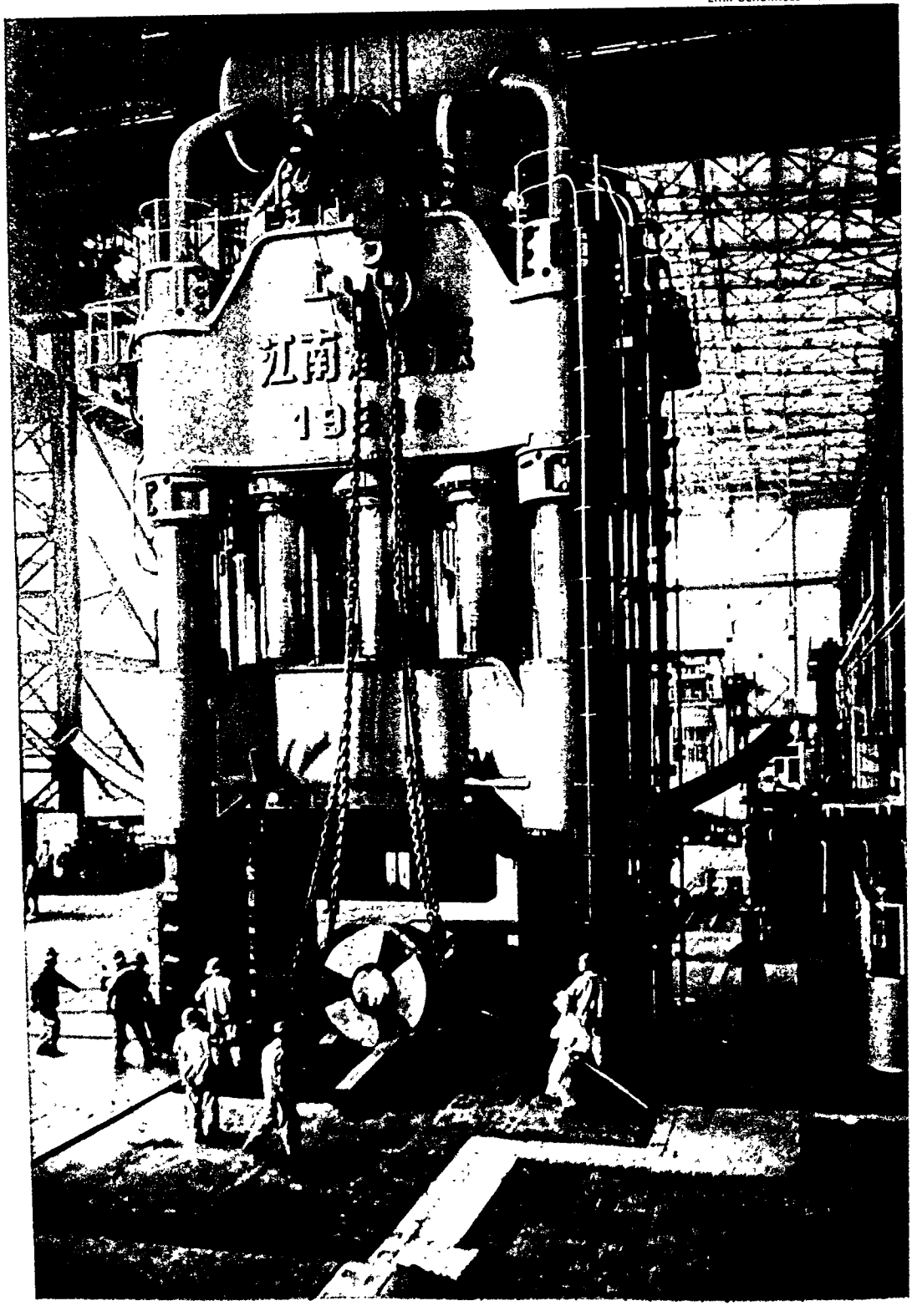
The organization of science

The importance of the fact that Mao Tse-tung "inherited" a nucleus of scientists and an organizational framework, albeit in a fragmented form, should not be underestimated. For many years "experts" concerned with development put a low priority on the need for less developed countries to have their own indigenous scientific capability. They argued that the industrialized countries were a veritable supermarket of technologies and all the less developed countries had to do was to shop around and choose what they wanted. Mao has always completely rejected this argument, and now most other less developed countries are following his line.



(Left) Jürgen Bitsch from Black Star, (above and opposite page) Emil Schulthess from Black Star

Emil Schulthess from Black Star



To begin with, most of the industrial technologies developed in the advanced countries are designed for conditions of large-scale production and a situation where capital is relatively abundant and labor is scarce. This is hardly the situation in China or other developing countries. Even more inappropriate for less developed countries is most of the agricultural and medical research done in the developed world. But probably the single most important reason why China and, now, the rest of the developing countries want their own scientific establishments is that otherwise they will be dependent on foreigners to make all the important technological decisions affecting them. This, they find, is economically unpalatable and—what is even more important—politically unacceptable.

The network of research institutions and facilities for training scientists and engineers that grew up in China in the 1950s was based largely on the Soviet system. The Academies of Sciences, Agricultural Sciences, and Medical Sciences each operated its own research institutes and together they carried out most of the advanced research being done in the country. Overall strategy was dictated by the State Scientific and Technological Commission, with applied research sponsored and carried out by the relevant ministry. Very few of the universities carried out advanced research, and most of the new research workers received their training on-the-job at the various institutes of the academies.

After an initial period in the early 1950s when the academies determined their own research priorities, the work of the various institutes became subject to an overall planning authority. In 1956 a 12-year plan for science was drawn up with a great deal of Soviet help. It was claimed that in the 10 priority areas identified in the plan China would aim to catch up with advanced-world levels by the end of the plan period. However, during the campaign of mass mobilization called the Great Leap Forward (1958–60), the earlier concept of central planning of research priorities seems to have been abandoned in favor of encouraging all innovations that originated with peasants and workers in whatever field they occurred. During the 1960s, although the State Scientific and Technological Commission continued to exist and continued to be the main policy-making body for science and technology, there was little reference to it in the Chinese press. It either operates in a very secret way or is largely ineffective.

The Great Leap Forward coincided with another event that was to have a major effect on Chinese science—as well as on foreign policy. This was the withdrawal of all Soviet aid. Between 1958 and 1961 all Soviet nationals were called home, and the massive Soviet technical assistance program came to a halt. The Soviets even took the blueprints of unfinished plants with them. This event still rankles very deep with the Chinese. Even in 1972 visitors to China were being told with evident bitterness about the fickle Soviets, and there can be little doubt that the Chinese attitude to the Soviet Union is heavily influenced by this event.

Industrial production suffered less than scientific research and education during the convulsions of the Cultural Revolution. The 12,000-ton hydraulic press (opposite page) was photographed in Shanghai.

The effect on Chinese science policy was immediate and long lasting. It made the Chinese distrustful of foreign aid, and "self-reliance" became the key slogan of the early 1960s. More and more resources were injected into the Chinese science system, and by 1965 it began to seem that the Chinese aim of catching up with advanced-world levels in certain priority areas was well on the way to reality. In 1964 and 1965 contacts with Western scientists were considerable, and formal scientific exchanges were arranged with many Western European countries.

The reports of the foreign scientists who visited China indicated that China was creating a solid foundation in most scientific disciplines. The Chinese scientists were apparently well informed of work going on in their respective disciplines in other parts of the world. In a few areas they were already making important new contributions themselves, although by and large there were few surprises—the most commonly used adjective of the foreign visitors was "sensible." The quality of the scientific papers published in the Chinese journals had become sufficiently high to warrant cover-to-cover translation of several of them by U.S. commercial enterprises. By the mid-1960s, judged by Western scientific eyes, it appeared that the Chinese science system was extremely healthy and vigorous and doing good work. But apparently Mao felt otherwise.



Rene Burri from Magnum

When the Cultural Revolution first began in 1966, the scientists were specifically excluded. This exclusion did not last long, however, and by early 1967 the activities of the scientists came under close scrutiny. For several months the Chinese press was full of accounts of upheavals within the institutes of the Academy of Sciences. The test was whether the institutes really had "served the people." Many scientists were accused of being too greatly influenced by the foreign scientific literature and too little influenced by Chinese problems; they were too eager for scientific awards and titles and sought personal fame rather than devoting themselves to relatively unglamorous work. In short, scientific research was not sufficiently integrated with the needs of society.

By the early 1970s these same charges were being made against the scientific community in most of the world's developing countries and, increasingly, in the more industrialized countries. The Chinese solution has been to put the direction of the research institutes under the control of "revolutionary committees," made up of representatives of the People's Liberation Army, the political cadres, and "revolutionary" workers. They have also experimented with different ways of integrating research with education and production, but too little is known about the details of these experiments to permit evaluation of their results.

Contacts with foreign scientists were broken off during the Cultural Revolution and, since the publication of Chinese scientific journals also stopped, it became very difficult to assess the effect of the Cultural Revolution on Chinese scientific research. In the early 1970s, however, China made a dramatic reentry into international affairs, and scientists were once again able to visit the research institutes of the Academy of

Sciences. They found that the institutes were working on more applied problems than had been the case in the mid-1960s and that, despite the criticism of scientists during the Cultural Revolution and the fact that many had spent time working in communes, most were now back doing research. They also found that, although foreign scientific journals were being received, there seemed to be less familiarity, especially on the part of the younger workers, with the latest research in the rest of the world than had been the case before the Cultural Revolution.

It is still too early to judge the long-term effects of China's isolation from the mainstream of world scientific research. It is possible that in some research areas Chinese scientists may have pioneered entirely novel approaches. But the rate of growth of scientific knowledge in the world is such that, by cutting itself off from much of this knowledge, China can only delay the time when it reaches its stated goal of catching up with the advanced countries of the world.

Like many developing countries, China faces the problem of whether a sophisticated, capital-intensive industrial sector can coexist with labor-intensive technologies that provide employment and involve workers in the system.





Brian Brake from Rapho Guillumette

Scientific and technical education

Although the Communist government inherited a nucleus of scientific institutions when it came to power in 1949, the actual number of fully qualified scientists and engineers was small. A major effort was launched to increase the complement of technical personnel, and certainly the number of persons with some technical training has risen dramatically. It is very difficult, however, to make comparisons either between China and other countries or between the situations that have existed at different times within China, largely because there seem to be no consistent manpower definitions. The best manpower estimates, based on admittedly conflicting Chinese evidence, indicate that the stock of scientists and engineers rose from 600,000 in 1955 to 2.4 million in 1967. Approximately 670,000 of the 2.4 million had been trained in full-time institutes of higher education in China after 1949. The rest either were promoted to the rank of scientist or engineer without receiving full-time training or were already trained in 1949.

It has been estimated that the number of college-trained scientists and engineers had reached 1.3 million when the Cultural Revolution erupted and all the schools and universities were closed. The universities remained closed for four years and only began teaching scientific subjects again in 1971. This represents a major loss of technical manpower. But even though the schools and colleges were shut down, the research institutes of the Academy of Sciences remained open, and a number of them tripled their staffs during the Cultural Revolution. Since most of the new recruits were secondary-school graduates, the Academy of Sciences must have played an important role in continuing to provide a scientific education, at least for some boys and girls.

When the colleges and universities were reopened in 1971, there had been many reforms. The new entrants were drawn mainly from families of working-class origin, and it was far more difficult for the children of the former bourgeois classes to gain entry. The period of instruction

was to be cut from four and five years to two or three years, and higher education was to be linked more closely with production. This meant not only changes in the curricula but also that students would spend part of their time working in factories or communes. Students had engaged in periods of manual work before the Cultural Revolution, but now such work was to be integrated more systematically into the students' schedules. These policies mean that the new scientists and engineers will enter the work force more as scientific and technical generalists than as specialists.

As important as the education of the most highly trained members of the society may be, perhaps equally important in a developing country is the scientific education given to the population as a whole. The Chinese have accorded this a high priority. Not only do full-time secondary schools stress scientific and technical subjects but a wide variety of spare-time and part-time educational programs have been provided especially for workers in factories. In fact, one of the most important educational accomplishments has been the training of para-technical personnel. This has been particularly successful in the medical sphere, where large numbers of "barefoot doctors" have brought rudimentary health care to millions of peasants. Also, great emphasis has been placed on giving all members of society some elementary scientific knowledge. This is seen by the Chinese as particularly important, since they look to the workers to provide many of the technical innovations taken up by industry. It is claimed that workers' innovations are more relevant to production than those generated by the "experts." This is a controversial issue in China, but certainly during the Cultural Revolution workers' innovations received the greatest publicity.

Science, technology, and society: industry

So far this article has focused attention on the ways in which China has built up its indigenous science system. In particular, it has concentrated on the organization of scientific research and on the training of scientific and technical manpower. However, research carried out in a country's own laboratories is only one way in which the production sectors of that country can acquire new technologies. The other way is by importation from abroad.

One of the most important science and technology policy decisions for any country involves how much and what to import and how much and what to generate at home. In the past, most developing countries have relied heavily on foreign imports. Now, however, it is recognized that such reliance can lead to economic and political dependence on foreign countries, and many developing countries are trying to find ways to diversify their sources of technology.

China has made a big issue of "self-reliance." Just how self-reliant has it been and to what extent has China, too, depended on foreign technology? Also, in their choice of techniques, to what extent have Chinese policy-makers been concerned with goals other than economic growth? The remaining sections of the article will attempt to answer

some of these questions as they apply to different sectors of the economy. Examples will be given that are illustrative of more general policy decisions and, wherever possible, comparison will be made with the policies of other less developed countries.

It is in the industrial sector that the policy conflicts over choice of techniques and issues of importing foreign technology can be seen most clearly. But here, as in almost all phases of Chinese development strategy, there has been no single approach that has dominated Chinese thinking over the entire period of Communist rule. Rather, there have been three or four periods, during each of which different policies had predominance.

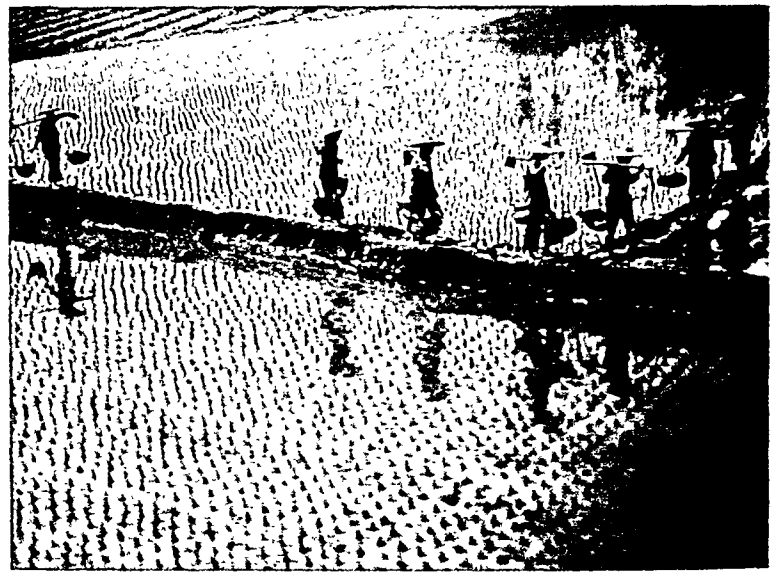
In the first period, immediately after 1949, Chinese industrial policy clearly aimed at copying the Soviet model. Emphasis was put on heavy industry, and technologies—mostly imported from the Soviet Union —were for the most part capital intensive. Rapid economic growth was China's principal goal. This period lasted until 1958, when problems of employment and income distribution assumed greater importance and a major switch was made to small-scale industries, especially in rural areas. Greatest publicity has been given to the backyard blast furnaces introduced at this time. They proved to be an economic failure, since the quality of the iron was too low to be of much practical use, but other local industries initiated in the communes—for making farm implements, for example—thrived. During this period, which lasted about three years, tremendous publicity was given to workers' innovations, and the role of the expert declined.

The next period began in 1961 and continued until the Cultural Revolution in 1966. It started with the severing of Soviet aid, the withdrawal of the Soviet technicians, and the canceling by the Chinese of orders for new Soviet plants. The enormous flow of Soviet technology into China, which had characterized the 1950s, became only a trickle, and "self-reliance" was the order of the day. This call for self-reliance led to a boost in indigenous research and restored the prestige of the research worker and expert, but it did not mean that China became autarchic. Although cut off from Soviet technology, China began to buy modern technology from Japan and Western Europe. Orders were placed not only for equipment and machinery but also for entire plants.

The Cultural Revolution once again led to new policies. Egalitarianism became the principal goal. The scientist and engineer were criticized for becoming a new "elite" and were accused of being the forerunners of a return to capitalism. The earlier policies were ascribed to the chief of state of the republic, Liu Shao-ch'i, and were deemed to be wrong. Once again emphasis was given to innovations that originated with workers. The importation of foreign technology declined from its previous levels but, despite the emphasis on self-reliance, it never stopped.

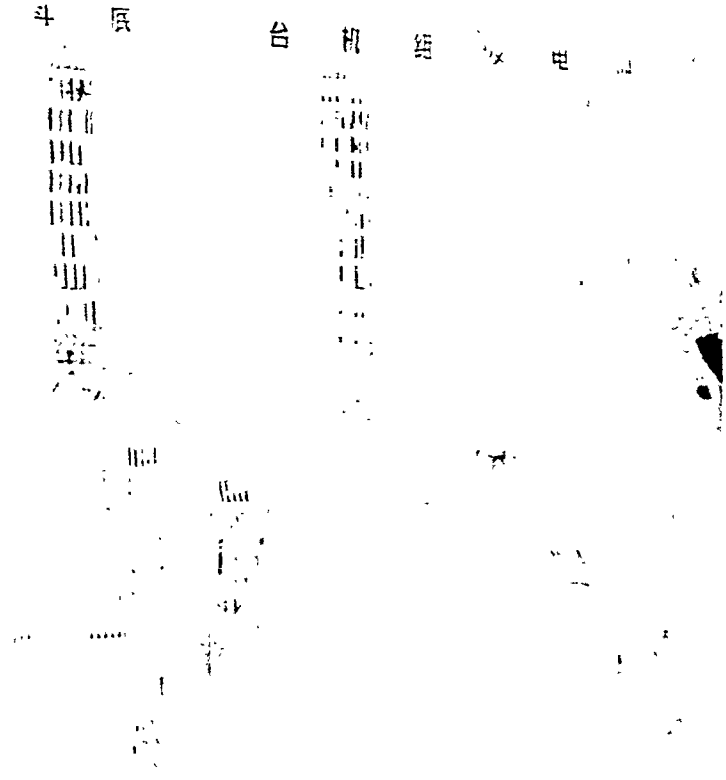
Finally, in 1971, the policy began to change again. The importation of sophisticated technologies increased in volume, and the policy of "walking on two legs," with roughly equal emphasis being given to

Frank Fischbeck—LIFE Magazine © Time Inc.

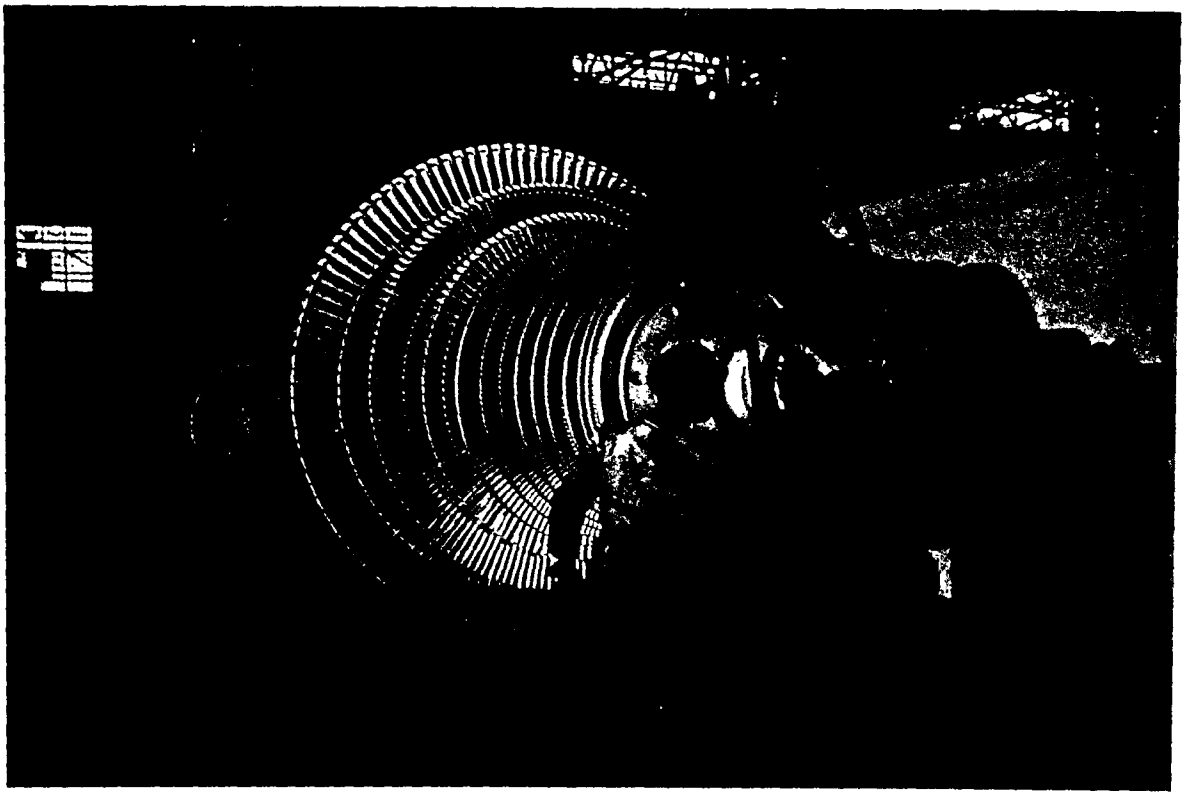


Agricultural laborers (right) still cultivate rice paddies as their ancestors have done for centuries. While much Chinese farming is carried on by traditional methods, the government has given high priority to the use of fertilizer and the construction of dams such as the San Men Dam near Peking (below).

Brian Brake from Rapho Guillumette



Emil Schulthess from Black Star



China's greatest industrial concentration is in Manchuria This steam turbine is in a factory in Harbin, in Heilungkiang Province.

modern, large-scale industrialization and local, small-scale industries, appeared to be the main policy guideline.

What lessons can be learned from these changing Chinese policies that may have some relevance for other developing countries?

First, undue reliance on one source of foreign technology may have disastrous short-term economic effects should that source dry up.

Second, the short-term economic disruption caused by cessation of a single-source foreign technology may have longer-term beneficial effects, since it stimulates self-reliance and encourages the process of shopping around for alternative sources of foreign technology that, in turn, may lead to imports more appropriate to local conditions. Great self-reliance and inventiveness were needed in China to cope with a situation in which plants were left unfinished, blueprints were taken away, and there was even an embargo on the importation of spare parts. In a different context, Cuba was placed in a similar situation vis-à-vis the United States when the latter country put an embargo on the export of goods to Cuba in 1960. Some Cubans argue that, in the long run, the benefits of the "technical learning effect" that this generated among Cuban engineers will far outweigh the short-run economic losses that the embargo caused.

Third, the goals of job creation and egalitarianism will probably call for different sorts of technologies than those that maximize short-term economic growth. The Chinese approach has been to utilize both sorts

of technologies, but it is doubtful whether relatively inefficient labor-intensive technologies can exist side by side with modern sophisticated technologies in a market economy. Thus, although there is great interest in job-creating technologies in many less developed countries today, it is by no means certain that the Chinese experience is particularly relevant.

Fourth, the Chinese experience certainly indicates that considerable economic and social advantages can result from involving the workers in "innovation." On the other hand, the vacillating policy toward experts indicates that, although China appears to have as much trouble as most other countries in getting its scientists and engineers to work on "relevant" problems, there is little evidence to suggest that the Chinese solution of political thought reform has been any more successful than the less dramatic solutions posed in other countries.

Agriculture

In the early years of Communist rule little attention was given to developing new agricultural technologies. In the late 1950s, when the decision was made to give agriculture first priority, two technical issues predominated. The first was how to increase yields, and the second was the more ideological issue of agricultural mechanization.

Technology plays an important part in increased production through its contribution to irrigation, fertilizers, pesticides, and new seeds. During the Great Leap Forward, when the communes were first introduced, the greatest emphasis was put on irrigation. Labor was mobilized on a massive scale to dig ditches and build dams. In the 1960s much more stress was placed on improving production by producing and applying more chemical fertilizer. The need for fertilizer has led to the invention of new techniques that enable small-scale plants to manufacture ammonia and urea efficiently. By the end of 1971 nearly half of all chemical fertilizer was being produced by local industry. It has been estimated that most of the increased grain output in the 1960s was due to the application of chemical fertilizer.

There is as yet no evidence that Chinese scientists have been able to breed new strains of rice and wheat as high yielding as those developed by the International Rice Research Institute in the Philippines and by the Wheat Research Institute in Mexico, which have contributed so much to the Green Revolution in much of the rest of Asia. These new rice and wheat seeds are not particularly appropriate to Chinese conditions. It would be logical to assume that the Chinese will put high priority on research to develop suitable high-yielding varieties since these, used together with water and fertilizer, will be needed if China is to meet its grain requirements over the next decades.

The mechanization issue is more clouded by ideological considerations. Mao has advocated that, in the long run, China should aim for the maximum possible mechanization of agriculture. The tactics to achieve this long-term objective were subjected to heated debate during the Cultural Revolution. The supporters of Liu Shao-ch'i argued that the

agricultural machinery to be allocated by the state should be concentrated in those areas most suitable for mechanized operations—*i.e.* large areas of arable land where draft animals are scarce. They also favored the concentration of research resources in a few centralized research institutes. Mao's supporters, on the other hand, were in favor of decentralization and of giving the initiative to the communes. If a particular commune wanted to mechanize and acquire its own tractors, it should be encouraged to do so.

Similarly, Mao's supporters favored decentralization of research. Instead of just one or two large research stations, Mao favored the establishment of dozens of semimechanization research stations, so that if a peasant had a worthwhile innovation he would be able to try it out in one of the research stations near his own commune. This not only would encourage a flow of new innovations but would give all the peasants a sense of involvement in the development of the country. Mao did not completely rule out advanced research—some resources, he argued, should be used to support it—but the bulk should be used to support the semimechanization institutes. The whole question became a controversial issue during the mid-1960s, and the extent of the debate was revealed in the Chinese press during the Cultural Revolution. As in almost all such debates, the reader is left in no doubt as to whether Mao's ideas were "correct" and are now being implemented.

There are obvious lessons here for other developing countries. Not only is Mao's policy more appropriate for generating labor-intensive technologies, it also has the further social benefit of providing more opportunities for individual peasants to become involved with development.

Medicine

It is probably in the field of public health and medicine that the Chinese experience has greatest relevance for other countries. There are several particularly notable aspects to the Chinese approach. First, the Chinese have stressed preventive rather than curative medicine. This is the reverse of what has been done in almost all other developing countries. Second, they have given a high priority to training paramedical personnel. Peasants are given from a few months to a couple of years of medical training in rural areas, and these workers provide the backbone of the medical service. Third, in certain branches of curative medicine the Chinese have surpassed even the more industrially advanced nations. Particularly notable have been the successes in rejoining severed limbs and in the treatment of burns. Fourth, the Chinese have achieved quite remarkable successes by combining traditional with modern medicine. Herbal drugs have been shown to have considerable therapeutic value, and the new successes in using acupuncture to replace anesthetics in several types of major surgery have gained worldwide attention.

The most significant and important features, however, are the concentration on preventive medicine and the introduction of a curative

Dr. Victor W. Sidel, Montefiore Hospital, Bronx, New York



...se medical practitioners have ...hieved considerable success ...mbining modern practice with such traditional methods ...s acupuncture, in which needles are inserted at specified points ...n the body. An ovarian cystectomy performed on the woman (right) under acupuncture anesthesia was witnessed by a group of American physicians at the Third Teaching Hospital in Peking. The patient was conscious and able to talk throughout the operation. Acupuncture charts (opposite page, left) are used by doctors in placing the needles for anesthesia. The "plastic man" (opposite page, right) is on display at the Industrial Exhibit Hall in Shanghai.

service in rural areas. Just how this has been done is graphically described by Joshua Horn, who recently returned to England after working in China as a doctor for 15 years. In his book *Away with All Pests*, he describes what happened in his hospital in Peking after the start of the Cultural Revolution, when the decision was made to speed up the rate at which rural areas were being provided with health care. Every urban hospital was ordered to make one-third of its staff available for duty in rural health centers. Horn's hospital sent its people to a center in Hopei. At the end of a year some chose to stay permanently in the country, but the rest returned to Peking to be replaced by another third of the hospital staff.

Horn describes in some detail the work of the hospital staff after they had arrived in the countryside. The first function of the rural teams was to accent the role of preventive medicine by stressing public health measures and sanitation. To this end, they helped organize campaigns to eradicate such pests as flies and mosquitoes. Next, the teams set up training courses for the barefoot doctors. During the first winter the new recruits from the communes received five months of medical training. At the end of that time they were able to give inoculations and first aid and to know when to call the hospital doctors. They returned for a second five-month spell of training the next year and were scheduled to undergo three such sessions. After training they returned to their communes to provide grass-roots medical service. The rural teams also provided instruction in family planning and worked closely with existing medical units in the area to upgrade their capabilities in both traditional and modern medicine.

This widespread effort to bring health services to rural areas must be reckoned as one of the really outstanding of all Chinese accomplishments. Nowhere else has the movement of doctors from poorer to richer areas and from poorer to richer countries been reversed.

Brian Brake from Rapho Guillumette



R. C. Hunt



Defense

Although the application of science and technology in the economic and health fields has greatest relevance for other less developed countries, it is the Chinese technical achievements in the development of military technologies that have gained the most notice. The timing of the events is well known, although the technical details are still vague. The first Chinese hydrogen bomb was successfully exploded only eight years after the inauguration of the first research reactor and less than three years after the first nuclear explosion. Chinese rockets have launched a guided missile and put two space satellites into orbit.

The scientific and technical work behind these successes was led by Ch'ien Hsueh-sen and Ch'ien San-chiang, both of whom had worked in the United States but who decided to return to China in the mid-1950s. Obviously, their work has been given massive research and engineering support, and although defense science and technology did not entirely escape political criticism during the Cultural Revolution, they do not seem to have undergone the same sort of disruption that civilian science experienced. The existence of such a high-technology enclave in China has ramifications far beyond its military value. Especially important is the fact that it must demand high quality, technically sophisticated products from Chinese industry. It is interesting to speculate on the extent to which lessons learned in the process of linking industrial production with research and with defense requirements have been transferred to the civilian sector.

Conclusion

Sufficient examples of Chinese science and technology policies have now been given to enable a synthesis to be made. What appear to be contradictory and at times even irrational policies make sense if Mao's long-term objective is kept in mind. This is, and has been ever since the People's Republic was founded, to set China firmly on the road to a truly utopian Communist society, a society in which there is no exploitation, no dichotomy between manual and mental labor or between urban and rural areas, and where everyone is both "red and expert" (*i.e.*, both ideologically committed and technically competent).

That Mao was disappointed with the progress being made toward this goal was clear as early as 1964–65. He apparently decided that a major midcourse correction was needed and in mid-1966 launched the Cultural Revolution. In the years preceding the Cultural Revolution, Mao had taken the "experts," many of whom had been trained abroad, and tried to make them into "reds," but with only partial success. It seems that as China developed economically, an elitist technocracy began to emerge—one that was pragmatic rather than idealistic. Mao believed that the actions of the pragmatists would lead China back into the capitalist camp.

Clearly, from Mao's point of view, drastic action was needed if the younger generation was not to be misled permanently. If he could not make reds out of the experts, then he must try to make a new kind of expert out of the reds. This was to be accompanied by an even greater effort to reeducate the scientists and other intellectuals in what seems to be an almost desperate attempt to attune them mentally to Mao's utopia.

The growing dichotomy between manual and mental labor appears to have been one of the key reasons for starting the Cultural Revolution and explains much of what has happened in the research institutes and universities. Once the revolution was under way, however, the other dichotomy—between city and village—took on increasing importance. Mao's efforts to decentralize education and health services and to

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encourage small-scale industries and intermediate technologies are consistent with his aim of narrowing the gaps in development between different parts of China itself.

That the revolution has caused a major interruption in education and scientific research there can be no doubt. There appears to have been less of an interruption in industrial and agricultural production, and in some sectors that are of military significance there have been major technological feats. There have also been major gains in public health. The interruptions in education and research appear to have been temporary. The objective of self-reliance means that Mao's determination to use science and technology to build a modern China has not faltered. But whether a really modern country can be built without, at the same time, creating a technocratic elite remains to be seen.

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The Tasaday Stone Age Tribe of Mindanao

In the mountain jungles of the Philippines a group of scientists in 1971 first encountered the Tasaday, people who lived in a Stone Age culture with almost no knowledge of other human beings.

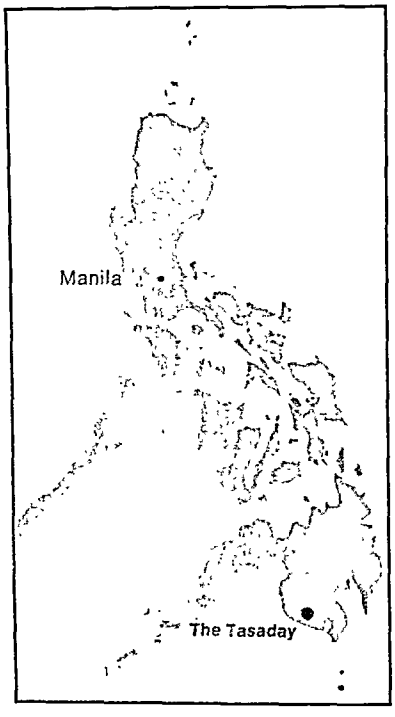
The recent discovery of the Tasaday Manobo—a tribe of food gatherers living in caves and still using stone tools—is providing dramatic new data on human ecology and on the ability of man to adapt to a highly specialized environment. For the Tasaday inhabit a vast, high-altitude rain forest located in the mountains of South Cotabato Province, in the southern part of the island of Mindanao in the Philippines. Here they have survived as a tribe for centuries even though they have been virtually without trade or other relationships with the rest of mankind.

Official contact with these unique people was made by Manuel Elizalde, Jr., president of PANAMIN, the Private Association for National Minorities, Inc., a nonprofit foundation undertaking critically needed medical and socioeconomic development projects among cultural minorities in the Philippines. Research among the Tasaday during periods of contact beginning in June 1971 and extending through May 1972 provide the basis for this statement about their discovery, their physical traits and language, and their society and culture.

When first contacted in 1971, the Tasaday had no knowledge of any cultivated plant such as rice, taro, the sweet potato, corn, cassava, or millet. The Tasaday language has no words for these widespread cultivated plants, nor for any tools or other notions associated with agricultural activities. The Tasaday apparently never had tasted salt or sugar, nor smoked tobacco, since they also lacked words for these common items. Perhaps the Tasaday are the only people now living in an agriculturally appropriate environment who neither know nor grow tobacco, sweet potatoes, corn, or cassava (plants of American Indian origin that swept the world in sailing vessels of the 16th and 17th centuries).

The information in this article is based on research and reports by the following scientists and officials associated with the PANAMIN foundation: ***Frank Lynch, Robert B. Fox, Teodoro Llamzon,*** *and* ***Carlos Fernandez.***





The Tasaday Manobo were discovered in a dense, high-altitude rain forest in the southern portion of the island of Mindanao. (Opposite page) Group gathers around fire, which is used both for cooking and for warmth.

Stone tools made by the Tasaday (and used to fashion such implements of wood and bamboo as the digging stick, fire drill, and a crude bamboo knife) are among the most primitive recorded in a tribe of modern times. They include hand scrapers made from flakes of quartz or from river pebbles ground to a sharp edge on one side and attached to wooden handles. Unmodified stones are also hafted as hammers; indeed, any handy cobble-sized stone may be picked up and used for pounding.

The archaeological record (supported by carbon-14 dates) indicates that such stone flakes and edge-ground scrapers still used by the Tasaday were effectively replaced throughout the Philippines by metal implements about 2,000 years ago. Study of the stoneworking techniques of the Tasaday may lead scholars back to an understanding of an art once thought to be lost.

The exploration of their forest habitat in March 1972 further disclosed that they inhabit or utilize three caves found in a limestone conglomerate, located 400–500 feet up a steep slope above a creek that provides drinking water and their major source of protein food. The manner in which the Tasaday live in these caves (said by them also to have been occupied by their forefathers) will provide singular new data on the period, tens of thousands of years ago, when ancient man characteristically inhabited caves and rock shelters.

The Tasaday at first seemed unaware that there were other societies of people, although they told of having occasionally glimpsed alien hunters or trappers or heard their voices in the forest. They were ignorant even of the names of such neighboring tribes as the Manobo Blit, Ubo, and T'boli. Later, however, they told of having recent intermittent contacts with neighboring forest groups, the Sanduka and the Tasafang. Indeed, it appeared that Tasaday men traditionally married Tasafang women.

Tasaday territory is in one of the most isolated, mountainous regions of the Philippines. All of this broken and rugged terrain is above 3,000 feet elevation, and is blanketed by hundreds of square kilometers of ancient (climax) rain forest. Those who daily fly airplanes (described by the Tasaday as "large birds") over the area found it difficult to believe that this vast sea of undisturbed forest was inhabited by man. Crowns of towering wing-seeded trees (dipterocarps) form a ceiling over the whole environment; even the small streams and creeks along which the Tasaday live and move are not visible from the air. Their world is the relatively warm floor of the forest, dark and damp under clouds that accumulate around the mountain tops; and their home caves. The sun, which Tasaday call the "eye of the day," filters through the forest only briefly at its zenith. Thus, features of earth and sky known to most people (such as lakes, oceans, open fields, and constellations of stars) are unfamiliar to the Tasaday and have no expression in their language. By contrast, most unique features of their forest habitat have a place name, and their knowledge of the local plants is most detailed.

Dolf Herras from Nancy Palmer Photo Agency





The only albino in the local group of Tasaday, a retarded child, suffers from rashlike sores over much of his body and is carried constantly by his widower father.

The Tasaday have remained apart from other men by successfully adapting to a forest environment that has resisted intrusion from outside. So far, the forest has provided them with a stable and favorable ecology that yields life's basic needs. Now, however, along with other great climax forests of Southeast Asia and the Philippines, Tasaday lands are being threatened. Loggers and miners are intruding, and lowland and neighboring mountain agriculturists faced by exploding populations are pushing into the mountains, cutting and burning clearings in the forests for their crops of rice and corn. It is estimated by United Nations sources that the primary forests in the Philippines will be wiped out in perhaps 35 years. And without the forests, the Tasaday (perhaps the last people on earth who live by collecting wild foods in a high-altitude forest) can only disappear as a unique tribal culture. Indeed, their survival even as a distinct biological subgroup of people seems imperiled.

Discovery of a lost tribe

Persistent rumors of a primitive people living in the forest had been reaching the PANAMIN staff at Kemato, the southern Mindanao location of the T'boli Development Project, from a few Ubo and Manobo Blit visitors. The Ubo and Manobo Blit are other isolated and conservative mountain-dwelling minority tribes who rarely have contacts with the populous lowland peoples. None of these mountain dwellers, however, offered more than hearsay until 1971. In that year Kemato was often visited by a Manobo Blit trapper named Dafal—popularly known as "The Bird," with a reputation of "walking through the forest like the wind." The trapper revealed to Manuel Elizalde that he had met primitive people in the forest and had stayed with them overnight.

Dafal told how he had first seen the Tasaday in 1967 (or 1966) while placing traps for wild pigs in the forest. At that time, he surprised a small group of naked Tasaday preparing wild yams (edible tubers) along a creek. They fled at his approach but finally stopped when he continued to run after them shouting in Blit: "I am good! I am good! I can do you no harm!" According to the Tasaday, this was their first contact with anyone from a human group different from theirs.

Dafal stated (as was later checked with the Tasaday themselves) that when he first met them they had no metal tools, cloth, beads, or any of the usual trade goods that have reached all other hunter-gatherer societies known in Southeast Asia. Indeed, he observed that they were exclusively a food-gathering society with no hunting or trapping devices. Dafal added that he visited the Tasaday in the forest about a dozen times while trapping wild pigs or gathering the pith of palms. He gave them a few metal items, the most important being two small bolos (knives for hacking vegetation), only one of which, broken and badly nicked, remained in 1971, and wire for brass earrings. He also introduced the group to the bow and arrow, a few types of baskets, rags of cloth, and even contributed their only musical instrument—a mouth harp—which one Tasaday man learned to play.

Dolf Herras from Nancy Polmer Photo Agency



Family group gathers around fire by the side of a stream. The Tasaday get much of their food, notably crabs and tadpoles, from such creeks.

Plans then were made by Elizalde to seek the Tasaday by helicopter during a socioeconomic survey of the Manobo Blit settlements near the forest where Dafal said the Tasaday lived. Dafal was sent ahead with a party of T'boli workers who would clear a landing place on the edge of the forest while Dafal himself searched for the Tasaday. Then, on June 7, 1971, shortly after the helicopter landed, Dafal emerged into the clearing from the forest with four frightened Tasaday men. They seemed terrified by the whirling blades of the "large bird" and by the "god" (Elizalde) who Dafal told them rode inside. Dafal stated that the Tasaday believed in a kind of messiah who, according to their ancestral.





Children in the local group of the Tasaday number 11 boys and 2 girls: all those pictured above and on the opposite page are boys. Hands of the teen-aged boy above are wrinkled and aged from constant food gathering.

tradition, would one day appear to help them find more food. Afterward, the entire local group of Tasaday—25 men, women, and children—came out of the forest to join their companions at the landing place.

The Tasaday later described this dramatic event as a "great noise" —sudden, thunderous, terrifying, and inexplicable. Nevertheless, even that day and during all periods of subsequent contact, they have been friendly, tolerant, and understanding toward the stream of visiting anthropologists, linguists, news reporters, and photographers; albeit often shy and sometimes bewildered. Their warm behavior with strangers suggests that they never have known unfriendly outsiders; aggression to them seems inconceivable.

Even at first sight the Tasaday were clearly identifiable as Mongoloid in physical type. Related racially to their neighbors and to the dominant Filipino population, the Tasaday are relatively short with light to medium dark skin, straight or wavy hair, and prominent cheekbones. The other societies in the Philippines that still are dependent upon hunting and gathering are the pygmoid Negritos (Aeta), found primarily on the island of Luzon and racially quite distinct from the Mongoloid majority.

The following data were obtained by Elizalde, anthropologist Robert Fox, and linguist Teodoro Llamzon during the first period of contact at the helicopter clearing on the edge of the forest, and later by anthro-





pologists Frank Lynch and Carlos Fernandez during a second exploration in March and April 1972 to the forest interior and to the caves in which the Tasaday live permanently. On both occasions, the researchers communicated best through a Manobo Blit woman named Igna who also spoke T'boli. Her information then was translated by T'boli members of the survey team who were familiar with the Philippine national tongue (Tagalog) or English. It was early established that the Tasaday, as do all peoples in the Philippines, spoke an Austronesian language, one specifically related to the many Manobo tongues on Mindanao. It appears that the Tasaday language has its closest ties to Manobo Blit; nevertheless, Igna was able to understand less than half of their first answers to endless questions, although she later gained fluency.

Habitation and social organization

The Tasaday permanently occupy or utilize a complex of three limestone caves, located about a day's walk for them from the helicopter clearing where they were first contacted. Access to the caves is difficult, as they are located 400–500 feet up a steep slope from a small creek. According to the Tasaday, there are no other habitable caves in this area of the forest. They further state that these caves were also used by their forefathers, and evidences of a refuse heap in front of the uppermost cave (the stone floor is swept daily with leaves) suggest



a lengthy period of past occupation. Other peoples in the Philippines still live in caves seasonally, even subgroups of horticulturists such as the Pala-wan living in the Ransang area of southwestern Palawan Island, but there is no local evidence of the use of caves for permanent habitation since Paleolithic times, thousands of years ago. Tabon Cave, also in Palawan, was occupied by Paleolithic hunter-gatherers for more than 40,000 years. But it is truly startling to find a contemporary tribe of food gatherers who live permanently in caves.

The only local group of Tasaday contacted was composed of six elementary families (the elementary family is the social unit of father, mother, and unmarried children). Of the total of 25 individuals, there were 12 adults; 11 of the 13 infants or children were male. Four elementary families were close blood relatives; indeed, the fathers of three families were either children or nephews of the oldest couple in the group.

Orphans and unmarried adults attached themselves to one of the families. All of the families lived and slept together in the uppermost cave, a warm, light, and airy chamber about 25 feet deep, 30 feet wide across the mouth, and 10 feet high. Balayem, an unmarried young man until April 1972, usually slept in the next lower cave, sometimes accompanied by younger children. As there appeared to be an optimum balance between the present size of the local group of Tasaday and the available food resources of the nearby forest, the group rarely foraged more than a kilometer or two away from the caves and most of the group was back in the main cave with sufficient food by midday.



The largest social unit of Tasaday society is the *nasagbung* or "local group" formed by a number of closely related families. This local group is not a band, as defined by anthropologists, since there is no formal leader who is solely responsible for jural (lawfully binding) decisions. Instead, decisions that involve group activities are shared by adults and family heads, the most active and experienced among them assuming temporary leadership (in the style of a committee or board of directors). The family is the basic social and economic unit, although its functions are considerably modified by the small size of the local group, shared food-gathering activities, and common residence in a cave.

Married couples sleep independently in the cave with their infants and younger children. Father and mother share the responsibility of child care. Older children were observed to be almost inseparable, playing, gathering fruit, and also sleeping in the same area. And they might eat with any of the adults. When not busy, they were seen sitting with arms around each other; penis play between individuals was noted. Although the family also tends to be the basic economic unit, the Tasaday emphasized that food gathered each day was shared communally among families when necessary. Their intention is that all members of the local group, particularly the children, can have a meal. Food for all families is prepared at one or the other of two hearths found in the cave (a third fire being used at night for warmth). Mealtime is irregular, al-

though leftovers or newly cooked food are usually eaten in the morning before the daily foraging begins. Food is also prepared around noon when the foragers have returned from the forest and/or before dark. Wild fruits are eaten at any time during the day.

The Tasaday may eat food raw, roasted, or cooked in the tough leaves of a river-bank plant (*Curculigo*) twisted together and placed on the coals at the edge of the fire. Their present practice of cooking palm starch and chunks of meat in bamboo tubes, widespread among other gatherer-hunters in Southeast Asia who possess metal tools, was unquestionably introduced by Dafal. One set of flint and steel was also given to them by Dafal, but they continue to make fire when necessary by rotating a wooden drill between the palms of their hands against another piece of soft wood and small bits of tinder. This type of fire-making drill has not been observed by the writer among any other Filipino people. The Tasaday usually carry a live ember when planning to stay away from the cave overnight or when moving from one place to another. Permanent fires are maintained in the cave. At night members of the families cluster for additional warmth around the hearths.

There is little evidence of formal division of labor between the sexes. The data of Carlos Fernandez seem to indicate that the women possibly bring more food back to the cave than the men, although the men appear to be responsible for such relatively arduous tasks as climbing trees for fruit and digging for deep wild yams.

The Tasaday rarely stay away from the caves overnight but, when necessary, shelter is found in the spaces formed between buttress roots of giant trees. Specific trees are selected near small streams and creeks, which form the principal trails through the rugged terrain.

As among all peoples in the Philippines, the Tasaday have a bilateral kinship system; that is, relationship is reckoned equally with both father's and mother's kin. The kinship terms used in reference and address are also similar to those found throughout the islands. Grandparents and grandchildren call each other by the same reciprocal term. Fathers and mothers are distinguished terminologically from uncles and aunts, but brothers and sisters are identified by the same term, which is also extended to include cousins.

Social and kinship behavior undoubtedly reflect both the small size of the group and the high mortality rate among infants and children. Unusually affectionate ties were noted between parents and children; the latter are carried constantly, even when they are three or four years of age. A characteristic and touching scene is that of a Tasaday mother walking down a stream bed with one child at her breast and another riding on her back. Parents seem reluctant to stop nuzzling and smelling their children; they do not kiss. Close and affectionate ties between husband and wife were evident during a sudden downpour, he rushing to prepare a temporary shelter of palm fronds for her and their younger children. There are signs of a deep expression of intimacy among all individuals; such close affiliation is not found generally within larger and more sophisticated groups of people.

Dolf Herras



Stone scrapers made from flakes of quartz and ground to a sharp edge on one side are used to fashion crude bamboo knives (opposite, top and bottom). A woman (above) uses her hands to comb the hair of another; both wear the traditional skirts made from leaves of a tufted herb.



To make fire the Tasaday rotate a wooden drill between the palms of their hands against another piece of soft wood and small bits of tinder. Anthropologists had never before seen this type of fire-making drill among Filipino people.

There is apparently no such formal social or occupational role as that of midwife among the Tasaday. Each mother was said to deliver her baby alone, cutting the umbilical cord herself with the sharp edge of a strip of bamboo; the father is responsible for burying the cord. Marriage is said to be arranged by parents, as among most traditional societies in the Philippines, but the advice of all adult members of the local group is considered. Wedding gifts were also mentioned. Since the group is small, there is little choice of spouse, and there may be an imbalance between the number of marriageable boys and girls. (The Tasaday group contacted had two unmarried young men; there were 11 male children, yet only 2 female youngsters.) Nevertheless, the Tasaday insisted that they practice neither polygamy nor polyandry; nor do they exchange or lend spouses, although these practices are known among other people in the Philippines who still hunt and gather in small local groups, such as the Negritos of Luzon. There seems to be no ancient moral precedent for the Tasaday to ban polygamy; indeed, their first male ancestor is said to have had two wives.

People who die of old age or injury (one man was recently killed by a falling tree) are said to be simply covered with leaves near the place where they died. People who die in the caves are carried into the nearby forest for "burial." There are no formal cemeteries.

Statements of the Tasaday indicate that the Sanduka and Tasafang still live in the surrounding forest, though the Tasaday have not contacted them in recent years and are not certain that these groups still survive. Three men were born among a local group living at Lambong, which possibly has died out as a social unit. The husband of one woman and his father traveled three nights to Sanduka territory in order to obtain the young bride. This is the longest trip away from their caves that any living Tasaday has made and was also the last contact with a neighboring group. The Tasaday have been asked by Manuel Elizalde to confirm the existence of the other groups, but they are extremely reluctant to leave the area surrounding their cave homes. The Tasaday believe that as long as they remain at the caves they will be safe.

The population of the Tasaday seems never to have been large, and to have been separated throughout its history into small local groups. The size of the local group is restricted, among other factors, by the level of technology achieved by the people, by their knowledge of how to exploit the resources of the forest, and by their ability to forage sufficient territory to support themselves. The local group of 25 Tasaday contacted seems a near minimal number for human group survival. It is consistent with norms of 20 to 30 people in local groups reported for other hunter-gatherer forest societies found in other regions of Southeast Asia.

The quest for food

When Dafal found them five years ago, the Tasaday were exclusively food gatherers with a Stone Age technology. Without trapping or hunting devices, they were unable to feed on such larger animals in the

forest as wild pigs, deer, civets, and monkeys. Dafal introduced a number of traps and the bow and arrow; these are now used by some of the men with limited success. Their major source of protein, however, is still river life (tadpoles and crabs) collected by hand. Conservationists would be pleased with the remark of one strong, active Tasaday man who does not use the new traps or the bow and arrow: "The largest animal I have ever killed is a frog." Dafal also taught them how to obtain the edible starch of wild palms and "palm cabbage" with the metal knives (bolos) he gave them. This exploitation of palms has provided the Tasaday with an important, readily available new staple. It is probable that palm starch will become their principal food, further testimony to the impact that Dafal had upon Tasaday life-ways.

The Tasaday's principal sources of food in the past, and still of great importance, are the roots (tubers) of yam vines (*Dioscorea*). These wild yams are similar in properties and food value to the cultivated potato. Used by food gatherers throughout Southeast Asia, at least nine different species of wild yams (Tasaday call them *biking*) are found in the Philippine forests and their tubers are available throughout the year. The tubers can be kept without spoiling for two weeks or more, and seem to have deep meaning for the Tasaday. Thus, when one of them was asked to name the most beautiful thing to him, he immediately answered: "For me, it is to find a large yam after digging deep in the ground." The yams are excavated with a digging stick traditionally pointed with a stone scraper (or now with a metal knife).

When gathering yams, like other peoples in the Philippines, the Tasaday may leave the head of the tuber attached to the vine in the ground—a sort of incipient agriculture. Knowing the location of the vines in their territory they can return the next year to reharvest the yams. The wild fruit of such larger plants as the climbing palmlike rattans, the wild banana, and the ground-level fruit of a wild ginger are also a significant source of seasonal food. The fruit, leaves, and flowers of many trees and bushes are also eaten.

Large and fleshy tadpoles of the giant mountain frog (*Rana*), small crabs, and a rare species of the halfbeak fish still form their major source of protein. These are abundant in the small creeks and are caught with the hands by simply feeling in crevices among rocks. The Tasaday have no weirs, nets, or other fishing devices. The giant frogs are killed for food with a striking stick, and meat (particularly of the wild pig, monkey, and rat) now occasionally is obtained with traps introduced by Dafal. Grubs from decaying fallen trees are a sought-after food.

Tasaday do not gather wild honey (although it is prized by other hunter-gatherers in the islands) since, as they say, "We do not know how to drive away the bees." They rarely exploit birds for food and have no term in their language for the egg.

In summary, the economy of the Tasaday is still based upon gathering wild vegetable and animal life, even though supplemented in a limited way by recently introduced trapping and hunting devices.



Chief scraping tool of the Tasaday is a stone (opposite) that has been ground to a sharp edge on one side and then attached by thongs to a wooden handle; thin river pebbles are used for the stones. Man above uses an edge-ground scraper to fashion a wooden implement.

Health, dress, and adornment

The Tasaday appear to be in fair physical condition despite problems of food supply and the damp, high-altitude forest in which they live without permanent shelter and protective clothing. The active children and younger individuals display muscular bodies—vaulting across streams with poles, climbing trees for fruit, and moving swiftly with great agility along the slippery bottoms of creeks. The hands of younger individuals strikingly resemble those of the aged, probably the result of their continual use in the absence of tools or other technology for exploiting the environment. Older Tasaday appear wan and sleep much of the time throughout the day; life span is short, with only one couple estimated to be as old as 50 or so. Goiter is present and one young man had a severe fungous disorder of the skin. Another boy had a pair of congenitally webbed toes. A retarded albino child with multiple rashlike patches and ulcers of the skin (his mother is dead and his father must carry him throughout the day) seemed to have little chance of surviving long. Genealogical data indicate that an average of only two children per family survive to the age of two or three years; only then are they given personal names.

Dental examinations revealed no cavities (caries), but diseases of the gums (pyorrhea) were seen. Most adults chew betel nuts (from a wild Areca palm) mixed with slaked lime (from the shells of land snails) and betel leaf (from a type of pepper plant). They file blackened front teeth with abrasive stones from the streams. The Tasaday use their teeth in lieu of tools, often using them in rounding a stick for use as a fire drill, in cutting a vine to be used as a belt, or in tearing away the skin or bark from plants.

Brief skirts and small coverings for the genitals (G-strings) are fashioned from the long, tough leaves of a tufted herb (*Curculigo*). The leaves resemble those of a ground orchid (*Spathoglottis*) which may also be worn. The men wear one or two *Curculigo* leaves running between their legs and under and over a vine waistband. Women wear a bunch of similar leaves (or a broader, still unidentified leaf) held up with a vine belt around the waist, an attractive tassel effect being achieved by the pointed ends of the leaves as they fall. They now prize the cloth that Dafal gave them for G-strings and skirts.

The hair of men and women usually reaches to the waist; sometimes it is worn by women in a bun. The men with long hair may tie it at the nape with a ribbon made of a plant leaf. The men and women spend considerable time combing their long hair with their fingers, but use no implement as a comb.

Ornaments seemed limited to brass earrings worn by both men and women as a series of rings attached from the outer edge (helix) of each ear to the lobe. According to the Tasaday, these rings were formerly made of plants, and were replaced by brass wire obtained from Dafal. Not one glass, stone, or shell bead was observed among the Tasaday, further evidence of their isolation for hundreds of years from other peoples. Glass and semiprecious stone beads have been a major item

of trade in the Philippines and in island Southeast Asia since about 500 B.C. Tasaday do not even use the black or white Job's-tears (seeds of the grass *Coix lachryma-jobi*) that are widely worn as necklaces by minority peoples throughout the Philippines.

Tasaday adults of both sexes tattoo themselves with thorns and dark plant sap on the inner side of the arms and legs, although the geometric designs fade rapidly. The early Spanish writers described natives of the southern Philippines as *Pintados* ("painted people") because of their extensive body tattoos. Tattooing is also characteristic of most minority groups in the islands, including the mountain neighbors of the Tasaday in Mindanao. Such evidence is to be considered along with their language in establishing the Tasaday's common cultural origins with other Filipino peoples.



Religion and philosophy

Tasaday attribute all of their knowledge and material possessions (before Dafal) to their ancestors—the *fangul*. Their first ancestor is called Bengbang; he is said to have had two wives—Dakwe and Fiyuwe. These women bore two sons (Sanumabat and Lantoy) and a daughter (Mangi) from whom all Tasaday are said to have descended. Tasaday relationships with the supernatural primarily involve the more recently dead (*sugoy* or "soul relatives") whom they say they see in their dreams. The dead are said to dwell in the tops of trees and continually to interact with the living by helping them find food. Tasaday also speak of Salungal (the "owner of the mountains") as aiding them; he too is held to live in the crown of the forest. One informant described a type of divination in which measurements are made on the arm with the outstretched fingers of the hand. If the remeasurements of the spans of the hand on the arm are the same or longer, then the answer to a question posed is yes; if shorter, no. Questions addressed to the dead, such as where food can be found, are answered in this manner. Similar divination practices are recorded among surrounding peoples.

Rituals were not observed among the Tasaday. Their religious beliefs and practices seem poorly developed as compared with those of neighboring agricultural people, and focus primarily on relationships with the dead. The origin myth of the Tasaday is similar to although less detailed than that of the Manobo Blit and T'boli. These and other social and cultural traits the Tasaday share with other Manobo groups in southeastern Mindanao indicate a widespread, older culture basic to this region.

Living in isolation for hundreds of years with an extremely primitive technology and dependent upon food gathering, the Tasaday have a philosophy or world view that expresses deep and intimate relationships with the surrounding environment. Their universe is the canopied rain forest. Not only are the dead believed to dwell in the crowns of the towering trees, the trees also form a ceiling over their known world. In contrast, neighboring peoples with whom the Tasaday share features of an ancient culture speak of their dead and deities as living in the sky.

Food gatherers have been described as "natural man," and this the Tasaday are. They have depended entirely upon spontaneous products of nature for their wants and needs. Moreover, they live in balance with the rain forest—without disturbing ecological processes. Their life contrasts sharply to that of modern, complex technology that reshapes the environment drastically.

Past and future

It seems clear that the Tasaday have survived with a Stone Age technology in a high mountain forest of southern Mindanao since prehistoric times. Evidence is that they are not a recently "banished people" who splintered from a neighboring group because of conflicts or who fled into the mountains to escape smallpox or other disease. The Tasaday retain distinctive elements of an ancient culture, indicating that they long have been isolated from the influences and developments that have changed other peoples with whom they have genetic ties.

Linguistic and cultural evidences demonstrate that the Tasaday have their closest relationships to the Manobo Blit, their mountain neighbors. The Tasaday and Blit form, in turn, a subgroup of a larger cultural-linguistic group in Mindanao described as the Manobo. The scattered distribution of the many Manobo groups, plus linguistic and cultural

Father and child demonstrate the affectionate ties that exist between Tasaday parents and offspring. Parents frequently nuzzle their children and carry them constantly, even to the age of three or four.



data, indicate that they once formed a closely related people who spread throughout Mindanao during the late Neolithic Period (probably before 1000 B.C.).

Jesuit priest Teodoro Llamzon, linguist at the Ateneo de Manila University, compared 150 words from 13 Mindanao languages, including Tasaday. His method measures the rate of retention of basic vocabulary, from which he has calculated the approximate date when Tasaday seem to have separated from the other Manobo speakers. Father Llamzon reports that the probable time of separation of Tasaday from Blit—the closest linguistic group—was about 700 years ago (13th century A.D.).

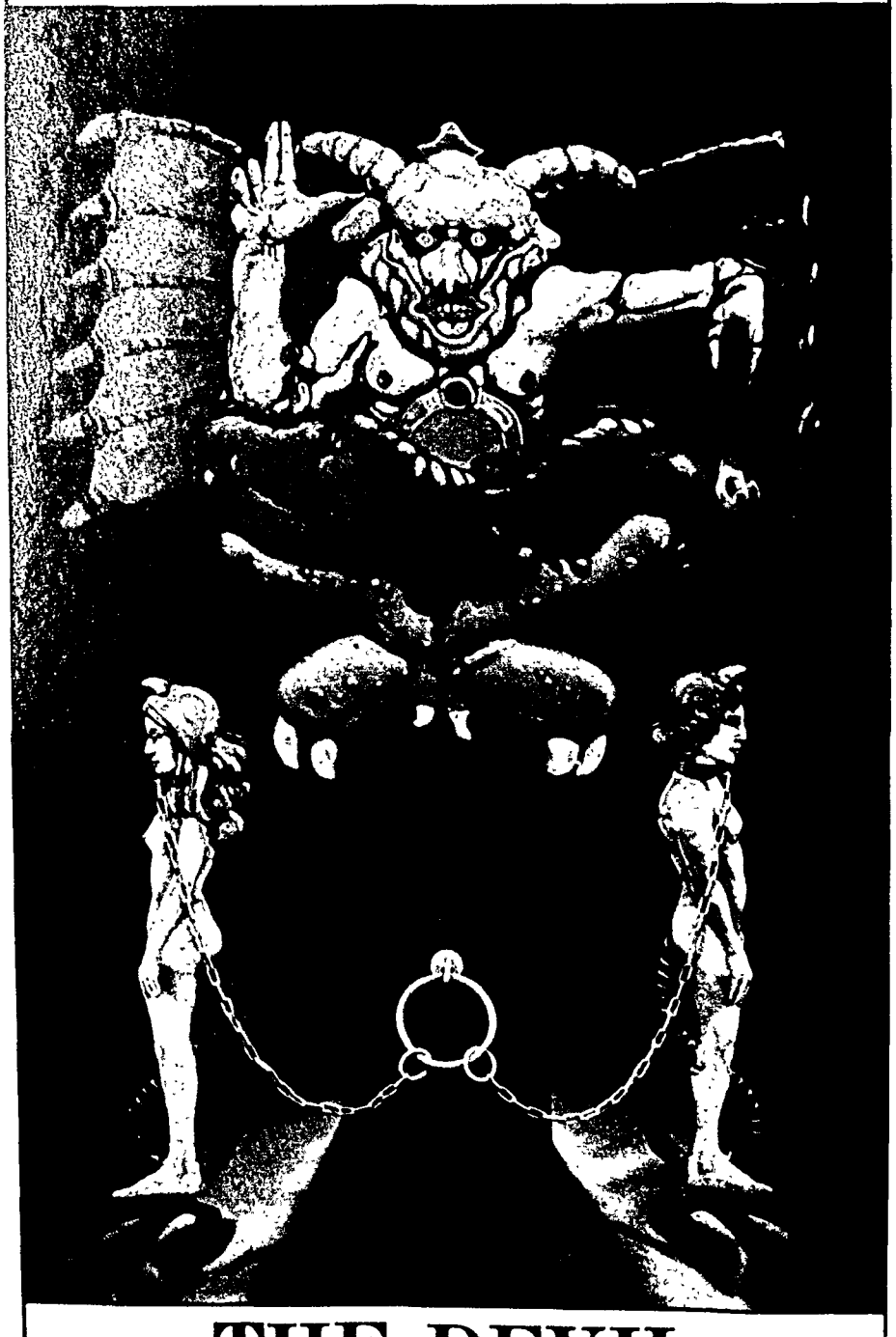
It is most unlikely, however, that the Tasaday separated from the Blit people as they are today. The Blit are agriculturist, and it seems improbable that in 700 years the Tasaday would have lost all knowledge of agriculture, metal tools, and hunting and trapping devices that would have added security for them in the forest. It would also mean that the Tasaday, after losing knowledge of metal tools and weapons, then would independently develop stone implements that show close relationships with similar artifacts recovered in prehistoric excavations throughout the Philippines. A more reasonable reconstruction would seem to be that the Blit were former gatherers who separated from the Tasaday to become agriculturists.

But what does the future hold for the Tasaday? News of their existence emotionally touched many who live in a troubled complex world. Some people reacted wishfully, as if the Garden of Eden had been found. It was widely insisted that the Tasaday remain free to live without external pressure. The outside world's concern for the Tasaday recalls that past contacts leading to conquests of primitive and peasant peoples have produced some of the blackest chapters in human history.

Tasaday contact with the outside world seems to have been inevitable. Their isolation was doomed to yield to the loggers and neighboring agriculturists, who are invading their forest sanctuary. The items of material culture they have already received from Dafal have created new needs and wants among the Tasaday; time has caught up with them.

In April 1972, President Ferdinand E. Marcos declared the forests the Tasaday occupy as a Philippine national reserve. The conservation of these forests is equally important to the preservation of the watersheds that support agricultural development for an expanding population in the adjacent lowlands. A program of research has been prepared by PANAMIN designed to provide fuller data on the Tasaday, one of the world's unique peoples. Hopefully the work will help the Tasaday to select a program of development that will prepare them for new experiences, and to cope with the social problems they can expect to face. Clearly, when a people are faced with change, as are the Tasaday, it should be with pride and dignity, at their own pace, and by their own choice.

XV



THE DEVIL

The Psychic Boom

by Samuel Moffat

Psychic phenomena—ranging from astrology to ESP to biofeedback—have stimulated considerable interest and controversy in recent years. Do they mean anything? Are they true?

On the opposite page is the Tarot card called the Devil—Key 15 from the Major Arcana. According to Eden Gray, author of *The Tarot Revealed*, when this card appears in a reading right side up (as shown), it means "domination of matter over spirit. Sensation divorced from understanding. . . . Bondage to the material. . . . Black magic." Turned around the other way, upside down, it indicates "the beginning of spiritual understanding."

Key 15 in its two configurations neatly illustrates the duality of our response to psychic phenomena. A real "psychic" boom has developed in the Western world during the last few years, encompassing interests from astrology to Zen meditation. Many individuals simply view such interests as modern manifestations of black magic—superstitions growing out of perennial human gullibility. Many others, however, believe psychic happenings are evidence of a cosmic force as yet poorly understood—and sometimes deliberately rejected—by modern science. Magic and superstition, or spiritual understanding—which do they represent?

(Below) Bettmann Archive; (opposite page) courtesy, U.S. Games Systems, Inc. © 1970 S. R. Kaplan



Varieties of psychic phenomena

In the popular understanding, "psychic" covers a motley accumulation of beliefs and happenings that defy a single definition. It may include occult, apparently supernatural, and (to some) irrational topics such as fortune telling (by astrology, Tarot, the *I Ching*, palmistry, etc.); character analysis by graphology or phrenology; dowsing (water witching); faith healing (perhaps including acupuncture, which involves treatment of disease by inserting needles at specific points in the body); witchcraft; poltergeists; out-of-the-body experiences; unidentified flying objects (UFOs); and reincarnation and communication with the dead. It may include phenomena within the realm of parapsychology, which many responsible scientific investigators reject as unproven but which others accept as verified: extrasensory perception or ESP (telepathy, clairvoyance, and precognition) and psychokinesis or PK (moving objects by mental effort). And finally it generally encompasses what have recently come to be called "altered states of consciousness"—hypnosis, dreaming, drug-induced states, and established Eastern forms of meditation such as Yoga, Zen, and transcendental meditation—as well as studies involving deliberate control of brain states.

All of these topics have at one time or another been categorized under psychic phenomena. In fact, however, they should probably not be lumped together. From the point of view of most scientists, some have no status at all and probably no basis in fact; most (but not all)

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Tarot cards originated probably in the 14th century to interpret the present and predict the future. The 22 cards on this page comprise the Greater Arcana; a second deck of 56 cards is the Lesser Arcana. Each card is subject to specific interpretations: the Sun, for example, suggests triumph, success, happiness. On the opposite page, a "diviner" in a central European village deals out a deck that has been placed before her facedown by the "questioner." The diviner must spread the deck in a prearranged manner, and the pattern that is formed is then used to tell the questioner's fortune.

















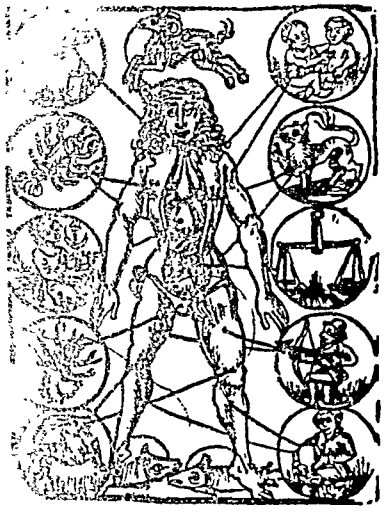








Bettmann Archive



Each constellation making up the 12 signs of the zodiac (above) in many cultures was believed to dominate a specific organ of the human body. The first known depiction of witches on broomsticks appeared in a French book of the 15th century. The human face (opposite) was thought to be divided into sections that had specific attributes (top) and that were dominated by particular stars and constellations (bottom).

of the occult topics fall in this category. Altered states of consciousness and deliberate control of brain states are generally accepted as fields of serious research. Parapsychology (ESP and PK) represents a controversial area, with both ardent defenders and skeptical disbelievers. The public thinks of these three broad subject areas as related even though they may not be. Any attempt to describe the psychic boom must acknowledge this confusion as part of the situation.

A booming phenomenon

Prominent people from almost every walk of life have expressed serious interest in psychic phenomena. Actress Marlene Dietrich tried to persuade the secretary-general of the United Nations to reschedule a General Assembly meeting because the astrological portents were bad for a certain time. James Reston, one of the world's leading journalists, was treated by acupuncture for pain relief following an appendectomy in China; his impressions appeared on page one of the *New York Times* and stimulated wide interest in this ancient practice. The Beatles traveled from Britain to India for an intensive course in transcendental meditation, which took on new popularity in Europe and the United States. A prominent U.S. clergyman, Bishop James A. Pike, revealed to the world his belief that he had communicated through mediums with his dead son from "the other side."

Courtesy, Bibliotheque Nationale



The exact amount of popular interest, stimulated by events such as these, is difficult to measure. To a certain extent, however, the communications media mirror it. Almost 70% of the daily newspapers in the United States carry horoscope columns, according to one estimate. An astrologer appeared on the cover of *Time*, and a witch was featured on the cover of *Look*. A novel about the exorcism of a demon headed the best-seller list for 17 weeks. A publisher specializing in occult books reported that between 1960 and 1971 his business increased 25-fold. The practice of witchcraft was notably increased following the appearance of the movie *Rosemary's Baby*, in which a witches' coven practiced black magic. These and many other indicators make it clear that millions of Americans take some if not all psychic phenomena seriously.

Culver Pictures





Bettmann Archive

A product of our times

Commentators have offered many reasons for this upsurge of interest. Most observers seem to arrive at a similar conclusion: The material needs of many Americans and Europeans are being met to a greater degree than ever before. Accordingly, these people have the time and inclination to look more closely at other aspects of life—its meaning, its value, its spiritual and philosophical aspects. They often become convinced that neither the traditional religions nor modern science has solved mankind's massive social problems—the threat of nuclear war, the inequities of poverty and racial discrimination, and many others.

Searching for new ways to improve mankind, many persons have actively challenged established values and approaches. They question the findings of "rational" science and may seek new avenues to fulfillment and involvement through an exotic experience such as meditation or exposure to the occult. They may argue that if rational man cannot control his own future, why not accept astrology and let the stars do it?

The occult and psychic boom unquestionably has its faddish elements. There are charlatans and fast-buck artists capitalizing on it just as they do on any other human interest. Even people who are very open to supernatural concepts, who sincerely believe that psychic events and energies influence the lives of everyone, acknowledge that a large proportion of the activity they observe may be fakery. There is sleight-of-hand trickery or carnival showmanship passing for true ESP, they say, and there are promoters pretending to be psychic who are solely interested in commercial or individual exploitation. Nevertheless, the movement appears to be too widespread to write off as a passing fancy. It seems obvious to many observers that the interest in the occult is a response to current elemental human needs.

The reaction of science

Given the tremendous public interest in understanding psychic events better, many laymen are puzzled that science has not taken psychic

Don Snyder





A "white" witch (above), one who makes good magic, practices her art with the necessary tools around her. On her altar, inside the stump of an apple tree, are shells, a tarot card, a butterfly, cornmeal, and a lighted candle. She holds a mink skin, wears a pendant-symbol of the "feet of Vishnu" on her forehead, and has a headdress made of cock feathers, beads, tassels, and pieces of amber and jade. Death masks (right) are believed to contain spirits of the departed in some cultures. Baba Ram Das (opposite), a guru, teaches transcendental meditation.

phenomena more seriously. Some scientists have clearly rejected the subject out of hand. One of the great physicists of the 19th century, Hermann Ludwig Ferdinand von Helmholtz, stated categorically, "I cannot believe . . . in the transmission of thought from one person to another independently of the recognized channels of sensation. It is clearly impossible."

Some present-day psychologists are almost as outspoken. Their point of view is well summarized in the comment on ESP contained in a college textbook published in 1970, *Psychology Today: An Introduction*, prepared by 38 contemporary psychologists. It states that "scientists today, for the most part, remain skeptical of ESP. It is axiomatic in science that a phenomenon be repeatable and predictable. To demonstrate conclusively that ESP exists, a scientist would have to be able to reproduce it whenever he liked. To date, this has proved impossible. . . . The best that can be said of ESP, then, is that it remains an unproven but fascinating phenomenon."

This is an area of heated controversy. In 1956 George R. Price of the University of Minnesota suggested in *Science* that results of some of the most widely accepted ESP experiments could have been produced fraudulently. Thirteen years later Edward U. Condon of the University of Colorado wrote, "Flying saucers and astrology are not the only pseudo-sciences which have a considerable following among us. There used to be spiritualism, there continues to be extrasensory perception, psychokinesis, and a host of others. . . . In my view, publishers who publish or teachers who teach any of the pseudo-sciences as established truth should, on being found guilty, be publicly horse-

whipped, and forever banned from further activity in these usually honorable professions."

Nevertheless, some researchers who are regarded with high esteem have been convinced of the reality of certain psychic phenomena. Carl Jung, the Swiss psychoanalyst who was a major figure in modern studies of the mind, believed in the existence of spirits and himself had prophetic dreams. William James, the first great American psychologist, served as president of the Society for Psychical Research (London, England) and investigated several phenomena himself, including the accomplishments of a medium. Of this particular woman he said, "[I] believe she has supernormal powers." But he also exposed another medium, about whom he wrote, "Everyone agrees she cheats in the most barefaced manner whenever she gets an opportunity."



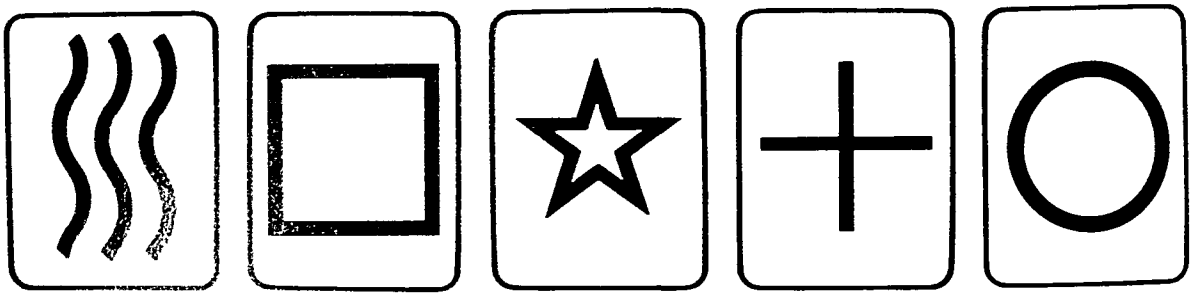
An experimental milestone

This article concentrates to a certain extent on laboratory experiments involving ESP because that is where the most definitive scientific investigations of disputed psychic occurrences have been carried out. While reports of spontaneous psychic phenomena are plentiful, scientists prefer to set up experimental situations where various sources of error, such as observer bias, can be ruled out. This has been most possible to achieve with ESP. If modern science rejects ESP, it is unlikely that many of the occult topics listed earlier will become accepted areas for serious investigation for some time.

The leading investigator of ESP for several decades has been Joseph Banks Rhine, first at Duke University and then at the Foundation for Research on the Nature of Man, at Durham, N.C. According to Martin Gardner, author of a book debunking pseudoscientists, Rhine "has done more than any one man in history to give scientific respectability to the investigation of psychic forces." In countless experiments, Rhine, his wife Louisa, and their associates attempted to produce acceptable evidence of ESP, and for many years their techniques set the pattern for research in the field.

The principal technique utilized by Rhine involved a pack of cards with only five symbols. Five cards with each symbol make up a pack of 25 cards. If an individual were to guess the identity of each card in order, without seeing it, just on the basis of chance he would get one out of five correct. An individual with ESP, however, should score considerably higher. The odds against chance occurrence of any particular score can be calculated statistically. Rhine conducted what he considered a milestone experiment in 1933.

The subject, Hubert E. Pearce, Jr., had performed well on preliminary trials (once scoring 25 "hits" out of 25) and was to be given a particularly careful test with "conditions thoroughly adequate to exclude all the factors that could produce extrachance scores except ESP." Pearce was in the Duke University library, 100 yards away from a building where Rhine's assistant, J. G. Pratt, was to turn over the cards. They conducted 12 runs or 300 trials. Pure chance would have produced 60



Five of each of the above ESP cards constituted the deck used by extrasensory perception researcher J. B. Rhine. Without seeing the cards, a subject tries to guess which symbol has been turned up.

hits, but Pearce scored 119. "A score as large as this," Rhine wrote, ". . . would be expected to occur by chance only once in approximately a quadrillion (1,000,000,000,000,000) of such experiments." Therefore, chance could be ruled out. "There are no known sensory processes that could be supposed to operate under these conditions. . . . We . . . were forced to decide that, whatever clairvoyance or the extrasensory perception of objects *is*, this was a case of it."

Experiments such as these have been criticized seriously by other scientists, however. They point out that the individuals who perform ESP poorly have been screened out so that good performers like Pearce are likely to exist simply on the basis of chance. This argument gains some strength because those who do ESP well, either with card tests or similar procedures, almost always lose their ability after a period of time—as if the law of averages were catching up with them.

In defense of selected subjects, those who believe the ESP tests are valid say that not everyone has highly refined psychic ability, just as few people can play the piano professionally, so that selection is perfectly legitimate. Regarding the second criticism, Charles T. Tart, an associate professor of psychology at the University of California, Davis, pointed out that the typical ESP card guessing procedure could be expected to destroy rather than enhance the ability to perform well.

Tart assumes that the ability to use ESP is latent in subjects and must be learned to some extent. But many experiments have shown that learning occurs when someone receives an immediate reward for desired activity (or punishment for incorrect activity). In card guessing, however, the subject does not know the result of each guess; he only finds out how well he has done at the end of one or several runs. "Any psychologist," Tart notes, "if asked to have *any* organism learn under [such conditions], will throw up his hands in disgust. . . . We have, unknowingly yet systematically, been extinguishing the operation of ESP" in those tested.

Another criticism of typical ESP results is that they are often subjected to repeated statistical analyses until the results bear fruit. And, aside from the statistics, ESP is greeted with skepticism by some because it seems to violate known principles of physics. It apparently works as well over great distances as at short range, for example, while other forms of energy transfer follow the inverse square law: at twice the distance the received energy will be one-fourth as great.

ESP investigation in the 1970s

Some of the past criticisms may become outdated as evidence from the present generation of experimenters accumulates. They are using new techniques, including the application of automation and sophisticated electronic circuitry, to overcome past objections. There are several centers in the United States carrying out extensive research in ESP and PK, including laboratories at the University of Virginia; the American Society for Psychical Research, New York City; Maimonides Medical Center, Brooklyn, N.Y.; City University of New York; the Foundation for Research on the Nature of Man and the Psychical Research Foundation, both in Durham, N.C.; and the University of California at Los Angeles.

A great deal of research also is being conducted in other nations. Significant activity has taken place in the Soviet Union and Eastern Europe, but accurate scientific reports are difficult to obtain in the West. The publication in 1970 of the book *Psychic Discoveries Behind the Iron Curtain* by Sheila Ostrander and Lynn Schroeder stimulated considerable interest in the United States and Europe. The book contains little quantitative detail, though, and many ESP investigators in the United States are making concerted efforts to obtain data and relevant technical information from the researchers cited by these authors so that experiments can be repeated, and either confirmed or disproved.

An example of the modern approach in parapsychology was described in the journal *Science* late in 1970: "Simple equipment is now available for counting hits in predicting which of four lights will be lit at random (averaging $^1/_{10}$ of a second later), when the randomness is based on the radioactivity of strontium-90. In one recent study with such equipment 3 subjects out of 100 showed very outstanding results which, taken together, were very improbable [probability less than one in one billion]. Special precautions were taken to prevent recording errors, to check the randomness of the generated numbers, and to eliminate the possibility of fraud by the test subjects." Somewhat similar equipment has been used to teach both clairvoyance and precognition to a single subject; the machine immediately notified her she was successful when she chose the right target (in this case 35-mm color transparencies).

Researchers also are reporting increasingly that altered states of consciousness, such as occur during hypnosis or dreaming, may increase the frequency of ESP. Staff members at the William C. Menninger Dream Laboratory of Maimonides Medical Center have investigated this phenomenon for several years. Subjects are allowed to go to sleep in the laboratory while connected to electroencephalographic equipment that measures their brain waves and detects eye movements that occur during dreaming. In a separate room a "sender" attempts to influence a subject's dreams by looking at a picture.

As reported in *Science*, "Independent judges, acting blindly, have ranked the correspondences between the picture and the dream tran-

script significantly higher than control pictures. This has also been done with hypnotic dreams." This approach is viewed as an advance in technique because it provides a way of stimulating ESP under conditions more closely approximating those associated with spontaneous ESP reported outside the laboratory, but still provides for laboratory controls. Investigation of such "psychically favorable states" is still at an early stage of development, however.

Is acceptance coming?

Rhine has charged that a majority of psychologists and a large number of other scientists refuse to accept ESP and PK because they cannot be explained by the present laws of physical science. Accepting a supernatural explanation "would cost [psychology] its hard-earned status as a natural science . . . and throw it back into the classification with the occult."

Is the "science establishment" being unreasonable in rejecting the evidence for the existence of ESP? Gardner Murphy, a George Washington University psychologist who was president of the American Society for Psychical Research from 1962 to 1971, views the matter more philosophically. In an interview published in *Psychic* magazine in 1970, Murphy said, "It takes an enormous amount of *powerful evidence, with a new theory*, before the orderly system can be shaken. It's not enough to have a lot of new facts, you've got to have a new theory as well. So in order to demolish the old theory, you've got to have a new one which is compatible both with the old data and the new data. . . .

"So when people question, 'Why don't scientists accept ESP?' I can only answer, 'Well, what *do* they accept that doesn't fit into an orderly scientific framework?'"

There are other reasons why scientists remain skeptical about psychic phenomena despite evidence that a minority accepts. For one thing, the whole field of psychic occurrences has been the domain not only of reputable scientists but also of quacks and frauds. More than one medium has been caught faking contact with spirits of the dead.

Another factor in scientists' skepticism is that until quite recently potentially reproducible experiments have not been possible. ESP ability faded in the laboratory, for example. But new approaches with psychically favorable states may overcome this difficulty. And other methodological improvements should enhance the overall quality of the research even further.

A final factor is the nature of psychology itself. It is not only a young science but also an exceedingly complex one. Observations in physics and chemistry can be relatively simple compared to those involving human behavior. Many observers believe that attempts to make psychology a natural science have led to premature theorizing and gross oversimplifications. This also applies to parapsychology. Much more information is needed, together with small-scale theories that can be tested, before it will be possible to draw up definitive master hypoth-

eses. Psychologists can be considered to be at the level of Galileo when he was measuring the acceleration of falling objects; they are not ready to devise a scheme as grand as Newton's laws of gravitation and motion.

With suitable changes, parapsychology and perhaps certain other psychic phenomena may win greater acceptance among 20th-century scientists. For many years parapsychology had to remain outside the house of science in the United States, but recently it was allowed inside the front door. In December 1969 the Parapsychological Association, which includes almost all of the recognized parapsychologists outside the Communist world, became an affiliate of the American Association for the Advancement of Science, the world's largest organization of practicing scientists.

The new frontier

Where will psychic research go next? One of the major domains undoubtedly will be altered states of consciousness (ASCs). For example, modern physiological measuring techniques are being applied extensively to the study of sleep and dreams. The scientific study of hypnosis has advanced to the point where it is largely accepted as a legitimate subject for psychologists. Several recent trends are pushing both psychology and psychic research toward greater interest in the other altered states.

One is the deliberate effort by many people to enter an altered state, either by taking such drugs as marijuana or LSD or by learning self-hypnosis or some meditative process. (Despite this activity, few scientific data have been collected about these ASCs.) A second trend is the growing use of techniques for teaching individuals to control their brain waves and therefore their state of consciousness.

It may not be sufficient just to observe ASCs from the outside. Tart argues that much current research is "relatively trivial" because it does not focus on the real experiences involved. "Experiences of ecstasy, mystical union, other 'dimensions,' rapture, beauty, space/time transcendence, transpersonal knowledge, and the like, common in ASCs, are simply not treated adequately in most conventional scientific approaches."

The solution, according to Tart, is to develop "state-specific sciences," utilizing skilled, trained researchers who are able to achieve certain states of consciousness. Within each state they can approach specific problems using the scientific method—making observations that can be confirmed by others in that state, theorizing about their findings, and then testing their theories by predicting the consequences and seeing whether the theories hold true. Observing an altered state only from man's normal, alert condition does not take into account that the pattern of communication may have changed, just the way a computer's program may be changed. Without a new approach to ASCs, Tart believes that modern psychology never will understand them adequately.

Nudity is an important part of many mystic rituals. The man below has painted his body silver to celebrate the rites of Pan.



Don Snyder

"Biofeedback," or voluntary control of internal states, already has been used in many laboratories to enable individuals to alter brain waves, blood pressure, blood flow, heart rate, and muscle tension. It is sometimes called autogenic training. The technique involves detecting the variable to be controlled, displaying information about it on a dial or with a light or sound, and then letting the subject practice controlling it. The procedure has been used experimentally in treating high blood pressure and migraine headaches.

While biofeedback may eventually have wide application in medicine, psychic researchers are concerned principally with its usefulness in investigating states of consciousness. Much work has been done with alpha waves, which are brain impulses that occur with a frequency of between 8 and 12 cycles per second. Most subjects are able to control their alpha waves fairly easily. About 90% of us can produce them just by closing our eyes. But with suitable training, subjects have learned to suppress them with their eyes closed, to produce them with their eyes open, or to alter the alpha frequency. The waves are detected with an electroencephalograph machine and then displayed to a subject as a sound or a light.

Alpha waves generally are associated with an alert yet passive mental state, lacking visual images. Their appearance is related to several ASCs. According to some studies, individuals who are highly susceptible to hypnosis produce alpha rhythms more often than those who are not so susceptible. Electroencephalographic studies of Zen monks have revealed that during meditation their brains produce alpha waves principally. Yogis have been shown to produce more of these waves while meditating, and individuals practicing transcendental meditation (the procedure taught the Beatles by Maharishi Mahesh Yogi) have more regular alpha waves, with increased amplitude.

Experienced Eastern mystics who truly have mastered meditation techniques can do much more than manipulate their alpha waves, however. In 1970 researchers at the Menninger Foundation in Topeka, Kan., spent several weeks examining an Indian yogi, Swami Rama of Rishikesh and the Himalayas. The swami could voluntarily maintain his production of theta and delta brain waves. Theta waves (four to seven cycles per second) often appear when a person becomes drowsy and eases toward sleep; delta waves (about one per second, with very large amplitude) are usually associated only with deep sleep. During one five-minute test, Swami Rama demonstrated theta waves 75% of the time. The next day he deliberately produced delta waves for 25 minutes; he appeared asleep and even snored gently, but afterward he could repeat almost perfectly things said in the room at that time.

These are not just exercises but have the potential for teaching science some of the as yet unexplained workings of the human brain. When in the theta state (with alpha or beta also present 50% of the time), Swami Rama became aware of many unconscious thoughts he normally suppressed. The swami maintained that when in a state of deep reverie he could heal himself of certain ailments by giving the

LIFE Magazine, courtesy, Maimonides Medical Center



Voluntary production and suppression of the brain impulses called alpha waves are monitored at the Maimonides Medical Center in New York. Alpha waves usually are associated with an alert but passive mental state

body suitable instructions in the form of images. Elmer E. Green, who directed the research at Menninger, also reported that Swami Rama "could diagnose physical ailments very much in the manner of Edgar Cayce [an American psychic who made thousands of medical diagnoses while in hypnotic trances], except that he appeared to be totally conscious."

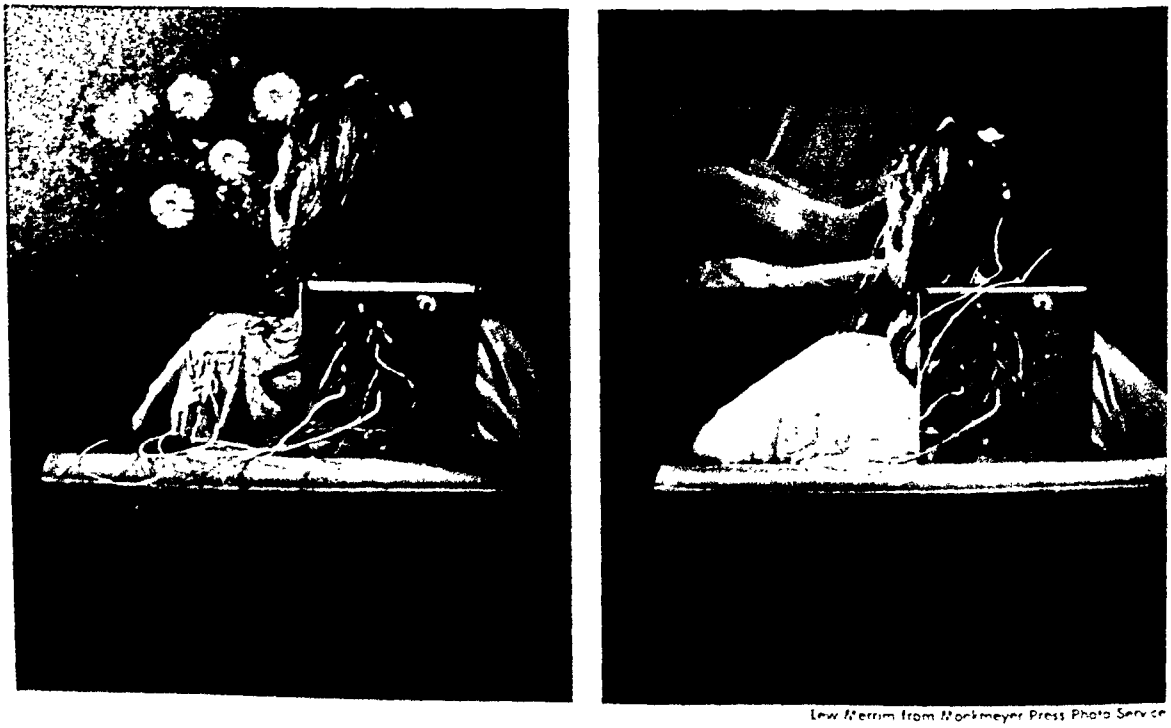
Green says: "The entrance, or key, to all these inner processes, we are beginning to believe, is a particular state of consciousness [or 'reverie' that] can be approached by means of theta brain wave training in which the gap between conscious and unconscious processes is voluntarily narrowed, and temporarily eliminated when useful. When that self-regulated reverie is established, the body can apparently be programmed at will and the instructions given will be carried out."

Another meditative procedure that is attracting scientific attention is transcendental meditation. It does not require the years of training that Yoga or Zen necessitate, nor does the practitioner need to master intricate physical positions or exercises. Because it is easy to learn and is reproducible in physiological terms, scientists believe it may provide a useful approach for further studies.

"Radiesthesia" and "radionics"

An area of psychic research that is much more controversial involves studying the sensitivity of living organisms to radiation of any sort from any source. This sensitivity is known as radiesthesia, and involves the five commonly recognized senses. Certain investigators believe that another manifestation of radiesthesia may be involved in such psychic phenomena as reading print or identifying colors with the hands (eyeless sight), a medium's communication with someone by other than the five senses while utilizing some object associated with that person (object reading, or psychometry), and dowsing. The existence of a "sixth sense" might explain ESP and PK as well.

Relationship between alpha waves and active attention is tested by showing a young man in an alpha state slides of flowers and a nude. When the flowers appear, the alpha state continues, but with the nude it disappears.



Lew Merrim from Monkmeyer Press Photo Service

Modern physical scientists generally have repudiated the hypothesis that the body "transmits" and "receives" electromagnetic radiation, with the brain as a source and the body serving as an "antenna," because brain waves are far too weak even to be detected a very short distance from the head. But a limited number of scientists believe that there are unrecognized forms of energy originating from living things, including plants. Could there be "psychic forces" or "psychic fields," or some other power generator than the brain? Numerous writers have devised schemes to account for such forces and fields, but their "theories" are more in the tradition of the occult than that of science. Many are based on Eastern philosophies. Most must be accepted on faith at this point because they cannot be tested by the scientific method.

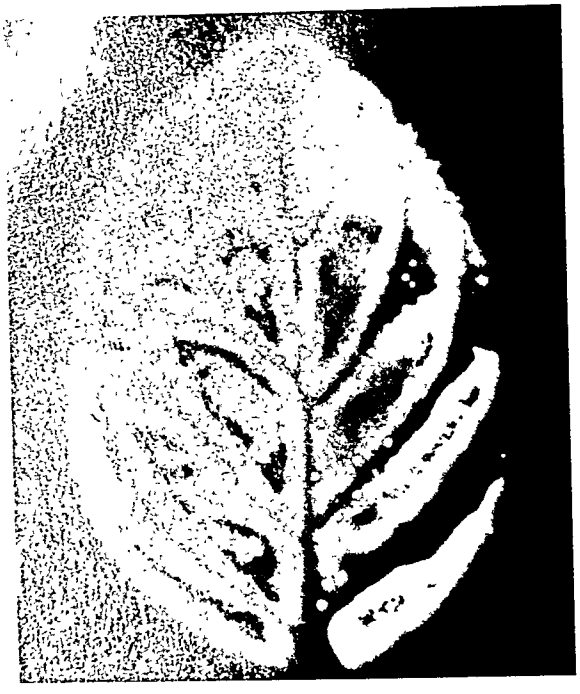
Nevertheless, some Western scientists have begun investigating radiesthesia and radionics (using instruments to detect the energy involved). At least initially they will probably follow the trail marked out by the researchers in Eastern Europe and the Soviet Union. Specifically, they are experimenting with devices capable of detecting or measuring various "psychoenergetic fields," which the Soviets have reported finding associated with the human body and with plants.

William A. Tiller of Stanford (Calif.) University was one of the first U.S. physical scientists to visit the Soviet Union with the objective of gathering technical information regarding its current psychic research. He returned from Moscow and Leningrad in 1971 with specifications for building several devices so that he could repeat some of the Soviet work. One instrument had been invented by Victor Adamenko, a Soviet physicist, who used it to identify points of low electrical resistance in the human body, in other animals, and in plants. In humans almost all of the points conform with the places where needles are placed in acupuncture therapy. After injection of radioactive phosphorus at one of the low-resistance points, radioactivity can be detected at other acupuncture points. Adamenko suggests this device has identified a new circulatory system of low-resistance circuits in the body that coincide with the meridians or channels believed to connect acupuncture points.

A second Soviet tool of interest to American psychic researchers is a photographic device invented by Semyon D. Kirlian and his wife, Valentina. It utilizes a high-frequency electrical pulse generator, somewhat like a radar power source, to produce photographs. Developed films show "flares" escaping from tissues such as the human finger or the leaf of a plant. According to Tiller the discharge involves cold electron emissions. Their characteristics change with the emotional state or health of an individual, and also with a healer when "in the healing mode" or when not healing. When up to 10% of a leaf has been cut off, the radiation pattern on film still shows the entire outline of the leaf.

The Soviets also conducted sophisticated tests on certain women they believed had demonstrated the ability to move objects by will

Courtesy, Dr. Thelma Moss, UCLA Center for the Health Sciences





The effects of stress and mutilation on living tissues can be seen in the photographs above and on the opposite page. They were taken with a device similar to one invented by Semyon Kirlian, which uses a high-frequency electrical pulse generator to produce its images. The leaf above was photographed in this way when freshly cut (left) and after being gashed with a needle (right) The tip of a right index finger on the opposite page was photographed when the subject was relaxed (top) and while the same subject was undergoing emotional stress (bottom).

power (psychokinesis). Tiller believes that this work, combined with the other Soviet projects, opens exciting new possibilities for future research. He began, therefore, to duplicate Soviet equipment in order to measure the variables involved and to try to develop equations for characterizing the events.

The "new physics"—or not?

The Oxford University zoologist Sir Alister Hardy has written: "The discovery that individuals are somehow in communication with one another by extrasensory means is, if true, undoubtedly one of the most revolutionary discoveries ever made. It is a biological phenomenon, if true, almost as fundamental as that of gravity between material bodies." Assuming that some of the phenomena investigated by the Soviet scientists and others relate to ESP, this statement takes on additional meaning.

But the "if true" qualification must be recognized. There are still other possible explanations besides the existence of a sixth sense involving psychoenergetics. Ernest Hilgard of Stanford University, co-author of a standard college textbook on psychology, has spent many years studying hypnosis and its potential medical applications and has become aware of how suggestible the human mind can be. His experiences have caused him to believe that all sorts of unusual "psychic" experiences, including the beneficial effects of faith healing or acupuncture, might be a result of suggestion.

Told how a visiting U.S. scientist had been able to do PK with the help of a Soviet volunteer, Hilgard said, "I'll bet he's hypnotizable. You

don't have to go through any formal procedure if someone is highly hypnotizable." And if suggestibility is not involved, sleight-of-hand or mechanical assistance (magnets, etc.) can be, Hilgard stated.

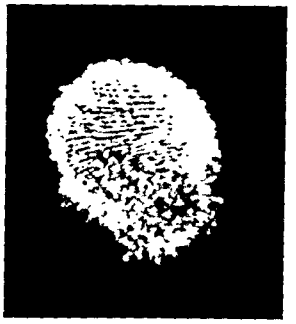
Are honest people deluding themselves, or being deluded? The experts disagree. But there seems to be a move toward increased acceptance of some psychic phenomena. Robert A. McConnell, of the University of Pittsburgh, who was the first president of the Parapsychological Association, says that there are now so many experimental reports on extrasensory perception they have "erode[d] disbelief in ESP until most psychologists are no longer willing publicly to deny the evidence for the phenomenon." Still, there is no "widely encompassing theory. . . . [ESP] is a fact without an overall theory. One suspects that it will someday cause a revolution in both psychology and physics."

Until that "someday" arrives, some words of Bertrand Russell's may serve as our guide. In his *Skeptical Essays* he wrote:

> The opinion of experts, when it is unanimous, must be accepted by non-experts as more likely to be right than the opposite opinion. . . . [However] when they are not agreed, no opinion can be regarded as certain by a non-expert.

One of the biggest benefits of the psychic boom may be that it will stimulate enough serious scientific interest to get some dependable answers about which phenomena are real, and which are not, and thus allow more of the experts to begin to agree.





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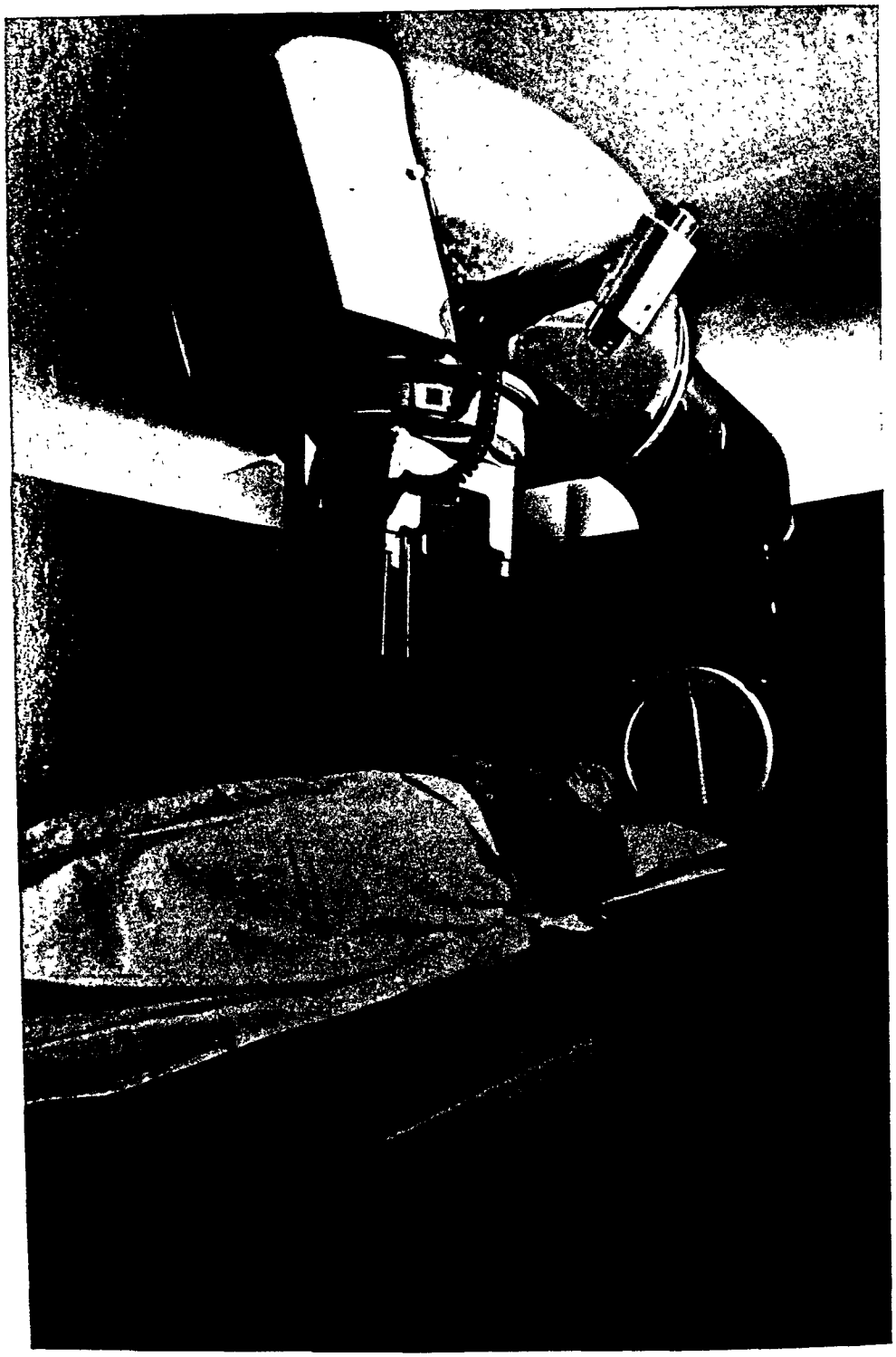
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Theratron-80, a computerized radiation therapy treatment machine. Photo, Dan Morrill, courtesy, Presbyterian-St. Luke's Hospital.

Cancer Under Attack

by Ronald Kotulak

Will ours be the last generation to suffer the ravages of cancer? As science embarks on extensive efforts that show promise of finding the cause of this dread disease, methods for detecting and treating it become increasingly refined.

Cancer is one of man's most dreaded diseases. It will kill one out of every six Americans who die in 1972, some only after prolonged suffering. Although people became able to talk more freely about cancer in the last decade, their feeling of fear and futility in the face of its diagnosis remained. The springs of medical research, which had promised to cure cancer in the 1950s, had seemed to dry up. A frustrating stalemate settled over the laboratories. That was yesterday. Today, the gloom and disappointment that overshadowed cancer researchers is rapidly giving way to a new era of hope. Scientists, at work for decades on the cancer problem, are finally coming close to understanding the transformation of normal to malignant cells that can attack any tissue of the body. There is a genuine optimism in scientific circles that cancer is at last yielding to man's efforts to conquer it.

Almost weekly researchers report new findings, adding pieces to the cancer puzzle. Among the most important discoveries have been viruses capable of altering the hereditary behavior of mammalian cells, evidence that viruses are linked to certain human cancers, and the possibility that cancer cells may be reconvertible into normal cells. Confirmation of the link between viruses and cancer is vital: if such a link exists, then a vaccine might be developed to prevent cancers. Malignancies associated with viruses include cancers of the breast, cervix, muscles, and blood (leukemia).

As scientists unravel the mystery of cancer, they are finding that it is intertwined with the secret of life itself. Persons may be born with the seeds of their eventual cancer within them, locked up in their genes. Whether these seeds produce a full-blown malignancy may depend on time, environment, and chance. The role of the virus, which is composed of nucleic acid and protein, also the basic constituents of genetic molecules, seems to fit naturally into this scheme.

Although no one can predict just when cancer cures may be achieved, experts are confident that if enough money is available for the needed research the cures will be forthcoming. "Given the resources, the funds, and the organizational capability, I am confident that we can achieve control of this disease," asserts H. Marvin Pollard, head of gastroenterology at the University of Michigan and a spokesman for the American Cancer Society. "A really massive effort to bring this disease under control during this decade demands that not one single possibility be neglected."

Encouraged by the new scientific findings, the United States is preparing to mount an all-out effort to win the cancer battle. The president and Congress have expressed their eagerness to spend whatever is required. On December 23, 1971, Pres. Richard M. Nixon signed into law the National Cancer Act, which was to provide more than $500 million annually for the next three years to support cancer research. The investment in research could even reach $1 billion a year by 1976, rivaling the budget of the U.S. space program during the early days of the effort to land men on the moon. Justifying this kind of large-scale spending, a national panel of 26 eminent scientists and laymen, authorized by the U.S. Senate to review the cancer field, reported that advances in the fundamental understanding of cancer in the past decade have opened up far more promising areas for major advances in cancer prevention and treatment than have ever before existed. The panel concluded that the conquest of cancer is a realistic goal.

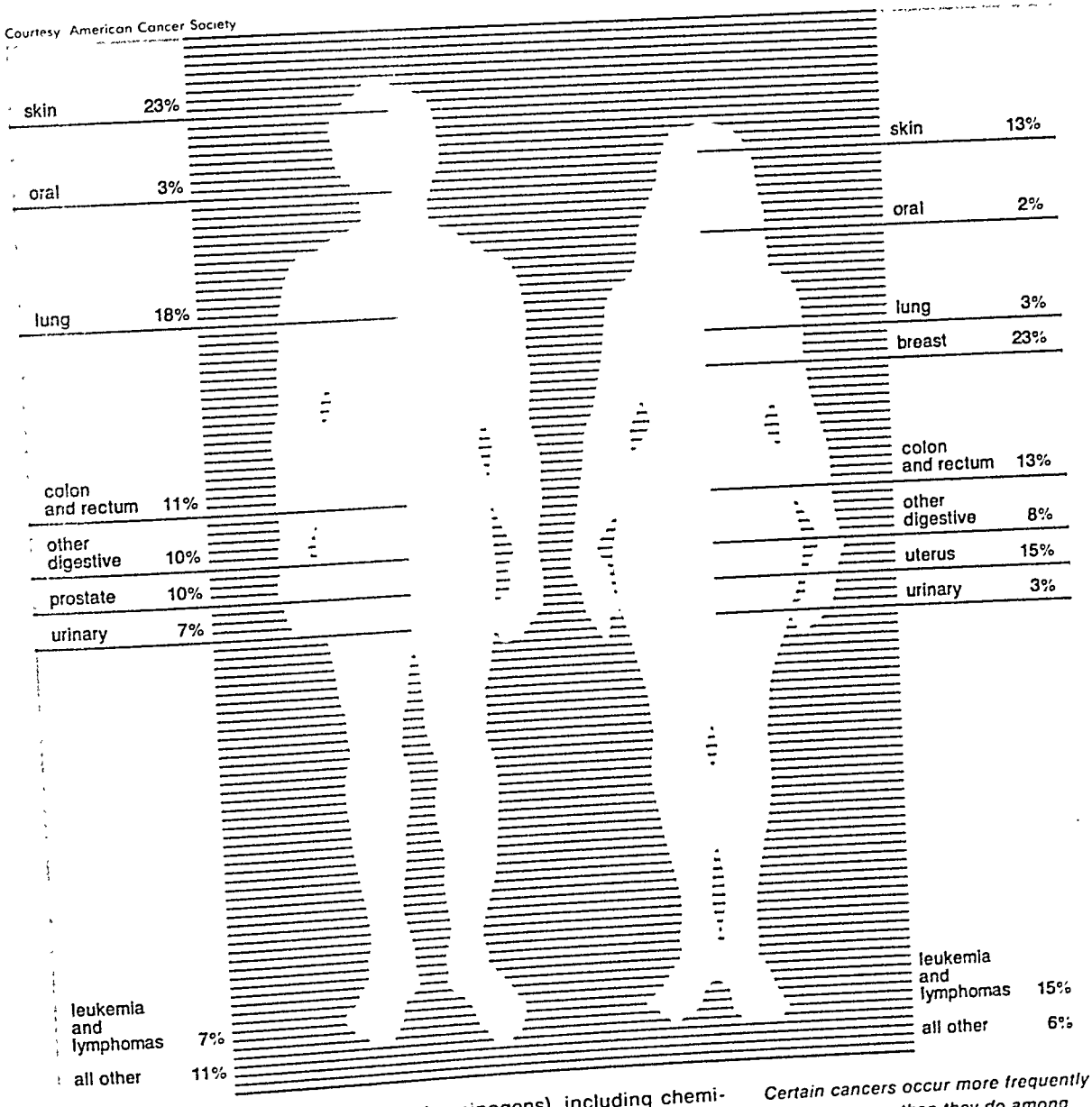
The changing picture of cancer

Although cancer ranks second, after heart disease, in the number of victims it kills, persons fear it more than they do any other affliction, and for several reasons. It appears to rise stealthily from one's own body, frequently hidden until it becomes so widespread that treatment is futile. It causes an ugly death, robbing the patient of dignity. During the course of the illness, a family's financial reserves may be consumed to pay for what is often treatment that does little good. Not only friends and relatives, but sometimes even doctors and nurses, will avoid cancer patients out of some dark fear of the disease. And although many physicians advise a family not to tell a dying relative that he has cancer, most know without being told.

Among men, the incidence of cancer is increasing. The National Cancer Institute (NCI) has reported that among males the rate of cancer rose from 280 to 304 per 100,000 between 1947 and 1969, and that more cases of cancer of the lung, prostate, and colon were being diagnosed. The cancer rate among females during this period dropped from 294 to 256 per 100,000, with decreases in the frequency of cancers of the cervix, stomach, and rectum. The significant drop in cervical cancer, especially, was assisted by mass programs for detection of this type of cancer in its early, curable stage.

Evidence indicates that man is probably responsible for many cancers. He releases into the environment or chooses to expose himself to

RONALD KOTULAK *is science editor of the* Chicago Tribune *and author of a prizewinning series of articles on cancer.*



Certain cancers occur more frequently among one sex than they do among the other. In men, cancers most often involve the skin or the lungs. Women are far less prone to these two forms but are highly susceptible to cancers of the breast and uterus.

many known cancer-causing agents (carcinogens), including chemicals and radiation. Cigarette smoking, for example, is blamed for 60,000 lung cancer deaths annually. A definite carcinogen—N-nitrosodimethylamine—was recently identified in tobacco smoke. A chemical culprit recently identified as a carcinogen by the U.S. Food and Drug Administration is diethylstilbestrol, which is used to correct estrogen deficiency disorders in women and is widely used to fatten cattle and sheep. The FDA warned that pregnant women should not be given the compound because of the risk that their female babies may someday develop vaginal cancer. Another source of carcinogens is polluted air. Some authorities believe that lung cancer could be

reduced by 20% if present levels of pollution in city atmospheres were cut in half. One of the more potent carcinogens is benzo(a)pyrene, a component of automotive and industrial soot.

But if man can cause cancers, he should also be able to prevent them by identifying and eliminating their causative agents. Exactly how carcinogens react in the body to produce cancers is not, as yet, known.

Almost everyone has been affected in some way by cancer. A relative or friend may have died of it. And one of every four living Americans will be stricken personally by cancer during his lifetime. The toll in 1971 was 339,000 cancer deaths, more than the number of U.S. troops killed in World War II. But there is some good news. The cure rate is steadily climbing. In 1930 one out of five cancer victims was cured; by 1972 the rate had risen to one in three. Many cancer experts maintain that the rate of cures could easily be boosted to one in every two cancer victims if every patient received the benefit of available early diagnosis and treatment with the best therapies now available.

But there still are needless deaths from cancer. James F. Holland, a past president of the American Association for Cancer Research, claims that doctors not specially trained to treat cancer or not interested in the disease will not ensure the best available care for their patients. He urges that any patient who has or suspects that he has cancer consult two or more physicians, including a cancer expert.

Another reason for needless deaths is the erroneous notion that all cancer is incurable. As a result, some patients delay seeing a doctor or refuse surgery or other treatment that might otherwise have saved their lives. This pessimism is being dispelled, however, by the startling advances against cancers that just a few years ago were considered incurable.

Hodgkins disease, a cancer of the infection-fighting lymph nodes, is one example. New radiation and surgical methods, along with newly developed chemotherapies, which use combinations of anticancer drugs, have boosted the five-year survival rate to 90% of the patients with early or localized advanced stages of the disease. Investigators at Stanford University are hopeful that most patients with even advanced Hodgkin's disease may soon look forward to an extension of life. The most vicious cancer of children—acute lymphocytic leukemia —has also begun to yield its deadly hold. With proper treatment (so-called total therapy), 60% of the children with acute leukemia admitted to one medical center have survived at least three years free of signs of the disease. Total therapy consists of administering combinations of anticancer drugs to destroy most of the diseased cells quickly and to prevent the patient from developing resistance to any one drug, and using radiation therapy to remove the remaining cells the drugs do not reach. Another type of cancer yielding to treatment is that of the larynx (voice box). A 35-year study at the University of Chicago showed that 95% of the localized, small cases of this cancer are curable through radiation, surgery, or both.

The three main therapies being used against cancer are surgery,

Dan McCoy from Black Star





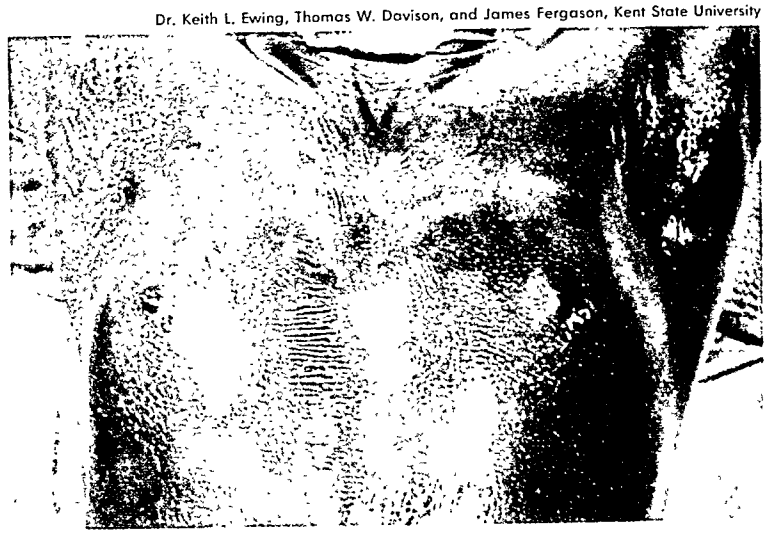
New devices improve the physician's ability to detect and treat cancers. The steel-domed machine (left) contains a radio-cobalt source that irradiates the cancerous white cells in a leukemia patient's blood outside his body. His normal tissue is thus protected from radiation damage. The "gamma camera" (right) searches for a brain tumor in three minutes. Faint flashes of light emitted by an isotope administered to the patient are amplified, relayed by a computer, and recorded as a series of dots that indicate a tumor against a dark background of normal tissue.

radiation, and chemotherapy (treatment with growth-inhibiting chemicals). Although therapists look forward to better anticancer drugs and improved immunotherapeutic techniques to reduce the need for surgery, surgery remains the treatment of choice in all but a few types of cancer and has scored impressive victories. Surgery is most effective when it is accomplished early to remove tumors before they have had a chance to spread cancerous cells to other parts of the body and establish new malignancies. Irradiation is used to destroy malignant cells. New drugs assist radiation therapy by preventing cells from repairing the radiation damage. For many cancers, these therapeutic techniques have produced excellent results. The NCI reports that of patients with operable tumors and no evidence of spread, 85% with uterine cancer will escape death from the disease. This holds true also for 75% of patients with ovarian cancer, and 60% of patients with cancers of the colon, rectum, breast, or bladder. With continually improving diagnostic and treatment methods, the outlook is even brighter.

Anticancer drugs can accomplish what neither surgery nor radiation can do effectively—fight spreading cancers. Today there are more anticancer compounds in various stages of development and testing than ever before. Some researchers believe that in only a few years drugs will be developed that will do to some cancers what penicillin does to bacterial infections.

One of the newest drugs is an antibiotic, bleomycin, which has had early success in treating some heretofore resistant forms of cancer. It

Dr. Keith L. Ewing, Thomas W. Davison, and James Fergason, Kent State University



A technique that may provide a simple means of detecting breast cancer is liquid crystal thermography. Cholesterol ester crystals applied to a patient's breasts produce patterns of iridescent colors that reflect temperature variations in the skin—reddish and green colors for cool areas, blue for warm. The blue area in what should have been a cool region of the right breast indicates a malignancy in the woman above.

has produced improvement in patients in the terminal stage of Hodgkin's disease, and has been called the best drug so far for some highly resistant solid tumors, such as squamous cell carcinoma. Initial tests with patients suffering from advanced lymphosarcoma, for which there has been little effective treatment, reveal that a new three-drug regimen —cyclophosphamide, vincristine, and prednisone—has produced a survival rate for at least two years of 73%. Animal tests have uncovered a highly promising class of drugs that contain platinum. These drugs may have action against more types of cancer than any other yet developed—if experience with animals proves out in medical trials.

Unraveling the malignant process

As therapists continue to make significant strides in the treatment of cancers, researchers are coming closer to an understanding of the malignant process, on which further cures can be based. A picture of what cancer is and how it may be caused is emerging.

Cancer appears to start in a single cell, which begins to function much like embryonic cells do after conception. Each organism begins life as one fertilized cell. The cell divides in two; the two divide into four; and so on. All of these cells carry all the information necessary to reproduce the complete organism, and all of this information is being used. The cells divide very rapidly, just as cancer cells do. As the embryo begins to take shape, however, some form of cellular communication takes place and chemical substances known as repressors are called into action. The repressors attach to different sections of the genes in the chromosomes of the forming cells so that only the information the cell needs to perform the particular role it is to have in the body, whether as tissue, muscle, nerve, or bone, is allowed to send out instructions. Once the complete organism is formed, the rate of cell division slows appreciably until it is reduced to a minimum level required for replacing dead or damaged cells.

A number of agents, however, can interfere with this orderly process

and produce cancer. Most of these carcinogens fall into three categories: certain chemicals and irradiation, both of which are known definitely to cause human cancers, and viruses, which most scientists suspect also cause human malignancies, although at present they are known to do so only in lower animals. While ethical considerations preclude the testing of potential cancer viruses in persons, experiments with laboratory animals have uncovered at least 100 viruses that produce cancer, and transformation of cells of human origin in tissue culture can be used in tests of suspect viruses.

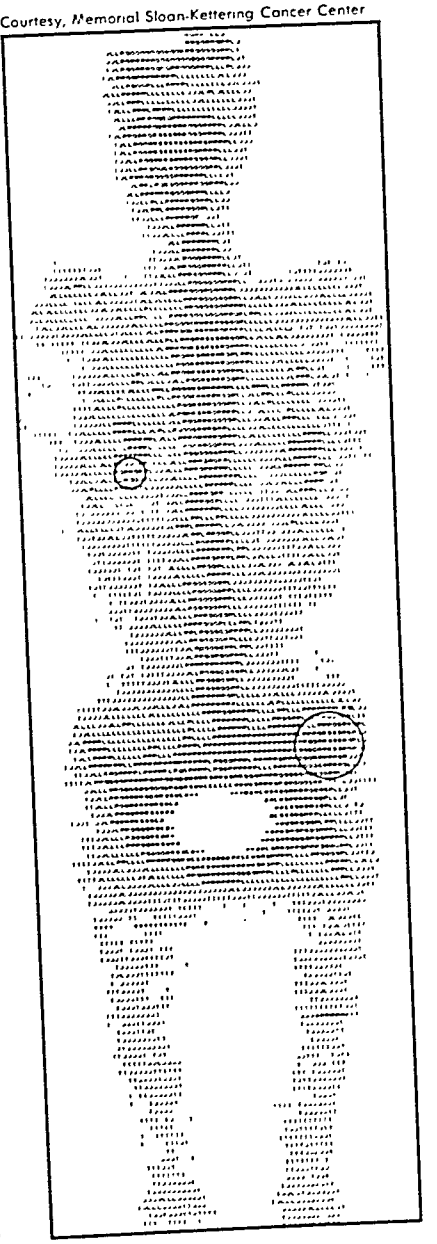
Not too long ago it was thought that radiation, and probably chemicals also, caused cancer by producing a mutation, or sudden, inheritable change in a cell's genes. Hypotheses now propose that these carcinogens somehow free gene repressors so that hidden genetic information may instruct the cell to begin dividing rapidly. The cancer cells reproduce in an uncontrolled way, growing and invading without reference to the health of the body, and finally destroying their host. This change in concept was important because it suggested that cancer consisted merely of a fault in gene expression, rather than being the product of gene damage, and that it might be reversible if suitable controls could be restored. Theodore Puck, professor of biophysics at the University of Colorado Medical Center, established that the repressor concept is well founded. He showed that one line of cancerous animal cells could be returned to their normal healthy condition—within an hour—by the use of two naturally occurring body chemicals, testosterone, a male sex hormone, and cyclic AMP (adenosine monophosphate), a chemical that permits hormones to effect changes in cellular activity.

"For the first time the reversal of cancer cells is possible," said Charles Huggins of the University of Chicago, who was awarded a Nobel Prize in 1966 for his discoveries linking hormones to cancer and its control. "If they couldn't be reversed, the entire outlook for cancer would be much more pessimistic." Huggins believes that hormonal imbalances play a major role in the development of a cancer. Studies at the Imperial Cancer Research Fund in London support his claim: records from more than 5,000 women patients indicate that the onset of breast cancer appears to be preceded by abnormally low levels of two hormones, androsterone and etiocholanolone.

When a normal cell is transformed into a cancer cell, it manufactures new antigens, proteins that the body recognizes as foreign. It is now believed that each type of cancer may have its own antigen; if this is true, then methods of detecting these chemical markers could be used to make early diagnoses of cancer. Several cancer antigens have been found to resemble antigens present during fetal development, when embryonic tissue is growing rapidly. These antigens are not generally present in adult cells. Their reappearance in cancer cells may be seen as further evidence that cancer may be a manifestation of a life process that has gone awry.

The body has a natural animosity to antigens, and the same immuno-

Courtesy, Memorial Sloan-Kettering Cancer Center



A computer that equates each letter of the alphabet with a radiation level recorded uptake of the isotope fluorine-18 by the skeleton of this patient. Doctors reading the scan found two areas where late letters indicated higher than normal uptake, evidence of a spreading bone cancer.

logical defense system that helps combat colds and other infections becomes aware of and attacks cancer cells that possess these abnormal proteins. Primarily, the cancer antigens trigger the production of antibodies, the specialized chemicals designed to neutralize antigens. It is possible that the transformation of normal cells into malignant ones is a common event and that the cancers that develop, called silent cancers, are destroyed by antibodies as soon as they appear. In three out of four persons, the immune response is so good that cancer never has a chance to develop. But the fourth person is in danger. His defense system may be defective because of disease, age, loss of the ability to recognize the antigens, or some other mishap that prevents it from searching out and killing the small pockets of cancer cells.

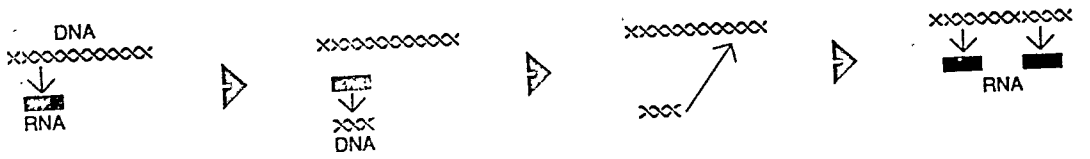
Failure of the immune system allows the cancer to grow rapidly to about the size of a pinhead, when it stops temporarily. This is the maximum size a cancer can attain by diverting nutrients from neighboring cells; to grow further it must elicit cooperation of the neighboring small blood vessels. The tiny tumor secretes a compound, called tumor angiogenesis factor (TAF), that stimulates a fantastic growth of blood vessels directly into the tumor, which previously had none. With this new source of food, the cancer begins growing again.

Viruses, enzymes, and cancer

New areas of research into the cause and progress of cancer are taking shape. One of the most important developments stimulating these efforts was reported in 1970 by a University of Wisconsin virologist, Howard M. Temin. He claimed to have discovered that some viruses have the ability to make genetic material that can be incorporated into the chromosomes of a host cell, bringing it new hereditable information. Some investigators think that this may be the missing link in the cancer puzzle, the means by which the cell acquires the deadly instruction that orders it to reproduce in a cancerous fashion.

Currently three major theories try to explain the cancer-inducing ability of viruses. One holds that viruses from a source outside the victim infect a cell and construct a gene that eventually produces cancer. This would support the straightforward notion that perhaps most cancers are caused by viruses. The second theory, one that is gaining in popularity, suggests that everyone is born with the genetic message of a cancer virus already incorporated within his chromosomes. Robert J. Huebner of NCI proposes that such viral genetic material was probably incorporated as a result of a viral infection in man's early ancestors and has been passed down through succeeding generations. In certain carriers an environmental shock, such as exposure to chemicals, radiation, another virus, or hormonal imbalance, turns on the virus information and a cancer begins to develop. The third theory, postulated by Temin, suggests that normal human chromosomes contain specific sections that can make virus-like particles capable of infecting other cells. Once inside a fresh cell they can alter the genes so that cancer results.

Adapted from "RNA-Directed DNA Synthesis" by Howard M. Temin. Copyright © 1972 by Scientific American, Inc. All rights reserved



The recent discovery of the reverse transcription process suggested that the cause of cancer may lie in one's own genes. The protovirus hypothesis proposed by Howard M. Temin suggests that sections of DNA in normal cells may be models for synthesizing RNA that has the ability to synthesize DNA, which becomes integrated into cellular DNA. Repetition of this process may produce regions of DNA that are activated to encourage cell differentiation during embryonic development, or to stimulate cancerous cell growth later in life.

Genes are composed primarily of deoxyribonucleic acid (DNA), which constitutes the master code for the chemical language of life. The DNA carries the information for making proteins, which are the materials that build cells and other structural components and that, in the form of enzymes, speed up the cell's chemical reactions. When a protein is needed, the section of the DNA governing that protein produces a working copy of itself in the form of ribonucleic acid (RNA). The RNA then carries the instructions for making the protein to subcellular particles called ribosomes, which assemble amino acids into the protein according to the RNA blueprint.

In 1970 Temin established the existence of an enzyme (now called either RNA-directed DNA polymerase or reverse transcriptase) that can cause an RNA blueprint to make DNA—rather than protein. Geneticists were amazed! They had maintained that DNA could make RNA, but not vice versa. Temin's discovery is important to cancer research because most viruses known to cause cancer contain only RNA. It explains how RNA tumor viruses might cause a heritable, cancerous change in the cells they infect.

Cancer detection, prevention, and treatment

Mounting evidence suggests that reverse transcriptase may be the key to controlling some cancers. Researchers have associated it with cancers, including leukemias, lymphomas, and breast cancer. The enzyme may serve as a diagnostic tool to indicate the presence of a cancer. Meanwhile, workers continue to investigate drugs to find ones that will block the action of the enzyme and perhaps control cancer. Two promising classes of compounds consist of derivatives of the antibiotics rifampicin and streptovaricin.

Reverse transcriptase has also been detected in embryonic tissue. This may mean that the same enzyme that induces cancer is also vital to the growth of fetal cells. This possibility fits nicely into both the Temin and Huebner theories: an enzyme that appears necessary for the rapid growth of fetal cells is also found to be active in rapidly growing cancer cells. The speculation is that a cancer cell, one with its genetic controls removed, essentially reverts to an embryonic state.

A remarkable piece of detective work has provided the most convincing evidence yet that a virus may cause human breast cancer. Reverse transcriptase, when mixed in a test tube with viruses known to cause animal cancers, produces DNA molecules. Since this artificially

GLOSSARY OF CANCER TERMS

TUMOR (or NEOPLASM): Any new, excessive growth arising without obvious cause and serving no physiological function. Such growths can be either benign or malignant.

BENIGN TUMOR: Any noncancerous tumor; that is, one that does not spread rapidly from its site of origin.

MALIGNANCY: The tendency to cause death. Tissues are deemed malignant when, under microscopic examination, they are found to display any of the abnormalities characteristic of cancer.

CANCER: The common name for any of the more than 100 distinct diseases characterized by tissue cells that grow more rapidly than normal, assume abnormal shape or size, and cease functioning in a normal manner (neoplasia), and by a tendency to spread from one part of the body to another (metastasis). Cancers are generally classified either as carcinomas or sarcomas according to their site of origin; prefixes added to these designations indicate the precise tissue of origin.

CARCINOMA: Any cancer originating in the epithelial tissue, which lines most hollow organs. A uterine adenocarcinoma, for example, is a cancer involving ducts or glands of tissue of the uterus.

SARCOMA: Any cancer originating in the structural frame of the body (nonepithelial tissue), including muscle, fat, connective tissue, bone, cartilage, and tendons.

METASTASIS: The transmission of cancerous cells that have broken off from the original lesion to another site through the blood, lymph, or membranous surfaces.

LESION: Any injury, abnormal change, wound, or diseased area in an organ or tissue. In cancer, the primary lesion is the one in which the cancer originated; a secondary lesion is one established through metastasis.

CARCINOGEN: Any substance capable of causing a malignant tumor. In general, there are three types of carcinogens: chemical, radiation, and viruses.

C-TYPE VIRUS: A virus with a central core of ribonucleic acid (RNA) and a double limiting membrane secreted through a budding process from the surface of infested cells and capable of altering the genetic character of the host cell; the type of virus most commonly suspected of being a human carcinogen.

REMISSION: A period of return to better health in any chronic disease. In cancer this must be associated with a persistent reduction in size of measurable metastatic tumors and cessation of tumor growth.

Dr. Nurul H. Sarkar, Institute for Medical Research



Electron micrographs detect the close resemblance of the virus particle (top) proved to cause breast cancer in mice to another (bottom) often found in the milk of women with known high genetic risk of breast cancer. Both particles have rounded heads of similar diameter, long irregular tails, and surface projections that differ from any noted on other viruses. The human particle passed several other tests indicating it may be a viral cause of human cancer.

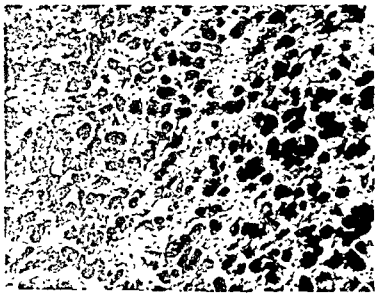
created genetic material was made from known cancer-causing viruses it should hook up with complementary DNA in virus-produced cancer cells, but not with other DNA free of the virus. In 70% of the cases tested it did, revealing that the human breast cancer cells contained genetic information identical to the genetic instructions of a cancer-causing virus.

It is of considerable importance that the virus that causes breast cancer in mice is similar to a virus discovered in the milk of women with familial histories of breast cancer. Likewise, reverse transcriptase is similar in both human and other animal breast cancers. This association seems more than coincidental. Prevention of breast cancer by immunization, or its control by antiviral drugs, is no longer a mere hope. Indeed, the mouse cancer virus has been used to produce a vaccine that protects mice from breast cancer when they are subsequently exposed to the virus.

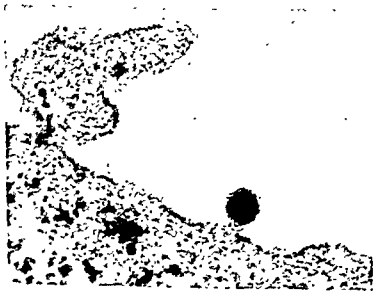
The search for a human cancer virus becomes more promising daily. Within a short period of time in late 1971 and early 1972 researchers from three separate laboratories reported finding viruses in cancer patients that might be human cancer viruses. These findings—by Robert M. McAllister of the Children's Hospital of Los Angeles; by Sarah Stewart at Georgetown University, Washington, D.C.; and by Elizabeth S. Priori and Leon Dmochowski at the M. D. Anderson Hospital and Tumor Institute, Houston, Tex.—await confirmation by other workers. All three of the suspected viruses are what scientists call C-type viruses, the kind that Huebner theorizes could be the product of cancer genes inherited from man's ancestors.

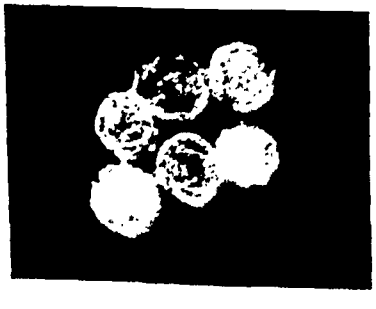
B. Gardner, University of Southern California











Another important bit of evidence to strengthen the virus-enzyme-cancer concept was the discovery by three other groups that two chemicals, called BUDR and 5-IUDR for short, can induce C-type viruses to appear in what are otherwise normal cells that previously had no viruses in them. It is believed that these chemicals, like an environmental shock, may jolt the cancer genes into action, again supporting the Huebner theory. The NCI is so confident that the viral cause of cancer will be substantiated that it has awarded a $1.8 million contract to Merck Sharp & Dohme Research Laboratories to develop vaccines against the viruses (including the C-type) known to cause tumors in animals.

The feeling of excitement that continues to mount in the fields of virology and molecular biology, is also being felt in immunology. Evidence that cancer flares up as a result of a breakdown in a person's immunological defense system has accumulated. Persons with immune-deficient diseases, for example, exhibit higher than normal rates of cancer, and malignancies increase in older persons, as the efficiency of the immune system diminishes. Perhaps the most incriminating information comes from the field of organ transplantation. In order to suppress the body's rejection mechanism—which would recognize a transplant as foreign matter—graft recipients are given drugs that depress their immune system. But an alarming trend has occurred: the incidence of cancers among these patients is unusually high. The drugs that successfully prevented rejection of the transplant apparently also impaired the patient's immune response against silent cancers.

A promising approach to helping the body fight cancers involves the use of a vaccine effective against tuberculosis, BCG, which seems to have the added benefit of generally strengthening the body's immune response. A special vaccine composed of BCG and cells from cancer patients has kept six leukemia patients alive for more than five years. These patients had a deadly form of leukemia that usually kills its victims within three years. These remarkable results with BCG are believed to be the first demonstration in man that an agent that stimulates cellular immunity also protects against cancer. BCG was also administered to 22 patients given up as hopeless because of malignant melanoma, a usually fatal skin cancer. Four patients underwent complete regression and eight others showed some stabilization of the disease. Promising support for the cancer-controlling properties of BCG came from the Canadian province of Quebec, where, in one town, when all the children were immunized against tuberculosis the expected incidence of acute leukemia fell off by 60%.

A second immunity-strengthening approach being employed against cancer involves the use of a compound called Poly I:C to stimulate the production of interferon, a natural cellular defense system against viruses. Mice given Poly I:C and then subjected to a known cancer-causing virus do not develop cancer. Animals not protected with the compound, however, do contract the disease. Preliminary studies indicate the compound may also be beneficial against human cancers.

One of the main goals of cancer research is the development of ways to detect cancers early, when they are most likely to be curable. A test for cancer of the colon, and possibly of the stomach and pancreas, is now undergoing clinical trials. It attempts to detect antibody response to an antigen known to be carried in the blood of colon cancer patients. The antigen is also known to be present in the gastrointestinal tissue of every unborn baby between the third and sixth months of gestation. It disappears before birth, not to be found again unless a cancer is present. It is hoped that the test for the antigen will do for colon cancer what routine use of the Pap smear has done in dramatically reducing cervical cancer in women.

Why a person's natural immune system may be powerless against cancer may have been uncovered by a husband-and-wife team, Karl and Ingegerd Hellstrom of the University of Washington. They found that patients with rampaging cancers had in their blood substances called blocking antibodies, which concealed the antigens on the cancer cells so that the defense system could not recognize and attack them. In effect, the immune system is blindfolded to the existence of the cancer. Their finding opens up a new approach for cancer therapy, for if a way could be found to remove the blocking antibodies, the patient's own immune response—already present but unaware of the cancer—may be able to destroy the tumor cells. The Hellstroms have had successful results in the test tube, and David F. Hickok of the University of Minnesota recently reported encouraging results with a similar technique in human subjects.

Because evidence of the natural history of cancers is accumulating rapidly, present treatments for malignancies may become outmoded in a few years. Also, if cancers can be spotted early enough and methods developed to block the growth of blood vessels to the tumors—a prospect currently being investigated—many cancers may be arrested and never grow bigger than pinheads. Although much remains to be done in cancer research, the massive strategy formulated in the United States may very well produce information that will not only speed man's eventual victory over cancer but also teach him more about the secrets of life.

See in ENCYCLOPÆDIA BRITANNICA (1972): CANCER; CANCER RESEARCH; IMMUNITY AND IMMUNIZATION.

Although no virus was a proved cause of human cancer, one study in which human sarcoma cells were injected into cat fetuses produced a C-type virus unlike any known in animals. Photomicrographs (opposite page, top to bottom) show human cancer cells forming a tumor (arrow) in a kitten's brain tissue, a kitten brain tumor made up of human cells, C-type virus particles (dark spots) near a human sarcoma cell in a kitten brain tumor, the virus budding off a sarcoma cell in a culture, and the isolated virus grown for 24 hours in a culture

FOR ADDITIONAL READING:

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Crick, F. H. C., "The Language of Life," *1969 Britannica Yearbook of Science and the Future* (Encyclopædia Britannica, 1968).

"Virus Theory of Breast Cancer Receives Some New Support," *Journal of the American Medical Association* (May 3, 1971, pp. 751–753).

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Mechanical Servants for Mankind

by John McCarthy

Robots—mechanical beings that can take over the dull and burdensome chores of life—have long been dreamed of by man. How soon, if ever, will this dream become reality?

A robot is an artificial intelligent being usually considered to have human form. The idea of making a robot by magic is ancient, and the idea of making one by science originated in Mary Shelley's *Frankenstein, or the Modern Prometheus* in 1818. The word "robot," from the Czech word for work, was introduced in a play *R.U.R.* by Karel Capek in 1920.

Mechanisms that imitate some of the functions of humans or animals have been constructed for several hundred years, but a real robot must have two properties that were not really feasible until the stored program digital computer was developed in the late 1940s. These are sensory input from the outside world so that the machine's actions will take the world into account, and an internal model of the outside world, the machine's goals, and the laws that determine the effects of the actions the machine may undertake. The pre-computer mechanisms, while sometimes very elaborate, essentially went through fixed, built-in sequences of actions.

Formulating the problem

The first modern discussion of the possibilities of intelligent machines was by the British mathematician Alan Turing in 1950. Turing was well fitted for this because in 1936 he had introduced the concept of a universal computational machine and had also taken part in the design of early computers. (A universal computational machine can do any computation that can be done by any machine, because it can use a description of the other machine in order to imitate it. All present computers are universal.)

Turing's article accomplished three things: (1) It set forth as a sufficient criterion for intelligence the ability to imitate a human over a teletype line. This clarified arguments with people who believed that a machine could not be intelligent because it does what it is told. (2) It established that the difficult problem is not the construction of the robot or the computer but the programming of it. It is possible to use any stored program digital computer, but the problem is to make up the rules that determine how it will act in any situation. These rules have to be understood very precisely in order to express them as a computer program. (3) It proposed the problems of making programs for playing chess and proving mathematical theorems as major goals for research in artificial intelligence, giving reasons why these are worthwhile problems and some ideas for getting started.

Since Turing's time, artificial intelligence has slowly developed into an important scientific field with numerous branches and with numerous ideas of the fundamental problems. At present, there are still no really intelligent robots. In fact, as described below, there are fundamental scientific problems to be solved and maybe even formulated.

Heuristics

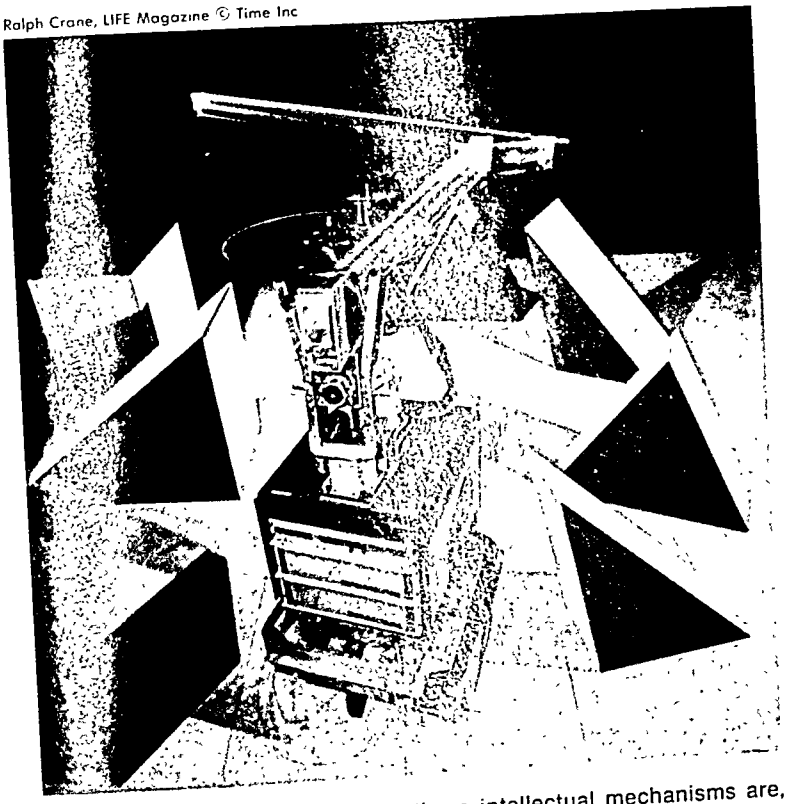
Artificial intelligence may be divided into three sub-topics: heuristics, representation theory, and robotics. Heuristics is concerned with the search for a solution to a problem among a collection of alternatives. Representation theory is concerned with the structure of the information a computer program or a person may have about the world, the facts that allow it to determine the effects of the actions it may take, and the methods available for getting more information. Robotics is concerned with perception and action in the physical world.

The most developed of these subjects is heuristics. Most of the insight gained in this area has come from comparing the performance of computer programs in playing games and proving mathematical theorems with human performance. The most studied game has been chess. The best result in comparison with human play was achieved in the 1960s by a program written by Richard Greenblatt of Massachusetts Institute of Technology (MIT). His program played class C chess at that time. In fact, it won its class C rating by winning the class D trophy in a regular chess tournament in Boston.

This performance is quite modest considering that these programs are capable of examining several hundred positions per second on present-day computers. However, even these results were achieved with a great deal of effort, and the earlier programs were much worse. Part of the progress involved the incorporation of specific knowledge about chess, but the major defects in early programs can better be described as their lack of aspects of general human intelligence. Moreover, the weaknesses of present programs seem to come from lack of general intelligence rather than lack of chess knowledge. Programs written under the direction of chess grandmasters have not done as well as those written by people interested in heuristic programming.

JOHN McCARTHY *is a professor of computer science at Stanford University and director of the Stanford Artificial Intelligence Laboratory.*

Ralph Crane, LIFE Magazine © Time Inc



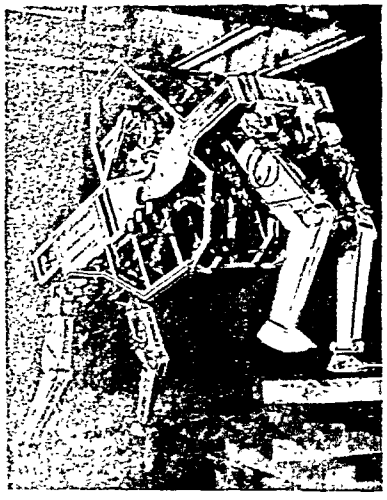
"Shakey," named for its unsteady movements and developed by the Stanford Research Institute, has motors, wheels, feelers, a television "eye," and a range finder. These are all connected by radio to a large time-shared computer. Shakey can explore a room, remember some of its contents, and from that information achieve some simple tasks. For example, it can push a box off a platform by finding a ramp somewhere in the room, shoving it against the platform, rolling itself up the ramp, and pushing off the box

In order to see what a few of these intellectual mechanisms are, consider how chess programs work. They all work by exploring the so-called move tree of the game. In an initial position the machine has a number of moves which can be regarded as the branches of a tree. Each move leads to a position in which the opponent has a number of moves that give another level of branches of the tree, and so on. Ultimately the branching stops at positions in which the game is over.

It would be easy to write a computer program that would play perfect chess by examining all the positions on the move tree. The program would be smaller and use less storage than present chess programs. The only problem is that it would take too long to move, because the full move tree is quite large. In fact, if every electron in the universe visible to astronomers were a computer that could examine a position in the instant of time that it takes light to cross an electron, then the time remaining until the stars dissipate their energy would not suffice to determine the best first move in chess.

Therefore, programs look only at a small part of the move tree, and the program's level of play depends critically on the rules that determine what positions are examined. Most programs do not consider all possible moves, even at the initial level. An effort is made to consider only moves that may contribute to some goal, and for each possible goal programs are written that generate moves that may contribute to it. Goals included in typical programs are attacking the opponent's king, defending one's own, getting a good pawn structure, disrupting

Courtesy, General Electric Research and Development Center



A four-legged "walking machine" mimics and amplifies the movements of its human operator. The right front leg of the machine is controlled by the operator's right arm, the left front leg by his left arm, the right rear leg by his right leg, and the left rear leg by his left leg. Designed by the General Electric Co. as part of a program to develop "man-amplification" machines for the military, this research prototype has walked across level ground, climbed obstacles, lifted a small vehicle out of a mudhole, and hoisted a 500-pound load onto a truck with one foot.

the opponent's pawn structure, etc. In order to prevent the program from going deeper and deeper, there are stop rules. In general, one tries to stop the analysis at quiescent positions that can be evaluated without further looking ahead. Besides this, it pays to set an initial level of aspiration that changes as the analysis proceeds and to stop the analysis of positions that clearly cannot lead to reaching this level. It also is necessary to keep a level of aspiration for the opponent based on the alternatives that have already been examined for him.

When a computer chess program makes a bad move in a position, it can be required to print out the tree of moves that it examined in reaching its decision. It usually turns out that the trouble comes from the program not having examined an important move, either its own or its opponent's. This is much more common than having examined the right moves but incorrectly evaluating a quiescent position. On the other hand, the computer will usually have spent much time examining moves that strike the human player as not worth looking at.

When the program has failed to look at a line of play that a human would look at, this is usually readily fixed by finding a new principle for looking at moves. Of course, this principle may make the computer program look at moves a human would ignore. This is all right provided it does not waste too much time. Unfortunately, this often happens, and it is much more difficult to devise principles that will allow a program to ignore moves safely.

There are several aspects of human game playing that no one has been able to make computers accomplish satisfactorily. First, a human will often break a position down into several sub-positions, analyze them separately, and then combine the analyses. There is still not any good way of programming a computer to identify such sub-positions. Second, a move often has properties that apply to a whole class of positions; thus, an opponent's move may capture one's queen in all the positions resulting from moves that do not move the threatened queen. Third, there is not yet a system for recognizing that an aspect of a position is one for which there is a general rule; thus, no present chess program can be instructed about smother mates in any general way, let alone develop the concept from its experience.

In a few board games, computer programs play better than the best humans; these are games in which the intellectual mechanisms we know how to program, such as look-ahead and evaluation, are adequate for successful play. Such a game is Kalah, an American commercial version of a game played in Africa and Asia.

The other area to which heuristic programming has been extensively applied is proving mathematical theorems. The results are similar to the game-playing results but not as good. Certain intellectual mechanisms have been identified and programmed. In domains of mathematics where these mechanisms are adequate, the programs do rather well. Unfortunately, the scope of these domains is still very narrow compared to mathematics as a whole.

continued on page 104

Robots in science fiction

Since most people have gotten their first ideas of robots from science fiction, it is worthwhile to consider how robots have been described in these works. First, while an author sometimes simply wants to tell what he thinks the future will be like, usually he has some other theme. Sometimes, he is simply writing an adventure story. Then the robots often help provide the conflict by trying to conquer the world on their own behalf or on behalf of their makers. There may be both good robots and bad robots in the story. Another common theme is the robot as the oppressed class or race. They may revolt or suffer helplessly and pathetically or be liberated because of a belief analogous to equal races living in harmony. In any case, the robots are given as many human motivational, emotional, social, or political attributes as will suit the author's purpose. Another theme is based on the story of King Midas, in which an apparent good thing is fated to turn out badly.

One of the popular science fiction concepts is Isaac Asimov's three laws of robotics—a robot must protect man, protect itself, and carry out its orders in that order of priority. Some of Asimov's plots hinge on complexities in the interpretation of these laws in particular cases, leading to neurotic behavior of the robot.

Most science fiction fails in one way or another to describe important aspects or consequences of robots. For example, in his stories Asimov ignores the possibility that a robot may do harm on account of its conception of the world being inadequate to determine the consequences of a proposed action. Similar unrealistic treatment appears in works of other writers. For example, they generally depict worlds with only one or two forms of artificial intelligence, whereas there are likely to be many. Writers have also generally found it difficult to depict an intelligence greater than man's and instead have concentrated on robots that are equally as smart.

But these shortcomings do not mean that the science fiction ideas of robots are worthless. We may get from them some ideas of opportunities to be exploited and problems to be avoided. The real development of artificial intelligence seems likely to differ from the science fictional in the following ways:

1. It is unlikely that there will be a prolonged period during which it will be possible to build machines as intelligent as humans but impossible to build them much smarter. If one can put a machine capable of human behavior in a metal skull, one can put a machine capable of acting like 10,000 coordinated people in a building.

2. The present stock of ideas is inadequate to make programs as intelligent as people even if these ideas are developed diligently over a long time. They may even be inadequate to make a program as intelligent as a dog. On the other hand, there is nothing to prevent the required new ideas from coming very soon. It may take 5 years, and it may take 500.

3. Present ideas are probably good enough to extend man's ability to have large amounts of information at one's fingertips, to check long trains of reasoning, and even to generate simple hypotheses.

continued from page 102

The efforts to make game-playing and theorem-proving programs have led to the identification of important intellectual mechanisms of general significance, but the programs themselves are quite narrow in their capability. Therefore, considerable effort has also gone into trying to make programs of general intellectual capability.

Representation

One approach, which was tried in the late 1950s and early 1960s, involved simulating evolution by having a machine or computer program that gave answers to problems. The machine or program was divided into parts, and each part had a certain probability of being changed at each time. When a problem was solved correctly, the parts that operated in the correct run were "rewarded" by having their probability of change reduced, and when an incorrect answer was given the active parts were "punished" analogously. Other schemes kept the same parts but altered their probabilities of activation according to their success. When applied to problems of pattern classification, such as identifying the letter of the alphabet shown in a picture, these schemes had some success, but none of them were capable of learning any generally intelligent behavior. The problem was that in the schemes used for representing behavior, meaningful changes of behavior were not represented by small changes in the representation.

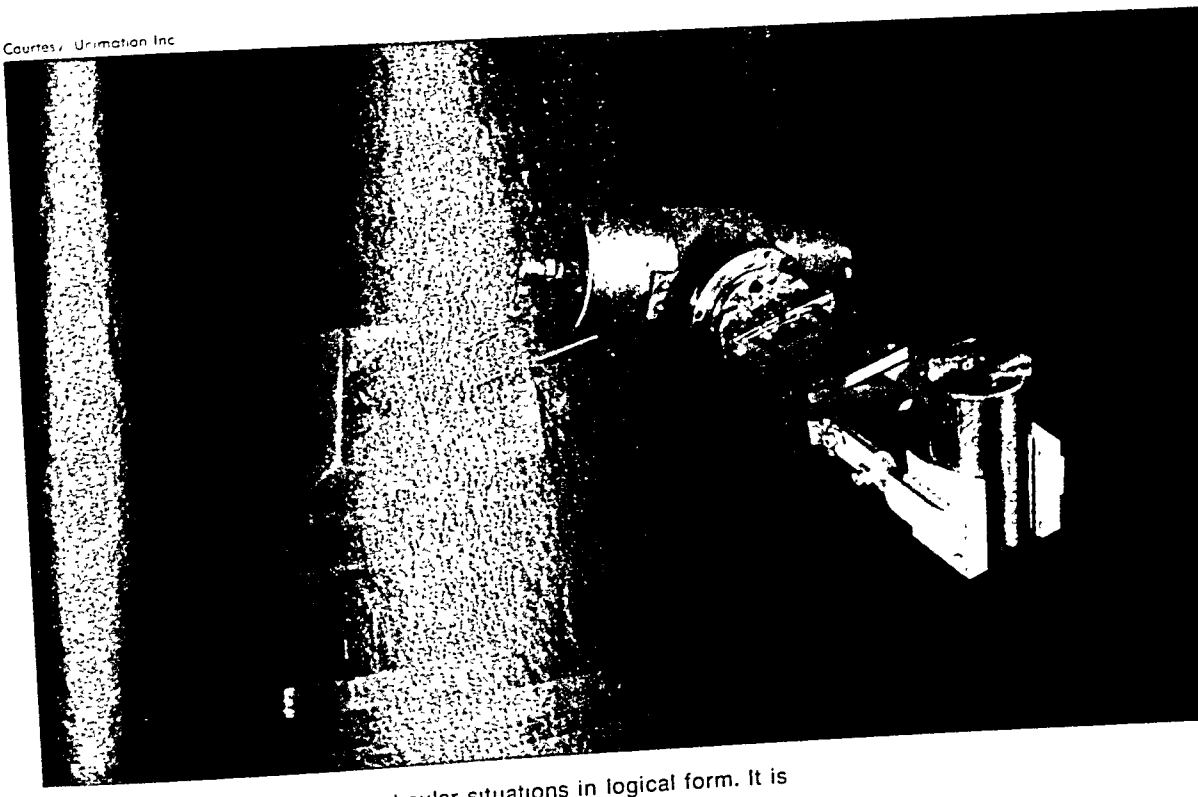
Another approach to general intelligence was the General Problem Solver (GPS) of Allen Newell and Herbert Simon. This involved representing an arbitrary problem as one of transforming one expression into another via intermediate expressions using certain allowed rules of transformation. A number of problems were put into this form and solved by the GPS, and the results were compared with the records of sessions in which humans solved the problems. In the end, however, the GPS was not general enough. In particular, the GPS could not achieve the goal of representing the problem of improving itself.

A third approach involves the use of mathematical logic. In the middle of the 19th century, the English mathematician George Boole began the development of a formal language for expressing mathematical ideas. This development was continued by such mathematicians as Gottlob Frege and Bertrand Russell. When we say a language is formal, we have three properties in mind: Effective rules are given that determine which strings of letters and digits and special characters are supposed to be sentences in the language; effective rules are given that determine when a sentence is to be regarded as an immediate consequence of several others; and, if the language is to refer to something outside itself, some rules have to be given in English that tell what the objects of the language refer to. The concept of "effective rule" used here by the mathematical logicians can be considered today to be the same as "checkable by computer."

The use of logic in artificial intelligence is in principle quite straightforward. The idea is to express what human beings know about the

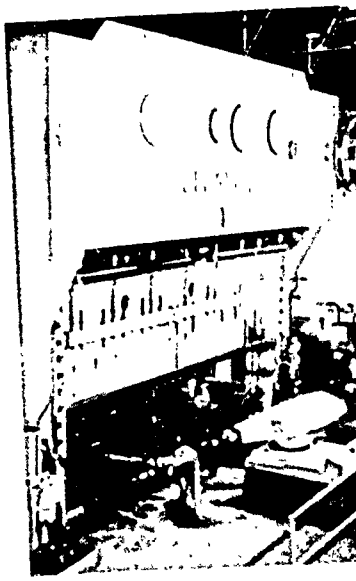
The Unimate (opposite, top) performs a great variety of heavy and delicate industrial jobs, ranging from loading machine tools to packing glass tubes. Its hydraulic-powered reach can vary from 3½ to 7½ feet, and it can carry loads up to 75 pounds while moving through an arc of 220°. The machine is "taught" by being led through its desired movements once, and its magnetic memory system has a capacity of 180 sequential commands. In the bottom photograph, Unimates are loading automotive presses.

Courtesy Unimation Inc



world in general and about particular situations in logical form. It is especially important to be able to express what is known about the effects of actions people may take and what is known about the future consequences of a present state of affairs. If this has been done, then the fact that a certain course of action will achieve a prescribed goal should follow from the aforementioned set of facts. Suppose we have a logical system and a particular set of facts such that it follows from these facts that a certain goal can be achieved by a certain course of action. We still need a program that, given the facts, can find the course of action and deduce that it will be successful. Different programs will have different capabilities, and no program will be able to achieve all goals whose achievability follows from the facts.

Therefore, the use of logical formalism splits the artificial intelligence problem into two parts: the problem of representing the facts in a logical system, and, given the facts, the problem of finding out what to do. The latter is a problem in heuristics as described in the previous section. The representation problem has much in common with epistemology, which is concerned with the nature and limits of knowledge. It is also connected with philosophical logic, which is concerned with the formal description of concepts like ability, causality, and knowledge.



Robotics

Putting all this together, what progress has been made toward making a mechanical man that will clank about and either try to conquer the world or suffer oppression from the prejudiced?

Consider first the hardware situation. Nowhere in 1972 was there any mechanical man with two legs, two arms, two eyes, and a brain. It was not certain that present-day mechanical engineering could package the necessary motors, joints, etc., in a frame light enough to be moved by the motors. At any rate, no one had tried. There were, however, many separate parts in use. Specifically, artificial arms, television cameras, microphones, and radio and TV connections to vehicles that can roll around on the floor had been attached to computers. The computers were large ones, weighing many tons, but suitable small ones existed even though they were expensive and not as convenient to use as a good laboratory time-shared computer.

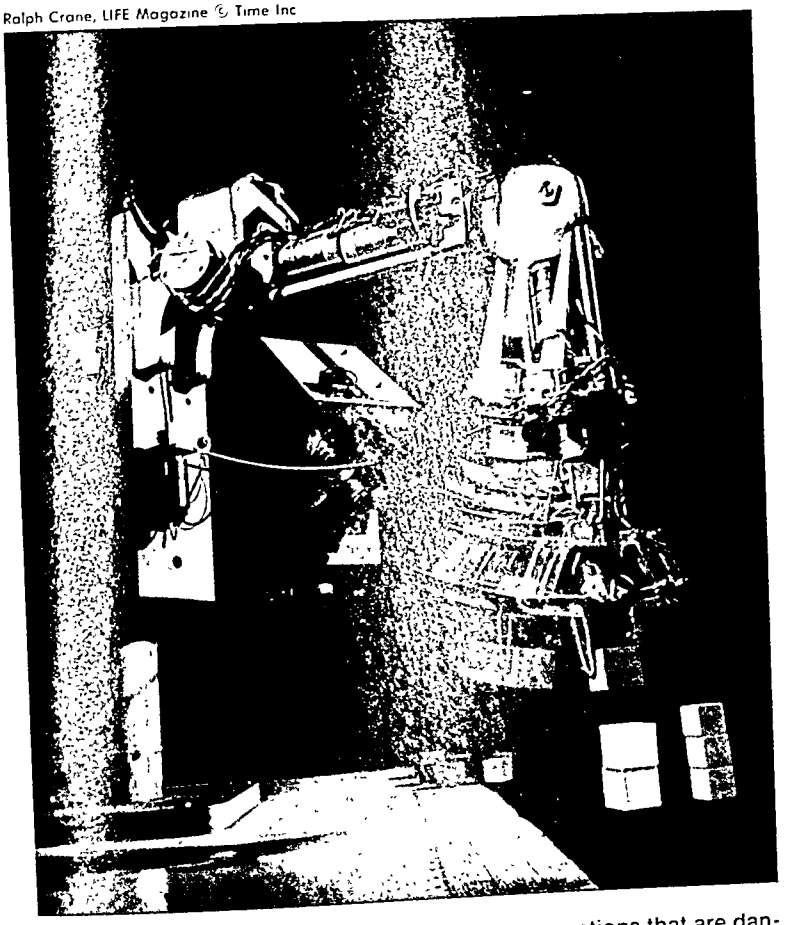
However, the main bottleneck in making a robot was not the hardware but the programming, and within programming the most immediate bottleneck was programming vision. In 1972 computer vision involved a television camera attached to the computer, allowing the computer to "read" a frame from the camera into its memory. The picture is represented by about $500 \times 500 = 25{,}000$ numbers, each giving the brightness of a point in the picture. If color is wanted, three frames can be taken, through red, green, and blue filters. That the picture is in the computer can be verified by printing it out again or displaying it on a television monitor connected to the computer. In fact, pictures can be improved by computer processing more flexibly than in a darkroom. The processing is used to eliminate noise, improve contrast, and transform pictures taken from different directions to a common direction and scale so that the pictures can be compared to look for changes.

None of these operations require the computer program to identify and locate the objects in the picture, but suppose we want a computer to physically build an object out of parts. In the simplest case, not requiring vision, the parts come mounted and oriented precisely on a belt. An artificial arm goes through a fixed sequence of predetermined motions in order to pick up each part and place it. Fasteners such as bolts and welding are also used, but also with precise motions. This procedure was introduced in the late 1960s by two U.S. firms, and there are now several hundred such arms in use. In particular, the new General Motors plant for producing Vega cars at Lordstown, O., uses many such manipulators, but even there they do only a small part of the work of putting together a car.

Such "robots" ordinarily are not directly computer-controlled but instead are operated by a tape or drum on which has been recorded the desired motions by a human being who had put the robot through the desired operation. The exact same motions (to the hundredth of an inch if the machinery is that accurate) are repeated each time. The only variability is in timing, since the machine can be instructed to wait after completing one operation until it receives a signal to perform the next one. These signals may be generated by switches, which detect that a part is in place before allowing the operation to proceed.

The applications of this kind of robot are somewhat limited. They

Ralph Crane, LIFE Magazine © Time Inc



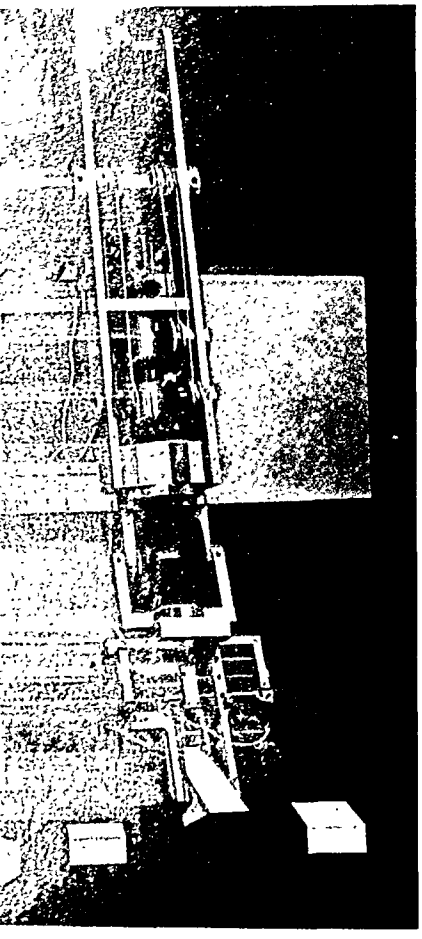
Obeying spoken commands is a function of the machine above, which uses a manipulator arm, a television "eye," and a large computer to analyze what lies before it. When the words "Stack the small blocks at the upper right" are spoken, the computer determines what steps are required. It then transmits this information to the arm, which turns itself as necessary to grasp each block by the sides and lower it on top of a pile. The machine, however, cannot cope with irregularly shaped objects.

are so expensive that they are used mainly for operations that are dangerous, such as putting a part in a press or a furnace. Also, it is often expensive or impossible to arrange for the parts to be so precisely made and so precisely placed that the required operations can be repeated exactly. Nonetheless, there are many applications for which this kind of first-level robot can be used, and many thousands will probably be installed in the 1970s.

The second-stage robot involves a computer-controlled arm with a television camera for an eye. The objects manipulated are simple and have flat faces. The program is designed to build a simple structure out of these objects. This work is still in the laboratory. Three examples of what recently has been accomplished there are as follows: At the MIT Artificial Intelligence Laboratory, a computer-controlled arm copied a structure made of blocks. At the Stanford University Artificial Intelligence Laboratory, a program did a puzzle requiring that a tower of four blocks with specified colors on the faces be built. At the Hitachi Central Research Laboratory, a program built a simple structure out of blocks working from a drawing giving an orthographic (involving right angles and perpendicular lines) projection of the desired structure.

All these tasks were accomplished in approximately the same way.

Courtesy, Hitachi, Ltd.



Japan is producing robotlike machines to use in light and heavy industry. One Japanese firm, Hitachi, Ltd., has developed the "visual robot," a model with two television eyes to provide binocular vision.

First the program found the edges of the objects in the scene by scanning the array of brightnesses of the picture that it had read from the television camera into the memory of the computer. When the program found a sudden change in brightness, it scanned in a circle about the point where the change occurred, looking for the dark-to-light transition. If it found this transition, the program took this point as the center of a new circle and thus traced along the entire dark-to-light boundary. In this way it found all the edges in the picture. (Actually edge finding is more complicated than this, because not all edges are between regions of different brightnesses; in some cases the edges themselves reflect the light. Also there are shadows to be ignored if possible.)

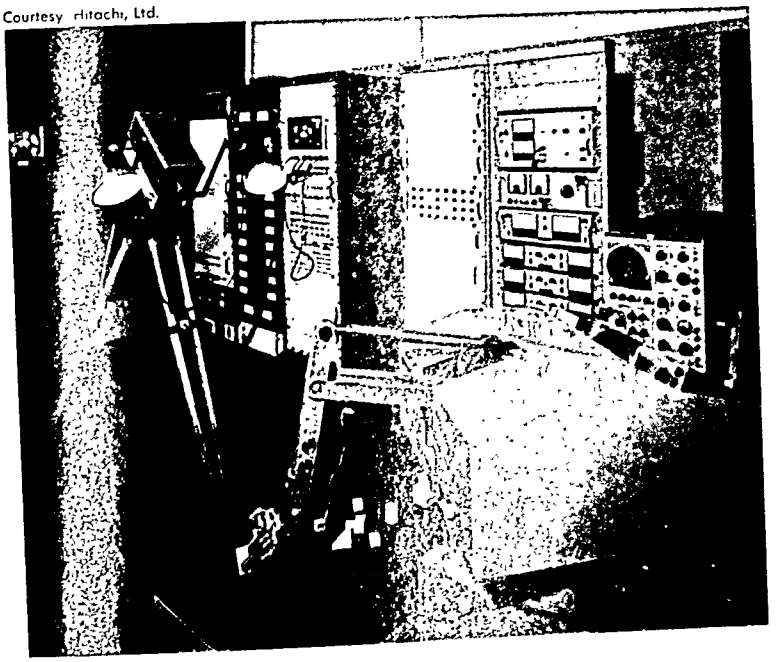
After the edges were found, the program determined the three-dimensional collection of objects that would give rise to this pattern of edges. Some of the objects might be partly hidden behind others, and the program had to make plausible assumptions about the hidden parts. However, present programs cannot deal with curved objects in any general way; either the objects must have all flat faces or each curved object to be found must be programmed for explicitly. Once the objects in the scene were found, the computer determined the trajectories of arm motion that would move them to the desired places. Generally the arm motion was done without visual feedback, largely because the arms were more complicated objects than the existing vision programs could handle.

Moving to the next higher level, one finds programs being developed to use more visual information than just brightness discontinuities. This work includes color-contrast edges and edges that occur when an object is seen against a background. While these techniques will make edge detection and region finding more versatile, they will not solve the basic problem of representation of visual information. An object with flat faces can be described by listing its faces, describing each face by listing its edges, and describing each edge by giving its endpoints. But how is one to describe a human head? The description must cover the subtleties of shape by which people can tell one human from another, but clearly should not be so detailed as to describe each hair. There are various ideas for dealing with this, mostly still too vague to be described here, but they are all too limited in their potential capability.

Although programming vision is perhaps the most immediate problem in robotics, even when this has been achieved we will still be far from having an intelligent machine. Suppose we want a robot capable of being a domestic servant. Then we need to program at least the following capabilities:

1. It must know the properties of physical objects: for example, to put eggs in a paper bag it must know that eggs must be placed gently and that the paper bag can change its shape as it is opened and things are put in it. It must also know about doors and drawers and stairs.
2. It must know about people and what they want and how they change their minds.

Courtesy Hitachi, Ltd.



3. It must have some understanding of speech.
4. It must know about how to divide tasks into subtasks.
5. It must be able to recognize any harmful side effects that might result from its planned actions.
6. It must know when to give up and whether to ask for help.
7. It must have at least a primitive ability to learn from experience, at least enough so that if it is shown how to do a task it will be able to do it again in similar circumstances.

The critical reader will recognize that this list of what a robot must know is itself incomplete and may include superficial items and leave out more basic ones. This reflects the present state of our understanding of artificial intelligence.



Courtesy, Los Alamos Scientific Laboratory



Nuclear Fusion

Power Source of the Future?

by Harold P. Furth

Power that is clean, inexpensive, and abundant—this long-sought goal may be achieved if the great energy released by nuclear fusion can be harnessed.

Since the explosion of the first hydrogen bomb in 1951—uncontrolled nuclear fusion—scientists have sought ways to harness and control this vast source of energy. Despite many difficulties, progress is being made. Controlled nuclear fusion reactions of the heavy isotopes of hydrogen promise to provide an economical and essentially inexhaustible new source of electrical power. Large-scale experimental work on controlled fusion is under way in the United States, the Soviet Union, Europe, and Japan. The principal scientific problem is the long-time confinement of the reacting fuel, which must be maintained at temperatures of typically 100,000,000°–1,000,000,000° C. Estimates based on recent experimental progress indicate that a demonstration of scientific feasibility of controlled fusion may be achieved toward the end of the 1970s; the first commercial application of fusion power is generally predicted for the late 1990s or for the following decade.

Fusion power has inherent economic and environmental advantages that make it the preferred solution to the world's long-range energy requirements. The basic fuel, deuterium, is inexpensive and abundant. Unlike nuclear fission power, fusion does not produce radioactive wastes except for activated structural materials of the reactor, and there is no possibility of a runaway fusion reaction. The thermal efficiency of the first fusion reactor designs is comparable to that of conventional power plants; but there is a prospect of future reactor designs with very low production of waste heat. The cost of fusion power and the required capital investment are estimated to be competitive with the corresponding figures for present-day conventional power.

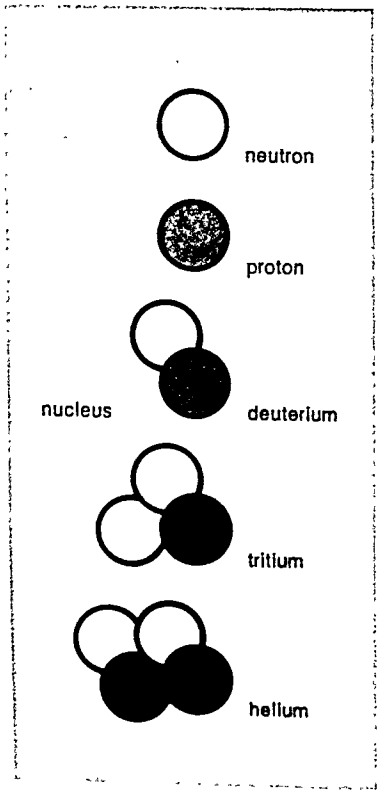
HAROLD P. FURTH is a professor of physical sciences and co-head of the Experimental Division of the Plasma Physics Laboratory at Princeton University.

Requirements for fusion power production

In order to understand the fusion problem, it is helpful to recall some basic features of the atom. The most common form of the hydrogen atom consists of a single electron revolving around a much heavier nucleus, the proton. Two rarer forms, deuterium and tritium, have nuclei that consist of a proton plus a neutron and a proton plus two neutrons, respectively. All three of these isotopes of hydrogen have nuclei that carry a single positive charge equal in magnitude to the negative charge of the electron. The positive charge of the nucleus attracts the opposite, negative charge of the electron, and thus binds the electron to the atom. On the other hand, *similar* electrical charges tend to repel one another. Thus, the fusion of two nuclei is opposed because the two positive charges repel each other.

Deuterium and tritium fuse more readily than other combinations of nuclei, and fusion reactor designs are therefore generally based on this process. When a deuterium and a tritium nucleus meet, however, they are most likely to glance off each other without fusing. Only if their energies of approach are sufficiently high is there any appreciable chance that they will come close enough to experience the non-electrical forces that give rise to nuclear fusion. The minimum energy of motion required for the deuterium-tritium reaction to take place is about 10,000 electron volts (eV). This is the energy acquired by an electron or proton in a 10,000-volt (V) accelerator, or equivalently, is the average energy of motion of particles at a temperature of about 100,000,000° C. (The term "thermonuclear reactions" refers to fusion reactions that take place as a result of this thermal motion.) Deuterium will also react with itself, but the reaction probability becomes appreciable only at temperatures above 1,000,000,000°.

Nuclei of hydrogen isotopes (deuterium and tritium) consist of a proton plus as many as two neutrons. The positively charged nuclei repel each other (opposite, top and center), but may fuse on sufficiently close approach (bottom).



The deuterium-tritium reaction yields a helium nucleus, a neutron, and 17.6 million electron volts (MeV) of energy, most of which is carried off by the neutron. Thus potentially there is roughly a thousandfold increase over the initial investment of 10,000 eV in the energy of motion of the deuterium and tritium nuclei. The actual energy multiplication factor obtained depends on the fraction of the hot fuel that reacts before escaping or cooling.

The fundamental criterion for a successful fusion reactor is that it should confine the hot fuel long enough so that a sufficiently large fraction will react and thereby release appreciably more energy than was invested in fuel heating. This is known as Lawson's criterion. For the deuterium-tritium reaction, the fuel confinement time in seconds times the density of nuclei per cubic centimeter should exceed 10^{14}.

In the period 1960–70 it had become relatively easy to achieve high temperatures and make fusion reactions in a laboratory experiment. To reach the Lawson criterion, however, remained extremely difficult; the best numbers that had been achieved were in the range of 10^{11}–10^{12}. In order to appreciate the difficulties involved and the nature of the experimental breakthroughs that are being made, it is necessary to review some basic properties of high-temperature matter.

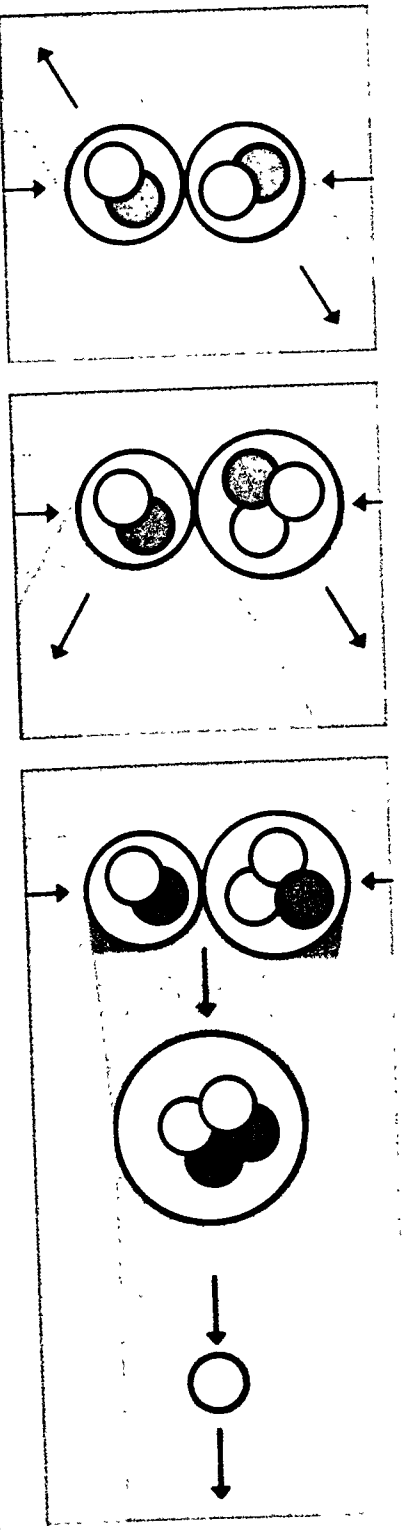
Thermonuclear plasma

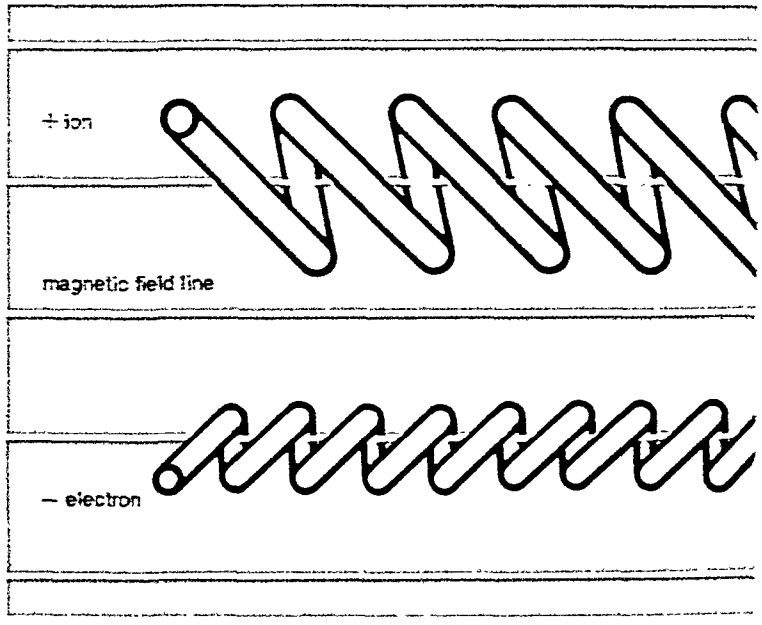
When a liquid is heated sufficiently, it becomes a gas: the atoms break free of each other. When a gas is heated further, it becomes a plasma: the constituent particles of the atoms, the electrons and nuclei, break free of each other. Free nuclei are also called ions, and the break-up process is called ionization. In hydrogen, ionization occurs at a temperature of about 10,000°—relatively low compared to the 100,000,000° temperatures required for fusion. On the earth natural plasmas are encountered quite rarely; for example in lightning strokes and in the northern lights. In the universe as a whole, however, the plasma state is by far the most common condition of matter. The sun and the other stars are giant fusion reactors, and the spaces surrounding them are filled with dilute plasmas.

Plasma produced in a fusion reactor on the earth cannot be confined by walls made of ordinary solid matter because the contact with the walls would cool the plasma. Fortunately, there is a natural way to confine the electrically charged electrons and ions of a plasma: by means of a magnetic field. In a uniform magnetic field, a charged particle must gyrate locally around a magnetic field line, though it can travel freely along the line. This constraint on the motion of plasma particles across magnetic field lines is the basis for the concept of the "magnetic bottle."

If the magnetic bottle is to confine a hot plasma and keep it away from cold walls, the magnetic field must be strong enough to bear the pressure of the plasma seeking to expand. The strongest magnetic fields technically attainable in large volumes in 1972 were about 100,000 gauss—100 times higher than the typical field strength of a small horseshoe magnet. A 100,000-gauss field can exert a maximum pressure of about 400 atmospheres (one atmosphere = approximately 14.7 pounds per square inch). To keep within this limit, a 100,000,000° plasma can be allowed to have a density of, at most, 10^{16} ions per cubic centimeter. Accordingly, the Lawson criterion requires that the fuel must be confined for at least a hundredth of a second. In most magnetic bottles the plasma pressure must be kept considerably smaller than the magnetic field pressure, resulting in plasma densities that range down to 10^{14} nuclei per cubic centimeter. At such densities the confinement times necessary to achieve effective fusion range up correspondingly to about a second. The great scientific challenge in controlled fusion research consists in making magnetic bottles that can provide such long confinement times for plasmas of 100,000,000°.

Fusion power can also be produced by freely exploding plasmas—not confined by a magnetic bottle—provided the initial plasma is sufficiently dense. For example, at the normal density of solid deuterium-tritium (4×10^{22} per cubic centimeter), the Lawson criterion requires a reaction time of only several times 10^{-9} seconds at 100,000,000°. During this time the plasma expands by only a few millimeters. The difficult problem is how to heat even a cubic millimeter of such a plasma to 100,000,000° in less than 10^{-9} seconds, since this requires





a highly focused energy input of approximately 10^5 joules at a heating power of 10^{14} watts. The recent development of high-powered lasers is beginning to bring this achievement within the realm of technological feasibility.

Magnetic bottles

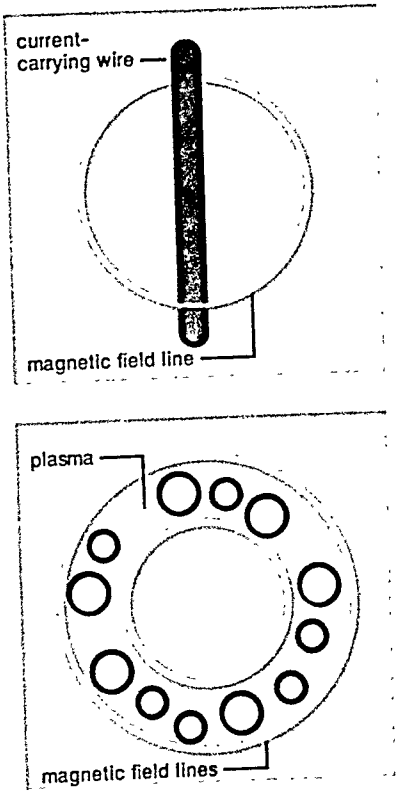
How can plasma particles be kept from escaping in the direction *along* magnetic field lines? One obvious solution is to bend the magnetic field lines in a circle, making a closed toroidal (doughnut-shaped) magnetic bottle. Another solution is to leave the magnetic bottle open-ended but make the magnetic field increasingly strong toward each end of the bottle, causing the magnetic field lines to converge toward each end. This is called a "mirror machine." How the mirror machine confines a plasma particle can be understood by an analogy with a compass needle between the poles of a C-magnet. A gyrating charged particle is a small magnetic dipole, as is a compass needle; furthermore, the particle dipole is always diamagnetic (*i.e.*, like a compass needle that is oriented so as to repel the two poles of the C-magnet). Consequently, the gyrating particle stays away from the two ends of the magnetic bottle. This confinement effect does not work for particles that are simply flying straight out along a field line instead of gyrating around it. In this sense, the mirror machine is a leakier magnetic bottle than the torus, which will confine a particle no matter in what direction it is moving.

As described above, the thermonuclear reaction process consists of energetic nuclei glancing off each other many times by electrical repulsion, until they happen to make a sufficiently close collision so that they fuse. The magnetic bottle is meant to be a kind of meeting

place for nuclei that are fusible. The bottle allows these nuclei to go through their bouncing and fusing interactions without being lost or cooled.

Unfortunately, the process of bouncing helps particles to escape rather rapidly from a mirror machine. Two gyrating nuclei may collide in just such a way that they both escape straight out the ends. In a toroidal bottle, the collision process gives rise to a more gradual diffusion of particles *across* the magnetic field lines. In either case scientists have calculated that plasma confinement times will be long enough to meet the Lawson criterion and make reactor operation possible. This is known as the "classical" confinement prediction for fusion reactors.

The main obstacle to progress with fusion power has been that actual plasmas escape far more rapidly from magnetic bottles than one would have expected from the classical prediction. The history of experimental advance in controlled fusion research thus far has been dominated by the process of encountering, analyzing, and partially overcoming these unexpectedly large losses. It is only quite recently that scientists have begun to approach the classically predicted plasma confinement times.



Magnetic field lines surrounding a current-carrying wire (top) form closed circles. Toroidal magnetic bottles have a magnetic field pattern of this type as their main ingredient (above). Charged particles must gyrate locally around a magnetic field line (opposite) or travel freely along the line.

Mirror confinement experiments

All hot-plasma experiments are conducted inside high-vacuum systems. Mirror-type confinement must be designed to minimize particle collisions, which are most frequent at low plasma temperature and high density; accordingly, the build-up of a hot, dense plasma in the vacuum must proceed mainly by raising the density of an initially hot, dilute plasma rather than by raising the temperature of an initially dense, cold plasma. In order to reduce collisions to the lowest possible level, open-ended reactors are ultimately expected to operate at temperatures above 1,000,000,000°—rather than the mere 100,000,000° required in a closed reactor.

The favored technical approach to plasma generation in open-ended fusion reactors is the injection of beams consisting of energetic ions or neutral (uncharged) atoms produced by externally situated high-current ion accelerators. A 100-kilovolt (kV) accelerator voltage corresponds to a 1,000,000,000° plasma. Initially, only a very small fraction of the injected beam is trapped in the plasma; as the plasma density rises, however, a stage is reached where the beam interacts mainly with previously trapped beam particles and the density build-up then grows exponentially.

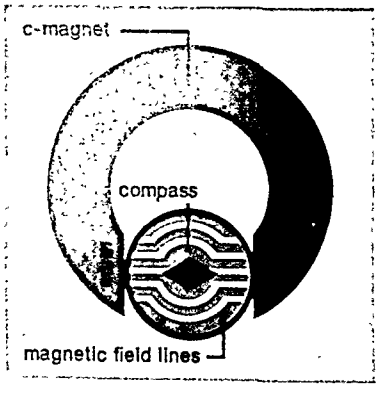
The plasma densities and confinement times achieved experimentally in open-ended systems have been limited primarily by unexpectedly large plasma losses due to instabilities. There are two principal classes of plasma instability: magnetohydrodynamic (MHD) modes, in which the plasma becomes grossly deformed or displaced; and microinstabilities, in which high-frequency electrical disturbances alter the velocity distribution of the plasma particles.

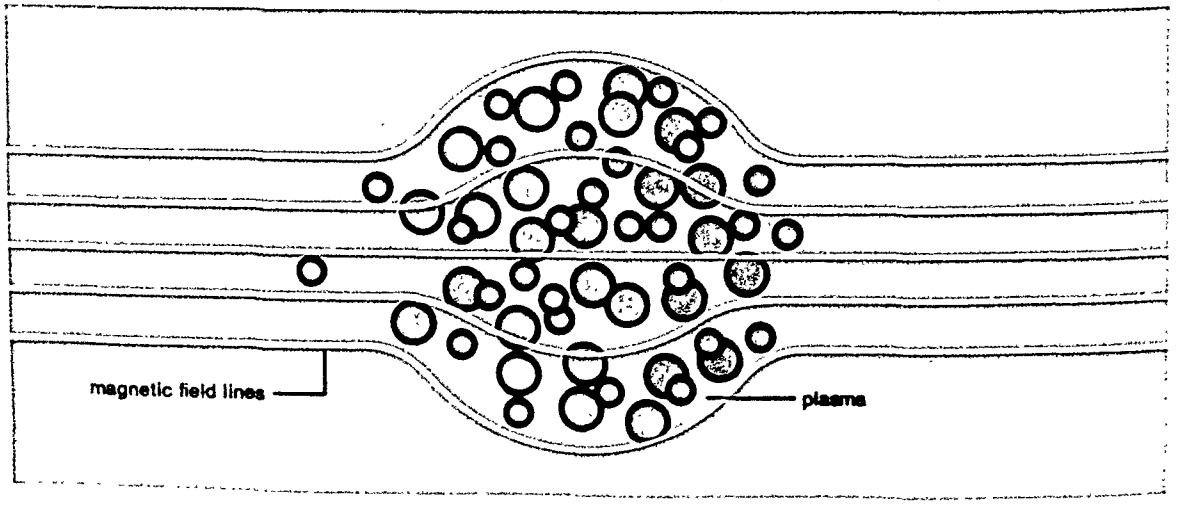
The most important MHD instability of open-ended systems is the so-called flute mode, in which a tube of plasma (or the entire plasma) is displaced into a region of reduced magnetic field. The equilibrium of the plasma on top of its "magnetic hill" is like that of a mechanical roller on top of a real hill: an infinitesimal displacement of the roller in either direction will increase exponentially. Such an equilibrium is called unstable. It can be shown that plasma elements lying along the same magnetic field line tend to move in unison, thereby accounting for the flutelike structure of the perturbations seen in the illustration on the following page.

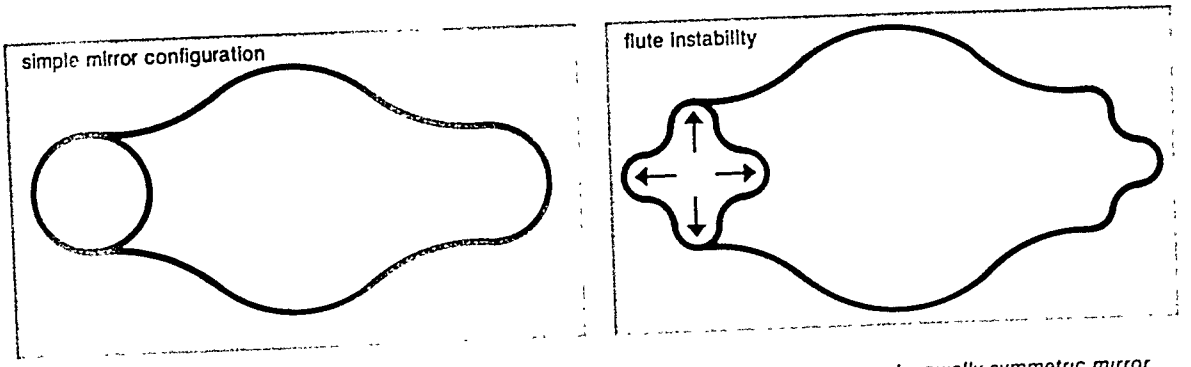
Early mirror machine experiments all encountered various forms of the flute instability. A number of flute-stabilizing techniques were found, but the most important breakthrough came in 1961, with the announcement of the first "magnetic well" experiment, carried out at the Kurchatov Institute in Moscow. As had been noted for many years by theorists in the United States and the Soviet Union, there exist special kinds of mirror configurations in which the magnetic field strength increases in *all* directions away from the plasma; a plasma confined in such a magnetic well would thus be expected to be absolutely stable against MHD modes. The Kurchatov experiment was able to operate alternately in the simple mirror machine configuration and in a magnetic well configuration. A dramatic flute-stabilization effect and increase of plasma lifetime was observed in the latter case. The typical plasma values of the PR-5, a more advanced embodiment of the Kurchatov experiment, were: ion temperature 50,000,000°, electron temperature 200,000°, density 10^{10} particles per cubic centimeter. The plasma lifetime was 3 milliseconds in the stable configuration and only 0.1 milliseconds in the unstable configuration.

Following the PR-5 results, the build-up of hot-ion plasmas in magnetic wells was pursued vigorously, mainly by injection and trapping of energetic neutral atom beams. The Baseball I experiment at the Lawrence Livermore Laboratory, Livermore, Calif., produced 100,000,000°

A magnetic bottle of the mirror type has nonclosed magnetic field lines that converge toward each end of the bottle (bottom), corresponding to an increase in field strength. A gyrating charged particle, which resembles a diamagnetic compass needle (below), is repelled by the ends of the bottle as the needle is by the ends of a C-magnet.







In a simple, axially symmetric mirror machine, the magnetic field strength increases toward the two ends of the magnetic bottle but decreases radially outward. Plasma, being diamagnetic, therefore seeks to move radially outward. It can do so either as a whole (above, left) or by means of flutelike deformations (above, right).

plasmas with densities up to 10^9 particles per cubic centimeter and confinement times of about a second. The somewhat similar Phoenix II experiment at the Culham Laboratory in England reached densities of nearly 10^{10} particles per cubic centimeter, and was the first to achieve incipient exponential build-up effects. These and other magnetic well experiments confirmed the complete removal of MHD instabilities as a limiting factor in mirror confinement. Experimental mirror machine plasmas, however, were not yet able to realize the ideal process of exponential build-up toward very high, collision-limited densities. Instead, the plasma lifetimes and attainable densities were found to be limited by the onset of microinstabilities.

Microinstabilities in a mirror machine take the form of high-frequency electrical waves. These waves are generated in somewhat the same manner in which light waves are generated in a laser. To set the stage for laser action, one needs to create an abnormal distribution of excited atomic states: these can then relax in unison and drive a giant light pulse. Because of the leaky ends of the open-ended magnetic bottle, its plasma always has an "abnormal" distribution of particle velocities. Large-amplitude plasma waves can arise spontaneously and help to knock plasma particles out the ends of the bottle.

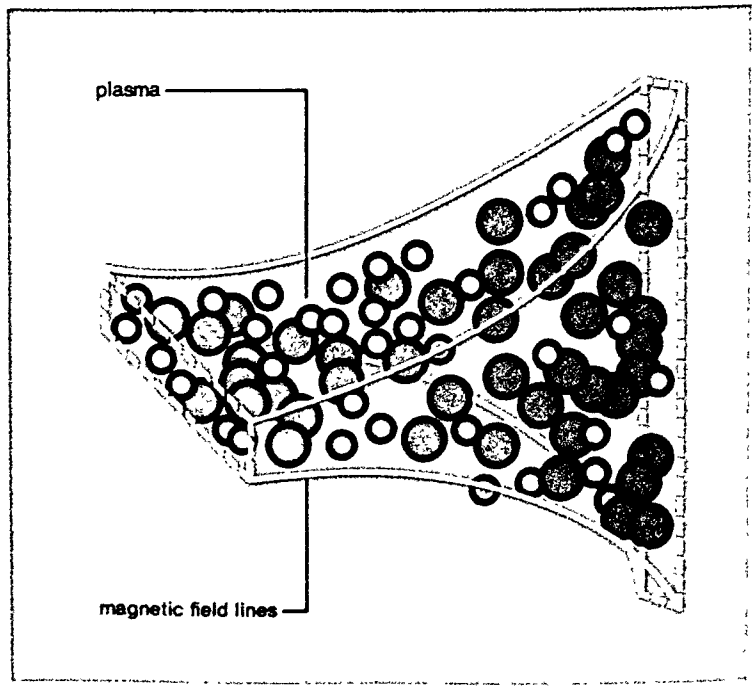
The severity of the end-losses depends on how "abnormal" the particle velocity distribution is. The worst distributions are produced by injecting a single beam of energetic particles, all with the same velocity and moving in the same direction. In the best distributions the particles are moving almost randomly in all directions, with a wide range of velocities.

In early mirror machine injection experiments, which used single beams with particles all at the same energy, severe microinstabilities and plasma losses were indeed observed, both in simple mirror geometry and in magnetic wells. In the Baseball I and Phoenix II experiments, new techniques were introduced to make the particle velocity distributions more nearly random; these techniques were shown to produce favorable effects on plasma stability. In the present generation of mirror injection devices, the favored plasma build-up plan is to maintain a nearly random particle distribution from the beginning. Calculations indicate that in this way it may be possible to realize stable conditions at plasma densities much higher than previously reached

by the injection technique. Confidence in these theoretical calculations is supported by the results of the 2X magnetic compression experiment at the Lawrence Livermore Laboratory. A nearly random plasma of 80,000,000° ion temperature and 3×10^{13} per cubic centimeter density was produced by compression of a lower-density, lower-temperature plasma in a fast-rising magnetic field of the magnetic well type. Evidence of microinstability was observed, but the typical plasma loss time of 0.3 milliseconds was found to be only about three times faster than the rate predicted for classical scattering loss.

Toroidal confinement experiments

In a closed magnetic bottle, where plasmas are not lost rapidly by classical scattering, the favored method of build-up toward a hot, dense plasma is by raising the temperature of an initially cold, dense plasma. The plasma, with its free electrons, is an electrical conductor, and so it can be heated by inducing a current to pass through it, usually the long way around the torus. Plasma resistance results from the collisions of the current-carrying electrons with stationary ions; the power dissipation associated with the collisions causes heating of the electrons. This is the same process of "resistive" or "Ohmic" heating that is employed in an electric toaster. The heating method is effective up to electron temperatures of about 10,000,000°, at which point a hydrogen plasma has about as low a resistivity as standard copper. At still higher temperatures, the plasma resistivity becomes so low that resistive heating is too slow to be effective. Auxiliary heating methods,

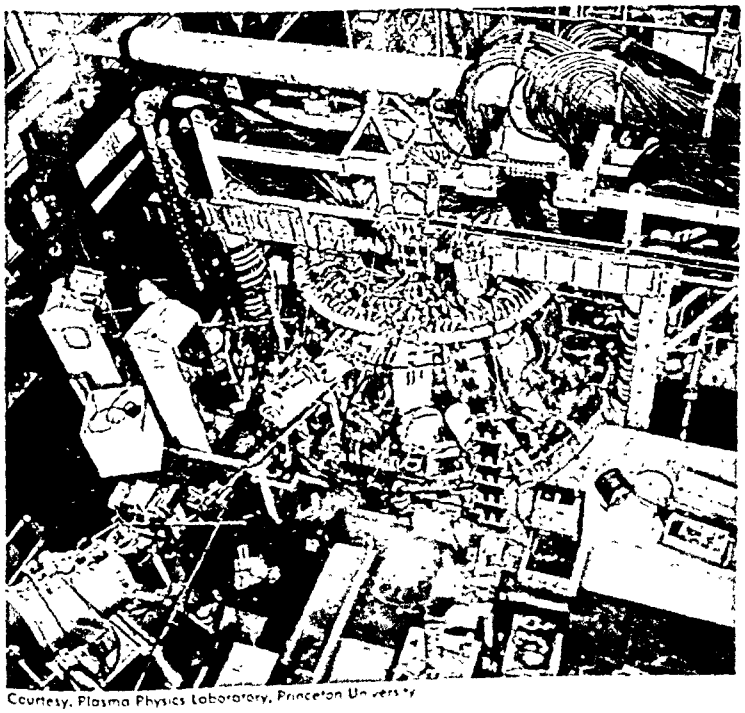


Advanced mirror machine of the magnetic well type has a magnetic field that increases in strength in all directions away from plasma. The plasma is stable against MHD instabilities.

therefore, must be used. Plasma compression and the injection of energetic neutral beams are considered the two most promising methods for advancing from the resistive-heating stage to the ignition of a thermonuclear reaction.

The magnetic field of a toroidal magnetic bottle must have a rather special structure in order to hold a plasma ring in equilibrium. A simple toroidal magnetic field, like that surrounding a straight wire, is not good enough: the plasma ring would expand continuously along its major radius (seeking to move in the direction of decreasing magnetic field strength). In order to provide a proper equilibrium, the toroidal magnetic field lines must be twisted into the shape of a helix. In the tokamak device, invented in the Soviet Union, this twist is provided by inducing a toroidally directed current around the plasma ring. This current also serves to heat the plasma by the electric toaster method. An alternative approach, invented at the Princeton University Plasma Physics Laboratory, is the stellarator. In this device the helical twist of the magnetic field is caused by currents in helical windings outside the plasma ring. Still other toroidal magnetic bottles use currents flowing in solid rings that are inside a hollow plasma ring, or employ circulating beams of high-energy electrons. The tokamak and stellarator, however, are generally considered the most practical approaches to a first-generation toroidal fusion reactor.

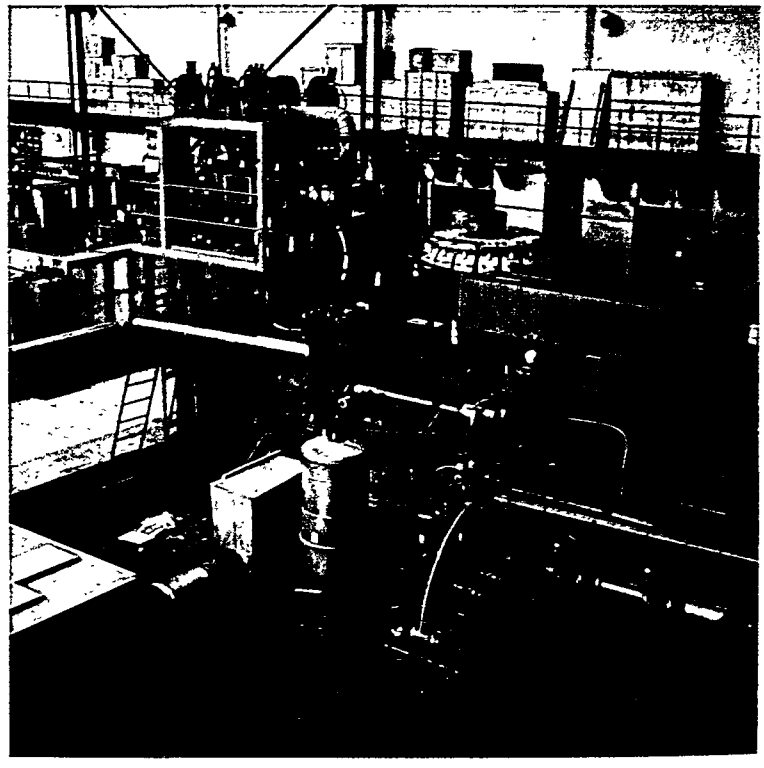
How do toruses fare in respect to MHD stability of the plasma? As in mirror machines there is a tendency toward flute instability. Even worse is the MHD "kink" mode, in which the whole plasma column buckles



Courtesy, Plasma Physics Laboratory, Princeton University

The ST tokamak at the Princeton University Plasma Physics Laboratory has been one of the most successful toroidal confinement machines. Electron temperature is measured by the scattering of ruby laser light from the plasma.

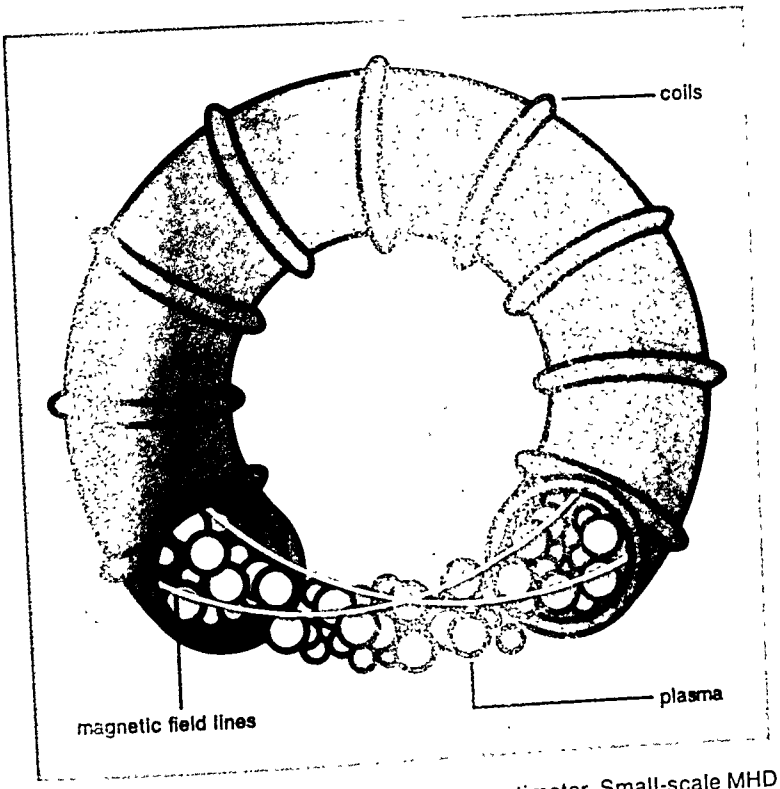
Sovfoto



The T-3 tokamak at the Kurchatov Institute in Moscow provided the first breakthrough to high temperatures and long confinement times in toroidal machines. Its magnetic field strength is 35,000 gauss, and currents up to 200,000 amperes are induced in the plasma.

in the form of a helix. The kink mode occurs when the plasma current of a torus is made too large. Stability against the kink mode is one of the advantages of the tokamak relative to the "pinch," a similar toroidal magnetic bottle with a much larger plasma current.

Experimental research directed toward a toroidal reactor began mainly with devices of the pinch type, during the early 1950s. The "pinch effect" is the name given to the magnetic self-constriction of conductors through which large currents are passed. (Evidence of pinching can sometimes be seen even on solid metal lightning rods that have been hit by large strokes.) High-current pulses of short duration, typically 100,000 amperes for several microseconds, were passed through straight plasma columns between two electrodes; or through toroidal plasmas by transformer induction the long way around the torus. In this way thin plasma columns at about 1,000,000° with densities of 10^{16} per cubic centimeter or more were readily produced; but these plasmas were highly unstable against kink and flute modes—just as predicted by MHD theory—and were lost typically in less than a microsecond. Following the prescriptions of the stability theory, a longitudinal (toroidal) magnetic field component was then added to stabilize the grossest MHD modes. This approach proved successful, notably in the large toroidal Zeta device at the Atomic Energy Research Establishment, Harwell, Eng., where plasma confinement times of about a millisecond were achieved at temperatures of 1,000,000°–



A tokamak uses a toroidal magnetic field generated by external coils. The field lines are twisted somewhat by a poloidal magnetic field component generated by a plasma current that circulates the long way around the torus.

2,000,000° and densities of 10^{14} per cubic centimeter. Small-scale MHD modes and other loss mechanisms, however, dominated the confinement time and presented an effective barrier to the achievement of higher temperatures.

During the 1950s grossly MHD-stable plasma confinement in tokamaks and stellarators was also demonstrated at the Kurchatov Institute and at the Princeton Plasma Physics Laboratory, respectively. Plasmas with temperatures of 100,000°–1,000,000° and densities of 10^{13}–10^{14} per cubic centimeter were produced by means of resistive heating currents. As in Zeta, unstable plasma fluctuations were found to persist in grossly MHD-stable regimes, and plasma confinement times were unexpectedly short. After several years of studying confinement times at the large Model C stellarator at Princeton, researchers found that all the data could be fitted, not by the predictions of classical theory but by a far more pessimistic empirical formula predicted in the late 1940s by David Bohm, on the basis of low-temperature plasma studies. It then became apparent that, if the Bohm formula continued to hold, there was no possibility of building a toroidal fusion reactor.

Later investigations revealed that, as in the case of mirror machines, the shortened confinement times resulted from the loss of plasma due to microinstabilities. In toroidal plasmas these electrical disturbances serve to transport plasma across the magnetic field rather than knocking it out the ends, as they do in a mirror machine. An important distinc-

tive feature turned out to be that microinstabilities in toruses are most severe when the plasma particles collide very often—that is to say, in very cold, dense plasmas. On this basis, it was theoretically predicted about 1965 that higher-temperature plasmas should show much longer confinement than that given by the Bohm formula—if only one could ever break through to higher temperatures.

The greatly encouraging experimental development in the period 1965–70 was that this prediction was, in fact, correct. The most exciting results were obtained on the T-3 tokamak at the Kurchatov Institute, a device with a plasma sufficiently large to permit electron temperatures above 10,000,000° to be reached by Ohmic heating when the plasma was at a density of 10^{13}–10^{14} per cubic centimeter. Confinement times of about 20 milliseconds obtained at this record temperature were approximately 30 times better than the Bohm value, and were still rising with temperature in approximate agreement with classical diffusion theory. These remarkable results were repeated and confirmed on the ST tokamak at Princeton, a modification of Model C.

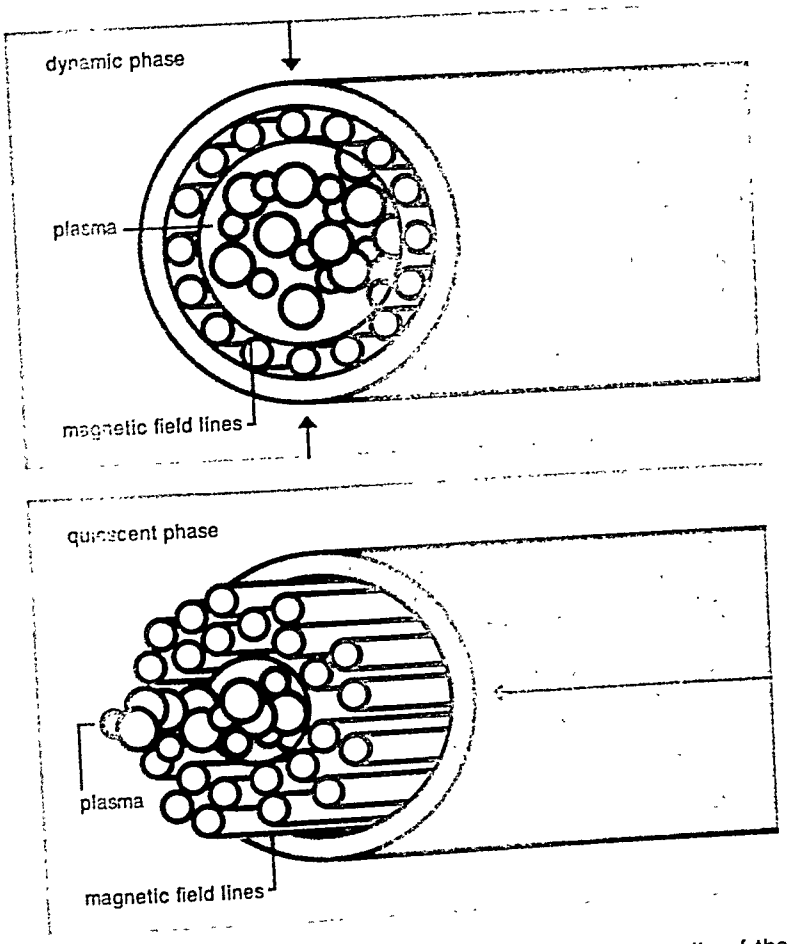
At present, larger tokamaks and stellarators are being constructed in many countries, including the Soviet Union, the United States, and Great Britain, to take advantage of the improved behavior of high-temperature plasmas. The tokamak is a relatively simple and inexpensive device, and is therefore favored for the initial approach toward developing toroidal reactors. The stellarator, on the other hand, has possible long-range advantages, such as for the confinement of high-pressure plasmas.

An important remaining technical problem is to demonstrate the heating of the plasma ions from their present typical temperature of about 5,000,000° to the required temperature of 100,000,000°. Plasma confinement times also still need to be raised to about a second, but scientists expect that this approximately hundredfold increase would be contributed automatically by the roughly tenfold increase in plasma radius when going from present experiments to the toroidal reactor regime. This is because plasma leakage from a torus takes place by diffusion, and so the loss times increase characteristically with the square of the plasma size.

High-density plasma experiments

High plasma density is advantageous in allowing appreciable fusion reactions to be produced in relatively small and simple experiments. In the "low-density" mirror and toroidal experiments described in the preceding sections, the thermonuclear neutron yields obtained from deuterium plasmas seldom exceeded 10^5 neutrons during any one plasma confinement time. From experiments with very dense plasmas, much larger neutron yields were obtained, even though the plasma confinement times were in the microsecond range, or below.

Initial high-density experiments were conducted during the 1950s with plasma pinches (as mentioned above). A pulsed current was passed axially between two electrodes, and the resultant azimuthal



In the linear theta pinch a strong axial magnetic field is pulsed on, compressing the plasma dynamically. The shock-heated and compressed plasma then escapes out the ends.

magnetic field caused dynamic self-constriction—"pinching"—of the current-carrying plasma. Temperatures of a few million degrees were generated by the shock-wave and compression associated with the pinching. During the 1960s the axial, or z-pinch, technique was refined in the form of the "plasma focus" by groups at the Kurchatov Institute, the Los Alamos Scientific Laboratory, and elsewhere. Their work made it possible to produce a constriction a few millimeters in size in a z-pinch current channel in which plasmas of 10^{19} per cubic centimeter densities are heated to some tens of millions of degrees temperature during times of a tenth of a microsecond. The neutron yields achieved by this method in deuterium plasmas exceeded 10^{11} per discharge. The plasma focus constitutes a neutron source of significant practical interest, but it could not be scaled up straightforwardly into an economical fusion reactor.

A second line of development starting from the original z-pinch is the theta pinch, in which a strong azimuthal plasma current is induced on the surface of a plasma cylinder by means of a pulsed axial magnetic field. In the Scylla I-IV experimental series at Los Alamos, N.M., plasma cylinders several meters long and about a centimeter in radius

Courtesy, Lawrence Livermore Laboratory

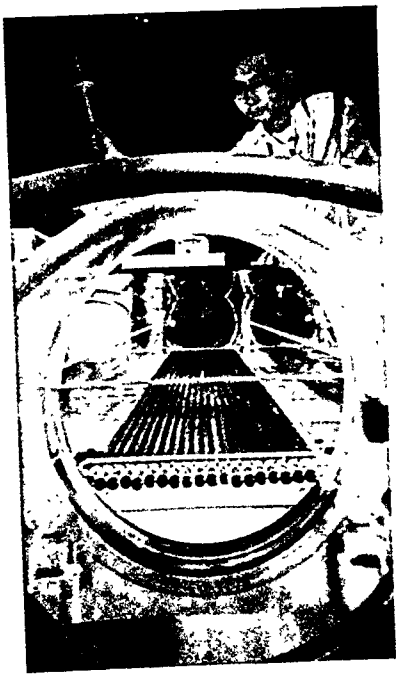


Possibility of direct conversion of plasma kinetic energy to electric energy is demonstrated with 20,000 eV ion beam. In experiments at Lawrence Livermore Laboratory, a conversion efficiency of 96% was achieved. This technique is especially useful in recapturing the energy of end-loss particles in mirror machines.

were heated by shock waves and magnetic compression to temperatures as high as 50,000,000° at densities of 10^{16}–10^{17} per cubic centimeter. The plasma pressure in these straight magnetic bottles is almost as large as the pressure of the 100,000-gauss magnetic fields. Neutron yields of 10^9 per discharge were typically obtained from deuterium plasmas in these experiments. Similar tests were carried out in West Germany and the United Kingdom. The plasma confinement times were limited typically to a few microseconds by the free expansion of the plasma in the direction along the magnetic field. (As a result of the high plasma density, the scattering rate is too high to permit long-time mirror-type confinement.) During the available confinement time there has been no sign of microinstability or anomalous diffusion. The theta-pinch approach could be applied to a reactor in several ways. A straight plasma column some kilometers in length would have a sufficiently long plasma end-loss time to allow the production of power. A more practical approach, pursued under the name Scyllac at Los Alamos, was to bend the linear theta-pinch into a stellarator-like torus of large major radius, thus eliminating the plasma end-loss altogether. The main drawback to this method is that the curved

magnetic field of a torus tends to induce MHD instability in high-pressure plasmas.

The highest densities of hot plasma were being obtained not with pulsed magnetic fields but by heating solid or liquid matter with highly focused external energy sources. High-powered lasers were particularly useful for this purpose. A single neodymium glass laser system could in less than 10^{-9} seconds produce an infrared light pulse of about 1,000 joules focused on a millimeter target. When a solid pellet (of about 10^{23} per cubic centimeter density) is used as the target, the resultant dense plasma absorbs this incident light pulse with high efficiency within a submillimeter surface layer. The resultant plasma has far too high a pressure to be confined by technologically feasible magnetic bottles (at field strengths below a megagauss) and thus expands at thermal velocity. Fusion-oriented research on laser heating is being carried on vigorously in the United States, the Soviet Union, and France. Neutron yields exceeding 10^5 were reported from deuterium targets. If the target can be precompressed by shock waves to densities higher than those of normal solids, the laser-heating task is evidently facilitated. The technical problems of adapting the laser system to the large-scale production of economical fusion power, however, are considered to be inherently severe.



Carbon dioxide laser is used in fusion research at the Lawrence Livermore Laboratory. The laser has a maximum energy of 100 joules.

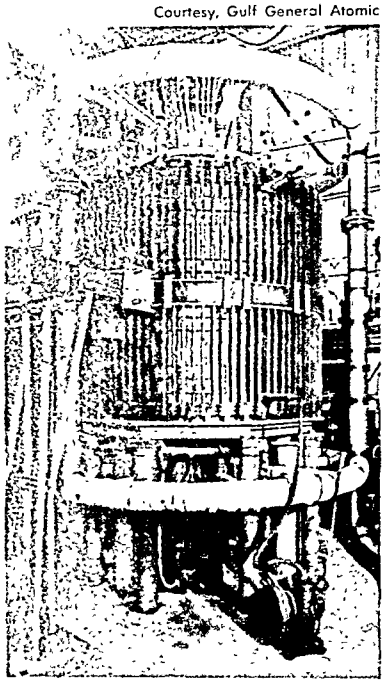
Engineering aspects

Since substantial experimental progress toward the attainment of the Lawson criterion is being achieved along a number of technologically quite different routes, the fusion reactor designs now being envisaged and the practical functions toward which these designs are aimed are correspondingly diverse. The moderate-pressure toroidal deuterium-tritium reactor will serve here as a representative example of the engineering problems involved.

The deuterium-tritium reaction produces a neutron of 14.1 MeV energy and an alpha particle (helium 4 ion) of 3.5 MeV. The tritium consumed in a fusion reactor must be regenerated, since tritium, unlike deuterium, occurs naturally only in minute amounts. (It decays with a half-life of 12.4 years.) The 14.1 MeV neutron is stopped in a blanket surrounding the plasma volume; the blanket is made up largely of lithium, in which the incident neutrons breed tritium by nuclear reactions. A blanket of liquid lithium or molten lithium salts is suitable for the breeding purpose as well as for the removal of the heat generated by the energetic neutrons and their secondary reactions. Breeding ratios of 1.3 tritium atoms per incident neutron are readily obtained. The generated heat can be removed from the blanket at a temperature in the range 500°–1,000° and used to drive a conventional thermal power plant. The lithium blanket should be about two meters in thickness to prevent any appreciable neutron flux from reaching the magnet coils, which surround the blanket.

The first fusion reactor plans, proposed during the early 1950s, had to divert a substantial fraction of the electrical power output to energize

Courtesy, Gulf General Atomic



The Doublet II device at Gulf General Atomic is a tokamak with a vertically elongated cross section. This is designed to permit stable confinement of very high-pressure tokamak plasmas.

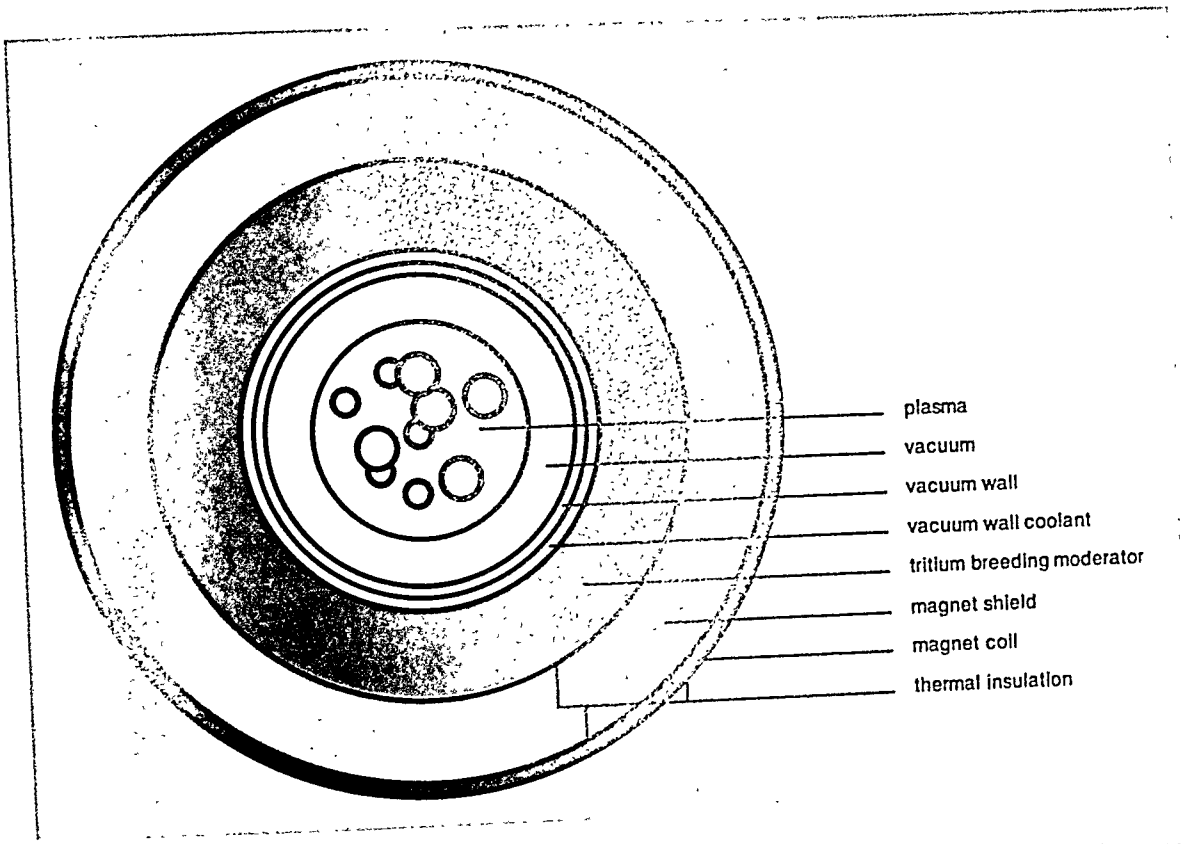
the magnet coil system of the magnetic bottle. However, the subsequent development of superconducting magnets with high field strengths conveniently removed this requirement. Magnetic field strengths of 50–150 kilogauss produced by superconducting coils are generally envisaged in present reactor designs. A large fraction of the fusion reactor capital cost is connected with the magnetic coil system and the blanket. In reactors designed to operate most economically the minor radius of the plasma should be at least comparable with the blanket thickness; that is, about two meters. The corresponding major radius is 5–10 meters. Such a reactor, given the plasma size, the maximum available magnetic field strength, and the maximum possible ratio of plasma pressure to magnetic field pressure (typically 0.05–0.10, for MHD stability), would provide a total electrical power output in the range of 1–3 kilomegawatts, enough to sustain a population of about two million. This is a practical size for modern power stations. The neutron flux through the vacuum chamber surrounding the plasma must not exceed about 10 megawatts per square meter of wall in order to avoid excessive rates of radiation damage.

In order to start up a fusion reactor, a plasma heating energy investment of about a hundred megajoules is required. Thereafter, the plasma "ignites": its temperature is maintained or increased further by the 3.5 MeV alpha particles of the deuterium-tritium reaction, which are trapped in the magnetic bottle. The principal process of plasma energy loss is expected to be the diffusion of hot particles. The earliest reactors will probably operate in a slow pulsed mode, burning the fuel as it leaks out and then beginning a new plasma heating cycle. The problem of true steady-state operation with continuous fuel injection appears more difficult, but can be solved in principle.

The basic fuel, deuterium, can be extracted from water at a price less than a thousandth of the present-day cost of electrical power. The dominant cost of fusion power will be due to the capital investment in the reactor, and is estimated to be competitive with the cost of both conventional and nuclear fission power. The earth's supply of deuterium would be sufficient for more than 10^{13} years at the present world rate of energy consumption. The known and probable land reserves of lithium would suffice for only about 10^4 years at this rate, but 1,000 times more lithium could be extracted from sea water.

The environmental aspects of fusion power are favorable. The amount of fuel present in the plasma is only a few grams, and there is no way in which a nuclear explosion could occur. The only radioactive element or product of the fuel cycle is tritium, which is not a waste product but a valuable fuel to be recycled. Activated structural materials, particularly the vacuum wall of the plasma chamber, are expected to constitute the only radioactive waste. The overall biological hazard potential is estimated to be sufficiently low so that in the long run it may be possible to locate fusion reactors close to population centers and utilize the waste heat from the thermal plant.

One of the most attractive features of fusion power is that even its



Schematic representation of the minor cross section of a toroidal fusion reactor. The typical minor diameter of the magnet coil is 5–10 meters.

remaining environmental defects are all of a kind that can be improved upon by future technology. With advances in fusion reactor design and size, purely deuterium-burning reactors should come into the range of economic usefulness. The problems of lithium consumption, tritium handling, and radioactive waste disposal would then be further reduced. Even the problem of waste heat becomes tractable, since a large fraction of the reactor power can be obtained in the form of charged reaction products and converted directly into electrical power.





Nutrition and the American Diet

by David Perlman

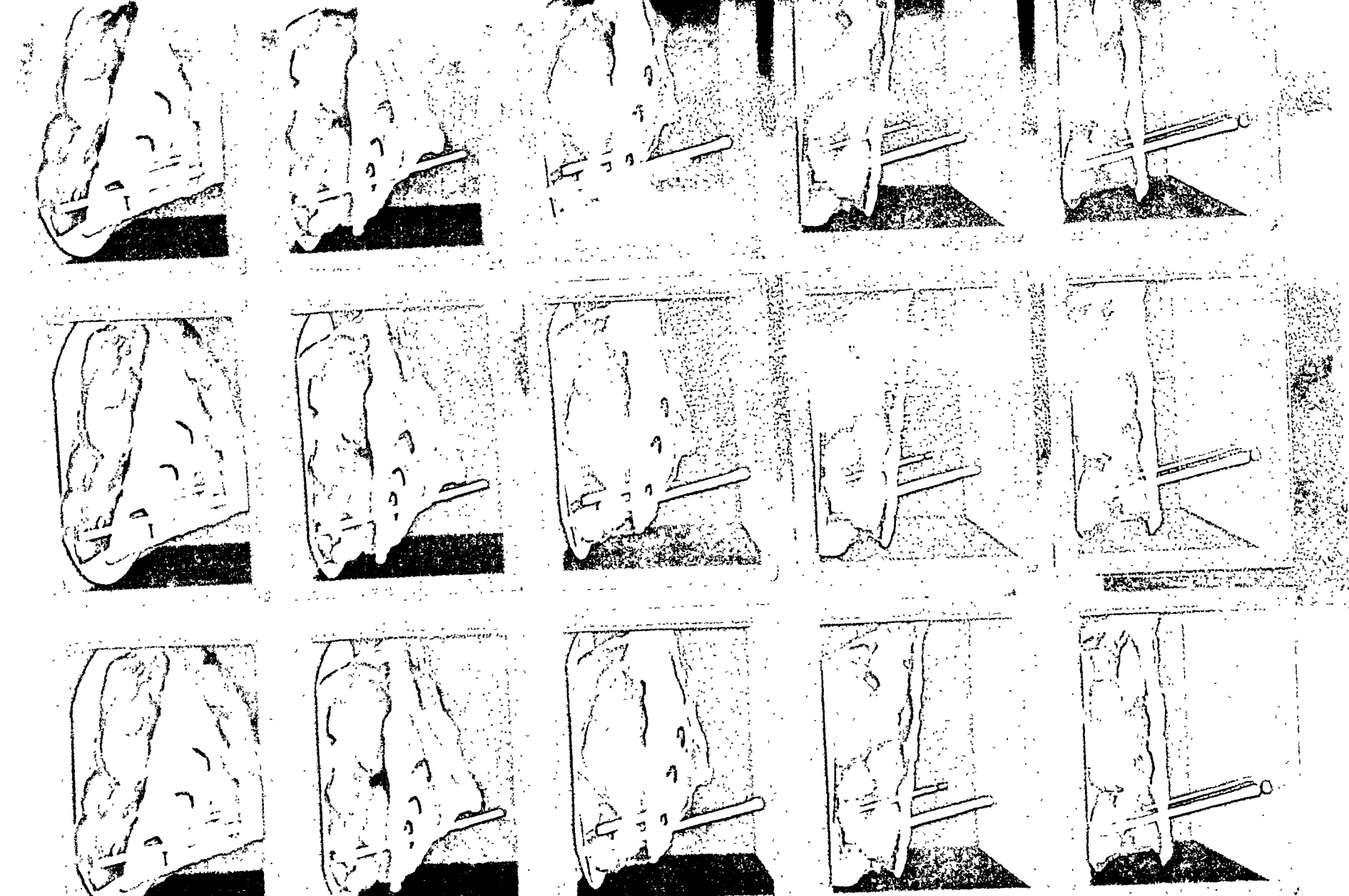
A "national disaster . . . something I would not feed to my cat or dog" was the way a leading nutritionist described the diet of the average American in 1972. A possible sign of change was the growing enthusiasm for organic health foods.

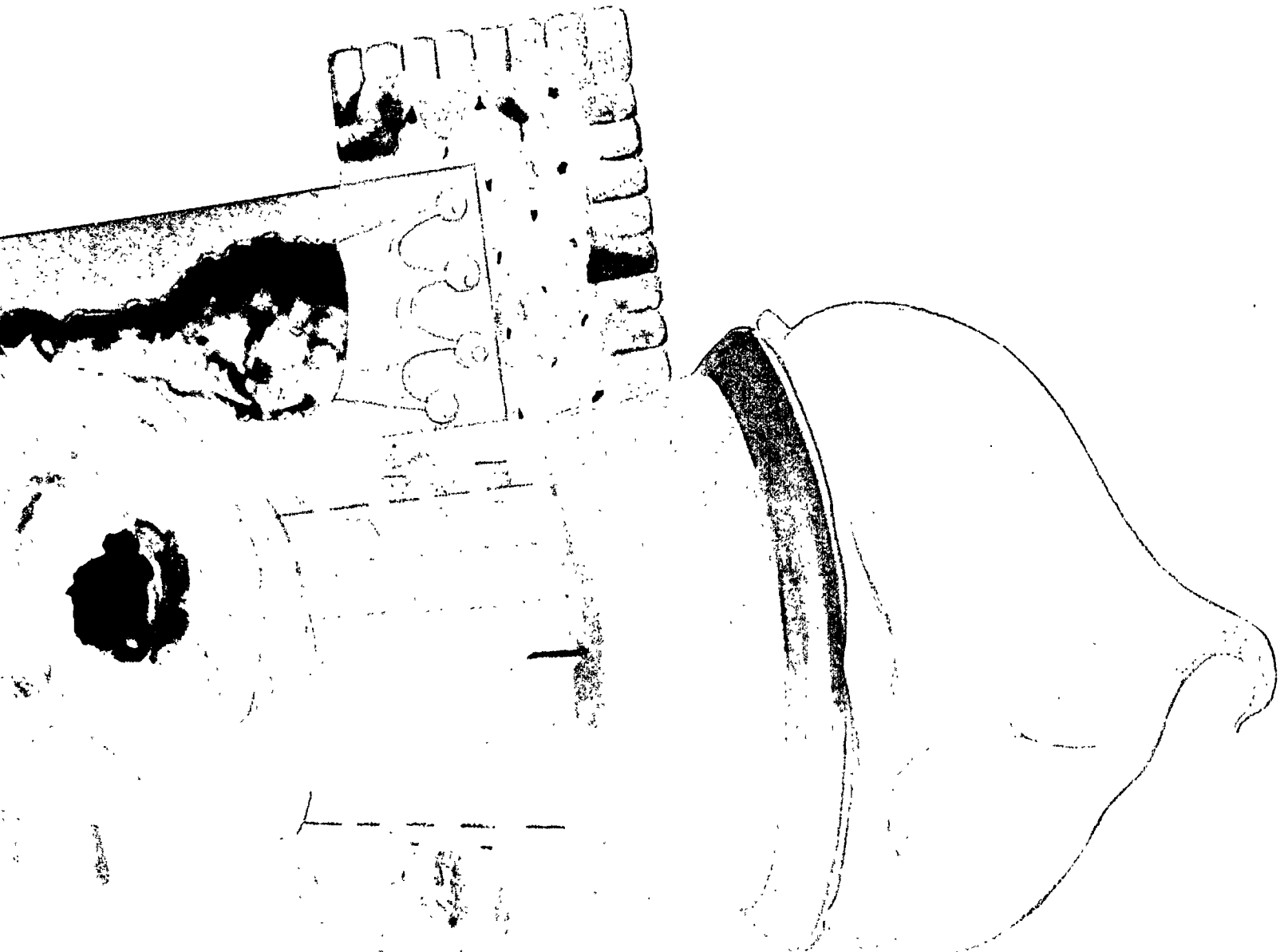


No subject in science generates more widespread popular concern than human nutrition. This is true not only in the poor, less developed countries of Asia and Africa but also in the United States and Western Europe. Among Americans, pockets of poverty produce genuine hunger and illness, infant mortality, and progressively disabling gaps in school performance. The more affluent struggle against obesity and worry about the insatiable appetites of youngsters who consume "empty calorie" snacks by the ton while ignoring all rational advice about vitamins, minerals, and adequate protein. The counter-culture fixes on the most bizarre of diets: fruit, fasting, or the brown rice of macrobiotics. At the same time, the businessman flirts with the "drinking man's diet" or battles his cholesterol level with safflower margarine, while the housewife curbs her appetite with amphetamines and "nourishes" herself with vitamin pills.









All of us put food into our bodies, and to many it becomes a mystique, a symbol, a cure, a preoccupation. Only rarely is it a guilt-free pleasure.

Science has made great strides in understanding the role that nutrients can play in keeping man healthy. The laboratory has produced valuable enrichments and fortifications for major items in the daily diet, as well as processed snack foods and advertised edibles that offer little nutrition at excessive cost. The laboratory can produce an imitation whipped cream with no food value at all, and textured soy proteins so valuable they may work a revolution in feeding the hungry. Agricultural science breeds steers with meat so well-marbled it is unhealthily rich in heart-endangering fats, but the same science breeds new high-lysine corn strains that will add critically important amino acids to meager peasant diets abroad.

A growing consumer movement in the United States demands stricter regulation of food additives, more explicit labeling of ingredients, and improved nutrition values in the marketplace. Yet millions of Americans eat fewer and fewer home-prepared "balanced" meals, while sales of pizzas, hamburgers, fried chicken, and fish-and-chips soar in the more than 30,000 franchised "fast food" outlets that crowd U.S. highways and shopping centers.

DAVID PERLMAN, *science editor for the San Francisco Chronicle, has been president of the National Association of Science Writers and is a member of the Council for the Advancement of Science Writing*

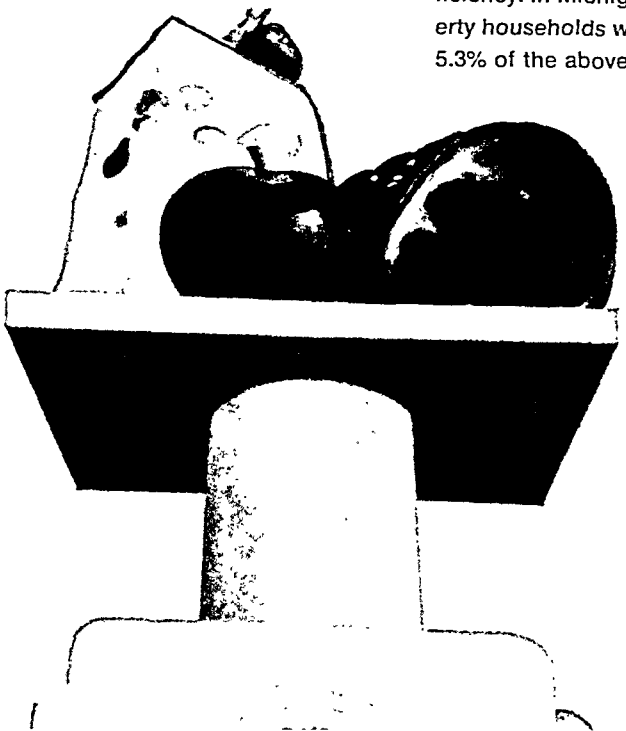


Malnutrition in the United States

America's food consumption is more abundant and more varied than that of any other nation, yet malnutrition is surprisingly widespread. Hunger and serious dietary deficiencies among the poor have made headlines in recent years; less well-known are the nutritional inadequacies of the nonpoor.

The U.S. Department of Health, Education, and Welfare, for example, completed in 1971 a detailed nutrition survey in 30,000 American homes of all income levels in 10 states. While nearly 8% of the families with incomes below the poverty level showed undesirably low intakes of two or more important nutrients, 2.5% of the nonpoor families had similar inadequate diets. Deficiencies in iron, vitamin A, vitamin C, proteins, and calories were common. Approximately 25% of the poor and 12% of the nonpoor families were not receiving enough iron; vitamin A was low in 8.5% of the poor and 7.5% of the nonpoor; and vitamin C was inadequate in 7.2% of the poor and 4.3% of the nonpoor.

In a report to the U.S. Congress, the National Center for Disease Control reported even more startling figures from individual states. About 21% of the low-income families it surveyed in Texas—whether below or above the recognized poverty level—had diets that provided less than half the officially recommended calories. In New York 13% of the poverty families and 9% of the above-poverty families were equally undernourished. In Michigan 17% of the poverty group were eating less than half the recommended calorie allowance, and 10% of the above-poverty group had the same inadequate diet. Protein deficiencies were also striking: 10% of all the Texas families were consuming less than half the protein they needed. In New York severe protein deficiency was found in the diet of 11% of the poverty families, although less than 3% of the somewhat more affluent families showed the same protein deficiency. In Michigan the difference was much smaller: 5.9% of the poverty households were eating less than half the protein they needed, and 5.3% of the above-poverty families were similarly malnourished.



George M. Briggs, a professor at the University of California's department of nutritional sciences at Berkeley has called the American diet a "national disaster," and insists that its deficiencies cost the public at least $30 billion a year in medical bills. "The costs of malnutrition are far greater than the cost of crime in our country," he says.

Briggs recently computed the quantities of foods that average Americans eat each year. Calculating them on a "dry weight" basis—to eliminate the essential but nutritionally valueless water content of various foods—he found this evidence for distorted nutrition:

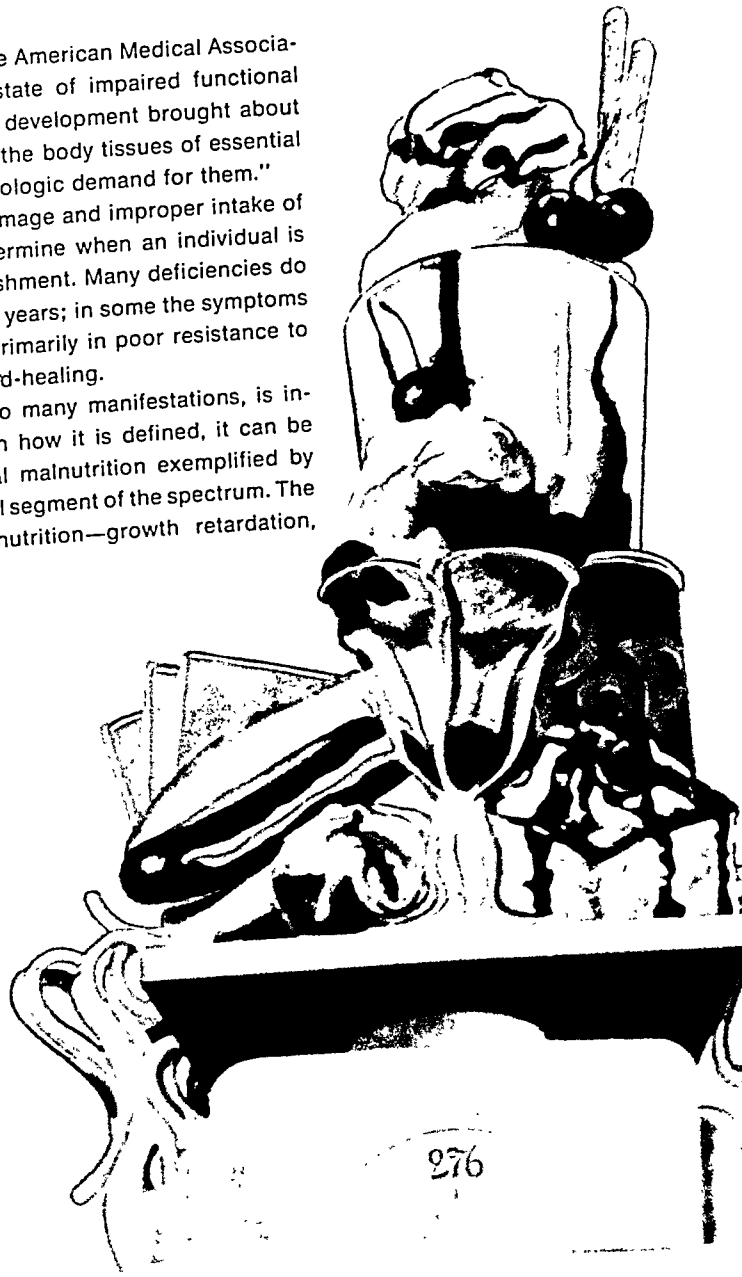
Americans eat an average of 259 pounds per person per year of fruits, vegetables, whole cereals, meats, dairy products, and legumes, while at the same time, he said, the average diet also contains 276 pounds of sugar, white flour, fats, and polished rice. "This is a terrible diet," Briggs said. "I wouldn't feed it to my cat or dog, let alone a farm animal."

What is malnutrition?

The Council on Foods and Nutrition of the American Medical Association (AMA) defines malnutrition as "a state of impaired functional ability or deficient structural integrity or development brought about by a discrepancy between the supply to the body tissues of essential nutrients and calories and the specific biologic demand for them."

This definition includes both bodily damage and improper intake of nutrients. It is difficult, however, to determine when an individual is suffering from the effects of poor nourishment. Many deficiencies do not demonstrate their consequences for years; in some the symptoms are obscure and manifest themselves primarily in poor resistance to disease or infection, or in delayed wound-healing.

"Malnutrition, because it can have so many manifestations, is insidious," says the AMA. "Depending on how it is defined, it can be found under many situations. Classical malnutrition exemplified by vitamin deficiency diseases is but a small segment of the spectrum. The less dramatic manifestations of malnutrition—growth retardation,



weight loss, increased burden of chronic diseases, depression, weakness, retarded convalescence from disease and trauma, poor performance in pregnancy—are widespread and of great significance. Infections in the undernourished are more devastating, persist longer, and result in a much higher death rate in malnourished children."

Since the White House Conference on Food, Nutrition, and Health in 1969, the U.S. government has moved more aggressively into the dietary picture. The Department of Agriculture distributed 1.3 billion pounds of surplus food to 3.6 million American poor people in 1971, and by early 1972, 11.2 million people were receiving government food stamps to increase their purchasing power. The food distributed by the government was fortified and balanced to include all the recommended levels of protein, minerals, and vitamins. Also by early 1972 the federal school lunch program covered more than 25 million children, of whom 8.1 million received their lunches free or at reduced prices.

The U.S. Food and Drug Administration (FDA) proposed new labeling rules requiring clearer identification of the nutrient content of processed foods. The FDA also proposed that even frozen TV dinners be required to contain at least one-third of the recommended daily nutrient allowances if they were advertised as complete meals. Scientists in the laboratories of the FDA, the Department of Agriculture, and industry all experimented with fortifying more foods, creating new foods richer in essential nutrients, and developing new products from protein sources as disparate as soybeans, fishmeal, algae, and bacteria.

Determining proper nutrition

What is proper nutrition? Almost any reasonably educated American thinks he knows the answer to this question, and many probably do. Yet the lures of suggestive advertising, the diet fads and phobias, and the confusing display of 7,800 different items for sale in the average supermarket all combine to distort eating habits among even the most affluent, and to warp wholesome nutrition patterns for everyone.

Fredrick J. Stare, the chairman of Harvard University's department of nutrition, says, "The one and only 'magic formula' for healthful eating lies in the variety of foods eaten and in not eating too much." Stare and his colleagues listed four basic food groups:

1. Dairy products—milk, cheese, ice cream, yogurt, and other foods made from milk.
2. Meat and other high-protein sources such as fish, poultry, eggs, cheese, dried beans and peas, and nuts.
3. Cereal products—enriched and whole-grain cereals of varying types.
4. Vegetables and fruits.

These four groups of foods, according to Stare, can provide all the nutrients known to be essential to man, plus a host of trace elements whose dietary role in tiny quantities is still being explored.

In the United States a group of scientists make up the Food and Nutrition Board, which is sponsored by the National Academy of Sciences-National Research Council and is responsible for setting

basic standards for the public's daily nutrient needs. These standards, called the Recommended Dietary Allowances, or RDA, are published every five years. The newest RDA list, compiled under the chairmanship of Harvard's D. Mark Hegsted, was scheduled to be published in 1973. Like the current tables, it will include recommendations for men, women, infants, and children and for pregnant and nursing mothers.

The basic document lists appropriate allowances of calories and protein, and of the known essential vitamins and minerals. The vitamins include A, D, E, and C, and the B-complex group of folacin, niacin, riboflavin, thiamine, B_6, and B_{12}. The minerals in the RDAs include calcium, phosphorus, iodine, iron, and magnesium. Other minerals that must be present in trace amounts in the diet—millionths to thousandths of a gram per day—include chromium, selenium, fluoride, molybdenum, copper, zinc, and manganese. Evidence is growing that tin, nickel, and vanadium are also essential trace minerals.

Setting allowances for these nutrients is a difficult task, and scientists by no means agree on appropriate levels. For in nutrition research, animal experiments are almost the only way of developing precise information. A rat, or a chick, or even a monkey can be deprived of a given nutrient, and the effects of the deprivation may then be closely measured as a decrease in stature, a swift onset of deficiency disease, or an alteration in blood levels of the nutrient's metabolites. But the applicability of these results to man is uncertain, and it is obvious that most human experiments to test the damaging effects of severe deficiencies are too dangerous to carry out fully even in volunteers. Studies of children and adults in malnourished families—among the American poor or the peoples of countries where starvation is endemic —can yield valuable information, but it is rarely precise.

There is ample evidence, for example, that thousands of children in the less developed countries go blind because their diets lack vitamin A. But how much vitamin A can safely be added to an average American's diet before toxic effects occur? Vitamin D can certainly prevent and cure rickets, although it is not needed at all where people receive adequate sunlight. But at what level can overenthusiastic fortification of foods with vitamin D lead to hypercalcemia and kidney problems?

Vitamin C deficiency is known to cause scurvy, and Capt. James Cook fed lime juice to his ship's crew in the 18th century to prevent the disease. Today a daily glass of orange juice, rich in vitamin C, is part of the American way of life for many. Because scientists have learned that excess amounts of vitamin C are normally discarded by the body, there is ordinarily little danger of overdosing.

A recent issue involving vitamin C is its relationship to the common cold. Can vitamin C in doses as large as several thousand milligrams prevent or cure colds, as Nobel laureate Linus Pauling claims? University of Maryland experimenters gave large doses (three grams a day) of vitamin C to a group of prisoner-volunteers and then inoculated them with cold virus (rhinovirus 44). The experimenters found no difference at all between the protective effect of the vitamin C and the

effect of placebos. Many other experiments also failed to prove Pauling's claims. "The . . . efficacy of vitamin C in the treatment of the common cold and other viral infections is still an open question," says Sheldon Margen, of the University of California's department of nutritional sciences at Berkeley. "However, I also believe that there is still inadequate evidence of its efficacy and safety and that—until further well-controlled, definitive studies are undertaken—advocating large doses of ascorbic acid [vitamin C] at this time is totally unwarranted."



Organic foods

Of all the recent trends in American nutrition, the most striking is the upsurge of interest in bizarre diets and so-called organic foods. To the true believer, organic foods are those grown without chemical fertilizers and without the use of chemicals to kill insect pests and weeds. If the organic products are processed, their natural nutrients must not be depleted—white flour, for example, is shunned—nor can the products contain additives.

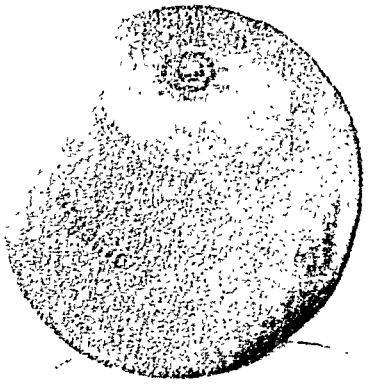
In this concern for purity and naturalness lies a deep suspicion that many of the achievements of contemporary science have added unknown hazards to the environment, and that more are being concealed. The suspicion is heightened by recurrent revelations: that chlorinated hydrocarbon pesticides can damage the eggshells of birds; that cyclamate sweeteners cause bladder tumors in rats; that monosodium glutamate, the widely used flavor-enhancer, causes brain damage in infant mice.

Some processed foods deepen this suspicion: William O. Caster, a researcher at the University of Georgia, tested the nutritional value of 38 commercial dry cereal products and found two brands that promoted excellent tissue growth when rats were fed exclusively on them. But he found 20 brands—including some of the most widely sold and promoted—that could not keep his rats alive at all, not even when he supplemented the packaged cereals with a complete mixture of vitamins and minerals.

When experiments like this become widely known, suspicion increases. A recent opinion survey commissioned by the food industry found widespread public distrust: 41% of the public expressed fears that the needs of food consumers were not being protected by government or industry in the marketplace.

So the preoccupation with organic and natural foods grows. And it is reinforced by deep psychological drives. Judd Marmor, clinical professor of psychiatry at the University of California at Los Angeles, says: "For all people, what goes into their mouths or into any part of their bodies is strongly associated with good and evil. 'Good' food is 'pure, clean, wholesome'; 'bad' food is 'impure, dirty, poisonous.' To eat well is to be secure, healthy, and happy. The converse means insecurity, starvation, and death."

The public's turn toward organic foods has been marked by a tremendous increase in the number of "health food" stores, and many supermarkets now carry lines of expensive organic products. Often the label "organic" means nothing at all: chemistry defines any matter containing carbon as organic, and this includes everything of plant and animal origin. Thus, it is possible to visit an apple cider plant, for example, and watch the two-pronged process: One batch of apple juice is filtered to a clear liquid and labeled as juice; another is unfiltered and labeled "organic." Both come from the same apple crop, from the same trees—fertilized, sprayed, yet wholesome nonetheless. But one costs far more than the other.



Diets

Far more dangerous than the interest in organic foods is the surge of extraordinary diets that has swept the country. Most are designed to attack obesity, but some aim at more profound changes: inner peace, spiritual growth, the cure of disease. Most range from useless to dangerous.

In the pursuit of slimness, Americans spend $100 million a year on reducing pills, diet books, special get-thin foods, and exercise machines. Jean Mayer, one of the world's foremost authorities on nutrition and overweight says:

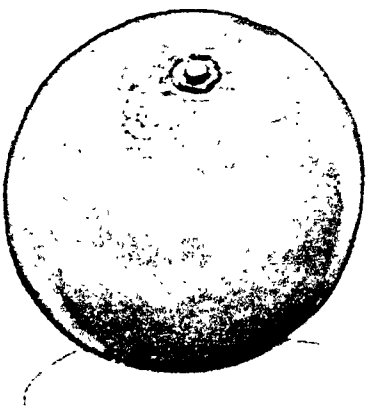
"The place for an obese person to obtain a reducing diet is the office of a physician . . . or a weight-reduction clinic which is applying sound nutritional principles under medical direction. What a good many people fail to recognize, however, is that no one particular diet is appropriate for everybody. Good but personally irrelevant diets and all quack diets would be forever ignored if each of us recognized the value of a varied diet, consisting of sufficient but not too much total content, tailored to individual needs."

Two of the most widely advertised reducing diets are the "Doctor's Quick Weight-Loss Diet" and the "Doctor's Quick Inches-Off Diet," both promoted by Irwin Stillman. The first emphasizes high protein and low carbohydrate intake, plus eight glasses of water a day. According to Philip L. White, director of the AMA's department of food and nutrition, the diet proposes a dangerously low level of carbohydrate consumption that can cause excessive protein breakdown and impair the maintenance of brain and nerve cells.

The "inches-off" diet involves cutting down drastically on protein, with the promise that the dieter can lose weight in specific parts of his body. "That's a complete fallacy," says White. "Even if it were true, this kind of diet would cause loss of muscle tissue as well as fat." And he adds: "In my judgment this diet can be extremely hazardous, because it is very low in protein. So low that it can in fact cause the dieter to lose protein from his own body, to use up muscle and organ tissue and generally weaken the body. Anyone who is already unhealthy because of organ damage—liver problems, kidney damage, heart disease, anemia—can be put in a very hazardous situation by further tissue depletion."

Nutritionists raise similar objections to most other diets that offer promises of dramatic weight reduction—banana diets, grapefruit diets, the "Air Force diet" that has nothing to do with the Air Force, and the "Mayo diet" that has nothing to do with the Mayo Clinic.

In a far different arena are the diets that promise to cure disease or enhance the spirit. By far the most dramatic of these is "Zen macrobiotics," a movement that calls itself "A return to natural living." The movement was founded by Georges Ohsawa, a Japanese philosopher and writer who died in 1966. Zen macrobiotics has little to do with Zen Buddhism—in fact, practicing Buddhists scoff at the diet and particularly at its claims of curing disease.



According to Ohsawa, modern medicine cannot cure cancer because doctors do not understand "the structure of the infinite universe." To Ohsawa "no illness is more simple to cure than cancer." His treatment: meditation plus a diet consisting of nothing but whole-grain cereals —unpolished brown rice, buckwheat wheat, corn, barley, or millet. For those of lesser faith, Ohsawa suggests the application of compresses made from ginger and yucca or taro root. Similarly, Zen macrobiotics prescribes whole-grain cereals and sesame salt for both high blood pressure and low blood pressure and whole-grain cereals plus soy sauce and raw eggs for heart disease

Basing its philosophy on the ancient Oriental concept of balance between opposing forces of yin (the female, passive principle) and yang (male, active), the cult of macrobiotics teaches that foods should be selected as nearly as possible to the mid-point between yin and yang. Cereals are closest to the ideal. Eggplant is extremely yin, while Japanese potatoes are extremely yang Beets and white cabbage are balanced. Snails and pheasant are at opposite extremes; yogurt and goat's milk, pineapples and apples are also extreme. Meats and all drugs are to be avoided.

In a typical macrobiotic breakfast, half the meal would be sauteed rolled oats, while the rest might include steamed carrots and soybean paste broth garnished with green onions. Lunch would be buckwheat noodles in broth, sauteed broccoli, and seaweed with soy sauce. Dinner might be whole brown rice, with beans, baked apple, and white soybean cheese. All this might seem absurd to most people—yet increasing thousands of young people are turning to variations of the macrobiotic diet, never recognizing its gross deficiencies.

Darla Erhard, a public health specialist in California, has worked with organic vegetarian communes and macrobiotic groups in an effort to make them understand some of the basic principles of nutrition. Fortunately, she found that in discussions with young people she could stress moderation and variety, and relate the essential amino acids of diet to the principles of yin and yang. She found that macrobiotic cooking, by emphasizing speed and sparing use of water, preserved most nutrients; and that at least some nutritional balance could be achieved by encouraging nutritious combinations of yin and yang in the selection of foods. Most young people experimenting with macrobiotics and other extreme diets, however, have little knowledge of true nutritional balance and reject such advice.

"Regardless of the underlying reasons or motives, however noble and sincere, the concepts proposed in Zen macrobiotics constitute a major public health problem and are dangerous to its adherents," says the AMA's Council on Foods and Nutrition. "Cases of scurvy, anemia, hypoproteinemia (wasting of body protein due to inadequate intake), hypocalcemia (decrease in body calcium), emaciation due to starvation, and other forms of malnutrition, in addition to loss of kidney function due to restricted fluid intake, have been reported, some of which have resulted in death."

According to Fredrick Stare: "There is nothing nutritionally wrong with vegetarian diets; they provide a variety of fruits and vegetables plus frequent use of legumes, particularly soybean products and nuts. Most vegetarians consume generous quantities of milk and eggs. Good vegetarian diets are very healthful." But to Stare the extremes of macrobiotics are "no more than an excursion into make-believe Oriental cultism . . . the most dangerous food fad around."

Nutrition and disease

Diet and disease are not linked in food fads alone; there is ample scientific evidence—and much scientific controversy—bearing on the relationship between what man eats and the illnesses he falls heir to.

Milk, the most nearly ideal food of all, can cause abdominal pain and diarrhea in many black children whose genes sometimes ordain a defect in the milk-digesting enzyme called lactase. In other children a genetic defect that prevents the breakdown of the amino acid phenylalanine is known as phenylketonuria, or PKU. Milk contains phenylalanine, and in PKU babies the penalty for milk-drinking is mental retardation. Milk-substitutes in their diet can prevent most of the brain damage if the disease is discovered early enough. Forty-three states now require PKU testing for all new-borns, and the tests discover 200 defective babies each year.

Far less clear are the relationships between diet and mental health, although evidence is strong that sound maternal nutrition before birth and adequate protein in early childhood are essential for full brain development. Some psychiatrists, such as Abram Hoffer of Saskatchewan, insist that schizophrenia is a vitamin deficiency disease, and that daily doses of the B vitamin niacin (nicotinamide or nicotinic acid) can prevent it. Linus Pauling, who coined the term "orthomolecular psychiatry," believes this too, but the vast majority of psychiatric professionals believe the evidence is tenuous if not delusional.

A new field for research is the possible relationship between diet and cancer. Denis P. Burkitt of the British Medical Research Council proposed recently that diets which are low in cellulose roughage—in other words, the typical refined-foods diets of highly industrialized Western nations—may be a major cause of cancer of the colon and rectum. This disease kills 46,000 Americans a year, and Burkitt contended that the cause may lie in the fact that refined foods move through the large intestine much more slowly than those containing roughage. Any cancer-causing elements, such as bacteria or obscure chemicals, would therefore have more time to initiate tumors in the colon before being excreted, Burkitt reasoned.

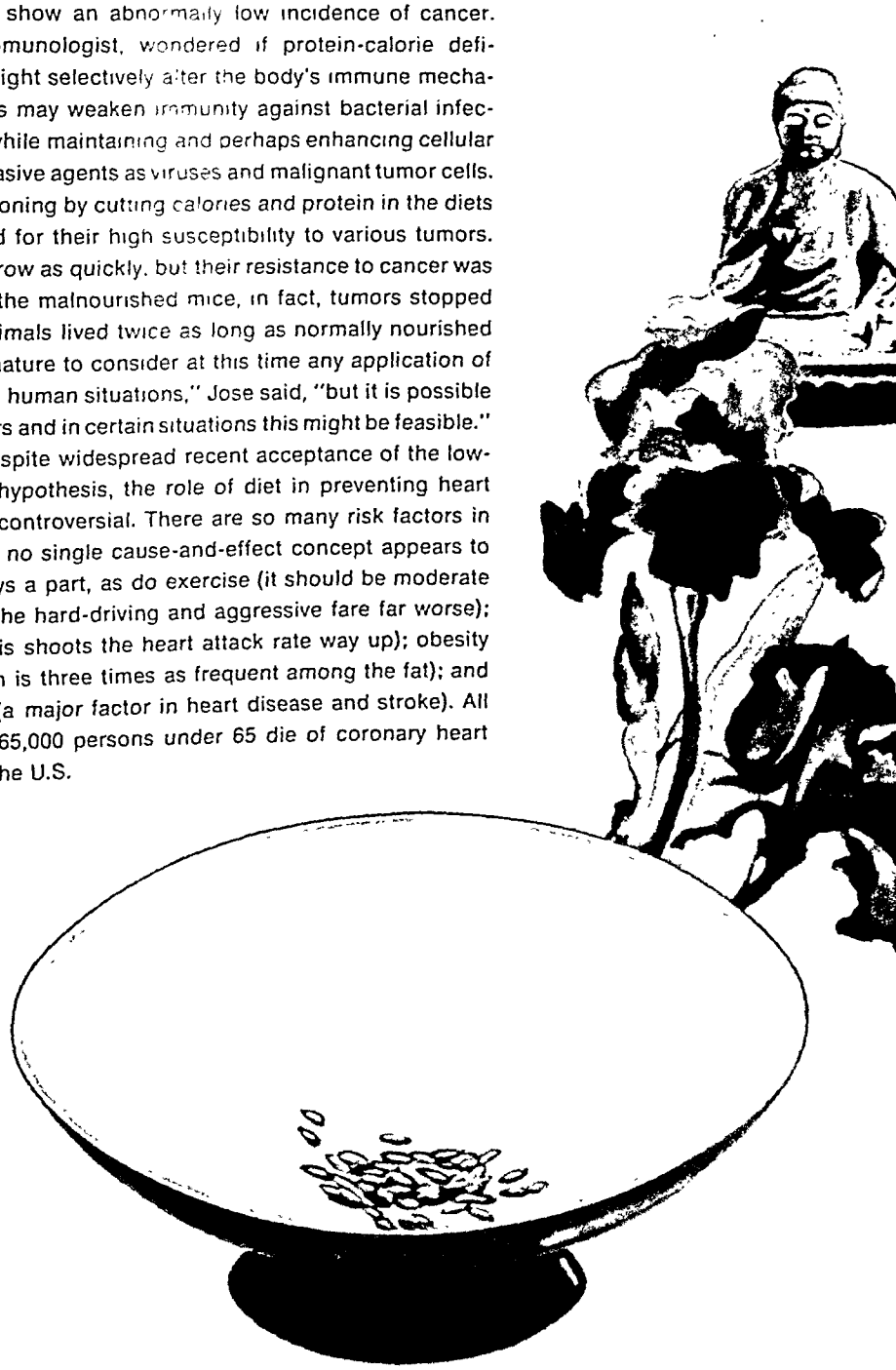
There is epidemiological evidence supporting this view. Corn-eating Bantu tribesmen in Africa have an exceptionally low incidence of colon cancer, and the incidence is eight times higher in Connecticut than in roughage-eating Cali, Colombia. Colon cancer is rare in China, but Chinese immigrants in Hawaii show rates approaching those of U.S. whites.

At present, this evidence only hints at an association, and H. Marvin Pollard, president of the American Cancer Society, warns against any changes in diet as a result of Burkitt's suggestion. "We don't really have much information on the relationship of high- and low-roughage diets and carcinoma of the colon," Pollard said as he urged a carefully controlled international study of the problem.

David G. Jose of the University of Minnesota was struck some years ago by the fact that although serious malnutrition is a major cause of infection and childhood death in Australian aborigines, these same malnourished people show an abnormally low incidence of cancer. Jose, a pediatric immunologist, wondered if protein-calorie deficiencies in the diet might selectively alter the body's immune mechanism. The deficiencies may weaken immunity against bacterial infection, Jose reasoned, while maintaining and perhaps enhancing cellular resistance to such invasive agents as viruses and malignant tumor cells.

Jose tested his reasoning by cutting calories and protein in the diets of rats and mice bred for their high susceptibility to various tumors. The animals did not grow as quickly, but their resistance to cancer was greatly increased. In the malnourished mice, in fact, tumors stopped spreading and the animals lived twice as long as normally nourished mice. "It's really premature to consider at this time any application of this type of therapy to human situations," Jose said, "but it is possible that with certain tumors and in certain situations this might be feasible."

In heart disease, despite widespread recent acceptance of the low-cholesterol, low-fats hypothesis, the role of diet in preventing heart attacks is still highly controversial. There are so many risk factors in coronary disease that no single cause-and-effect concept appears to be valid. Heredity plays a part, as do exercise (it should be moderate and regular); stress (the hard-driving and aggressive fare far worse); cigarette smoking (this shoots the heart attack rate way up); obesity (sudden cardiac death is three times as frequent among the fat); and high blood pressure (a major factor in heart disease and stroke). All told, approximately 165,000 persons under 65 die of coronary heart disease each year in the U.S.



The American Heart Association began urging diets low in the proportion of saturated fats in 1968. By 1971 most doctors were heeding the recommendations of the Inter-Society Commission for Heart Disease Resources, a group of 150 specialists from 29 leading health agencies appointed by the Department of Health, Education, and Welfare to evaluate the coronary controversies and to recommend action. The commission acknowledged that there is no conclusive proof yet that lowering fats and cholesterol in the diet will curb heart attacks. It did note that in every nation where custom or necessity dictates diets low in these elements the heart disease rate is likewise low.

In monkeys, the commission noted, the case against cholesterol has been proved experimentally; in man, Jeremiah Stamler of Chicago, one of the nation's most famed heart specialists, believes he has shown the same thing. The commission, therefore, recommended that overweight Americans reduce their caloric intake to slim down; that cholesterol in the average diet be cut in half from its present level of about 600 milligrams a day; and that dietary fats be limited to less than 35% of total calories, with only 10% coming from foods such as fatty meats, egg yolks, whole milk, butter and cheese, solid shortenings, pies, and doughnuts—all of which contain large amounts of saturated fats or cholesterol.

Significantly, the commission also made major recommendations to the government and the food industry for clearer labeling of the fat content of foods, and for the development of low-cholesterol dairy products, leaner livestock, and revision of the dietary content of school lunches and food allowances for the poor.

By 1972 some of these recommendations were being implemented: school lunch menus were changing, and the FDA was proposing that labels of processed foods be required to contain precise information as to the source of fat content—such as beef fat, cottonseed oil, and corn oil. Manufacturers would also be permitted to label foods with precise figures as to percentages of fat, the caloric content of average servings, and the proportion of unsaturated fats to total fats.

America's most intensive long-term study of heart disease has been conducted in Framingham, Mass., by the National Heart and Lung Institute. More than 5,000 of the community's residents have been checked and tested and followed closely since 1949. William B. Kannel, medical director of the Framingham project, says:

"The typical diet in North America gives every indication of being a contributor to our high atherosclerosis mortality. There is much indirect evidence that a diet too rich in saturated fat, cholesterol, sucrose, and calories is a prominent feature of our current life style contributing to the high death rate."

Like the Inter-Society Commission, Kannel is careful to qualify his conviction: "This is not to say that we have *direct* evidence that what a free-living person eats is, in fact, a major determinant of their blood lipid characteristics and whether they develop clinical atherosclerotic disease." Kannel acknowledges that most people would far rather take

bitter pills or do almost anything than change their diets, or get more exercise, or give up smoking. But he has a simple and practical suggestion, which is seconded by the American Heart Association:

"Until some modification of the national diet is finally agreed upon and implemented," Kannel says, "those interested in lowering their own blood cholesterol value can attempt this by low-fat cookery which emphasizes fish, poultry, and lean meats and by avoiding organ meats [liver, kidney, heart, etc.], butter, whole milk and fatty cholesterol-rich cheeses, with fruit substituting for artificially sweet desserts at the end of the meal. For persons with high serum cholesterol values, particularly those with associated hypertension, impaired glucose tolerance, obesity, and cigarette habit, this becomes a matter of some urgency."

The American diet today is certainly a rich one; far too many over-eat and eat wrongly. In poverty areas deficiencies of many kinds abound, yet malnutrition is also widespread among the affluent. Scientific knowledge can now point to a more rational diet for everyone, and as the American Medical Association's Council on Foods and Nutrition says:

"The cost of a massive attack upon hunger and malnutrition will be great in money; the cost of doing nothing will be immeasurable in terms of lost human potential and social unrest."

FOR ADDITIONAL READING:

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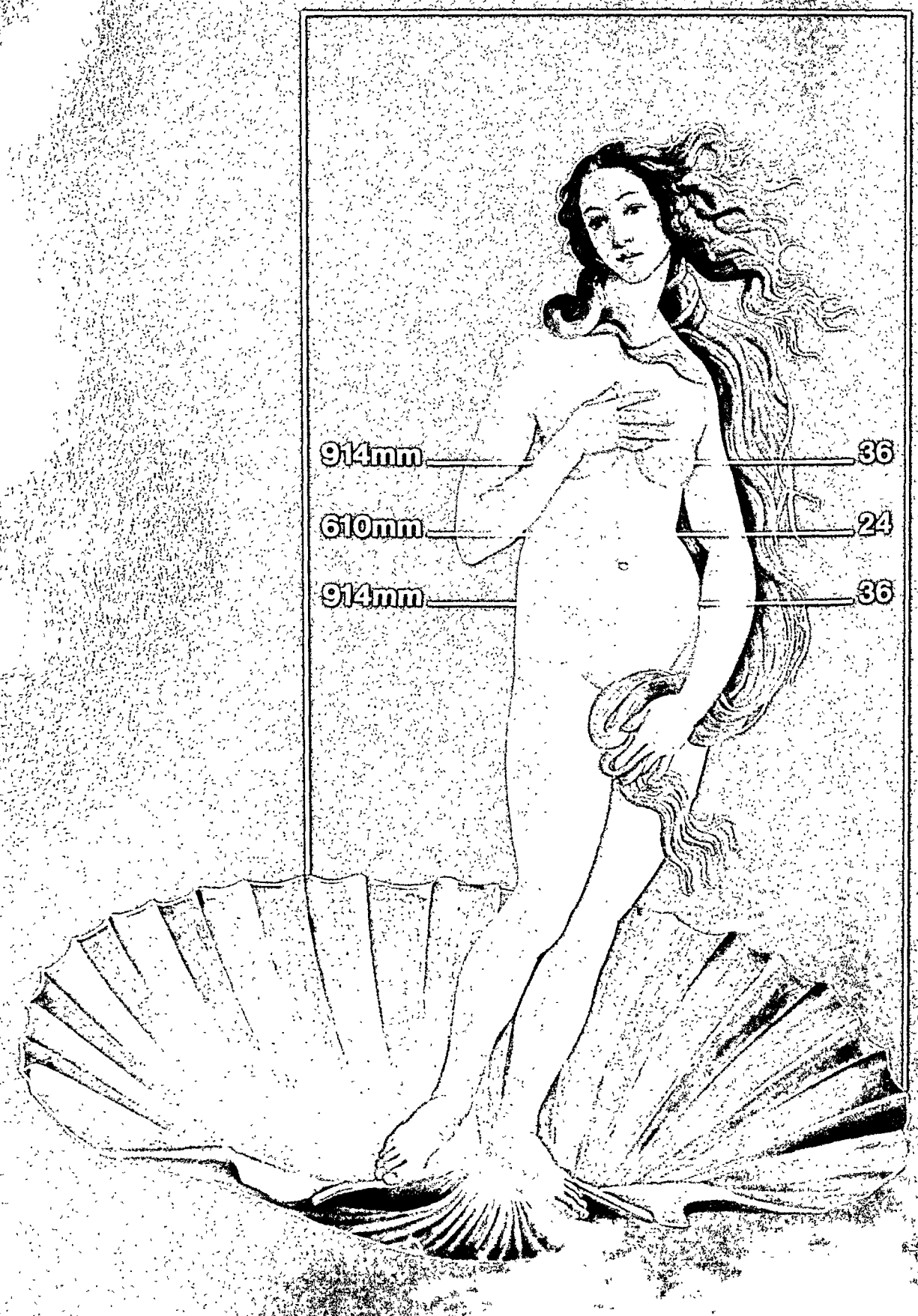
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914mm
36
610mm
24
914mm
36

Will the U.S. Go Metric?

by Lewis M. Branscomb

The United States remains one of the few holdouts in an increasingly metric world. Will the nation convert, and if so, how will we be affected?

In July 1971, U.S. Secretary of Commerce Maurice H. Stans sent to Congress a report entitled "A Metric America; A Decision Whose Time Has Come." He added his own recommendation "that the United States change to the international metric system deliberately and carefully." Thus opened what may be the final chapter in a 200-year-old debate over the measurement language to be used in America. Should the United States replace its familiar pints and pounds, inches, feet, and miles with liters, kilograms, meters, and kilometers? The decision is up to Congress, but before the decision is made, many voices will be raised in public debate over an issue that has defied clear-cut resolution for the nation's entire history.

Thomas Jefferson first proposed a decimalized system of measurement in 1790. Thus the young American nation faced the difficult question of whether to establish formally the British system of weights and measures, or to adopt a new system such as Jefferson's or the metric system adopted by France in 1795.

The Constitution (Art. I, Sec. 8) authorized Congress to "fix the standard of weights and measures." President George Washington asked Congress in 1790 to address its responsibilities in this area, saying "Uniformity in the currency, weights, and measures of the United States, is an object of great importance, and will, I am persuaded, be duly attended to."

The issue was raised again in 1821, when Secretary of State John Quincy Adams submitted to Congress his "Report Upon Weights and Measures." Adams' report did not settle the issue, for although he made a very strong case for the advantages of a simple, rational, and internationally compatible system of measurement based on decimal mathematics, he noted that the principal trading partners of the United States were not agreed on a single system that would insure international compatibility. Indeed, Napoleon already had rescinded the requirement for metric usage in France. Thus Adams concluded that metric conversion was premature.

Keystone



This is not a foot it's 300 mm

Think metric

CITB

Eye-catching posters displayed throughout Great Britain by the Construction Industry Training Board were designed to help the nation convert to the metric system. Two other examples are shown on succeeding pages. Common equivalents between the metric and present U.S. systems are shown on the opposite page.

***LEWIS M. BRANSCOMB** until May 1972 was director of the U.S. National Bureau of Standards and now is chief scientist and vice-president of IBM Corp. His many publications include several articles on conversion to the metric system.*

While one European nation after another adopted the metric system, the United States continued to use inch-pound measures, and built the greatest engineering and industrial capability the world has ever seen.

Today, the task of simplifying and harmonizing the U.S. system of weights and measures remains unfinished. Congress, in the Miller-Pell-Griffin Act of 1968, asked the executive branch to conduct a three-year study of the advantages and disadvantages of U.S. adoption of the metric system. The report, prepared by the National Bureau of Standards, found many of the circumstances faced by John Quincy Adams profoundly changed.

There no longer is any doubt whether the metric system will be accepted internationally as the predominant measurement language. Since World War II, Japan, India, Greece, Egypt, Saudi Arabia, Pakistan, North and South Korea, Indonesia, Vietnam (North and South), and many other nations have changed from a variety of measurement systems to the metric system. More important to the United States, the British Commonwealth nations have also committed themselves to the change. The United Kingdom is more than half-way through a 10-year conversion process. South Africa and Australia are also in the process of conversion. Even Canada, which has close commercial and technical ties with the United States is committed to change, with only the timetable remaining to be set. The United States is one of only 13 nations, including Tonga, Trinidad, Sierra Leone, and Yemen (Aden), that have not yet adopted the metric system. All the industrialized trading partners of the United States now are committed to an internationally harmonized metric system.

Arguments for the metric system

Why have so many nations voluntarily assumed the task and expense of changing their system of measurement? Adams noted how deeply the language of weights and measures is rooted in every phase of life. "The knowledge of them, as in established use," he wrote, "is among the first elements of education, and is often learned by those who learn nothing else, not even to read and write. This knowledge is riveted in the memory by the habitual application of it to the employments of them throughout life." Proponents of the metric system argue that the system is simpler, easier to learn, and much more amenable to arithmetic operations because the units are compatible with decimal arithmetic. The metric system, properly called the "International System of Units (SI)," is the first complete, streamlined, internally compatible system of measurement the world has known, designed to best serve the needs of scientists and engineers in all disciplines. But neither of these arguments is necessarily persuasive. Many who infrequently need to make exact calculations find convenient the great variety of customary units for the same quantity (inch, foot, yard, mile).

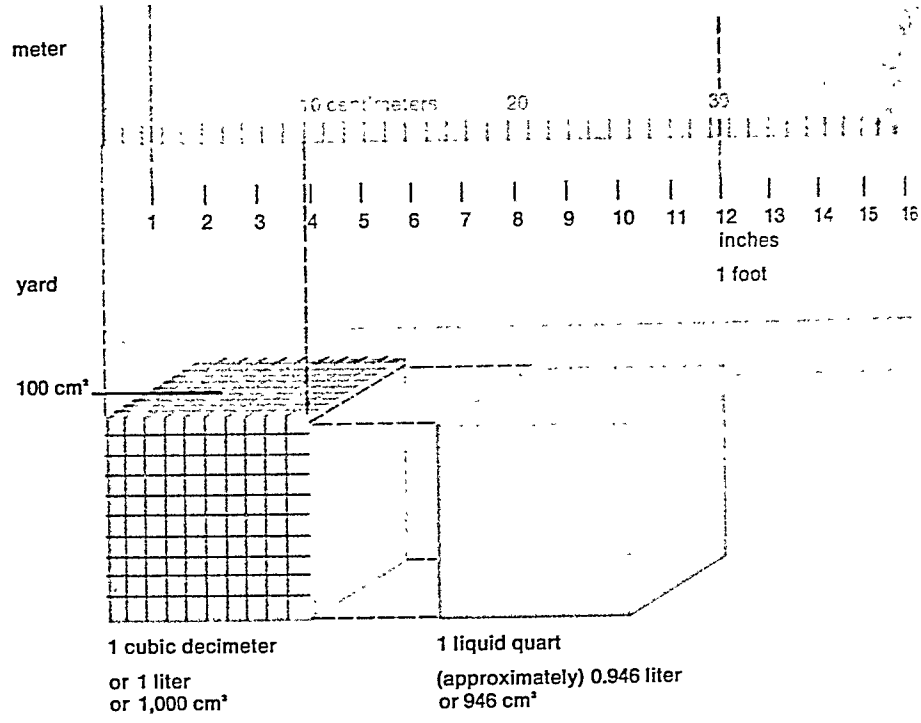
The strongest argument for general adoption of SI is found in the predictable and persistent inconvenience and expense of having to use both systems simultaneously. Because the United States is the

approximate common equivalents

1 inch	= 25 millimeters	1 millimeter	= 0.04 inch
1 foot	= 0.3 meter	1 meter	= 3.3 feet
1 yard	= 0.9 meter	1 meter	= 1.1 yards
1 mile	= 1.6 kilometers	1 kilometer	= 0.6 mile
1 square inch	= 6.5 square centimeters	1 square centimeter	= 0.16 square inch
1 square foot	= 0.09 square meter	1 square meter	= 11 square feet
1 square yard	= 0.8 square meter	1 square meter	= 1.2 square yards
1 acre	= 0.4 hectare	1 hectare	= 2.5 acres
1 cubic inch	= 16 cubic centimeters	1 cubic centimeter	= 0.06 cubic inch
1 cubic foot	= 0.03 cubic meter	1 cubic meter	= 35 cubic feet
1 cubic yard	= 0.8 cubic meter	1 cubic meter	= 1.3 cubic yards
1 quart	= 1 liter	1 liter	= 1 quart
1 gallon	= 0.004 cubic meter	1 cubic meter	= 250 gallons
1 ounce	= 28 grams	1 gram	= 0.035 ounces
1 pound	= 0.45 kilogram	1 kilogram	= 2.2 pounds
1 horsepower	= 0.75 kilowatt	1 kilowatt	= 1.3 horsepower

nation with the largest volume of foreign trade and the most pervasive economic and cultural impact on the rest of the world, the invasion of metric language and designs into our everyday lives is assured. Indeed, the use of metric measures is surprisingly widespread in the United States today. Now the dominant language for scientific and medical research, metric usage is increasing steadily in engineering. The pharmaceutical, frictionless bearing, and photographic industries are substantially metric today. Not only imported cars, but some domestic autos contain metric parts and need metric tools for their maintenance. The Olympic Games have made sports fans accustomed to metric events, and U.S. swimming pools are often made to metric sizes for this reason. A growing number of packaged goods in retail trade are labeled in metric as well as customary units, and most American school children now encounter metric units in some of their books. The testimony of thousands of respondents to the questionnaires of the U.S. Metric Study reveals that a substantial majority of U.S. businessmen believe increasing use of the metric system in the United States is in the best interest of the nation.

Therefore, with metric language becoming more commonplace, Americans will have to contend with difficult arithmetic conversions not only within the customary system, but back and forth between

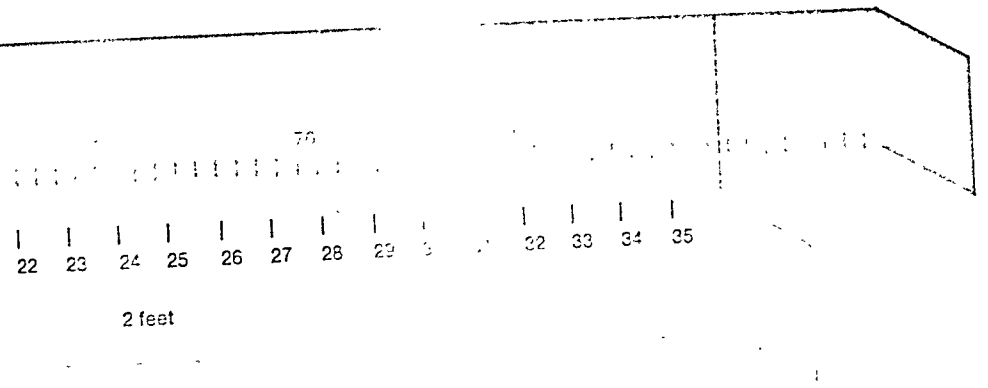


customary and metric. This situation already prevails in technology; scientists and engineers must make these conversions in order to interpret one another's work. It will affect increasingly skilled workers, teachers, and lawmakers. Although the large multinational corporations have demonstrated that they can manufacture U.S.-designed products in metric countries without major difficulties, added costs are incurred, such as two sets of drawings to different dimensions. Workers and small business subcontractors face greater uncertainty in a mixed measurement society because they can predict less easily when they may be called upon to deliver work designed to metric specifications.

The problem of mixed measurement languages cannot be resolved quickly, since a generation must pass before everyone finds the metric language intuitively familiar. In fact there are significant vestiges of imperial units in countries that have been metric for decades, just as the *vara* (a Spanish unit of land measure) persists in Texas and the Southwest. But the implications of metric change for standard designs and dimensions—the hardware aspects of going metric—suggest a more rapid timetable of 10 years for a U.S. changeover.

Relationships between common weights and measures of the metric and U S systems are shown graphically. A meter is compared to a yard, a centimeter to an inch, a liter to a liquid quart, and a kilogram to a pound.

During the decade of the 1970s, the metric report concludes, there probably will be developed through international engineering organizations a set of metric language industrial standards. These standards are the dictionary of the marketplace in a technologically advanced nation, describing the sizes, test methods, product characteristics, and other conventions for every kind of component and product. Used as





1 kilogram

1 pound

1 pound = 0.45359237 kg

purchase specifications or integrated into product designs, these standards can have great commercial force. The U.S. Metric Study concluded that if U.S. industrial practices and conventions are adopted in these international standards, wherever their technological superiority merits their acceptance, the burden of going metric—that is, of harmonizing national industrial practice to the demands of the international marketplace—will fall on other nations as well as on the United States. For today there are still relatively few international standards, and metric countries use the same language but do not by any means use the same sizes, shapes, and conventions. The United States cannot hope to persuade the more than 60 nations active in the International Standards Organization to adopt its customary measurement language. But we can expect that U.S. determination to participate fully in international negotiations leading to a set of metric language standards for worldwide use—including U.S. domestic use in the future—would remove a significant barrier to world trade while best protecting U.S. commercial interests. If European and Asian powers successfully harmonize their industrial practices through their own international metric standards, without adequate participation by U.S. interests, the result will be to make eventual U.S. conversion to those standards much more costly and difficult.

In summary, it is now, while the metric countries still have divergent standards and practices, that U.S. adoption of metric language and development of metric standards would be most beneficial. However costly the changeover now, it would be more costly in the future.

Keystone



How conversion would work

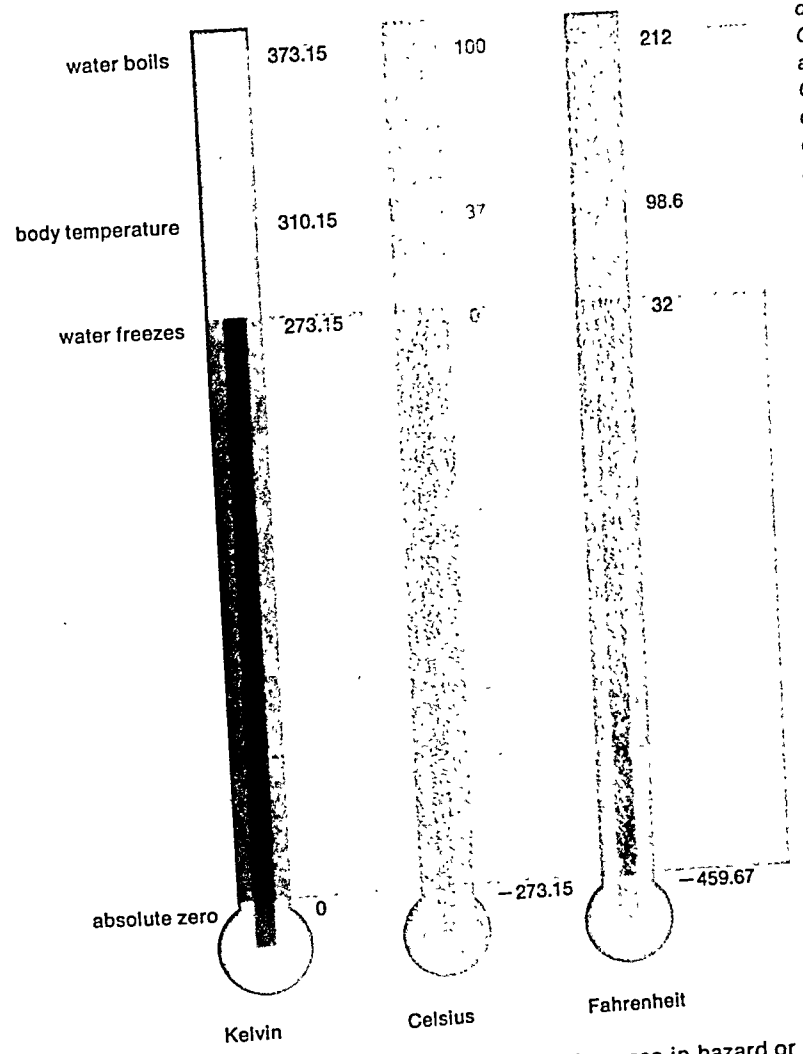
How should a 10-year program of conversion be carried out? Secretary of Commerce Stans recommended that while the changeover should be substantially voluntary, it should be accomplished through a coordinated national program. The Congress could establish a suitable central coordinating body to guide the changeover. This organization would be responsible to all sectors of the U.S. society, and would facilitate the generation of detailed plans and timetables. After these plans have been made, under which some sectors might change in only a few years and others might take 20 years or more, Congress would establish a date ten years later by which time the United States would be predominantly, though not exclusively, metric.

Two tasks would need to be undertaken immediately and pressed with some vigor. First, as soon as a new cycle of school textbooks was ready for introduction all public school children would begin to gain a practical mastery of the basic metric dimensions, areas, volumes, weights, and temperature scales. This effort, strongly supported by the major national organizations representing teachers, would be needed to prepare the six-year-olds starting school that year for life in the metric world of the 21st century.

Second, the task of generating new metric language standards for domestic U.S. use, and hopefully for international adoption, would have to begin quickly because conversion of our economy to metric practice would not be possible until the standards exist. This job (like most of the tasks in metric conversion) will fall primarily on the private sector, working through the many voluntary standards-generating bodies in the United States. The American National Standards Institute (ANSI), which arranges for U.S. representation in international standards organizations, would be expected to play a major role in coordinating this effort.

In the process of generating new metric standards, some improvements might be made that could provide substantial savings to the economy once conversion was accomplished. An example is in the area of thread sizes on nuts and bolts. A study by the Industrial Fasteners Institute suggests that the present 59 varieties of U.S. customary thread diameter-pitch combinations, plus the 57 metric sizes in common use in Europe, might be replaced by 25 new metric sizes that could do the job of all 116 old sizes. Substantial inventory savings and design simplifications might result. The British found this aspect of "metrication"—housecleaning of their industrial standards—a major opportunity for productivity improvement.

The standardization of common plumbing will serve to illustrate another area in which savings might result. The present common pipe standards date back to the 1880s and the wall thicknesses reflect the state of metallurgy at that time. Since American pipes are standardized on their inside dimensions, while European pipes are standardized by their outside dimensions, the rationalization and harmonization of pipe standards internationally might provide the opportunity to reduce



Three scales on which temperature is measured are the Kelvin, Celsius or centigrade, and Fahrenheit. Celsius is used in the metric system and Fahrenheit in the United States. On the Kelvin scale the unit of measurement equals the Celsius degree, each being 1/100 of the interval between the freezing and boiling points of water. Kelvin is most often used in scientific work. Another of Britain's conversion posters is on the opposite page.

the pipe wall thickness significantly without any increase in hazard or failure rate. However, it would be a mistake to assume that U.S. pipe standards would have to be changed in the event of a metric changeover simply because the names of pipe sizes are "one-quarter inch," "one-half inch," etc. In fact, nowhere on a piece of one-half-inch threaded pipe does the pipe actually measure one-half inch. The savings in this area thus derive from the use of less metal in pipe production through modernization of the engineering content of the standard.

Following on British experience, and the conclusions of the U.S. metric study, Stans recommended that the costs of metric conversion "lie where they fall." This does not rule out government sharing the cost of its participation in the metric conversion; special consideration might have to be given to the problems of the small businessman and self-employed artisan. The argument against subsidies to defray the

Origin of our present system of measurement

The origin of American customary units of measurement is lost in antiquity, for it evolved from ancient Roman, Anglo-Saxon, and Norman customs. But England, as a great maritime nation, was an early leader in measurement standardization. King Henry II standardized the yard, and Elizabeth I the avoirdupois pound, both of which are very similar to today's units. The volumetric units are more complicated, since the United States adopted the British wine gallon, about 20% smaller than the Imperial gallon adopted by the British in 1824. Furthermore, American colonists used a different measurement for liquid and dry volume as a matter of convenience because of different types of containers then in use. (John Quincy Adams thought this inconsistency would cause the United States less trouble than other nations because "Wine is an article of importation; an article of luxury; the exactness of the measure by which it is distributed, is not an incident which every day comes home to the interests and necessities of every individual.")

In general, dimensional units of the customary system had an anthropomorphic origin. Limbs of the body were used as conveniently available measurement gauges, the inch being the knuckle of the thumb and the early yard being the distance from King Henry I's nose to the end of his thumb when his arm was fully outstretched.

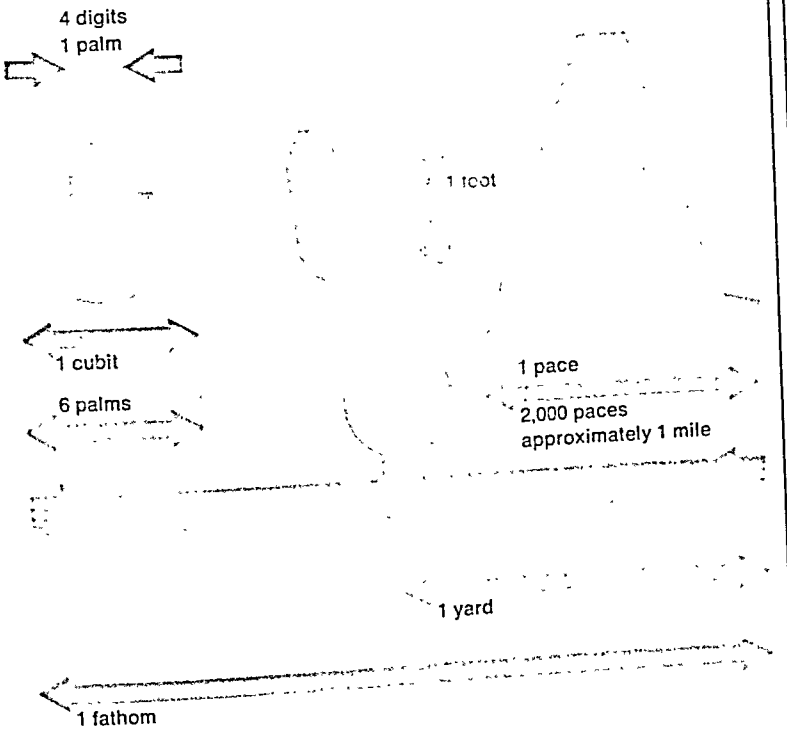
The metric system derives its anthropomorphic character from the 10 fingers on which many people learned to count. Thomas Jefferson had early seen the advantages of a measurement system based on decimal arithmetic, and proposed the use of a pendulum whose time of swing and length would simultaneously define both length and time.

The metric system was born of the French Revolution, with provisional standards issued in 1795. The definition of the unit of length,

costs of conversion rests on the fact that these costs are difficult to identify and there are many opportunities to reduce them by careful management at the company level. Americans will pay much less for metric conversion as consumers and stockholders than they would as taxpayers.

Even after the planning of timetables for a metric conversion, several years would pass before metric labeled goods would predominate on the grocer's shelves and "kilometers per hour" signs would adorn the roads. It has been estimated that about three years would be required to modify the dial-plates of scales used in retail trade. The changeover of highway signs could be accomplished over several years by concealing metric speeds, distances, and load limits under removable labels in miles per hour, miles, or tons. These two changes, which exemplify encounters that the average citizen would have with metric language

the meter, was one ten-millionth of the earth's quadrant from pole to equator. The kilogram, unit of mass, was realized by the water contained in a volume of one liter, that is a cube 10 centimeters on a side.



in his everyday life, also illustrate the need to be very practical about arranging the conversion. It probably would be advantageous from the safety point of view to change speed limit signs all at once. But a period of two or three years of dual labeling might prove most helpful to the shopper who could gain familiarity with the new units. After this transitional phase, it could be expected that the states (which regulate the weights and measures used in retail trade) would agree on a date after which metric units must be used in package labeling and retail measures. Customary equivalents also could be given for as long as anyone desires.

It probably would not be necessary for Congress to intrude on the states' authority to set the weights and measures regulations in retail trade, even though it would be quite important that timing of a change to metric be uniform in all 50 states. All the states now coordinate their



efforts through a National Conference of Weights and Measures, whose technical recommendations for regulations are adopted by administrative proceedings in most states. Thus, once the conference determined a timetable for conversion, in collaboration with the national coordinating body, it could seek the simultaneous implementation of this schedule in all states. It is, therefore, unlikely that any new mandatory federal authority would be needed to effect an orderly conversion program.

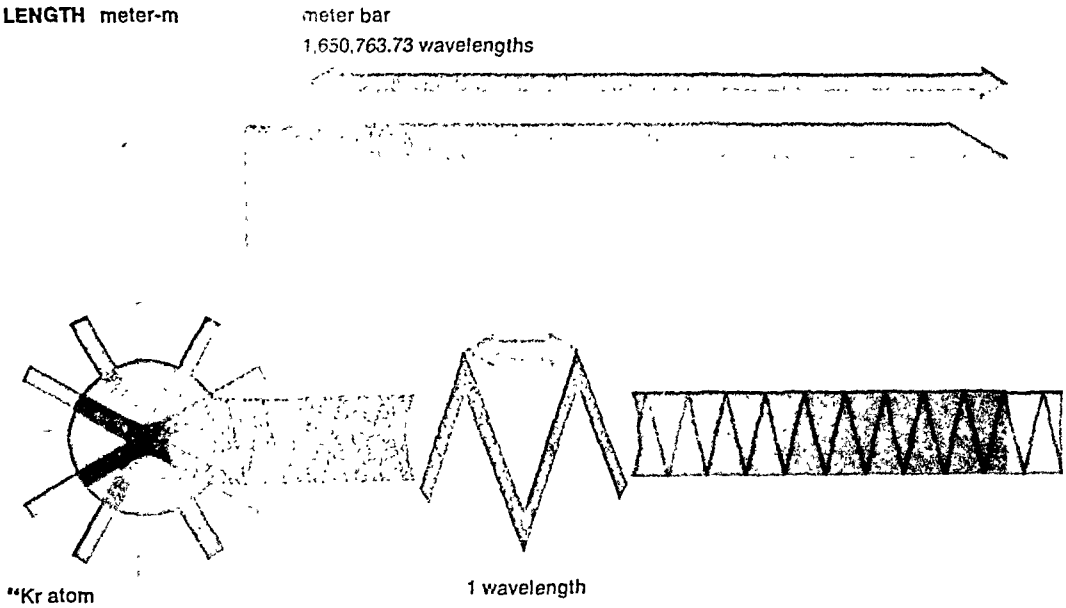
The purchasing power of the federal government would provide a useful market demand for metric products and services in metric language. However, the timing of the government's own actions would have to be dovetailed with timetables developed by the private sector through participation of both sectors in the proposed national coordinating body. Thus, government would not be expected to move first to demand metric products but should set a good example by adhering to the timetable agreed upon by all.

Reaping the benefits

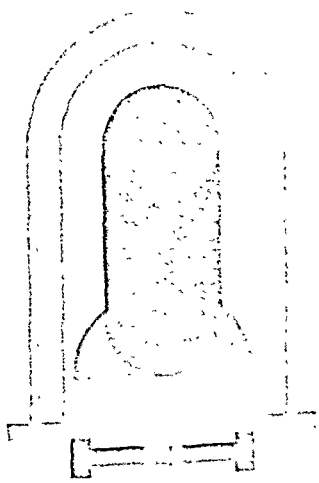
At the end of the conversion period, the public would be accustomed to metric language predominating in their shops, workplaces, and newspapers. About 5% more milk would appear on the doorstep (the margin by which the liter exceeds the quart), and a meter of cloth would be three inches longer than the yard. But basically the change would not be very noticeable. For many years to come horses, 16 hands high, still would be competing over furlong measures, football fields would remain 100 yards long, skeptics would say, "Give him an inch and he'll take a mile."

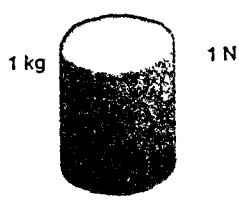
Estimating the costs and benefits associated with going metric is elusive. British experience indicates that while the planning is difficult and time-consuming, most companies found the actual cost and complexity of conversion easier than they feared it would be. Conversion costs in general were found reasonable in relation to other uncertainties in ordinary operating costs. Indeed, the "rule of reason" for metric conversion suggests that this should be the case, for no sector should be expected to convert on a timetable that would make the costs unacceptable. Detailed cost surveys, conducted by over 100 companies that volunteered their data to the U.S. Metric Study, showed wide variations from company to company in the same industry on the cost impact of conversion. In extreme cases the estimated cost of conversion provided by each of two companies engaged in the same business differed by as much as 100 to 1. Thus these data reflect a wide variation in experience and perception of metric conversion by different companies. Their problem in making the estimates was compounded, of course, by the fact that the metric standards to which their hypothetical conversion was directed do not in fact exist and had to be imagined. Finally, those U.S. industries that have undertaken a "pay as you go" conversion in recent years report that the process was accomplished with relatively little confusion and that costs, in general, were absorbed in ordinary operating expense.

LENGTH meter-m



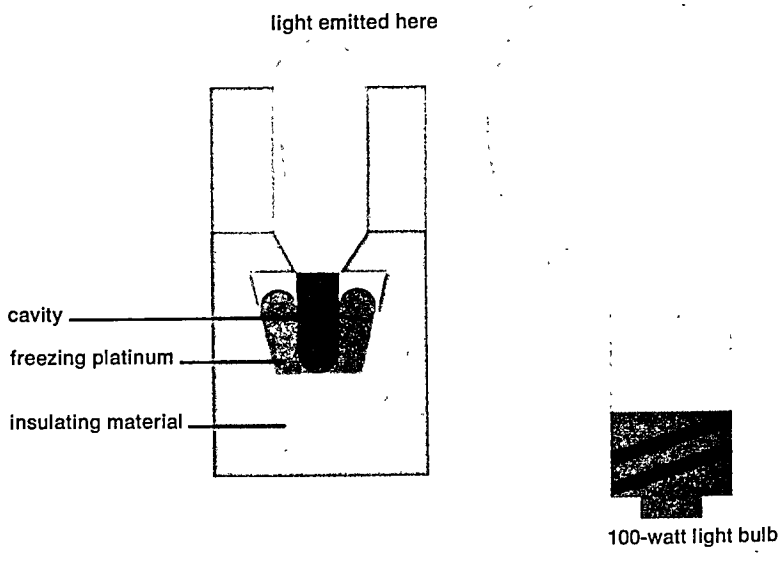
MASS kilogram-kg





Common metric units are based on specific physical entities. A meter (above) is 1,650,763.73 wavelengths, in a vacuum, of the orange-red line in the spectrum of krypton-86. A kilogram (left) is the weight of a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures in Paris. The metric unit of force, one newton (1 N), when applied for one second to one kilogram will give it an acceleration of one meter per second per second. On the opposite page is another British conversion poster.

LUMINOUS INTENSITY candela-cd

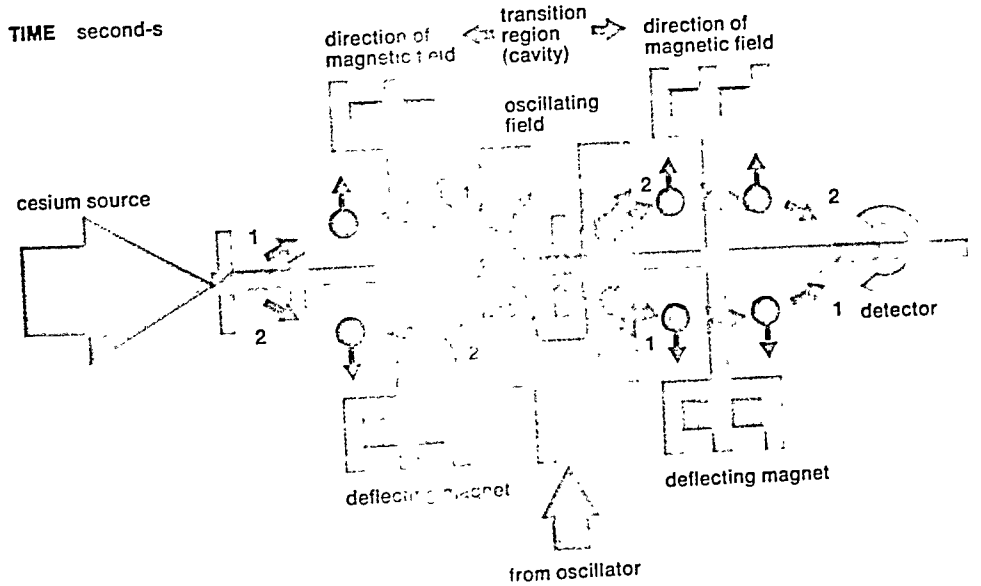


The metric candela (above) is 1/60 of the luminous intensity of one square centimeter of a blackbody surface at the temperature of platinum at its solidification point (2,042° K). A source having an intensity of one candela in all directions radiates a light flux of about 12.5 lumens. By comparison a 100-watt light bulb emits about 1,700 lumens. One second (opposite page) is the duration of 9,192,631,770 cycles of the radiation associated with a particular transition of the cesium atom. A second can be realized by tuning an oscillator to the resonance frequency of cesium atoms as they pass through magnets and a resonant cavity into a detector.

Costs of hardware changes would be determined in large measure by the extent to which the time scale for conversion is commensurate with the normal life of the affected equipment. Machine tools could in many cases be converted from inches to meters by a simple change in the drive gears. Since the inch is internationally defined as 2.54 centimeters, a gear of 127 teeth can be used with a gear of, for example, 50 teeth to produce a metric tool.

On the benefits side, importers and exporters expressed the view that measurement language was not a strong factor in determining the course of international trade. Nonetheless, this survey revealed an estimated net benefit to the U.S. balance of trade of about $600 million a year. About one-fourth of the manufacturers surveyed estimated that savings resulting from conversion would compensate for added costs in a period of time comparable to the conversion process itself. In addition, this survey identified an annual cost of maintaining dual capability for the manufacture of standard parts and materials of about $500 million a year, a cost that will be faced for as long as the United States is making substantial use of both measurement systems. In addition to this cost of "being dual," manufacturers identified a fixed cost of conversion that the study estimated as between $6.2 billion and $14.3 billion for the 10-year period. The study concludes that no matter what the cost of conversion, it would be less costly, and the costs would be recouped sooner, if the nation changes to metric by plan rather than by leaving the change to chance.

All of the analyses in the study were based on examination of today's world. A more relevant question to answer is, "What measurement language will Americans want to be using during the nation's third century?" In view of the extraordinary changes that have swept over



the world in the last 50 years, largely brought on by technology, what can we expect for the year 2000? Technology will continue to make the peoples of all nations more interdependent. Advanced technology will play an ever more important role in U.S. economic life, and we will find ourselves competing with increasingly sophisticated trading partners. Barriers to the transfer of goods, of technology, and of personal communication would become increasingly disadvantageous for the United States. In the light of the needs of future generations of Americans who will live in a metric world, it is time for a decision on this issue which has been too long unresolved.

The Science Year in Review: A Perspective by John H. Lannan

Skyrocketing research costs, unmet human needs in such areas as health and environment, and the threatened loss of U.S. technological and industrial preeminence combined to place science and technology high on the list of national concerns in 1972. This came about despite—or perhaps as a result of—the "antitechnology" sentiment that had gained momentum in recent years. Concerned by what science and technology were doing to them as well as for them, people had begun to take a more critical look at both.

In part, at least, their concern stemmed from environmental considerations. That concern led, among other things, to a conflict between the antitechnology advocates in the developed nations and the less developed countries, where the pursuit of science remained the mark of societal sophistication and where the resulting technology was a source of jobs and better lives. Nowhere was this dichotomy more evident than at the first UN Conference on the Human Environment, held in Stockholm in June 1972, where an impasse developed between those who sought to protect the world's overall environment and those who felt the world environment had little meaning in the face of poverty and underdevelopment.

In the U.S. strong environmental and consumer pressures brought demands for a "look before we leap" approach to legislation and regulation. Congress reaffirmed the broad regulatory powers it had given to the Environmental Protection Agency, intensified the ongoing attacks on disease, poverty, and functional illiteracy, and took steps toward the creation of an Office of Technology Assessment, designed to evaluate new technologies before they are implemented.

On the executive side, the new emphasis meant additional attention to and direction for the scientific and technological enterprise. Early in 1972 the administration put before Congress the largest science and technology budget ever proposed—$17.8 billion. Significantly, the budget emphasized the civilian or domestic side of the economy as opposed to the military, space, and atomic energy efforts that had long commanded the lion's share of the federal government's research and development funds. Energy research, health care, transportation, education, and the effects of pollutants on health were among the areas designated for significant increases.

The first presidential message on science and technology, promulgated in March, called for broader-based support of fundamental research by government, the channeling of scientific and technological capacity to meet existing needs, and the expansion of international cooperation.

By midyear a search for ways to support basic research was under way throughout the federal establishment. With added funding in sight and a presidential directive calling for new applications of science and technology, the government—which supports more than half the nation's research and development—began moving toward new goals.

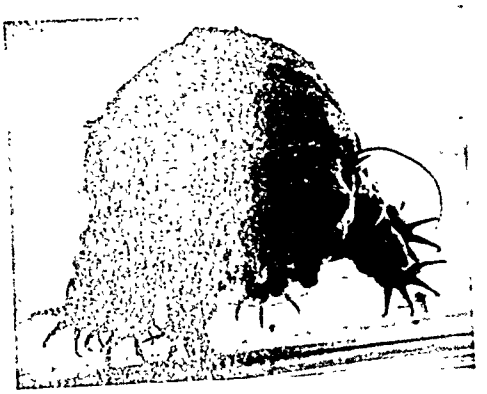
On the international front, Pres. Richard Nixon's diplomatic initiatives had important implications for science and technology. The beginnings of political and cultural rapprochement between the U.S. and China opened the way for exchange visits between scientists and physicians of the two countries. On the other side of the world, the series of landmark agreements signed during the president's official visit to the Soviet Union had striking science and technology components.

Of these, the strategic arms limitation agreement —itself made possible by scientific and technological developments stemming from space, geophysical, electromagnetic, and oceanographic research—won the widest public attention, but agreements on space, environment, health, and science and technology all called for joint efforts or cooperation in areas where both countries would benefit. Significantly, the agreements provided for cooperation on a government-to-government basis. Previously, cooperative arrangements had been made between individuals or institutions through the two governments' foreign offices. Furthermore, the new agreements would be monitored not by diplomats and politicians but by joint commissions of industrialists, scientists, technologists, and concerned government agencies.

While the highlights of the year were in the policy area, scientific and technological details were not lacking. The new 200-GeV accelerator near Batavia, Ill., came on line and reached its designed beam power and intensity. The Apollo program, begun as a cold war initiative, approached its conclusion with a series of scientific triumphs. By way of beginnings, the construction of a new ground-based radio-astronomy facility, a Y-shaped interferometer with 13-mi arms, was authorized by Congress.

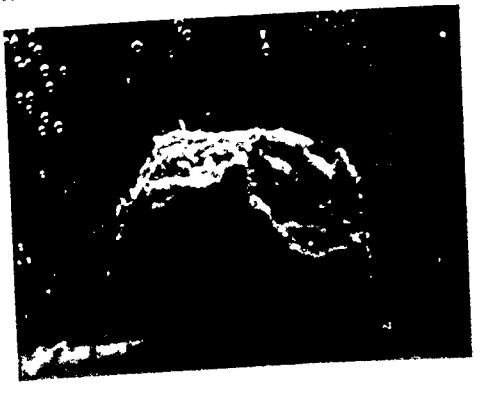
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Agriculture

For more than a century, research pursued by agricultural scientists has been instrumental in making United States agriculture the most productive in the world. Two of the more outstanding research accomplishments of recent months have far-reaching implications in man's search for clues to the causes of human diseases.

Early in 1972, scientists announced that they had isolated a tiny disease-producing particle called a viroid. This discovery opened new paths for research into diseases whose causes have eluded scientists. The viroid is an infectious particle that causes potato spindle tuber disease. Smaller than any known virus, the viroid is a fragment of ribonucleic acid (RNA) with a molecular weight of only approximately 50,000. The smallest known virus is 80 times larger than a viroid. The infectious capabilities of viroids may give scientists new clues to the cause of some human cancers, infectious hepatitis, multiple sclerosis, scrapie of sheep, and other diseases.

A second major scientific breakthrough was the development of the first vaccine found to be effective against a naturally occurring cancer. The vaccine is used in the prevention of Marek's disease, which occurs widely in chicken flocks throughout the world. A highly infectious form of avian leukosis, it has caused losses of an estimated $200 million annually to the U.S. poultry industry. The vaccine proved to be a safe and effective way to control this disease, and its discovery was considered to be among the most important in current cancer research.

Pest and weed control. Because recent research has revealed potential dangers in the use of some pesticides, scientists from the Agricultural Research Service (ARS) of the U.S. Department of Agriculture have pioneered the reduction of pesticide use by developing other methods of pest control. Sex attractants may play a more prominent role in future pest management programs than they have in the past. Attention in 1972 was being directed toward their possible use as a direct control rather than as a detection tool. Scientists believed that the attractants might be released in sufficient quantity so that the environment of insect pests would be permeated sufficiently to disorient males in their efforts to find females.

A newly identified sex attractant for houseflies, called muscalure, may reduce the amount of in-

Romaine lettuce damaged by air pollutants (left) and ozone damage to a leaf of corn (right) dramatically illustrate a problem faced by thousands of U.S. farmers. The Council on Environmental Quality estimated the annual loss to crops and livestock at $500 million.



Courtesy, Dr. O. C. Taylor, Statewide Air Pollution Research Center, University of California-Riverside

secticide needed if it can efficiently attract flies to a small, selected area treated with insecticide. This would eliminate spraying large areas, which often involves a heavy application of insecticide. Scientists also developed a strain of houseflies that produces only male offspring. This could help streamline the procedures used in sterilization programs for insect control. Sterilization has been successfully employed against several kinds of flies but not houseflies. In recent months however, preliminary tests showed that this approach could be employed in some control programs against this carrier of human diseases. Sterilization programs involve rearing insects in a laboratory, sterilizing the males, and releasing them in quantities sufficient to significantly outnumber other males; as a result, almost all matings would occur between normal females and sterilized males.

ARS scientists were examining ways to manipulate nematodes—tiny parasitic worms—to attack the bark beetle that carries Dutch elm disease from tree to tree. They hoped that the nematodes could sterilize effectively or at least seriously debilitate the beetles.

For the first time, the launching of a full-scale biological attack against the cereal leaf beetle—a serious threat to the production of wheat and other small grains—appeared to be possible. The most promising technique for biological control was the importation, rearing, and release of insects that become parasites on the beetle in its native habitat. In this technique insectaries—places for the rearing of insects—are established in heavily infested grain fields located in wildlife areas or on farms retired from production, where pesticide drift will not be a hazard to newly hatched parasites. During 1971 the ARS and cooperating states released more than 800,000 parasites in 109 locations across the U.S., and nearly 100,000 larval parasites were freed at 11 sites in Indiana, Michigan, Ohio, and West Virginia.

An artificial diet packaged in capsules resembling insect eggs was being used as food to rear large numbers of aphid lions, a beneficial predatory insect. The aphid lion, which is the larva of the green lacewing (*Chrysopa carnea*), eats many kinds of crop insects and their eggs, but most often attacks bollworms and tobacco budworms on cotton plants. In addition, it is resistant to several insecticides, a factor that favors its use in integrated control—a concept in which a minimum amount of insecticide is applied to reduce the number of pests, followed by the release of large numbers of aphid lions to finish the job.

Scientists employing chemical control were using foam experimentally as a better method to control the corn borer, with less chance of environmental pollution. A nozzle was designed and built to generate foam formulations of (1) DDT (used only as the best available standard for comparison) or (2) *Bacillus thuringiensis*, a bacterium that produces protein crystals toxic to some insects, including the corn borer. Each of the two insecticides was combined in a nozzle with water, liquid foaming agent, and air and then forced through a meshed material. The volume of foam and its consistency were controlled by the amounts of insecticide, foaming agent, and air that were used. In the tests *B. thuringiensis* demonstrated potential for reducing pollution by replacing potentially hazardous chemicals.

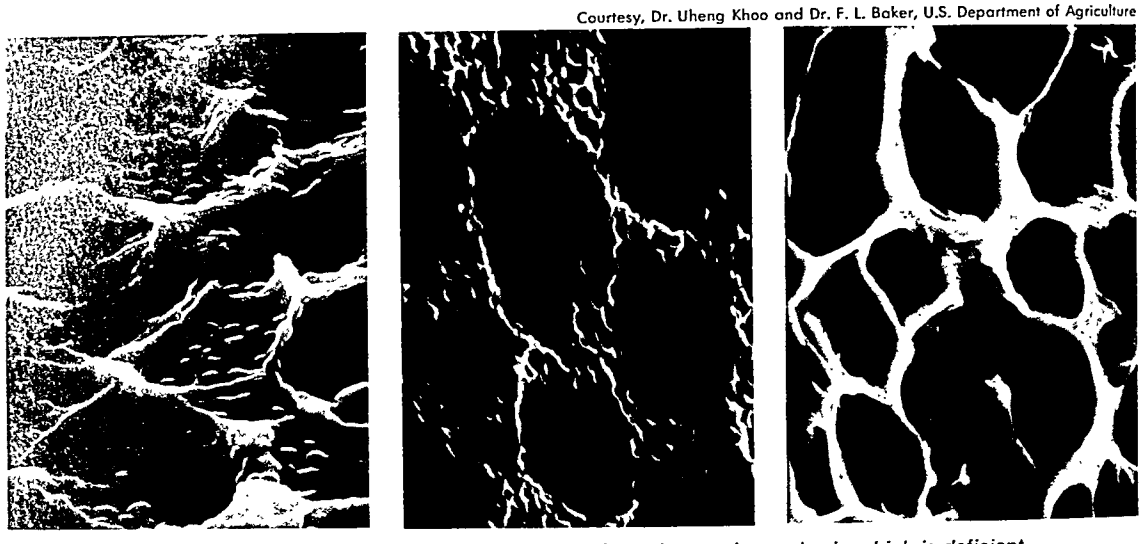
Weed control is also essential if man, animals, and wildlife are to survive. Scientists discovered that some aquatic weeds can be effectively controlled with the herbicides diquat and paraquat without harming fish. Aquatic weeds obstruct water flow, cause large losses of water through transpiration (evaporation of water from plant parts exposed to air), and prevent proper drainage of land. The weeds may interfere with navigation, prevent fishing and recreation, depress real estate values, and present health hazards. Losses from aquatic weeds amount to tens of millions of dollars annually.

The discovery of an additive that enhances the efficiency of herbicides may lead to effective weed control with fewer applications and at lower herbicide rates per application. Phenylcarbamate herbicides are readily degraded by soil microorganisms, and repeated applications often are needed to control weeds effectively. But research has shown that certain methylcarbamate chemicals (some of which are insecticides), when applied along with certain herbicides, temporarily inhibit the degradative action of the soil microorganisms. Experimenting with pure culture and soil systems, ARS scientists found that p-chlorophenyl methylcarbamate (PCMC) strongly inhibited the biodegradation of the herbicides propham and chlorpropham.

Treating agricultural wastes. Dealing with agricultural wastes as a major resource rather than as a necessary evil may hasten the recycling of those materials as one way to help cleanse the environment. Scientists chemically treated barn wastes to increase their digestibility and then blended them into rations for use as feed for sheep. This research demonstrated that barn waste rations do have potential as a forage substitute.

The potential role of nitrogen fertilization in polluting water created renewed interest in ways of suppressing nitrification. Scientists found that small amounts of potassium azide added to anhydrous ammonia fertilizer helped to insure against possible nitrate pollution of groundwater. Main-

Courtesy, Dr. Uheng Khoo and Dr. F. L. Baker, U.S. Department of Agriculture



Normal corn endosperm with starch removed (left) consists of matrix proteins and zein which is deficient in the essential amino acids lysine and tryptophan; center, endosperm after dissolution of zein. Removal of starch from high-lysine "opaque-2" strain (right), which lacks zein, leaves principally the amino acid-rich matrix protein glutelin.

taining fertilizer nitrogen in the ammonium form with such nitrification inhibitors would not only restrict loss through leaching and runoff but also keep applied nitrogen available to plants for a longer time.

Finding more efficient uses of materials that man cannot eat and that may pose potential pollution problems is another way to aid in cleaning up the environment. Scientists found a unique solution to a part of this problem by feeding old newspapers mixed with molasses to ruminant farm animals. Replacing some forage in the feed ration with newsprint had no adverse effects on the animals, and research showed that newsprint could substitute for at least 8% of the feed ration roughage.

Animal and plant science. Although there was considerable emphasis in the past year on environmental studies, research in animal and plant science continued to make important advances. A major breakthrough in the freezing of boar semen promised to bring the full benefits of artificial insemination to the swine industry. Researchers credited the success to their development of a new additive and a special procedure for handling the semen before it is frozen. The use of this new procedure in conjunction with artificial insemination was expected to increase the rate at which genetically superior sires can be used to produce pigs with more lean meat and less fat.

Corn genes with extra food potential were recovered in studies of a primitive South American corn. Scientists discovered that the aleurone, the site of B vitamins and high-quality protein just under the kernel hull, is two to five cells thicker in primitive Coroico corn than in U.S. commercial hybrids. Coroico may serve as parent stock to improve the nutritional value of U.S. hybrids.

A new biochemical technique, called mitochondrial complementation, or MC, promised to shorten the time required for the development of improved crop varieties and hybrids. The technique permitted plant breeders to evaluate the production potential of crosses between proposed parent plants in the laboratory. It would be used to screen out crosses that would produce less vigorous offspring; only plants showing a high performance potential when tested biochemically would need to be crossed and field tested.

Future outlook. A hybrid sunflower that could become an important cash crop in the southern U.S. and a replacement for flax in the North was one of the hoped-for results of future research. The outlook for sunflower research was bright because scientists found the missing ingredient for breeding hybrid sunflowers. Called the restorer gene, it restores fertility to male-sterile plants and makes possible the breeding of hybrid sunflowers of consistent high quality with good yield.

Three experimental compounds offered promise as replacements for DDT and dieldrin as mothproofing agents. Because of their chemical nature, they were expected to be much less persistent than either DDT or dieldrin in the discarded solutions.

A highly toxic substance that may occur as a contaminant in a few pesticides synthesized from chlorophenols was under intensive study to learn its chemical and environmental significance. The contaminant, 2,4,7,8-tetrachlorodibenzo-p-dioxin

(TCDD), causes chloracne, a condition characterized by skin eruptions and irritations of the face, arms, and shoulders. TCDD is an important consideration in the recent review of uses of the herbicide 2,4,5-T.

—Robert B Rathbone

See also Feature Article: NUTRITION AND THE AMERICAN DIET.

Archaeology

During the year, archaeologists became increasingly concerned with the destruction of archaeological sites caused by the burgeoning international market in antiquities. The illicit trade also served to exacerbate the growing political problem of arranging for excavations in foreign countries, although this latter phenomenon appeared to have its roots in rising ethnocentrism, national pride, and resistance to the idea of foreign researchers unraveling the ancient history of one's own region. This, in turn, was leading to many more arrangements for international cooperation in excavations, more training of diggers in the less developed countries, and a somewhat different outlook on archaeological objectives.

Africa. The search for ancient man and his progenitors in Africa continued. Bryan Patterson of the Museum of Comparative Zoology in Cambridge, Mass., announced the discovery of a lower jaw with one molar in place, dated at 5.5 million years ago. The specimen was found in deposits on Lothagam Hill in northern Kenya in 1967, but was not announced until several years of research had established its date and identity. Dating of the jaw in the Pliocene period was determined not only by radioactive techniques but through correlation with animal bones of known age from other regions.

Patterson concluded that the bone is from a creature closely related to *Australopithecus*, a hominid ancestral to man, which was first reported from South Africa many years ago. Previously the oldest date for *Australopithecus* had been 3.5 million to 4 million years ago. The discovery of 5.5 million-year-old *Australopithecus* remains fills part of the evolutionary gap between *Ramapithecus*, a "man-ape" dated to 14 million years ago, and the first of the hominids. There was still a question as to when earlier forms developed the upright posture and ground-living habit of *Australopithecus* and the later hominids.

The history of the famed Benin art style, which reached its apogee in the Benin bronze sculptures of Nigeria, was being elucidated by excavations at Owo, 70 mi N of Benin. Some years ago extraordinary sculptured heads found at Ife were dated to the 9th century A.D., indicating that the Benin bronze art had its roots in an ancient African tradition, not in contacts with Europeans in the 16th century as was once supposed. Excavations at Owo were begun by Ekpo Eyo in 1971 after fragments of terra-cotta sculpture in the Ife style were found there by a surveyor. The site turned out to be a former sacred grave used in the worship of the goddess Oronse.

A large amount of sculptured material was found and, although detailed studies had yet to be made, it was clear that the older Ife art tradition did not die out in Owo before at least the 15th century. It now appeared that the Benin tradition was derived from Ife through Owo, and that the art form we know as Benin existed in West Africa for at least a thousand years.

Near East. At a site on the Lebanese coast between Tyre and Sidon, presumed to have been the ancient Sarafand referred to in the Bible (I Kings 17), excavations made in 1971 by James Pritchard of the University Museum, Philadelphia, turned up the personal seal of a man from Sarepta, inscribed with the Phoenician letters *s r p t* ("Sarepta" spelled without vowels in the Phoenician mode). Even more significant than this rare circumstance of identifying a site by an inscription was the fact that this was the first Phoenician city ever found on the homeland. These people, who transmitted the

Leopard in a crouched position with a human leg in its mouth was unearthed at Owo, Nig., in 1971. Authorities hope the Owo finds, when fully analyzed, will shed new light on the evolution of the famed Benin art style.

Courtesy, Federal Department of Antiquities, Lagos, Nigeria



alphabet to the West, are best known from their colonies, such as Carthage.

The late Minoan site on the island of Santorini (Thera), being excavated by Spyridon Marinatos, continued to make world news, probably because it is theoretically connected with the lost continent of Atlantis. The most significant discovery during the year concerned frescoes pieced together from fragments of wall paintings in buildings buried during the volcanic explosion that destroyed the Minoan town. They were described as the finest frescoes ever discovered in the Mediterranean region, more delicate, free, and rhythmical than the famous frescoes of Knossos on Crete.

Europe. Some clue to the facial appearance of men who lived in Europe 200,000 years ago was unearthed during the year in France. This is a period, preceding the age of Neanderthal man (the popular stereotype of the caveman), that had been known primarily from deposits of primitive flint tools. In July 1971, Henry de Lumley and his wife,

"Fresco of the Princes" is one of the wall paintings painstakingly reassembled from fragments discovered at the late Minoan site Akrotiri on the island of Thera and installed in the National Museum in Athens.



Dmitri Kessel

from the University of Ais-Marseilles, found a largely intact skull with massive teeth in a cave above the village of Tautavel near Perpignan. Previously, two jawbones had been found in the same deposit, but neither of them fit the skull. One jaw is that of a man and the other of a woman. The skull is believed to be that of a youth about 20.

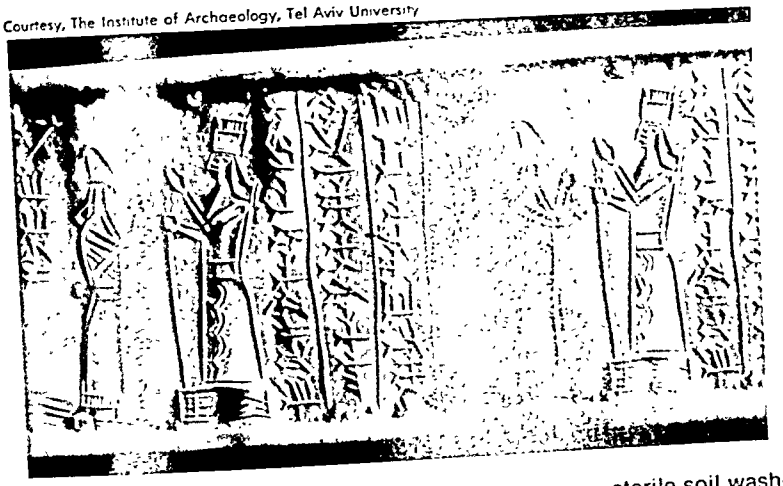
The new discovery shows extreme prognathism (snout-like, with jaws protruding far in front of the upper face) and unusually thick jawbones, both characteristics of ancient hominids. The skull is described as "lantern-jawed" and lacking the chin knob characteristic of modern man. There are sharp structural differences between the male and female jaws.

The cave contains 15 ft of deposit and 20 distinct habitation levels, each laid down during the period of the skull. More than 100,000 pieces of worked stone were found. There were also many bones of rhinoceroses, horses, bears, panthers, elephants, turtles, deer, a big archaic cow, wolves, rabbits, and birds. Broken bones indicate that these animals were eaten. The discovery fills in some of the huge time gap between *Pithecanthropus* (400,000–500,000 years ago) and Neanderthal (90,000 years ago), and suggests that many other links in the chain of hominid evolution will be found. The discoverers were inclined to believe the skull is evidence that Neanderthal man developed independently of his contemporaries in Africa and Asia.

Archaeologists and historians have often raised the question of what motivated the Greeks to colonize southern Italy and Sicily in the 8th century B.C. At least a partial answer emerged from recent discoveries at a new archaic Greek site on the island of Ischia in the Bay of Naples. The buildings at the new site are not simply private dwellings but the remains of a metalworking center. Large and small chunks of raw iron "bloom," fragments of broken implements, and nodules of vitreous slag occur in great abundance. The buildings themselves appear to be designed as metalworking shops. Bronze as well as iron was worked in these shops. Pieces of bronze sheets and wire, lumps of lead, a bronze ingot, and a miscast bronze fibula all attest to the manufacture of metal objects.

There are no ore deposits on the island of Ischia, and the obvious sources of the raw materials found there are the island of Elba and the Etruscan mines in central Italy, near Populonia. Diodorus of Sicily, writing at a later date, describes such a commerce in iron ore, which was carried to emporia, then fashioned into implements and exported throughout much of the known world. Strabo tells us it was men of the Euboean aristocracy who led the Greek colonists westward. It now appears that metal manufacture and trade played a basic role in the

Courtesy, The Institute of Archaeology, Tel Aviv University



Assyrian-Babylonian cylinder seal of provincial workmanship was recovered at the Tel Beer-sheba site in Israel by an expedition directed by Yohanan Aharoni of Tel Aviv University The sanctuary of ancient Beer-sheba, a fortified city which divided the land of Israel and Egypt, yielded a rich find of cult objects, all of pagan origin showing strong Egyptian influences Further excavation was expected to shed more light on questions of early Israelite history and religion

first colonization. Work at the site was continuing under the direction of Giorgio Buchner and Jeffrey Klein for the Italian Antiquities Service and the University Museum, Philadelphia.

Mexico. In January 1939, in the Olmec country of eastern Mexico, Matthew Stirling of the Smithsonian Institution found a fragment of an inscribed stone monument recording a date in the Mayan calendrical system. The beginning cycle number (Baktun) was missing, but Stirling predicted that it would be a seven, making it the oldest known recorded date in America. During the year another fragment, recently discovered and reposing in a jail cell in the village of Tres Zapotes, Veracruz, was reported by Francisco Bevirido and Michael Coe to be a matching piece of Stirling's original discovery. The beginning cycle number is indeed Baktun 7, confirming a date equivalent to 31 B.C. in our own calendar.

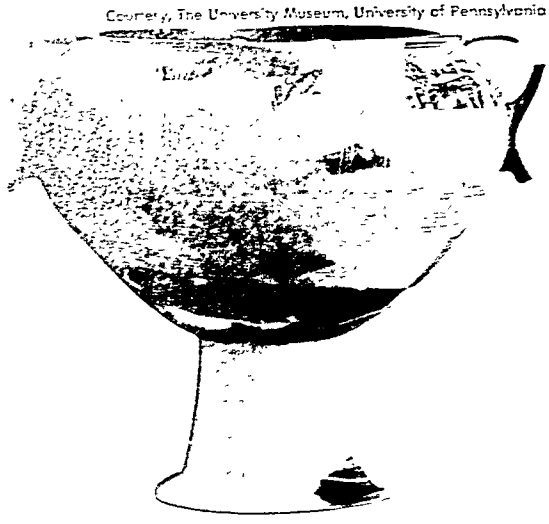
The discovery is significant not only because it is the earliest recorded date in America but because it helps to confirm a theory that the Olmecs, rather than the Mayans, invented this particular calendrical system. The earliest known recorded date in the Maya lowland region, found at Tikal in Guatemala, is A.D. 292. Other archaeological evidence also points to Olmec as the earliest civilization in America.

North America. Deep, stratified archaeological sites, normal in the Near East where the debris of thousands of years of human settlement are often found at a single site, are rare in North America. At the Koster site in the lower Illinois River Valley, however, excavations in 1971 were carried down to 18 ft and to an occupation level dated at 4200 B.C.; testing indicated that there are four lower levels that should date by the radiocarbon method to about 5000 B.C. Even more remarkable is the fact that the site's 12 cultural horizons, or occupation periods, are neatly separated by deposits of sterile soil washed in during periods when the site was abandoned. Such a separation of levels tends to preserve artifacts and other human and animal remains because they are not disturbed by later occupation. The only other known site in North America with this kind of separated stratigraphy extending over a very long period is at Onion Portage on the Kobuk River in Alaska, where caribou hunters settled repeatedly over a period of about 9,000 years.

Stuart Struever of Northwestern University began excavations at the Koster site in 1969. It is located on a slope in an old stream bed tributary to the Illinois, where loess deposited during periodic floods formed the stratified deposition. Continued excavation posed difficult problems. The depth of the cuts already completed raised the danger of cave-in and problems of earth removal. The two lowest horizons known from soundings are below the groundwater table, so that excavation would require constant pumping. Moreover, this kind of excavation requires a considerable team of researchers, including zoologists and botanists.

In British Columbia, University of Colorado archaeologists under the direction of James J. Hester discovered a site near the village of Namu in Fitz Hugh Sound where the earliest occupation was radiocarbon-dated at approximately 7000–8000 B.C. The significant point about this occupation lies in the fact that the material seems to have no connection with other material in the interior of southern British Columbia, but instead is allied with the earliest occupation at Onion Portage, which dates at approximately the same period.

These occupation levels in British Columbia and Alaska marked the earliest known horizon in the northern regions, though they fell far short of the period assumed for the original settlement of America from Asia. Another interesting aspect of the Namu site was the indication that the artifacts



Ancient Greek vessel decorated with an uncomplicated geometric motif was discovered at the Mezzavia site on the island of Ischia. Other finds indicate that the site was a commercial metalworking center.

reflect a coastal type of culture. This may have a bearing upon the theory that man first moved into North America along the sea front of what was once a land bridge in the Bering Sea area.

Techniques. The development of remote sensing devices in aircraft has greatly enlarged the scale of archaeological reconnaissance, and it was expected that further discoveries would result from experiments carried out by Earth Resources Technology Satellites. As an example of the technique, features that look like very straight roadways were traced nearly 15 mi in a northerly direction from Pueblo Alto in Chaco Canyon, New Mexico. Remote sensing from aircraft located a network of five of these so-called roads converging on masonry walls just east of the pueblo. They were first thought to be elements of a water system, but this was disproved by further study, and their nature remains a puzzle.

The discrepancy between radiocarbon (^{14}C) dates and certain astronomically fixed dates in the Egyptian calendar was first noted several years ago. Subsequently, comparison of the tree rings of 4,000-year-old bristlecone pine trees in the American Southwest, which could also be radiocarbon dated, indicated that ^{14}C dates prior to about 1000 B.C. are too young by several centuries. (See *1971 Britannica Yearbook of Science and the Future*, Feature Article: DATING THE PAST.) The MASCA Laboratory at the University Museum, Philadelphia, and the ^{14}C laboratory at the University of California in San Diego have both published systematic correction factors applicable to dates older than 1000 B.C.

Several papers published during the year by Colin Renfrew pointed out that European prehistory is being revolutionized by the corrected ^{14}C dates for Neolithic and Bronze Age sites in Europe and the Near East. For many years it has been generally agreed that major cultural advances in ancient Europe were derived from the Near East. With corrected dates, however, megalithic tombs in Western Europe and copper metallurgy in the Balkans proved to be older than their presumed prototypes in the eastern Mediterranean region.

One difficulty that emerged in the Renfrew papers involved the reliability of archaeological dates from Egypt and the Near East. A few of those dates, which can be correlated with actual astronomical phenomena, are certain, but the entire chronology built up from inscriptions recording the reigns of kings and other events is not so reliable. It may well be that much of the accepted Near Eastern archaeological chronology may need correction. In any case, radiocarbon dates around the world were being changed, and the effect on theories of diffusion, centers of origin, and time-relations of human events in different regions was sure to be significant.

The contributions of archaeology to the earth sciences were first noted when radiocarbon dating stations began to observe the increase of carbon dioxide in the atmosphere resulting from the burning of fossil fuels and the rapid dispersal in the earth's atmosphere of the fallout from nuclear tests. During the past year another example came to light. Radiocarbon dates for charcoal from aboriginal fireplaces at Lake Mungo in New South Wales, Austr., provide a record of a brief reversal of the earth's geomagnetic field about 30,000 years ago. The event apparently encompassed no more than 2,500 years. Additional evidence for such controversial events in the earth's history was also coming from Czechoslovakia and Mexico.

—Froelich Rainey

Architecture and building engineering

The great skyscraper race, abruptly suspended with the completion of the Empire State Building in 1931 and not resumed until the 1950s, continued to accelerate in 1972. As it did so, a new basic architectural concept, tubular design, established itself.

A new generation of skyscrapers. The invention of architect-engineer Fazlur Khan, of Skidmore, Owings & Merrill of Chicago, tubular design was only eight years old, but it had been used in four of the world's five tallest buildings. Tubular design

permits economical construction because with it the building's perimeter columns resist the lateral force of wind pressure, eliminating the need for expensive internal bracing in the floor system. Khan introduced the concept in a 43-story reinforced-concrete apartment house in Chicago. He then applied it to the design of two other Chicago structures, the 1,105-ft (337-m), steel-skeleton John Hancock Center and the 1,450-ft (442-m) Sears Tower, under construction as the new claimant of the title of world's tallest. The tubular concept was also used by other designers for the 1,350-ft (411-m) towers of the World Trade Center in New York City, and for the 1,136-ft (346-m) Standard Oil Co. of Indiana Building in Chicago.

On the Hancock project, the tubular design was visually marked by diamond-like diagonal truss bracing on the building's exterior, giving it something of the appearance of a bridge standing on end. The unique design saved $15 million and answered the problem of constructing a high-rise building that would have the great flexibility of interior space required to accommodate both office and residential use.

Following the Hancock, Khan used the tubular idea for the One Shell Plaza Building in Houston, Tex., a reinforced-concrete tower that rose 52 stories, setting a new record for all-concrete structures. In it Khan used what he called "tube-in-tube"; the inner tube, the walls surrounding the service core of the building, supported the interior dead loadings, while the closely spaced perimeter columns resisted the wind loads. Khan believed that concrete could be carried much higher by the tubular system and envisioned a 110-story concrete tower with criss-crossed bracing like that of the Hancock. Under construction in Chicago in 1972 was a 63-story combination hotel-office-commercial-residential building of concrete using tubular design. In another modification of his basic design, Khan used steel-and-concrete perimeter columns to take the wind load and a steel interior frame for the floor loadings of three new buildings, a 24-story office tower in Houston, a 36-story structure in Chicago, and a 50-story tower in New Orleans, La.

On the Sears Tower, Khan combined the tube design with a modular system. Nine continuous steel modules, each 75 ft sq in plan, form the tower from the street to the 50th floor. There the northwest and southeast modules stop, with the remaining seven modules continuing up through the next 16 floors. The northeast and southwest modules drop off at the 66th floor, and three others do so at the 90th. The final two continue to create the 20-story upper tower reaching to 1,450 ft (442-m). Common interior columns stiffen the interior of the modular skeleton. The modules create 75 × 75-ft column-free squares on every floor that can be organized freely to meet space requirements. Nine floors contain the building's mechanical operations such as heating and air-conditioning; three sets of two floors each (30th and 31st, 48th and 49th, 64th and 65th) and a single set of three (106th, 107th, and 108th) in the upper tower are clad with louvers, giving a striking exterior appearance of horizontal black bands.

Despite the large floors, the Sears building has an efficient floor-area ratio of 32 to 1, that is, 32 sq ft of building space to each square foot of the site. "We wanted to maintain a decent environment at ground level," said Khan, who planned the building's plaza to be dotted with art pieces. This consideration, rather than a desire to break a record, lay at the basis of the height decision. Sears, Roebuck and Co. required 3.7 million sq ft of office space; to preserve the plaza the building had to rise 110 floors.

If the site—a single square block on the west side of Chicago's Loop—was small for so large a building, it made up for the narrowness of the foundation by its depth. More than 180,000 cu yd of earth were excavated to make room for 240 caissons set on bedrock and hardpan. The hardpan caissons were to support the plaza and lower levels of the building, while the bedrock caissons underpinned the tower, one caisson for each interior and exterior column, which, at 15-ft intervals, made up the nine modules. The bedrock caissons are 6 ft in diameter and were sunk to a depth of 100 ft, some penetrating 9 ft into the rock for secure anchorage. Two 10-ft-diameter caissons in the center module support two columns that rise the full height of the building. The floor of the lowest basement consists of a 5-ft-thick mat that transfers the wind shear forces from above to the bedrock; the caissons take only vertical loadings. The world's largest drill rigs, one of which had a 500,000-ft-lb torque, were used to install the caissons.

Originally the Sears site consisted of two small city blocks separated by a narrow street. Khan and his colleagues considered two slim towers with a crossing over the street, a sort of modern version of the Wrigley Building, a Chicago landmark of another era. They even considered a single building with the street running through it, which would have made use of the tubular design impossible. The Sears Company solved the problem by purchasing the street from the city, but another problem immediately developed. Under the street ran a main sewer line that had to be protected as well as relocated. It was moved under the plaza and given 47 hardpan caissons for support.

...her new Chicago giant, the Standard Oil ..., rising on the south bank of the Chicago ... close to the lakefront, used the tubular de... to eliminate interior wind bracing. The work ... two architectural firms, Edward Durell Stone and Associates of New York and Perkins & Will of Chicago, the building uses a time-saving fabrication and erection system devised by Perkins & Will vice-president E. Alfred Picardi. Folded-plate perimeter columns in the shape of V's and pressed-plate spandrels (exterior panels) were shop-fabricated, eliminating welding at the site. The folded-plate columns were mass-fabricated in three-story sections by automatic cutting and welding techniques and simply bolted in place during erection. The column-spandrel units gave the building a unique appearance during construction, that of a rising forest of crosses.

As in other tubular designs, the core columns of the Standard Oil tower helped take the floor loadings while the perimeter columns handled the wind bracing. The floors act as diaphragms to transfer lateral wind load to the V-shaped columns. The floor trusses, all identical, were also mass-produced. The building had no setbacks. The foundation pad was supported by 56 caissons extending 100 ft to bedrock. The columns were mounted on an "egg crate" concrete grid whose ribs connected the tops of the caissons. Five subplaza floors had reinforced-concrete load-bearing walls and interior columns bearing on caissons in hardpan.

A notable innovation of the building's construction was the use, at the initiative of Standard Oil, of a computerized system of cost-estimating and control developed by the company for use in tanker design and in oil and mineral exploration. The basis of the system is the Monte Carlo simulation technique, which calls for an input of the expected, lowest, and maximum costs of each item. The computer then generates a series of random numbers that are transformed into either the lowest, the highest, or the expected cost of each item, and adds them to arrive at the total cost of a hypothetical project. By repeating the process a thousand times, a realistic low, high, and expected cost figure is reached.

Perkins & Will later developed a second, similar program of its own, in conjunction with Massachusetts Institute of Technology, and was applying it on other projects. "The traditional cost estimate of a building," said Picardi, "has had at best a contingency factor having no really good relation to the numerous variables and conditions that influence the final cost." The Monte Carlo system gave a highly reliable set of estimates (provided of course that the data was sound) and helped alert designers and builders to trouble spots. Picardi pointed out that "this is not a cost-cutting technique; it is a cost-control technique, telling us more accurately what our costs are."

A cost not anticipated by the computer in the Standard Oil and other buildings of the new generation of skyscrapers may be that of solving the television ghost problem. Completion of the World Trade Center in New York brought ghosts (double images) to thousands of TV screens because some of the signals from the antennas atop the Empire State Building were reflected off the new twin towers and so arrived at New Yorkers' sets a split second late. The phenomenon was repeated in Chicago as the Sears and Standard Oil buildings began to rise in the paths of signals sent out from the John Hancock Center and Marina City antennas. Many other cities, both in the U.S. and abroad, were similarly threatened. Relocating transmitting antennas is expensive, and other solutions, such as using signal-absorbing construction materials, were under study. The maturing of cable television (CATV) appeared to be an ultimate solution.

The new skyscraper competition showed signs of stretching across the Atlantic to Europe, where it originated with Alexandre Eiffel's airy 984-ft (300-m) tower built in 1889 for the centennial of the French Revolution and ever since the major landmark of Paris. The tallest building in the world until the Empire State and Chrysler buildings surpassed it in the early 1930s, the Eiffel Tower remained by far the tallest structure in Europe. The 1970s might see it eclipsed, however. A 600-ft (185-m) conventional office building was begun in London in 1972 to house the Westminster Bank. It was a product of Britain's most controversial architect-engineer, Richard Seifert, who was accused of putting commercial considerations ahead of aesthetic ones and of threatening to pollute the low-rise atmosphere of London.

Opening the Iron Gate. A long-dreamed-of Eastern European engineering project was finally brought to fruition in 1972 with the completion of the Djerdap Dam over the Danube at the historic Iron Gate, a 70-mi (1,100 km) stretch of swift water, swirling with rapids, between Yugoslavia and Romania. The two countries spent nearly $1 billion to tame the dangerous torrent, with anticipated vast benefits in increased shipping on the river that had been called Eastern Europe's most underdeveloped resource. The project survived the Danube's worst flood of the 20th century in 1970 and stayed on schedule. In 1972 barges moving upriver negotiated the Iron Gate in 31 hr compared with 120 hr required previously, even with the aid of locomotives on shore.

The earthfill dam was 196 ft (60 m) high and

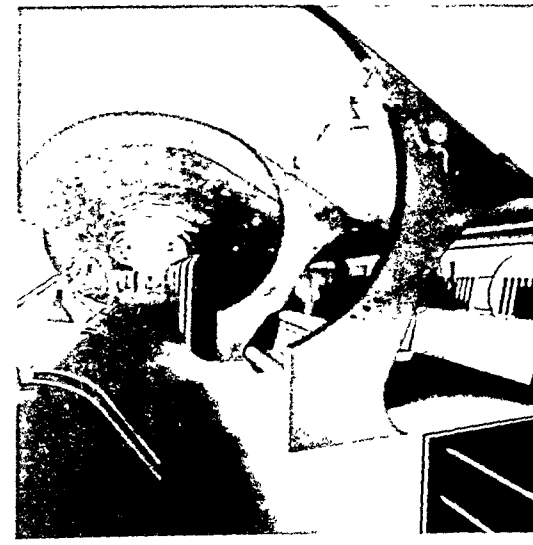
4,100 ft (1,250 m) long, had a two-chamber ship lock on either side, and identical powerhouses that produced 1,050,000 kw for each country. Besides sharing costs and benefits, Romania and Yugoslavia contributed jointly to the engineering design and the labor force. Construction was executed in three stages: (1) cellular cofferdams were built to enclose the lock and powerhouse structures on both sides; (2) sections of the dam were extended out into the river to match completion of powerhouse passages for the water flow; and (3) the final gap in midstream was closed by dumping a mass of concrete blocks. Each powerhouse was equipped with six generators, four of which tied the owner nation's grid, while the other two could be connected to either grid, allowing for varying peak demand in the two countries. In addition, power was to be sold to other Eastern European nations.

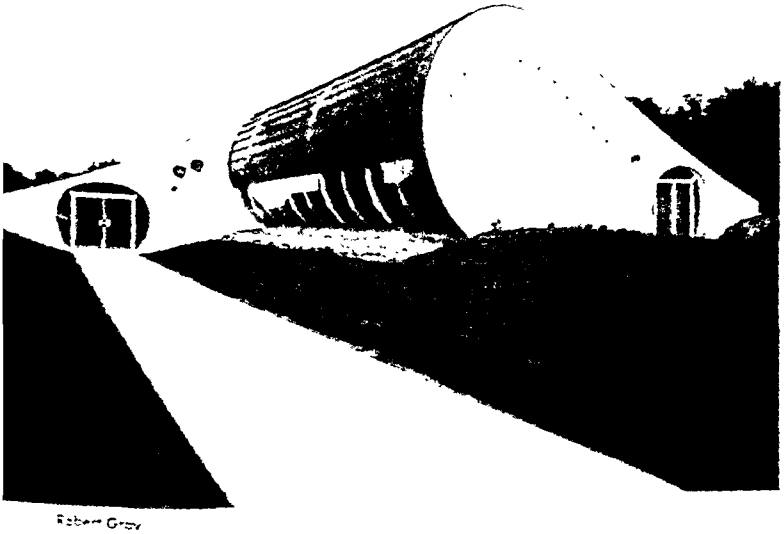
One detail of the project furnished a parallel to the rescue of the ancient Abu Simbel temple during construction of Egypt's Aswan High Dam in the 1960s. Yugoslav engineers carefully cut out of the canyon wall a Roman bas-relief and inscription commemorating the road built at the site by the Emperor Trajan nearly 20 centuries before and repositioned it above the new level of the back-up reservoir.

Pollution control projects. Air, water, and other types of pollution continued to draw the attention of engineers and public officials in 1972.

The Chicago Metropolitan Sanitary District, for example, began construction of the Salt Creek Water Reclamation Plant, which would pioneer a new two-step aeration process to reduce ammonia to less than 2.5 parts per million (ppm), suspended solids to 5 ppm, and basic oxygen demand (BOD) to 4 ppm. The plant was designed to meet the new, strict standards laid down by the state of Illinois. The plant would be capable of handling 50 million gal of flow per day, and a peak one-hour flow rate of 67 million gal per day. Storm flow was given primary sedimentation and chlorination treatment before being discharged into Salt Creek.

Sweden announced a new incentive plan whereby industries and towns that began to build anti-pollution systems or install air or water purification equipment could receive government grants

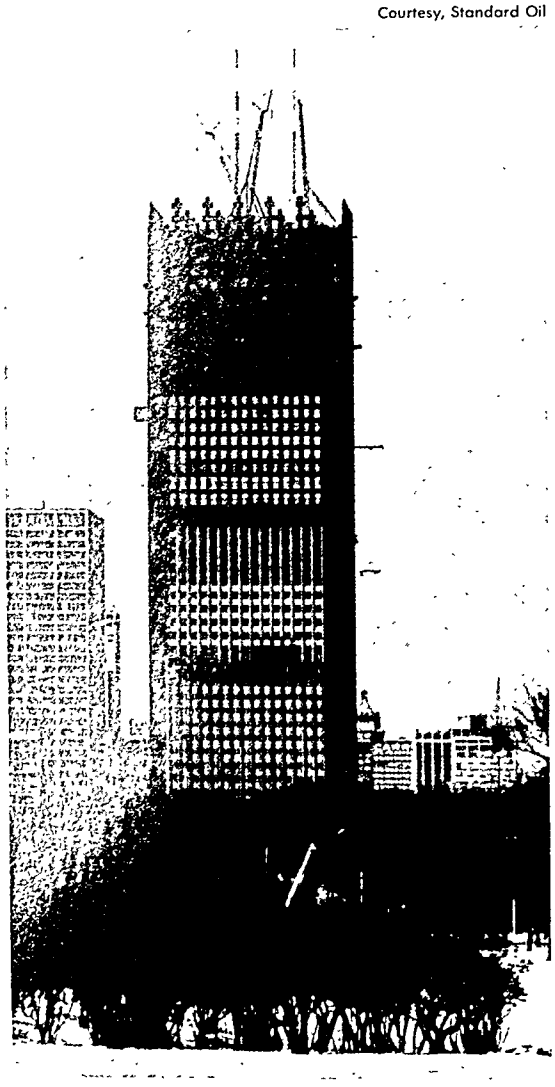




Robert Gray

A double-airfoil silhouette and entrance portholes (left) are the distinguishing exterior characteristics of an orthopedic clinic in Allentown, Pa. Designer Noel Schaffer also planned the 14,300-sq ft interior (above), using a modular concept that can be subdivided or expanded almost at will to meet changing requirements.

Courtesy, Standard Oil



Shop-fabricated column-spandrel units form a series of crosses atop the Standard Oil Building in Chicago during construction in 1972. The building also utilized tubular design to eliminate interior wind bracing.

covering 75% of the cost. The plan was designed simultaneously to ease Sweden's unemployment and improve its antipollution situation.

Sweden was also the site of the first world meeting to discuss the pollution problem. In June 1972, the United Nations Conference on the Human Environment met in Stockholm seeking to develop environmental control techniques on the international level through monitoring, resource management, and education, including assistance to less-developed countries in finding ways to advance economically while maintaining sound environmental practices. A number of antipollution steps were taken on the international level in Western Europe, where the European Economic Community agreed on continent-wide automobile emission standards, with the British and Swedish governments joining in.

Tunneling ahead. One engineering approach to pollution problems may be to dig. Underground construction, definitely on the upswing throughout the world, promised certain advantages in respect to the environment, as Ellis Armstrong, commissioner of the U.S. Bureau of Reclamation, among others, pointed out. Armstrong spoke at a symposium held by the Geological Society of America in Washington, at which another engineer forecast 554 mi (886 km) of transportation tunnels would be constructed in the 1970s, and up to 1,500 mi (2,400 km) in the 1980s.

Transportation tunnels could provide high-speed mass transit without damage to the environment. They could also be beneficial as automobile carriers because the auto emissions might be collected and treated before release to the atmosphere. Tunnels might appear in a new form for one of their oldest functions, that of water transport: a proposal was under study for an offshore pipeline, built as an immersed tube sunk in a trench of the continental shelf, to help solve the water shortage in southern California. Sweden, Norway, and other countries increasingly employed underground chambers for storing petroleum products, including compressed gas cooled to a liquid state.

Behind the growing popularity of tunneling for a variety of purposes was the improved capacity of tunneling machines (moles), especially for tunnelling through hard rock. Within the next decade the giant borers were expected to become capable of 500 ft a day in hard rock and 1,500 ft a day in soft ground. Their progress might soon make economically feasible an important antipollution measure under consideration in many cities: underground storage chambers for storm waters. Such chambers would permit the treatment of all wastewater, including storm water, received by a combined sewer system (virtually the only kind in existence). In the absence of a reservoir, this wastewater must bypass treatment plants whenever a heavy storm flow occurs.

France's new port. French engineers completed a major maritime construction project in the Gulf of Fos, 19 mi (30 km) west of Marseilles, a man-made harbor that took advantage of a fine natural harbor site. A long sandspit hooking out from the mouth of the Rhone River on the west side of the gulf half enclosed the inlet. The Marseilles port authority engineers built a 2-mi (3-km) jetty extending from the base of the gulf toward the point of the sandspit, leaving an entranceway between. Along the interior of the jetty four huge berths were built

for the new giant oil tankers. To give the jetty a firm foundation, a wide trench was first dug and filled with hard sand from the mouth of the Rhone. Gravel fill and rock fill completed the embankment. Within the harbor three broad channels were cut into the uninhabited marshland to receive ore carriers and container ships. The Fos harbor, added to that at Marseilles proper, made the area Europe's second largest port.

The Disney World water problem. Construction of the 30,000-ac Walt Disney World near Orlando, Fla., which opened in October 1971, was made possible by an ingenious system of hydraulic engineering that overcame the table-flat site's two conflicting meteorological phenomena, seasonal droughts and tropical rainstorms. To prevent the water table from dropping and killing vegetation, and to keep the entertainment area unflooded through the year-round tourist season, a network of 50 mi (80 km) of canals with 30 gated control structures, and double-acting levees was built. The gates had to act automatically to cope with the suddenness of Florida downpours. The device employed was not electrical or mechanical, however, but relied simply on a counterweight and a buoyancy compartment; when the counterweight was adjusted for a particular water level, the buoyancy compartment operated the gate unattended.

The world's largest powerplant. By mid-1972 work was nearing completion on the foundation and abutment clearing work for the Sayano-Shushenskaya hydroelectric project in the U.S.S.R. When completed in 1977, it was expected to produce a world's record 6,400,000 kw of electric power. The project was part of the development of Siberia's Yenisei-Angara river basin. The arch dam that would block the narrow Yenisei canyon was designed to rise 774 ft (236 m).

Soviet planners hoped to build as many as 15 dams in the project. This would produce enough power to provide the basis for a vast industrial development to exploit the metal-ore riches of the region.

—Joseph Gies

Astronautics and space exploration

The pace of manned space exploration slowed during the year under review with only one flight to the moon by the United States and none by the Soviet Union. But in unmanned flights considerable activity took place. Highlights included probes to Mars and Venus and the first spacecraft ever to be launched to Jupiter.

Earth satellites

Earth-oriented satellites utilize the vantage point of space in a number of ways, seeking increased knowledge of the earth, economic benefit, and military security. Also called applications satellites, there are three general classes: communications, earth-survey, and navigation. By 1972 each had developed greatly in performance, capability, sophistication, and promise for the future.

Communications satellites. The Communications Satellite Corporation (Comsat), a U.S. firm, operates the global space communications network for an 83-nation consortium. Four fourth-generation Intelsat 4 satellites were in orbit by mid-1972. Each of these 18-ft-tall by 8-ft-diameter satellites provides an average of 6,000 two-way telephone circuits or 12 color television channels or tens of thousands of telephone circuits. The operational lifetime of each is seven years. Thirty-nine countries are now linked through 63 earth stations. By 1979 it was estimated that there would be 90 ground antennae in about 58 countries.

All Comsat satellites are launched into geostationary, or synchronous, orbits. This means that at a certain orbital altitude, 22,300 mi, the satellite velocity matches the angular rate of the earth's rotation and thus remains fixed over one portion of the earth's surface.

When U.S. Pres. Richard Nixon made his historic eight-day trip to China in February 1972, nearly 200 hours of satellite time were used for high-quality color television transmission. After the trip China leased four Comsat circuits for voice, teleprinter, and telephoto service. Earlier in February, the Winter Olympic Games in Sapporo, Jap., were televised by Comsat to Europe and the United States.

The development of satellites for secure communications by U.S. military forces advanced in 1971–72. In November 1971 two high-powered geostationary satellites were launched using a Titan IIIC booster. Four more were planned to replace the smaller, lower-powered, and limited-bandwidth military satellites. In early 1972 this early class of military satellites numbered 21 in operation using 29 earth terminals. The satellites were designed to turn off automatically during the period 1972–74. The development of a tactical communications satellite system for application to small ground terminals and the U.S. fleet continued. Receiving antennae as small as 1 ft in diameter might be feasible in this system.

Several applications were made by Comsat and other U.S. firms for licensing systems to transmit nationwide television by geostationary satellites. The Comsat proposal would employ three satellites larger than Intelsat 4s, each with a capacity

color television channels, and would utilize tal ground network of 132 stations.

Among the advantages that might be gained by increased development of communications satellites is the reduced cost of long-distance communications, both for the private consumer and for data transmission by industry. In the realm of television broadcasting, however, such satellites perhaps offer their greatest promise of impact and general benefit. The satellites in operation in 1972 required large, powerful receiving stations that transmit television by microwave or landlines to a local broadcasting station whose own transmitters then beam the television image to home receivers. Eventually, however, scientists may develop satellites capable of broadcasting directly to home receivers. Such a satellite must have high broadcast power and a large antenna. To meet these needs, the U.S. National Aeronautics and Space Administration (NASA) was currently developing the Applications Technology Satellite F (ATS-F). It was to be equipped with a 30-ft-diameter antenna, the largest yet deployed in space.

In 1973 the ATS-F satellite was scheduled to be used by the government of India in a program of mass education. Receiving television signals from an Indian transmitter, the satellite would then rebroadcast from its vantage point in space to approximately 5,000 villages. Each village, according to the plan, would have an antenna and at least one low-cost large-screen television receiver. Initially, the programs were to deal with improvements in agricultural practices and methods of population control. The possible expansion of this experiment within India could lead to direct linkage of all of that nation's approximately 560,000 villages. Since interlinking television landlines do not exist and the country has insufficient funds to build them, the broadcast satellite holds immense potential as the most effective way of educating India's 524 million people.

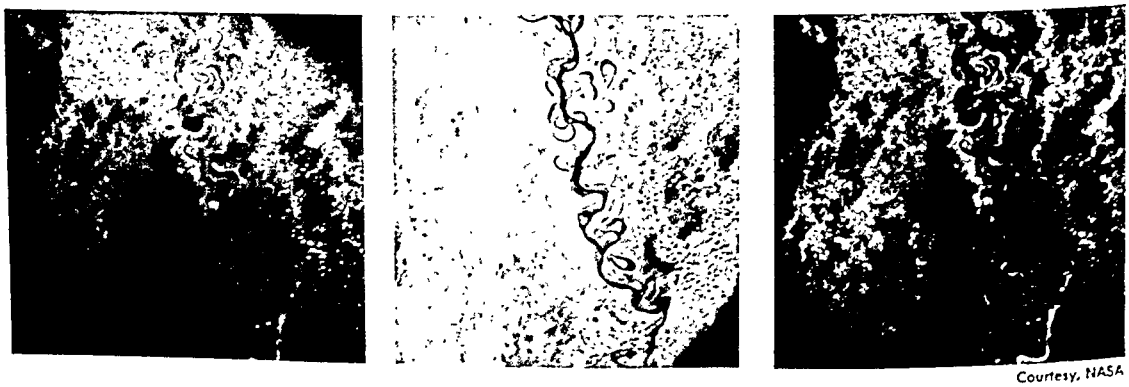
Meanwhile, Canada was moving ahead to orbit Anik 1, the world's first domestic communications satellite, late in 1972. Three of these satellites were being constructed for Telesat Canada, and each was designed to relay 12 communications channels. Each channel could provide one color television program or as many as 960 voice channels. Anik is an Eskimo word meaning brother.

In Europe development of the Franco-West German Symphonie satellite continued. It was not completed in time for the 1972 Olympic Games at Munich, but a launch of the prototype in early 1974 was thought feasible.

Two more Molniya 1 and the first of the Molniya 2 communications satellites were launched in the U.S.S.R. in 1971. The new design operates on higher frequencies than the Molniya 1, more closely approximating those of Intelsat 4.

The Soviet Union's approach to communications satellite systems remained quite different from that of the U.S. Beginning in 1965, the U.S.S.R. launched a series of Molniya 1 satellites in an orbit inclined about 65° to the equator. The orbital path was not geostationary but eccentric, moving closest to the earth in the Southern Hemisphere and reaching its highest altitude over the Northern Hemisphere. This path permitted a Soviet satellite to travel for a relatively long time, about eight hours, over the portion of the earth visible to U.S.S.R. ground terminals. Because the Soviet craft are higher powered than corresponding U.S. satellites, relatively low-cost ground terminals can be used. Three such satellites, by proper spacing, can achieve 24-hour coverage within the Soviet Union. Ground terminal construction in the U.S.S.R. continued at the rate of 6 to 8 per year, and by late 1972 there were about 50 stations.

Three simultaneous photographs of a portion of the earth's surface, exposed on (left to right) black and white film with a green filter, near infrared black and white film, and black and white film with a red filter, were taken by a camera system developed for the Earth Resources Technology Satellite, launched in 1972.



Courtesy, NASA

In late 1971 Cuba joined Intersputnik, the Soviet bloc equivalent of Intelsat. The Cuban ground station was scheduled to become operational in 1973.

Earth-survey satellites. In this category are included meteorological (weather), geodetic, earth resources, and reconnaissance satellites. Such satellites are designed to survey the earth with various sensors, both photographic and electronic, in order to obtain and transmit data that could not be gained by other means.

Weather satellites. Only the U.S. and the Soviet Union in 1972 had operational satellites with continuing global daily coverage. In the U.S. the National Environmental Satellite Service (NESS) was responsible for weather satellite operations. NESS is a major element of the National Oceanic and Atmospheric Administration of the Department of Commerce. Developmental work on advanced design satellites and all launchings into polar orbit were conducted by NASA.

In early 1971 NESS was controlling four operational meteorological satellites. Two of these spacecraft were primary sources of operational cloud-cover data, and two were backup in case of failure of the primary system. In mid-1971 failure did occur and the two older, standby, spacecraft were "called up." Their sensors and transmitters were activated and they provided data as required.

Two major uses are made of these U.S. satellites. One is to store global cloud-cover data and then "dump" it (or read it out) on command by one of two U.S. command and data stations. This information is then transmitted to central processing centers for operational use on a global scale. The other use for the satellites is the direct readout for immediate local use. This latter worldwide availability of Automatic Picture Transmission (APT) permits direct interrogation of the satellite by more than 500 APT stations located in 94 countries and trust territories. Because the NESS satellites are in polar orbit any point on the earth's surface can have direct access to a picture of regional, cloud-indicated weather at least once a day.

While NESS conducted regular weather satellite operations, NASA continued to develop advanced systems and components. These included Nimbus 4 and two Applications Technology Satellites (ATS-1 and -3). Nimbus 4 carried, among other sensors, an infrared spectrometer, data from which is converted into a description of the vertical temperature distribution in the atmosphere. The ATS satellites were geostationary, and their daytime pictures covered most of the Western Hemisphere. By use of a time-lapse movie sequence technique the development and motion of large- and small-scale cloud systems are studied to estimate low- and upper-level wind speed and direction and in the diagnosis of hurricane and severe local storm situations. National television weather reports now alert regions on a daily basis as to where severe storms may occur.

In 1971 the U.S. operational weather satellite system completed five years of uninterrupted service. During this period great quantities of data on global weather movement were acquired, stored, and studied at the National Meteorological Center, Suitland, Md. They proved useful in forecasting weather conditions that endanger livestock in western ranching regions, in marine advisories, in sea and lake ice forecasts, and in tracking and forecasting the movements and intensities of severe storms and hurricanes.

NESS is conducting a number of studies, including the monitoring of polar ice packs, snow mapping and snow surface temperatures, and the manner in which tropical heat is injected into the middle latitudes. The results of such studies are expected to lead to a better understanding of how weather develops, thus improving short- and long-term forecasting.

The Soviet Union continued to launch its Meteor class of weather satellites, with four orbited successfully in 1971. A cooperative program of rapid exchange of weather photographs was established between the U.S. and the U.S.S.R.

Geodetic satellites. By simultaneous observation of a satellite from two distant points on the earth's surface the distance between these two points can be determined with an accuracy not previously possible. The first satellites used for geodesy were launched in the early 1960s. In 1971 a program using laser observation equipment was carried out by the U.S., several Western European countries, Australia, and Japan. Three French and four U.S. satellites were used for observations. Such data can correct maps and properly locate continents as well as measure the small annual continental drift.

Earth resources satellites. As a logical outgrowth of growing sophistication of observations of the earth from the vantage point of space, NASA launched an Earth Resources Technology Satellite (ERTS) in mid-1972. Many of the sensors and subsystems were advanced developments of those tested in the ATS series, Nimbus, and other spacecraft. ERTS-A was launched in a near-polar, circular orbit at an altitude of 492 mi. It weighed about 1,800 lb and had an estimated lifetime of one year. The satellite carried three main systems: a television camera, multispectra scanners, and a data collection system.

The multispectra scanners detect the distinctive electromagnetic radiation reflected by every object

the earth, including its subsurface strata, its atmosphere, and its oceans. Vegetation, for example, has a distinct reflective "signature" different from water or bare earth. Different crops or trees have different signatures. Moreover, diseased plant life has a different signature from the healthy crop.

ERTS-A circled the earth every 103 minutes, completing almost 14 orbits a day. It thus could see any spot in the U.S. every 18 days. The satellite scanned a 100-sq mi area, relaying overlapping pictures back to earth or storing them to be relayed later. A number of remote automatic data collection platforms were located in the U.S. and its coastal areas. Each platform had as many as eight sensors, which sampled such local environmental conditions as stream flow, snow depth or soil moisture, and air and ground temperature. Information from any platform was available to users in less than 12 hours from time of measurement. Three U.S. data acquisition stations are planned: Fairbanks, Alaska; Mojave, Calif.; and NASA, Greenbelt, Md.

Both ERTS-A and ERTS-B, to be launched in 1973, are essentially concerned with further developing the technology of this type of spacecraft. Many scientists expect these satellites to be the most useful of all applications of space flight. The data that they obtain will be made available to hundreds of scientists in universities, state and local governments, and federal agencies.

Listed below are the hoped-for benefits from earth resources surveys:

In agriculture, the information gathered will aid in land use planning, range management, identification and combatting of crop diseases, and improved irrigation planning.

In geology, scientists envision ERTS data being used in monitoring glaciers and volcanoes, in improving earthquake predictions and warnings, and in identifying terrain features usually associated with oil and mineral deposits.

In hydrology, the ERTS system promises to produce information useful in detecting water-pollution trends, in providing an inventory of lake and reservoir levels and rain and snow levels, in predicting the potential of floods, and in the locating of other water reserves.

In oceanography, the ability of ERTS sensors to detect changes in sea temperature may produce information useful in showing the probable location of schools of fish. ERTS data also promise benefits in aiding maritime commerce by better charting of sea conditions, and in spotting ice fields for iceberg warnings.

In geography, ERTS sensors will produce a constantly updated map showing the various changes in the earth's surface, as the result both of natural events and of building by man. This information promises to be of great value for use in urban development and transportation planning.

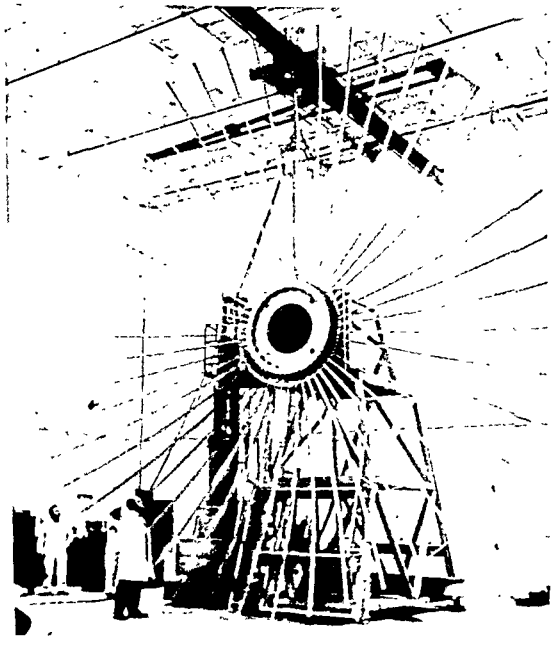
From the standpoint of environment it is possible that ERTS will provide a powerful tool to assess and monitor the earth's ecology on a global scale. Infrared scanners, for example, can detect thermal pollution in water—both day and night, while conventional photographs from space can show discoloration and patterns in bodies of water for tracking and controlling pollutants. Ecologists agree generally that only by dealing with the problem on a worldwide basis will man be able to save his oceans and atmosphere from being destroyed by pollution.

Reconnaissance satellites. The U.S. and Soviet Union continued their reconnaissance satellite programs, but they continued to be highly classified for security purposes and no details about them were released. It was known, however, that the spacecraft involved in these programs utilized extremely high-resolution photographic and narrow-band electromagnetic radiation surveillance techniques.

Since the early 1960s both countries have launched more than 175 military observation low-orbit, satellites. All payloads were recovered after a few days in orbit.

One additional type of U.S. military reconnaissance satellite that deserves mention is the Vela. Its purpose is to detect nuclear explosions in the atmosphere and in space. Two Vela satellites were placed in orbit in 1970, the sixth pair in a series that began in 1963.

Thirty-foot-diameter antenna was developed for Applications Technology Satellites designed to pioneer new educational television, data relay, air-traffic control, and information transmission systems.



Courtesy, NASA

Navigation satellites. In the area of navigation satellites, the U.S. Navy Transit system continued to be fully operational and in use by the U.S. fleet throughout the world. Although commercial ships were permitted to use this system, it required a shipborne computer to calculate position from the Doppler shift of the satellite's signal and was thus probably too expensive for widespread public use. Future civilian systems were more likely to depend upon a signal transmitted from a ship via satellite to a shore-based computer, where position data could be determined and broadcast back.

The Soviet Union claimed to have an operational navigation satellite system, but released no details. NASA and the European Space Research Organization were holding joint studies concerning satellites that would be used for communications and for surveillance of aircraft flying in the North Atlantic air routes. This was expected to permit aircraft to fly closer to one another. Thus, while in 1972 airplanes must be separated laterally by distances of about 120 mi, a satellite monitoring system could permit continuing "fixes" of aircraft only a few miles apart. Tests by the U.S. Federal Aviation Administration indicated that such a system could be in operation in the late 1970s.

—F. C. Durant III

Manned space exploration

During the past year, manned space flight was reduced. The United States successfully completed the Apollo 16 lunar exploration, while the Soviet Union did not launch any manned missions following the tragic Soyuz 11 flight that ended with the death of the three cosmonaut crewmen. In the U.S., the manned space flight program continued to be criticized by some members of the Congress, the science community, and other public leaders. There was a growing feeling that the resources being used for the manned space flight program should be used in the solution of the nation's domestic and welfare problems. Notwithstanding this criticism, U.S. Pres. Richard Nixon announced that he had decided that the U.S. should proceed with the development of a new type of manned space transportation system called the space shuttle. In addition, preliminary planning continued on a joint U.S./Soviet Union international rendezvous and docking mission.

Apollo. Apollo 16 was launched from Cape Kennedy on April 16, 1972, after a delay of one month for various technical problems. The commander for the mission was John W. Young. It was his fourth space flight, as he had previously flown on Apollo 10 and Gemini 3 and 10. The lunar module pilot was Charles M. Duke, Jr., and the command module pilot was Thomas K. Mattingly II, both rookies in space. The launch and flight into lunar orbit were accomplished as scheduled except for some minor problems with the S IVB section of the Saturn V booster rocket.

The first major problem encountered in the mission occurred in lunar orbit after separation of the lunar module from the command module prior to the start of lunar landing operations. It was found that a secondary yaw gimbal actuation on the service module propulsion system was oscillating. Tests and analysis showed, however, that the system was still usable and safe. This problem delayed lunar landing approximately six hours.

The landing site for the 11-day mission was 45 mi N of the ancient crater Descartes on the hilly, grooved, and furrowed edge of the Kant Plateau in the central lunar highlands among the highest mountains on the face of the moon. The landing site coordinates were 9°00'01" S and 15°30'50" E. This area of the moon was important to geologists because rock and soil samples from this site were expected to provide information about the composition and age of the lunar surface and also increase our knowledge about volcanic activity and the role it played in the evolution of the moon. Near the landing site were two large craters, North Ray and South Ray, which had thrown out huge blocks of the basin fill.

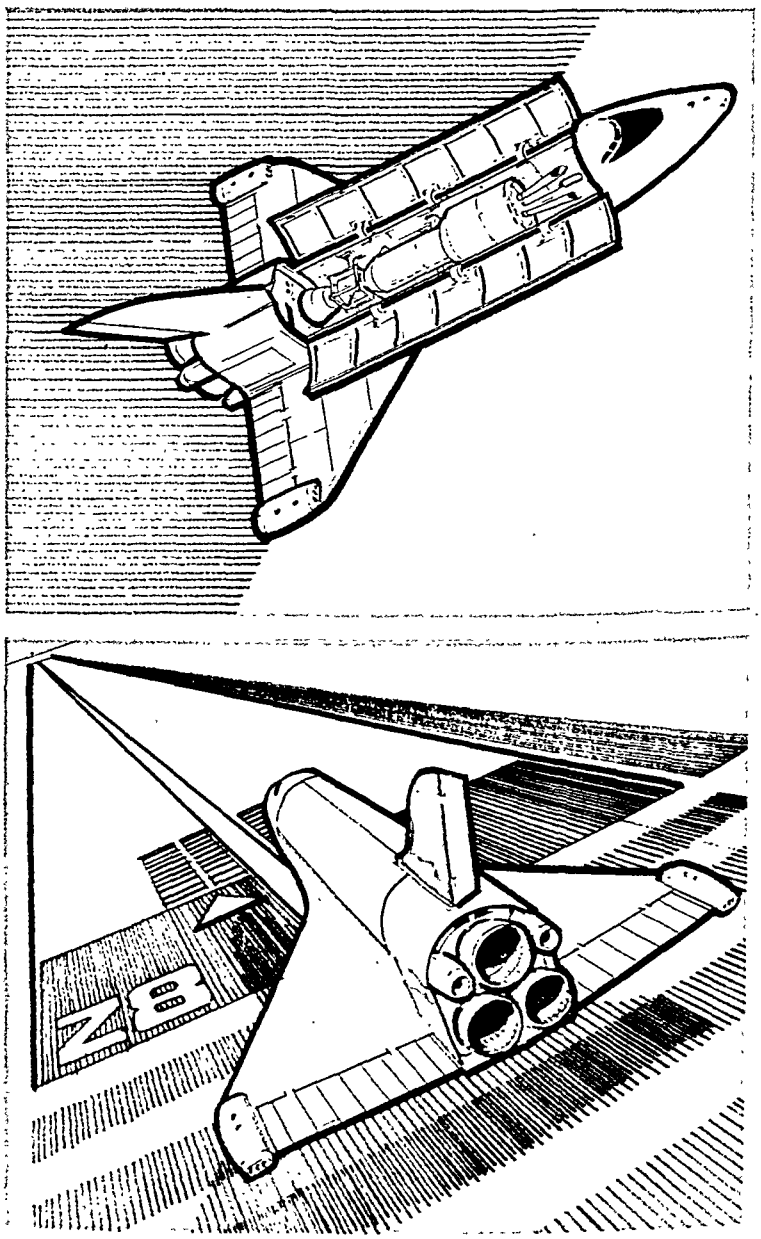
Three lunar surface excursions were taken by Young and Duke. On the first, an electric-powered four-wheeled lunar rover was deployed, an Apollo lunar surface experiments package (ALSEP) was placed on the surface and activated, and geological samples were obtained. The astronauts also deployed the first lunar astronomical observation device, a Far Ultraviolet Camera Spectrograph. This device took photographs of the earth, various galaxies, and the Magellanic Clouds. From these pictures, scientists expected to be able to study the earth's atmosphere and magnetosphere and their interaction with the solar wind. In addition, the spectrograph was designed to help astronomers study the interstellar gas that is present throughout space and the ultraviolet halos that appear around galaxies. This experiment would thus provide an evaluation of the moon as a possible site for future astronomical observations.

On the first excursion by Young and Duke, two lunar exploration stations were made in the vicinity of the Flag and Spook craters. On the second, geological investigations and lunar sampling were conducted at Stone Mountain and at several craters. On the third trip the crew drove to the rim of North Ray Crater and examined this area in detail, obtaining both rock samples and photographs. In total the Apollo 16 astronauts spent 20

hours and 14 minutes in lunar surface exploration, traveling almost 17 mi and collecting about 213 lb of rock and soil samples.

After approximately 71 hours on the moon's surface, the crew initiated lunar ascent and rendezvous and docked with the command module. The mission was terminated one day early. Landing and recovery took place in the Pacific Ocean.

Apollo 17, scheduled to be launched in December 1972, is the last mission in the current U.S. lunar landing exploration program. The landing site selected is Taurus-Littrow in the northeastern portion of the moon at 20°10'N latitude and 30°48'E longitude, and on the southeastern rim of the Sea of Serenity. The area is characterized by material that is believed to be ancient highland crustal blocks emplaced by faulting and uplifting at the time of the formation of the Serenity basin. Both very old and much younger surface material are expected to be present at the site. The objectives of the mission will be to conduct lunar surface geological exploration, to establish another ALSEP



The reusable space shuttle is designed to make possible a more economical manned space program. After being launched by a reusable booster rocket, the shuttle can deliver scientific payloads into earth orbit through its open hatches (top). When its mission is completed, the shuttle can be landed like an airplane (bottom).

station, and to conduct lunar surface traverse experiments. In addition, lunar orbital experiments will also be conducted from the command module. The same basic spacecraft and lunar rover vehicle were to be used as in Apollo 15 and 16.

Skylab. The fourth U.S. manned space flight program, Skylab, was designed to use existing Apollo spacecraft and launch vehicles with modifications for long-term earth orbital flights. The third stage of the Saturn V, the S IVB, was modified to serve as an orbital workshop. It contained living quarters and the necessary provisions for sleeping, eating, and housekeeping to support three crewmen for one 28-day and two 56-day missions. It also contained medical and other science and engineering experiment equipment. The workshop was 22 ft in diameter, 48 ft long, and had two floors. Its environment was to be maintained at a pressure of five pounds per square inch with an atmosphere of 70% oxygen and 30% nitrogen.

An airlock module, consisting of a special hatch, an airlock compartment, and equipment for supporting space walks by the Skylab crewmen to retrieve science experiments, was to be joined to the orbital workshop. It also contained additional crew working areas to perform earth-resources and space-manufacturing experiments and housed the controls and displays for the Apollo Telescope Mount. A third module, the multiple docking adapter, was designed to provide facilities for docking the Apollo command module, which was to be used to transport the Skylab crewmen to and from the orbital workshop.

During operations, scheduled to begin in the spring of 1973, the unmanned orbital workshop with the airlock module and multiple docking adapter was to be launched by a Saturn V into earth orbit at an altitude of 270 mi. One day after the Skylab launch, three crewmen would be launched in the Apollo command module by a Saturn IB. They would fly the command module to a rendezvous and docking with the orbital workshop. The three crewmen would then activate the orbital workshop and carry out various experiments within it for 28 days, after which they would deactivate the workshop and return to earth in the command module. Sixty days later, another three-man crew would be launched into orbit to revisit the orbital workshop for 56 days. A third three-man crew would be launched 60 days later for another 56-day mission.

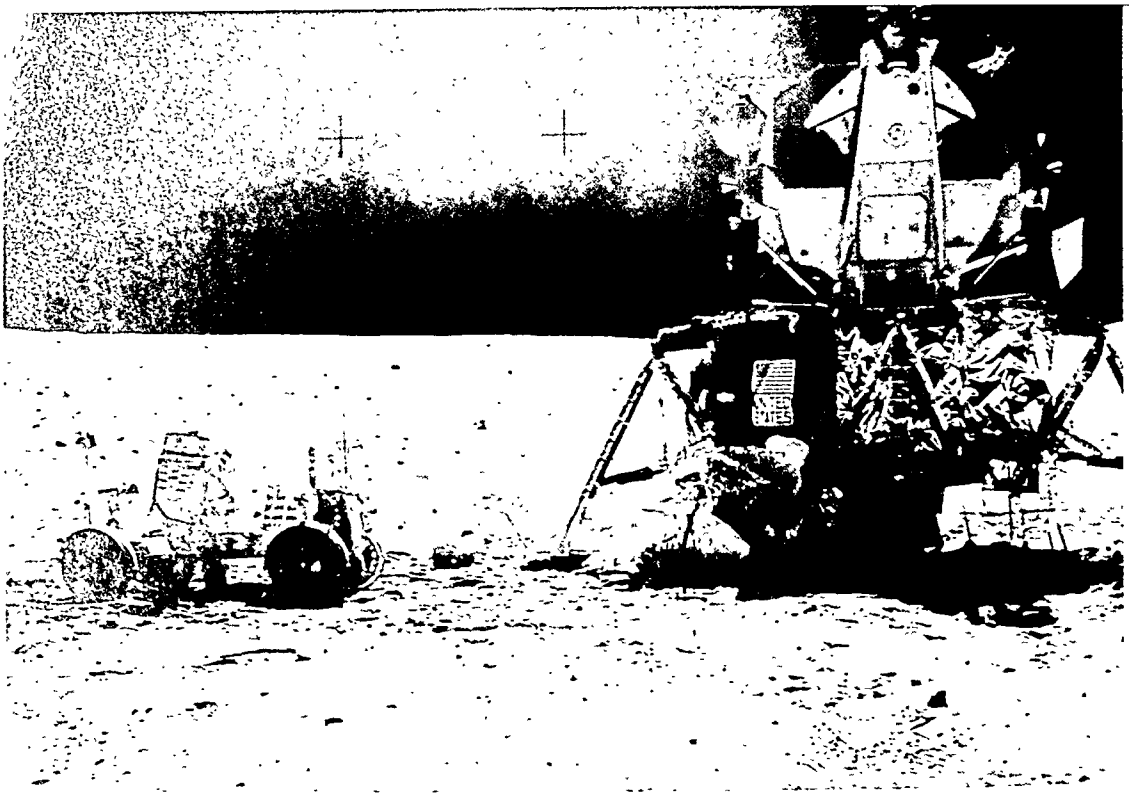
In the Skylab program, the crews were scheduled to perform experiments in many technical fields. Medical experiments would be conducted to study the various body systems. From these studies, scientists expected to obtain information on the physiological responses to long-term manned space flight and the crew's ability to adapt to a weightless environment. These medical studies were considered to be of extreme importance to future manned flight programs. Science experiments were expected to include geophysics, physics of the upper atmosphere, astronomy, and studies of the sun. The Apollo Telescope Mount was to contain a complex solar observatory that would permit observations and measurements to be made on the sun that are not possible to make from the ground because of the earth's atmosphere. An earth resources instrument package was to be used to conduct broad surveys of crops, geological formations, weather conditions, and gross vegetational regions. Engineering and technology experiments were to include material processing and manufacturing in the weightless environment.

Space shuttle. In the past year, preliminary design concepts were established for a reusable manned spacecraft called the space shuttle. Space engineers conceived it to be an airplanelike vehicle that could be used repeatedly to take satellites into orbit and bring them back for repair and service as well as performing manned orbital missions on its own. It was hoped that the shuttle would reduce the cost of manned and unmanned space flights. The space shuttle was to consist of an orbiter and booster. The orbiter would resemble an airplane and be about the size of a small jet airliner. It would be powered by three hydrogen-oxygen rocket engines and have a cargo bay 15 ft in diameter and 60 ft in length. A two-man crew would fly the orbiter, which would also be able to accommodate 2–14 scientists or technicians. The booster would be an unmanned recoverable solid-fueled rocket.

During operation the orbiter stage would be launched in a "piggybacked" position by the booster. At a predetermined altitude, the orbiter would separate and fly into orbit like a spacecraft. In orbit, the crew and scientist passengers would be able to launch unmanned satellites and space probes, conduct experiments, make observations of the earth and solar system, and retrieve and/or repair satellites previously placed in orbit. When the mission was completed, the orbiter would re-enter the earth's atmosphere and land like a conventional airplane. It would then be serviced and made ready for future flights. The first space shuttle flight was scheduled for 1978.

Soviet manned space flight. In the past year, the U.S.S.R. did not launch any manned missions. The ill-fated Soyuz 11, launched June 6, 1971, was the last manned Soviet space flight. In this mission, the crew was launched in the Soyuz spacecraft and then rendezvoused with Salyut, a large orbiting space station 66 ft long and 13 ft in diameter.

Courtesy, NASA



Apollo 16 commander John W. Young works on the Lunar Roving Vehicle (left). Astronaut Charles M. Duke, Jr., piloted the lunar module (right) and astronaut Thomas K. Mattingly II remained with the command and service modules in lunar orbit during NASA's fifth manned voyage to the moon.

The crew transferred to the Salyut space station and performed biomedical studies similar to some of the planned Skylab medical experiments. Studies in astrophysics and meteorology were also conducted. The crew made observations on the earth's weather conditions, and these were then coordinated by earthbound scientists with photographs transmitted from unmanned weather satellites.

The crewmen terminated the mission 24 days after the launch. They moved back into the Soyuz 11, separated from the Salyut, and started the procedures to reenter the earth's atmosphere. Shortly after the reentry rockets were fired, there was a loss in communications. When the spacecraft landed, ground crewmen found that the three cosmonauts, Georgi T. Dobrovolsky, Vladislav N. Volkov, and Viktor I. Patsayev were dead. A Soviet commission appointed to study the cause of the accident reported that a hatch or valve failure created a rapid decompression of the Soyuz 11 spacecraft, killing the three cosmonauts. The Salyut remained in orbit until Oct. 11, 1971, when retro-rockets were fired and it was destroyed during reentry into the earth's atmosphere.

International cooperation in space research. The U.S. and the Soviet Union continued to work together to determine the feasibility of an international docking mission. As envisioned in 1972, three Apollo crewmen would be launched in an Apollo command module to rendezvous and dock with three crewmen aboard the Soyuz spacecraft. The crewmen would move from one spacecraft to the other to perform joint operations. This mission would lay the foundation for international space rescue missions. Engineers and scientists from the two countries exchanged technical design data to establish the required docking interfaces between the two spacecraft. Formal approval of the mission was made during President Nixon's visit to the Soviet Union in May 1972.

In other international cooperative efforts between the U.S. and U.S.S.R., biomedical specialists met in Moscow in the fall of 1971 to start the exchange of medical data from the manned space flight program. A second meeting was held at the Manned Spacecraft Center in Houston, Tex., during May 1972 to exchange medical results from Soyuz 11 and the Apollo program.

—Richard S. Johnston

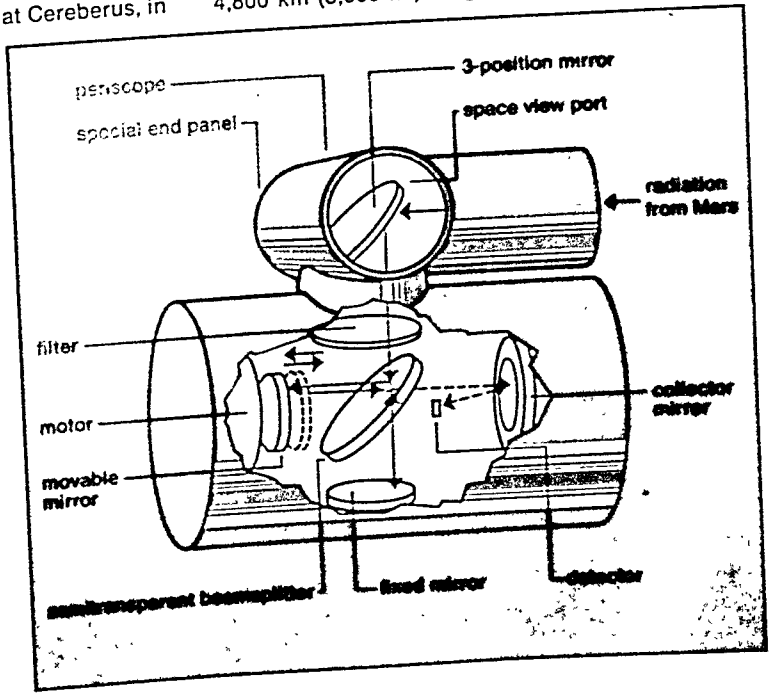
Space probes

Despite the landing of still more men on the moon, 1972 was clearly the year of Mars. As the year dawned, three probes were in orbit about the planet, transmitting an incredible amount of information about its topography, geochemistry, and atmospheric physics. In addition to the manned landings by Americans, the moon was also the target for unmanned probes from the U.S.S.R. The year also saw man's first probe launched to Jupiter and another launched to Venus.

Probing Mars. With both the United States and the Soviet Union concentrating on studies of Mars, scientists of the world had high hopes for cooperation between the two nations. Indeed, a peaceful "hot line" was operating in November 1971, between the Jet Propulsion Laboratory, Pasadena, Calif., and the Academy of Sciences of the U.S.S.R. in Moscow, to exchange data from the two country's probes. It soon became apparent, however, that the "hot line" was a victim of the cold war. As a scientist at the Jet Propulsion Laboratory remarked, "The big disappointment to some of us is that they haven't responded to our suggestions of some cooperative ventures." Since the Soviet and U.S. spacecraft each had instrumentation that was unique, the lack of a cooperative exchange of data between the two countries was all the more disheartening. However, the "hot line" was not wholly unused. At one point, the Soviets on January 9 detected a 15° rise in temperature at Cereberus, in the Eastern Hemisphere of Mars near the equator. They asked their American counterparts if they too had noted it. A review of data from Mariner 9 did show a 10° rise in the area at the same time. Late in December, the Jet Propulsion Laboratory scientists sent a Mariner 9 photograph of the landing of the Soviet Mars 3 pod to their Soviet counterparts.

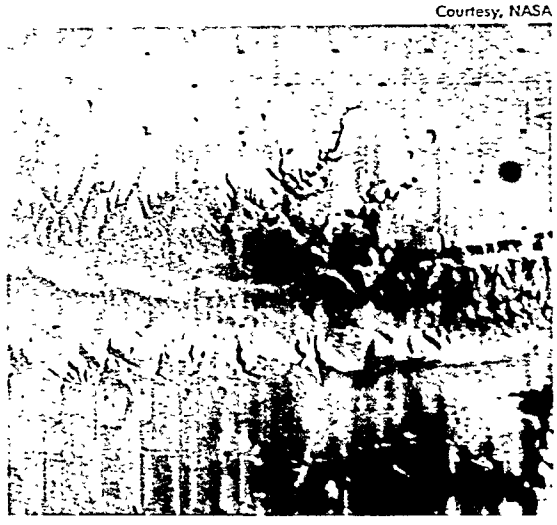
Mariner 9 entered orbit about Mars on Nov. 13, 1971. It initially completed one orbit in 12 hours and 34 minutes with a periapsis, or point closest to the planet, of 1,397 km (868 mi) and an apoapsis, or point farthest from it, of 17,927 km (11,135 mi). A maneuver was made two days later that slightly reduced the time of orbit and lowered the apoapsis to 17,048 km (10,655 mi), while changing the spacecraft's angle of inclination to the Martian equator from 64.28° to 64.36°. Since Mariner 9 had arrived at Mars during a violent dust storm, scientists at the Jet Propulsion Laboratory were skeptical of what the photographs from its two television cameras would reveal. Instruments aboard the spacecraft indicated that dust particles stirred up by the storm were thrown as high as 74 km (46 mi) into the planet's extremely thin atmosphere. However, by mid-December the dust storm began abating to such an extent that a decision was made to begin systematic photo-mapping of the planet's surface on Jan. 1, 1972.

The photographs soon revealed a wealth of geological features. Typical of these was a great rille or chasm along the Martian equator about 4,800 km (3,000 mi) long and 96 km (60 mi) wide,



The infrared spectrometer aboard the Mariner 9 measures atmospheric and surface characteristics of Mars. Radiation from the planet is reflected from a three-position mirror and then passed through a filter that screens out all but a certain range of infrared light. The light waves are then reflected from a fixed mirror to a beamsplitter and a movable mirror. The latter changes the distance that the waves travel, thereby either strengthening or canceling out the waves reflected to the beamsplitter. The detector senses the wave interference caused by the movable mirror, and analysis of the interference patterns identifies gases and particles affecting the infrared radiation that passes through the Martian atmosphere.

Courtesy, NASA



Wide-angle photograph of Mars taken by Mariner 9 on Jan. 12, 1972, reveals a vast chasm with canyons branching into adjacent plateaus. Crust subsidence and wind erosion may have sculpted this unique landform.

unobservable from the earth because of its orientation with respect to the sun's rays. Similar features elsewhere found the scientists at Jet Propulsion Laboratory hard put to describe their origin to anything except erosion by running water, although there clearly was no liquid water currently on the planet.

From the pictures a concept of Mars emerged that was radically different from that which scientists held after studying the photographs from Mariners 6 and 7. Harold Masursky, U.S. Geological Survey, said that instead of a dead, primordial planet, "Our photographs show something very, very different indeed. By seeing much more of the planet we can see great volcanic piles and because of the crispness of the edges and the lack of craters, we think these are geologically-young. The only thing we can keep as a primitive body are the two Martian satellites. Those do look like unevolved bodies, but Mars itself turned out to be even more dynamic than we had hoped."

Equally as exciting and important data were returned by the other instruments of Mariner 9. Data derived from the analysis of the refraction of signals from the craft by the Martian atmosphere indicated that the atmospheric pressure ranged between 3 millibars at the highest points on the surface to 8.3 millibars at the lowest point. The average atmospheric pressure was about 5.5 millibars (compared with an average on earth of 1,013 millibars). The same experiment showed that the Martian ionosphere was at an altitude of approximately 149 km (93 mi) compared with a height of only 135 km (84 mi) measured in 1969 by Mariner 7. The dust storm was probably the cause for the difference.

Gravitational variations in the planet caused considerable discussion among scientists. From an analysis of the variations in the velocity of the spacecraft, it appeared that Mars has a bulge of about 1 to 2 km (0.6 to 1.2 mi) on the equator at 110° W and a similar one at 70° E. In between these bulges, at 90-degree intervals, are slight depressions. There was no immediate explanation for this observation.

An infrared spectrometer on Mariner 9 indicated that there was about 0.001 the amount of water vapor in the atmosphere above the Martian south pole as there is in the same region of the earth. It also indicated that the amount of water vapor was greater over the south pole than elsewhere over Mars. The ultraviolet spectrometer provided data which showed that as much as 379,000 l (100,000 gal) of water per day could be lost from the Martian atmosphere. The source of this water was assumed to be volcanic.

Measurements of the Martian surface temperature seemed generally cooler than those reported by previous probes. The daytime high at mid-afternoon was about 240° K (−32.8° F), and it was about 200° K (−104.8° F) at night.

Published information from the Soviet Mars 2 and 3 probes was sketchy at best. Arriving at Mars on Nov. 27, 1971, Mars 2 went into a highly elliptical orbit with a periapsis of 1,376 km (860 mi) and an apoapsis of 25,000 km (15,600 mi). The periapsis was lowered by 149 km (93 mi) a month later. The orbit had an angle of inclination to the Martian equator of 48° 54′ and completed one orbit in 18 hours. Just before the probe entered orbit, it detached a capsule toward the planet. Apparently the capsule was not intended to soft-land.

Mars 3 arrived at the planet on Dec. 2, 1971. It assumed an orbit with a periapsis of 1,484 km (530 mi) and an apoapsis of 192,000 km (120,000 mi), which produced an orbital period of 11 days. Mars 3 also ejected a capsule, which soft-landed on the planet south of its equator in the Simois Strait. Unfortunately, the instrumented pod was damaged on landing, or it sank into a deep layer of Martian dust. Only 20 seconds of video signals were received. The pod was a highly sophisticated scientific package that would have provided a wealth of information on surface conditions had it operated. Among these instruments were sensors to measure the temperature and atmospheric pressure, a mass spectrometer to analyze the chemical composition of the atmosphere, an anemometer for measuring wind velocities at ground level, and instruments to determine the composition of the soil as well as its mechanical properties.

Both the Mars 2 and 3 orbiters had infrared radiometers for mapping surface temperature patterns. Radiofrequency telescopes in the 3-cm (1.2-in.) range probed the properties of the Martian soil. Ultraviolet photometers measured the luminescence of the upper atmosphere to detect atomic hydrogen, oxygen, and argon. In addition, the radiowave signals from both craft were analyzed as were those of Mariner 9 for their diffraction by the Martian atmosphere to determine pressure profiles and altitude of the ionosphere. Each probe also had two cameras, as did Mariner 9, for taking wide-angle and telephoto pictures of the planet. However, the pictures taken by the Soviet cameras were developed on board the orbiters and then transmitted to the earth, while in the Mariner 9 the pictures were converted electronically to signals for dark and light areas and the information was transmitted to the earth for reconstitution as pictures by computers.

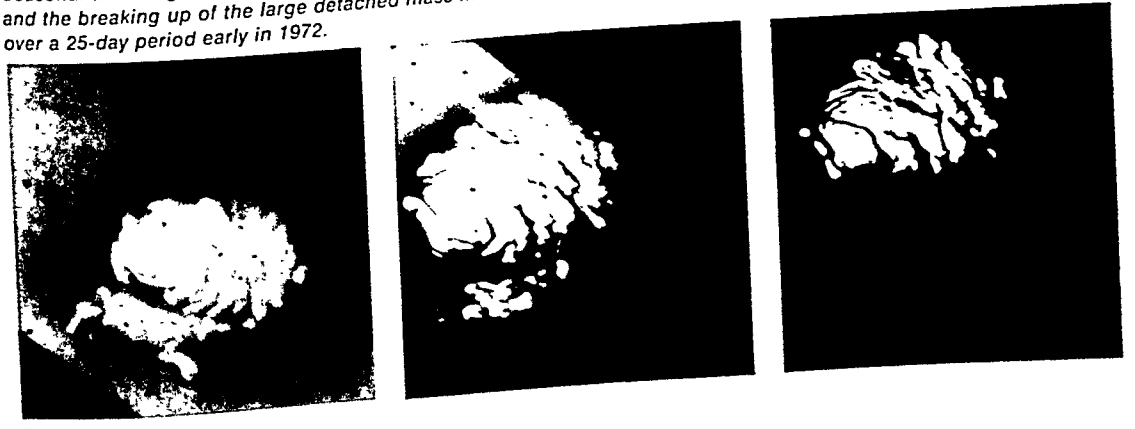
Mars 3 reported that temperatures along the planet's equator did not exceed 15° C (59 F). Temperatures along the terminator, or boundary between the dark and sunlit side of the planet, ranged between −80° C and −90° C (−112° F to −130° F). The craft also reported that the maximum daytime temperature in the mid-latitudes was only −15° C to −20° C (5° F to −4° F). Among other data released by the Soviets from their Mars probes were that water vapor was greater in the atmosphere over the Hellas region than at other parts of the planet except the polar regions. Analyses of the orbits of the craft suggested that Mars is almost 50% flatter at the poles than is the earth.

Exploring the moon. Throughout July and August 1971, Lunokhod 1 continued to surprise and delight its Soviet developers. The eight-wheeled, self-propelled vehicle moved about its landing site in the Sea of Rains, sampling the soil and taking a variety of panoramic and stereo photographs. Toward the end of its ninth lunar day, it explored a relatively fresh crater approximately 90 m (297 ft) in diameter. By the end of the day it had covered a total distance of 10,237 m (33,782 ft). By Sept. 11, 1971, it had survived 11 lunar days (1 lunar day = about 14 earth days), but its power supplies were weakening drastically. On October 4, Lunokhod 1 ended its mission of active lunar exploration. In 10 months and 17 days, it had travelled 10,540 m (34,782 ft) and taken 200 panoramic pictures and another 20,000 single views of lunar features. It also made mechanical and physical analyses of the lunar soil at 500 different places and chemical analyses at 25 locations. (The chemical analyzer failed after seven months.) The robot was left parked in a position so that its French-built laser reflector was pointed toward the earth, insuring that it could be used for years to come.

On Sept. 2, 1971, the Soviet Union launched Luna 18 from Tyuratam. It entered a lunar orbit on September 7 at an altitude of 96 km (60 mi) at an angle of inclination to the equator of 35°. After making 54 orbits of the moon, Luna 18 crashed into the Sea of Fertility, while trying to make a soft landing.

Luna 19 followed Luna 18, being launched from Tyuratam on September 28. It entered a circular lunar orbit at 140 km (87 mi) altitude on October 3. On November 26 and 28, it made a series of maneuvers that placed it in an elliptical orbit with a perilune of 77 km (48 mi) and an apolune of 385 km (239 mi). The angle of inclination remained unchanged at 40.5°, but the time of one orbit was lengthened from 122 to 131 minutes. By January 1972, the craft had made 1,358 orbits of the moon with no apparent intention of landing. Its major experiment appeared to be the long-term study of the moon's gravitational characteristics. How-

Seasonal shrinking of the south polar cap of Mars is clearly evidenced by the widening separations and the breaking up of the large detached mass in this series of photographs taken by Mariner 9 over a 25-day period early in 1972.



Courtesy, NASA

Courtesy, Tass from Sovfoto



Portion of a circular panoramic photograph taken by Lunokhod I's astrotelephotometer in 1971 shows portions of the landing stage and the original tracks made by the self-propelled vehicle against a background of the night sky.

ever, it also investigated the lunar magnetic field and cosmic radiation in the vicinity of the moon.

Luna 20, the back-up probe for Luna 18, was launched from Tyuratam on February 14 and entered a circular orbit four days later. For three days it continued to orbit the moon at 99.2 km (62 mi) at an angle of 65° to the equator. It soft-landed on February 21 in a highland region between the Sea of Fertility and the Sea of Crises about 120 km (72 mi) north of the landing site of Luna 16.

The probe featured a much improved drill that, unlike the wholly automated machinery on Luna 16, was controlled by engineers in the Soviet Union via television. The drilling operation required 30 minutes and reached a depth of approximately 33 cm (13 in.). The drill struck extremely hard material at a depth of 14.5 cm (5.7 in.), and it took seven minutes to remove the drill core from its hole. The return capsule with about 100 g (3.5 oz) of lunar soil lifted off from the moon on February 23 and landed in the U.S.S.R. on February 25.

A probe to Jupiter. Pioneer 10 was launched on March 2 from Cape Kennedy, Fla. The 258-kg (570-lb) probe was designed to pass within 144,000 km (90,000 mi) of Jupiter on Dec. 3, 1973, after a voyage of 800 million km (500 million mi). Launched on a direct ascent trajectory, the craft reached a velocity of 51,840 km/hr (32,400 mph), making it the fastest probe ever to be sent into space. A mid-course maneuver was made on March 7 to ensure that the craft was on the desired trajectory to Jupiter.

The probe contained 11 scientific instruments to investigate the interplanetary medium, the asteroid belt, and the environmental and atmospheric properties of Jupiter. These included an imaging photopolarimeter, a helium vector magnetometer, a plasma analyzer, a charged particle counter, a Geiger-tube telescope, a trapped radiation detector, an ultraviolet photometer, an infrared photometer, and an asteroid-meteroid detector.

The trajectory of the probe was planned to take it directly through the asteroid belt between Mars and Jupiter. While the possibility existed that Pioneer 10 could be destroyed by a collision with one of the millions of fragments in the belt, such a probability was believed to be very small. Indications were that it would come no closer than 48 million km (3 million mi) to any of the known asteroids. After swinging past Jupiter and gaining velocity in the process, Pioneer 10 was designed to escape from the sun's gravity and fly into interstellar space, the first man-made object to do so.

New data from the sun. OSO 7 (Orbiting Solar Observatory) was launched on Sept. 29, 1971, from

Cape Kennedy. The second stage malfunctioned and the probe went into a slightly elliptical orbit rather than the circular one planned. The spacecraft's perigee was 342 km (214 mi), the apogee was 597 km (373 mi), and the angle of inclination to the earth's equator was 33.1°. The primary mission of OSO 7 was to obtain high-resolution data of the solar corona in special ultraviolet spectra and to investigate the intensity and spectrum of solar and cosmic X rays. By the end of November, scientists had gathered enough data to term the mission a success.

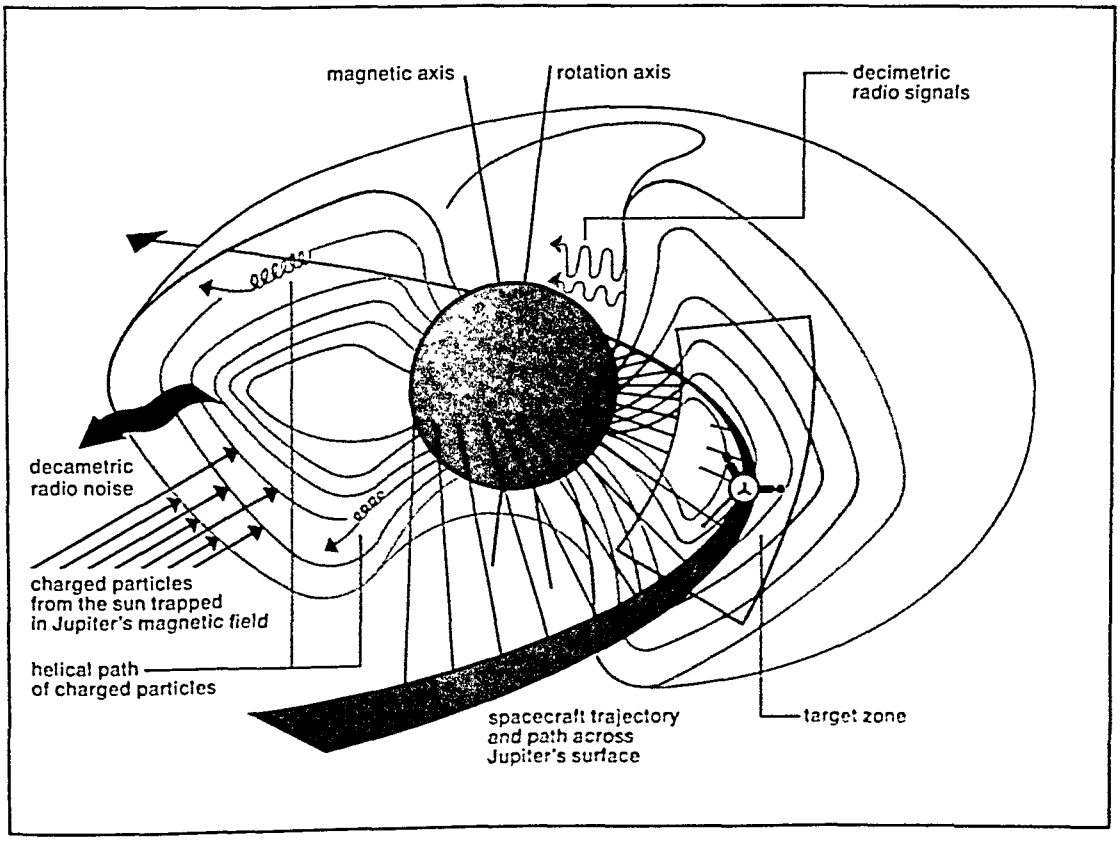
Among the data received from OSO 7 was the fact that the polar regions of the sun were cooler than its equatorial regions, a difference of 1,000,000° C (1,800,032° F) being reported by the probe. It also reported clouds of hot, energized gas erupting from the sun's surface that were 20 to 40 times the size of the earth. The energy involved in these eruptions was equal to the total electrical power requirements for the U.S., at the current rate of consumption, for the next million years.

Another try at Venus. On March 26, the Soviet Union launched the 1,180-kg (2,596-lb) Venera 8 on a trajectory toward Venus. Like its predecessors, the probe was designed to soft-land a spheroidal instrument package on Venus to measure temperatures and pressures at ground level.

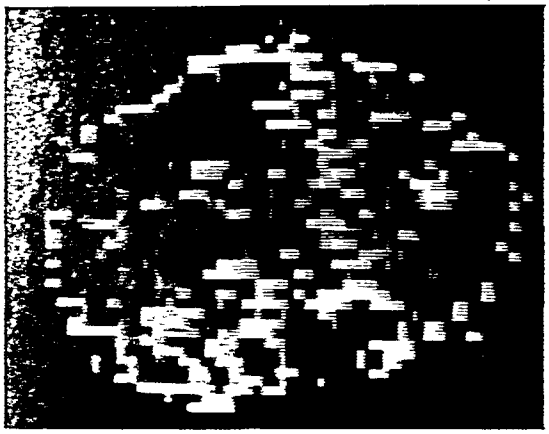
A look into the future. Scientists throughout the world were disappointed with the announcement in 1972 that the U.S. National Aeronautics and Space Administration (NASA) had cancelled its ambitious "Grand Tour" that would have sent a probe to the outer reaches of the solar system in 1977–79. The Grand Tour envisioned a probe that would utilize a lineup of the planets that will not reoccur for about 180 years to propel itself through the solar system by the additional velocity imparted to it by the gravitational fields of the various planets. The program was cancelled because of the decreasing space budget.

As an alternative to the Grand Tour, NASA proposed to launch two Mariner probes in 1977 on flyby missions to Jupiter and Saturn. Plans were

The path of the U.S. space probe Pioneer 10 will take it within 90,000 mi of the surface of Jupiter in December 1973. Launched on March 2, 1972, the probe must travel 500 million mi to reach its destination, the longest journey yet attempted for a spacecraft.



Courtesy, NASA



Map of the solar corona, obtained by the Orbiting Solar Observatory 7, is presented on a computerized display. The white areas are the hottest and contain the greatest quantities of ionized gas.

also revealed for flyby missions in 1973 to Venus and Mercury.

During 1972, work continued on the Viking, an unmanned probe scheduled to land on Mars in 1976. The 1,200-kg (2,400-lb) probe was expected to be heavily instrumented to analyze the Martian soil for the presence of microbacterial forms of life. However, the wealth of geological data returned by Mariner 9 prompted many scientists to ask the space agency to consider placing more emphasis on geological than biological instrumentation.

—Mitchell R. Sharpe

Astronomy

During the past year, astronomy of the solar system gained a temporary prominence because of new findings about the moon and Mars. Even so, the underlying trend was a growth in radio astronomy and in high-energy astrophysics, directed toward the problems of stars, the Milky Way, radio sources, galaxies, and the universe.

New Mexico radio telescope. In March 1972, the U.S. National Science Foundation announced the selection of a 3,000-ac desert site near Socorro, N.M., as the proposed location for the world's most sensitive radio telescope. This instrument, known as a VLA (very large array), was designed to consist of 27 dish-shaped antennas, each 82 ft in diameter. The antennas are to be movable along each of three 13-mi arms of a Y-shaped layout of railroad track. This array would afford a resolution 10 to 100 times greater than that given by any existing array. The VLA would be managed by the National Radio Astronomy Observatory. If the U.S. Congress appropriates the funds for the $76 million project, the facility could go into partial operation by 1976 and full operation by 1982.

The significance of the New Mexico undertaking is that it would be the first major new U.S. radio astronomy facility in a decade. Its construction would tend to restore the U.S.'s lead in radio astronomy, which had been slipping in favor of the Netherlands, West Germany, and the Soviet Union.

The moon's interior. By 1972, the state of lunar science had become much healthier than a decade earlier, as its emphasis changed increasingly from speculation to weighing a great variety of empirical facts. A large amount of this new information was afforded by the successful visits of Apollo 14 to the Fra Mauro region in February 1971, and of Apollo 15 to Hadley Rille in July of that year. Many of the findings from Apollo 14 and some from Apollo 15 were first announced at a lunar science conference held in January 1972, at Houston, Tex. A significant aspect of that conference was the emergence of a fairly detailed picture of the moon's interior, which not so long ago had seemed hopelessly inaccessible.

Seismometers were left behind on the moon by Apollos 11, 12, 14, and 15. While the first of these devices ceased to function after a few weeks, the other three stations registered hundreds of seismic events, including both moonquakes and impacts. To locate the epicenter and depth of a seismic event requires records from a minimum of three suitably spaced stations, which became possible only in August 1971, when the Apollo 15 seismometer was planted.

In new controlled experiments, the impact of the spent third stage of Apollo 15 as it crashed onto the moon's surface was detected by the Apollo 12 and 14 stations, while the lesser impact of the discarded Apollo 15 ascent stage was registered at all three stations. These tests confirmed again that strong oscillations persist for at least an hour when the moon's surface is struck a violent blow. This prolonged vibration time is explained by the presence of a surface layer a few kilometers thick, which scatters seismic waves effectively and tends to confine their energy.

Gary Latham of Columbia University, the leader of an active group of lunar seismologists, was able to distinguish between true moonquakes and meteorite impacts through a study of wave forms (curves representing the conditions of wave-propagating media at particular instants). Despite the extreme sensitivity of the Apollo 15 seismometer, which can detect surface displacements as small as 10^{-5} cm, moonquakes are few and weak, even the largest amounting to only 1 or 2 on the Richter scale. (On earth, such quakes are at best barely

perceptible without instruments.) Seismically, the moon is much less active than the earth. According to Latham, each square mile of lunar surface releases only 10^{-5} as much seismic energy, on the average, as does a square mile on the earth.

Most of this energy release is in the form of periodic moonquakes that tend to occur near the times when the moon is nearest and farthest from the earth (perigee and apogee). These quakes appear to originate only in a dozen or so separate locations. One of these places is responsible for about 80% of the seismic energy. It is located near the crater Bullialdus, at a depth of 500 mi. The seasons of activity (perigee and apogee) are the times when the tides produced in the moon's crust by the earth's gravitational attraction are greatest. Hence, the periodic moonquakes seem to originate in recurrent rock slippages triggered by tidal forces. The existence of a focus 500 mi deep means that even halfway down from the surface to the center the moon's interior is still rigid enough to support appreciable stress. The moon's interior, thus, cannot be molten at that level.

From an analysis of travel times of moonquakes in the Mare Imbrium region, it was found that the velocity of seismic waves increases with depth to about 4 mi/sec at a depth of near 15 mi. The material above 15 mi is thought to be primarily basalt. Then, down to a depth of about 40 mi, the velocity remains nearly constant. This layer is believed to be either eclogite or anorthosite. At about 40 mi, the velocity of compressional waves increases abruptly to about 5½ mi/sec, indicating a discontinuity beneath which the material is probably olivine.

Further information about the moon's interior is furnished by studies of magnetism. The instruments left by Apollo 14 indicated at that site a steady magnetic field for the moon of little more than 50 gammas (10^{-3} of the earth's field). The steady field at the Apollo 12 base was 38 gammas, and at the Apollo 15 site only 5 gammas. Thus, the present general magnetic field of the moon is very weak, as was also shown by magnetometers used aboard orbiting Apollo spacecraft.

Oddly enough, however, most of the rock samples brought back by the astronauts and measured in terrestrial laboratories showed large remnant magnetism. In the remote past when these rocks were formed, they must have solidified in a magnetic field much stronger than the moon now has.

The moon's response to the changing magnetic fields of the earth and the sun has been studied. The results are compatible with a three-layer model of the moon, in which a 60-mi-thick outer crust at 440° K overlies an intermediate zone at 800° and a

Courtesy, NASA

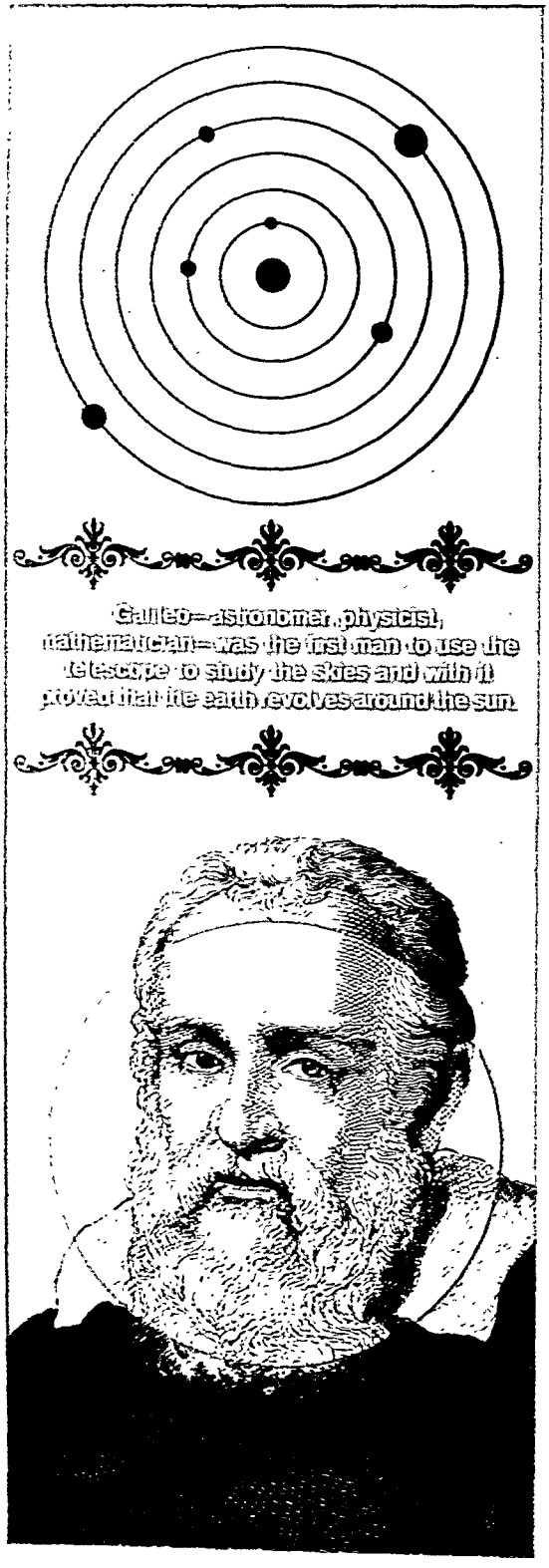


Tiny green glass fragment was taken from an Apollo 14 core tube sampling. The fragment, constituted mainly of iron and magnesium, has been nicknamed the Genesis bean because of its great age, possibly dating back to the beginnings of the solar system.

1,100° central core of 1,200-mi diameter. This model assumes that the moon's interior consists primarily of olivine.

A number of lines of evidence pointed to the moon either being solid throughout, or having only a small molten core. One argument is based on the weakness of the steady magnetic field; this field, according to some astronomers, would be much stronger if the moon had a large liquid core, free to move relative to the crust. Another argument is that the deviations of the moon's surface from a sphere are so great that they can persist over long periods of time only if the moon's interior has considerable rigidity.

However, an apparent contradiction is offered by measurements of heat flow outward through the moon's crust. In one of their more difficult tasks while at Hadley Base, Apollo 15 astronauts David Scott and James Irwin drilled two holes into the ground in which they emplaced temperature-sensing probes at depths of 3 ft and 5 ft below the surface. Because of the excellent heat-insulating properties of lunar soil, there is no perceptible day-night temperature at depths of more than 2 ft. Below that, the temperature was observed to increase at a rate of 0.5° K per foot. This implies a heat flow from below the Hadley site about half that in the earth's crust—considerably higher than astronomers had expected. It seemed to indicate very high temperatures in the moon's interior.



One explanation for this finding was that the Hadley site may not be typical of the moon and that the *average* heat flux could be much smaller. An alternative hypothesis was that lunar radioactivity is concentrated in the moon's outer layers, heating them and thus producing a larger outward heat flux than occurs in the deep interior. This possibility is supported by the high uranium and thorium concentration measured in many of the rock samples returned from the moon's surface.

New observations of Mars. An exceptionally favorable opposition of Mars occurred in August 1971, when that planet's distance from the earth became as small as 34.9 million miles. Mars would not be as close again during the rest of the 20th century. With headquarters at Lowell Observatory in Arizona, an international photographic patrol program was mounted at a network of observatories in Europe, Africa, Asia, and North America, whereby thousands of excellent photographs were obtained on a uniform plan. Many other observatories conducted their own photographic or visual programs.

However, these optical observations were severely hampered for several months by a vast dust storm on the surface of Mars, which was first photographed on September 22. It spread rapidly and about two weeks later had enveloped the entire planet in a heavy yellow veil, dimming or obliterating the surface features. This storm did not begin to abate until January 1972.

The U.S. spacecraft Mariner 9 began orbiting Mars on Nov. 13, 1971. Once the planet's atmosphere began to clear, the craft's television cameras obtained highly detailed pictures of the Martian surface. These views provided strong evidence that many features on Mars are of volcanic origin. For example, there are numbers of craters clearly resembling the earth's calderas —depressions made by the collapse of the central parts of volcanoes when magma is drained from beneath them.

A striking Martian example of this is Nix Olympica. Mariner 9 photographs showed this as a 4-mi-high mountain, 300 mi across at its base and topped by a volcanic vent about 40 mi wide. This great mountain is similar to, but even larger than, Mauna Loa in the Hawaiian Islands, which rises from the Pacific floor to a summit volcano.

Other newly discovered Martian surface formations included a long, 75-mi-wide trough cutting through the Tithonius Lacus region, and sinuous valleys that superficially resemble terrestrial arroyos. However, these features are in most cases probably the results of collapses along lines of weakness in the crust, combined with erosion by wind-blown dust. There is too little water on Mars

for running water to be an important agency in shaping the surface, although it might have been a factor in the past.

The Mariner pictures gave the general impression of a planet that has been geologically active in the past and whose surface has been greatly altered by volcanism, crustal movements, and erosion. A large proportion of Mars's craters must, however, continue to be regarded as resulting from meteorite impacts.

Close-up Mariner photographs revealed that the Martian satellites Phobos and Deimos are irregularly shaped dark bodies, respectively 14 and 8 mi in diameter. Each is densely cratered, one Phobos crater being 3 mi wide.

Instruments carried by Mariner to measure the planet's ultraviolet and infrared radiations provided interesting findings. For example, a new temperature measurement of the south polar cap confirmed that the cap material is primarily carbon dioxide frost and not frozen water. The observed temperature closely matched that which solid carbon dioxide in equilibrium with its vapor must have at the atmospheric pressure obtaining on Mars. A second result was that the planet-wide obscuration in late 1971 was due to airborne silicate dust, resembling in its optical properties the surface material of Mars's ocher (yellowish) deserts.

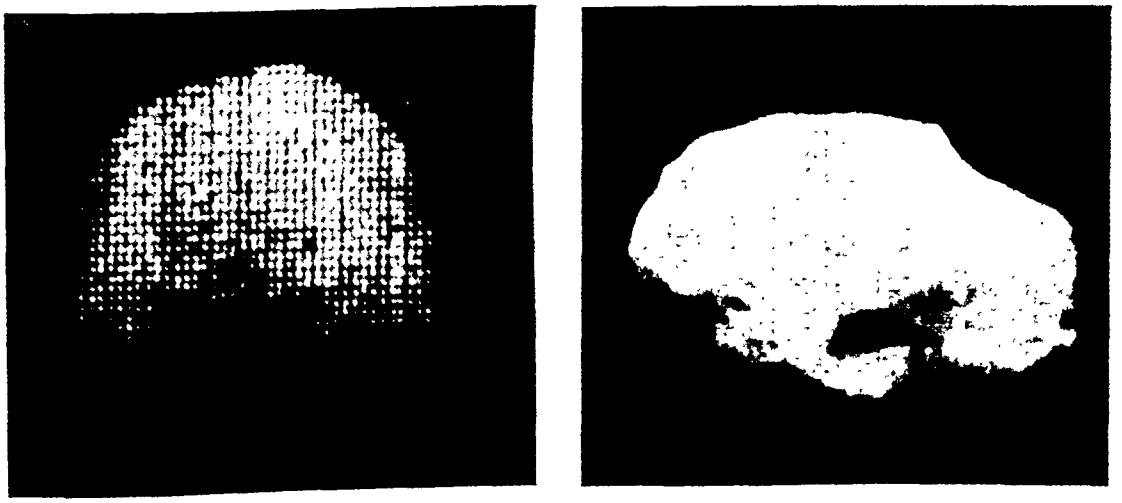
Two Soviet spacecraft also orbited Mars beginning in late November and early December 1971. Both Mars 2 and 3 ejected instrumented capsules to make soft landings on the planet. Although the second attempt succeeded, the capsule's radio transmitter failed soon after landing.

Few early results were made public from the instruments operated aboard Mars 2 and 3 while they orbited the planet. A faint airglow of atomic hydrogen extends 500 mi above the Martian surface, and ultraviolet emissions from atomic hydrogen reach much higher. The Soviet observations confirmed the very low abundance of water vapor in the Martian atmosphere, giving it as less than the equivalent of a 0.005-mm layer of liquid water.

Extensive studies of Mars were also made with large earth-based radar telescopes operated by scientific teams at the Massachusetts Institute of Technology (MIT) and the California Institute of Technology (Caltech). A radar observation gave the distance from the telescope to the nearest point on the Martian globe; as the planet rotates, successive observations yield a profile of the vertical relief along an east-west strip of the planet's surface. Such observations had been made since 1963, but by 1971 techniques had become so refined that elevation differences on the order of 200 ft could be measured. Both the MIT and Caltech teams reported that they could detect many individual Martian craters identifiable on Mariner photographs, and that they could determine rim-to-floor depths for the larger craters.

Occultations by Jupiter. An astronomical event of extreme rarity occurred on May 13, 1971, when the planet Jupiter passed in front of (occulted) the 2.6-magnitude star Beta Scorpii. It was the brightest star occulted by this planet since observations began with the invention of the telescope in the early 17th century. Moreover, on the same night Jupiter also occulted the 4.9-magnitude compan-

Man's first close-up views of the Martian satellites Deimos (left) and Phobos (right) were obtained by means of a high resolution television camera aboard Mariner 9. Both moons are irregularly shaped; the dark spot near the bottom of Phobos is a crater about four miles in diameter.



Courtesy, NASA

ion of Beta Scorpii, located 14 seconds of arc to its north. This companion was also occulted by Jupiter's satellite Io.

The occultations by Jupiter were visible from South Africa, India, Australia, and Antarctica. Expeditions were sent from the University of Texas to monitor photoelectrically the gradual fading of the stars as they disappeared behind Jupiter's disk and their reappearances about an hour later. These observations gave an accurate determination of the vertical density gradient in the planet's atmosphere.

A remarkable phenomenon recorded during the fading of each star into occultation was the repeated occurrence of short-lived flashes as the star would momentarily recover to nearly its full brightness. These flashes were conspicuous to visual observers. The photoelectric records showed that the same pattern of flashes was observed from widely separated places on the earth. Astronomers believe that the flashes are associated with a layered structure in the Jovian atmosphere. There are at least three warm layers present at both the eastern and western edges of Jupiter, apparently part of a planet-wide pattern of stratification.

One result from the Beta Scorpii occultations was the most accurate determination yet of the dimensions of Jupiter. According to the analysis by W. B. Hubbard and T. C. Van Flandern, the equatorial radius of the planet is 71,880 km (44,565 mi) and the polar radius is 67,500 km (41,850 mi).

The occultation of the companion of Beta Scorpii by Io was visible about seven hours later from a limited region in the Caribbean Sea and Florida. Both the disappearance and reappearance were sudden, indicating that Io has no appreciable atmosphere. The radius of the satellite was found to be 1,829 (±3) km. Io, therefore, is about 5% larger than our moon.

Companion of Sirius. As seen in fairly large telescopes, the bright star Sirius has a much fainter companion, moving around it in a period of 50 years. This companion, Sirius B, is the most familiar example of the several thousand white dwarf stars now known with more or less certainty. These are tiny, hot stars of extremely high density, comparable to the sun in mass but only as large as planets. Since Sirius B happens to belong to a well-studied binary star system, its distance from us is reliably established as 8.7 light-years and its mass as 1.02 times that of the sun.

According to general relativity theory, the spectrum of a white dwarf such as Sirius B should show a red shift as a result of the star's high surface gravity. Attempts to measure this gravitational red shift were made at Mount Wilson Observatory in the 1920s, when it was mistakenly announced that the prediction was confirmed. But the very difficult spectroscopic observations were in fact inconclusive: the companion's spectrum was badly contaminated by the overpowering glare of Sirius itself, 10,000 times brighter and only a few seconds of arc distant.

Late in 1971 a team of astronomers from Hale Observatories, Pasadena, Calif., announced that this problem had finally been overcome. Using the 200-in. Palomar telescope and taking extreme precautions to avoid stray light from the brilliant primary star, they managed to obtain the first uncontaminated spectrograms of Sirius B. These observations were taken at a time when the companion, in tracing its elongated orbit, was approaching its maximum angular separation from the primary star. Analysis of these observations established that Sirius B is 0.85 the size of the earth, has a surface temperature of 32,000° K, and a density 3,000,000 times that of water. By measuring the wavelength displacement of a hydrogen line in the Sirius B spectrum, the astronomers found a gravitational red shift of 81 km/sec, agreeing well with the predicted value of 83.

Algol as a radio source. At the National Radio Astronomy Observatory, Green Bank, W. Va., C. M. Wade and R. M. Hjellming examined various stars as possible radio sources. (The sun, flare stars, and a few novas were already known as sources.) As of early 1972, these astronomers had discovered four optically "normal" stars that were radio emitters: the companion of Antares, the star in Cygnus associated with the X-ray source Cygnus X-1, Beta Lyrae, and Beta Persei (Algol).

Discovery of the latter two stars was announced in February 1972. In both cases, the position of the source, as measured with a large radio interferometer, agreed so exactly with the known optical position of the star that no doubt existed as to the correctness of the identification.

The case of Algol is remarkable. During October and November 1971, it was detectable as a weak radio source at wavelengths of 3.7–11 cm. But in February a new phenomenon appeared: frequent, strong bursts of radio noise, lasting several hours or more, occurring at irregular intervals of a few days. Meanwhile, photographs of the optical spectrum of Algol made at David Dunlap Observatory, Toronto, Can., revealed the unprecedented appearance of bright lines of calcium and other elements.

Both of these anomalous observations were probably connected with the long-known fact that Algol is a close binary system with a period of 2.8673 days, in which occasional burps of gas are ejected from the secondary star. Previously, the most noticeable effect of this gas ejection was to

produce minute changes in the period of orbital revolution. Astronomers believe that an unusually marked ejection of gas took place in January or February 1972 and that both the radio bursts and the optical emission lines originated in this transitory gas cloud.

Future outlook. In the coming year, an eagerly awaited astronomical event is the total solar eclipse of June 30, 1973, visible from Africa. It will be remarkable for the long duration of totality, more than seven minutes. In late 1972 the Pioneer 10 spacecraft will be traversing the asteroid belt prior to its flyby of Jupiter in December 1973. Astronomers hoped that in 1973 the world's largest reflecting telescope (aperture 236 in.) and largest radio telescope (a stationary dish nearly 2,000 ft across) will go into operation at neighboring sites in the Soviet Union.

—Joseph Ashbrook

See also Year in Review: ASTRONAUTICS AND SPACE EXPLORATION, *Space Probes*.

Atmospheric sciences

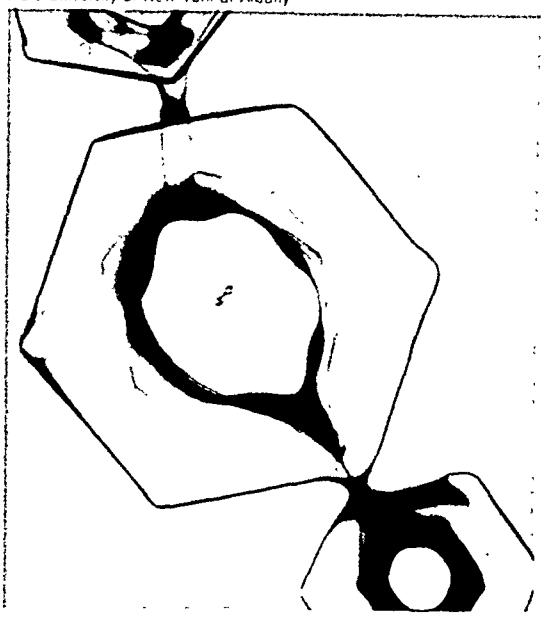
As in previous years, atmospheric scientists in many countries were concerned with the same broad problems. The search continued for new techniques for making better observations of the properties of the atmosphere at more places and at more frequent intervals. Greater attention was being devoted to the development of indirect probing techniques to replace the direct sensing instruments that need to be transported on balloons or aircraft. Various radar, laser, and radiometric methods continued to show great promise.

Major efforts were being devoted to scientific programs aimed at improving the accuracy of weather forecasts. This was being accomplished by the development of more realistic mathematical models of atmospheric phenomena and by the use of the most advanced electronic computers.

Although progress appeared to be slow, important advances were made in the study of weather and climate modification. The possible ecological, legal, and other societal consequences of intentional weather modification came under the scrutiny of social scientists as well as of the public at large. On the other side of the coin, inadvertent effects of human activity on the atmosphere also were receiving increasing attention. Scientists and the public were becoming more concerned about the degree to which environmental pollution may be affecting the global climate.

Atmospheric sciences in the '70s. In 1971 the Committee on Atmospheric Sciences of the National Academy of Sciences issued a report entitled

Courtesy, Dr. Roger Cheng, Atmospheric Sciences Research Center, State University of New York at Albany



Electron micrograph shows a lead-nucleated ice crystal formed by the combustion of gasoline in the presence of iodine vapor. Study of the nucleating particles could result in new techniques for cloud seeding.

The Atmospheric Sciences and Man's Needs. It briefly notes the progress made in the 1960s and looks ahead over the next decade. The document focuses on those aspects of the atmospheric sciences that can contribute to important human needs and proposes an ordering of priorities. The problem areas are weather prediction, air quality, weather and climate modification, and weather dangers and disasters. The report notes that these subjects are receiving far from adequate attention.

Greater knowledge in these fields will not only satisfy the never ending hunger to learn but will also benefit society enormously in tangible ways. For example, in the United States alone violent storms do billions of dollars worth of damage and take hundreds of lives each year. In exceptional years and in other countries, destruction and deaths greatly exceed even these figures. The tropical cyclone that hit East Pakistan in November 1970 killed between 200,000 and 300,000 people and damaged some 400,000 homes. Better observations of violent storms, improved forecasts, more effective warnings to the public, and, finally, the development of techniques to weaken the storms would thus provide substantial advantages.

Observing the atmosphere. Most observations of the atmosphere are still made in the traditional way—using such instruments as thermometers, barometers, anemometers, and radiosondes. Since

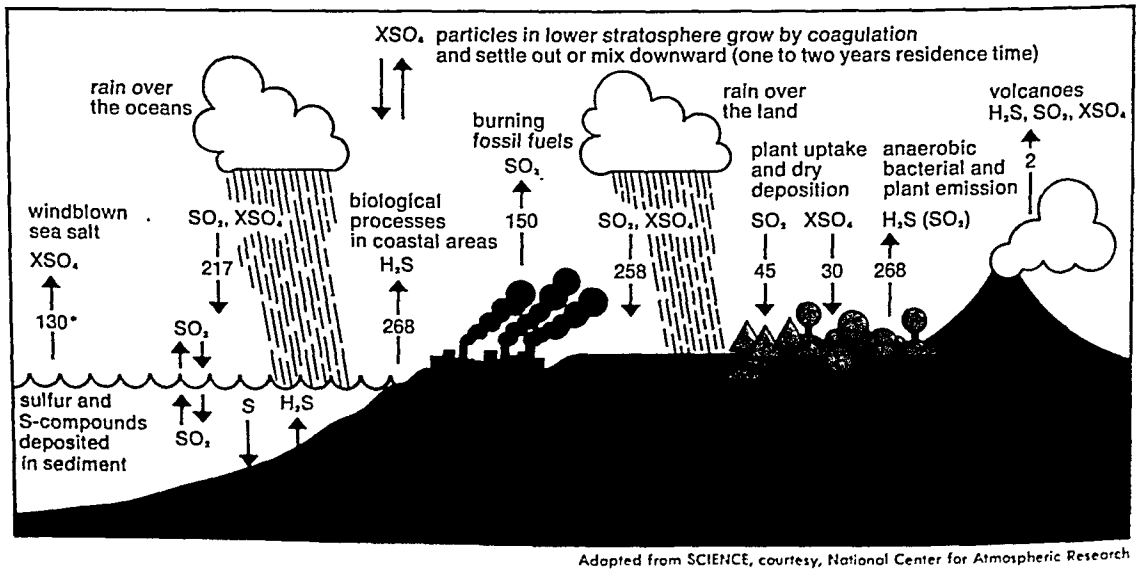
the 1950s radar has been used extensively to observe the location, size, and movement of storms. The 1960s saw the introduction of earth-orbiting satellites carrying instruments to observe cloud cover and measure the radiation emitted and reflected from the atmosphere below the satellite. Beginning in about 1970, various types of infrared spectrometers on satellites have supplied information from which cloud top heights could be estimated and the vertical structure of temperature and humidity of the atmosphere could be calculated.

The presence of extensive clouds interferes with the use of infrared radiometer techniques, but apparently this difficulty can be overcome by means of radiometers operating at microwave frequencies. The U.S. National Aeronautics and Space Administration was planning a Nimbus E meteorological satellite which would be equipped to make spectrometer measurements at both infrared and microwave frequencies. The satellite was scheduled for launching in late 1972 or early 1973, and shortly thereafter scientists should be able to tell whether such a combined system can supply reasonably accurate data on the temperature and vapor distributions in the lower atmosphere. Some scientists predicted that these indirect satellite techniques would make the balloon-borne radiosonde as obsolete as the old weather kite, but such predictions seemed premature.

Progress in the use of microwave radar for observing clouds and precipitation was slow during the year. Various promising programs concerned with the development of new pulsed-Doppler radar systems did not advance as rapidly as had been expected. On the other hand, there was enthusiastic interest in the use of lidar, *i.e.*, laser radar, for atmospheric probing. A wide variety of programs in several countries were developing techniques for measuring various properties of the atmosphere, particularly the sizes and numerical concentrations of particulates. An appropriate lidar can monitor the depth of the polluted layer over a city. Lasers were also being used to measure the water vapor content and some of the other gaseous constituents over an extended horizontal path.

Several scientists, notably Gordon C. Little and Donald W. Beran and their colleagues at the Wave Propagation Laboratory of the National Oceanic and Atmospheric Administration, did some exciting work by means of an acoustical echo sounder. Such an instrument is sometimes called an "acoustical radar," but this is not appropriate because the term radar implies the use of radio waves. The echo sounder transmits a sound pulse and detects sound echoes reflected back from the atmosphere. The instrument measures a fantastic amount of detail about the structure of the atmosphere in the lowest 500 m and sometimes higher. Relatively small inhomogeneities of temperature, water-vapor pressure, and wind velocity yield detectable backscattered signals. The echo sounder measures these quantities and allows investigations of low-level wind patterns, wave motions, and turbulence.

The compounds of sulfur present in the earth's atmosphere have various sources, with man contributing about half as much as nature to the total. In the figure, XSO_4 represents sulfates or sulfuric acid formed by the three-body reaction of SO_2 with atomic oxygen and a molecule of either oxygen or nitrogen.



Adopted from SCIENCE, courtesy, National Center for Atmospheric Research

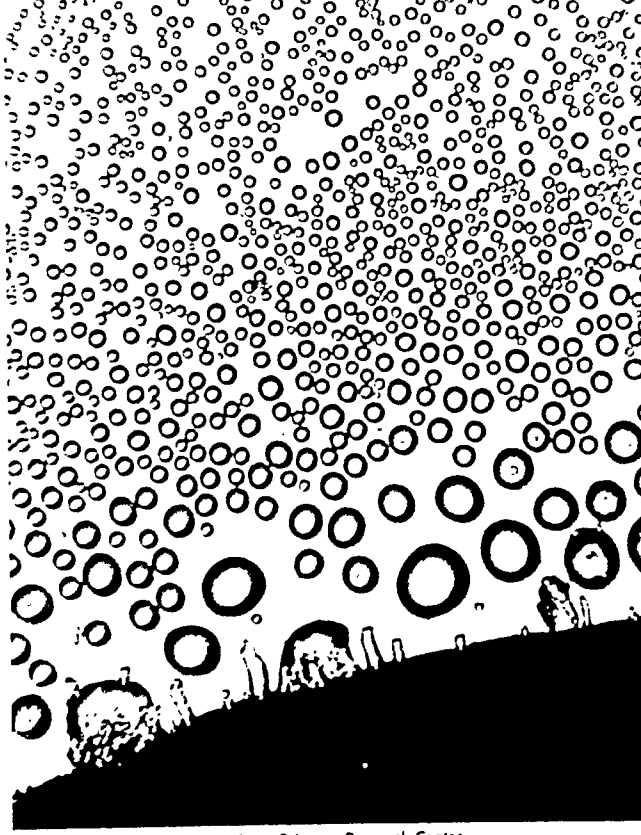
Mathematical modeling. In some ways, modern meteorology can be said to have started when electronic computers were first employed to construct mathematical models of the atmosphere by numerical methods. Early work in the 1950s dealt with weather over North America. As computers became bigger, as more was learned about the interaction of the solid and liquid earth and the atmosphere, and as better mathematical techniques were evolved, scientists developed models of the global atmosphere. To a certain extent these theoretical conceptions outstripped the observations. Adequate testing of their validity awaited the collection of worldwide observations. This was one of the major goals of the Global Atmospheric Research Program (GARP).

In recent years many scientists have been working on the development of mathematical models of the global climate. The difficulties involved are great, but the potential value is tremendous. When calculating changes in the global weather, each time step in the computation represents perhaps 10 minutes and the computation is extended for periods of a few days to a few months. When examining global climate, however, the computations extend over periods of hundreds of years. William Sellers at the University of Arizona used time steps of one month in his studies of this problem.

If we are ever to understand man's effect on the worldwide climate and predict what it will be in the future, much more progress must be made in the development of such global climate models. This general problem has been of special interest to Soviet scientists, particularly M. I. Budyko, director of the Main Geophysical Observatory in Leningrad. During August 1971 he hosted a meeting of experts from various parts of the world to examine the questions involved in climate change.

For a decade a number of scientists have been working on the development of numerical models of individual cumulus clouds. Edwin Danielson and his colleagues at the National Center for Atmospheric Research formulated a numerical model of a hailstorm that takes into account the evolution and changes of updrafts and downdrafts. In addition, it includes the initial cloud droplet population, the probability of ice particle formation, the breakup of water drops, and the growth of hail.

In the past relatively little effort has been devoted to the mathematical modeling of mesoscale phenomena, that is, those having horizontal dimensions from perhaps 10 km to a few hundred kilometers. A possible exception to this statement is the hurricane, which for several years has had the attention of many outstanding scientists. Nevertheless, much more research was needed in order to develop techniques for mathematically predicting the future intensification and path of hurricanes. Another mesoscale system that can be treated numerically is one specifying the air pollution concentrations over cities. George Cressman, director of the U.S. National Weather Service, indicated in December 1971 that new techniques for this purpose were being considered.



Courtesy, Roger Cheng, Atmospheric Sciences Research Center, State University of New York at Albany

Supercooled water drop emits tiny, positively charged microdroplets as it freezes; the parent drop retains a negative charge. This separation mechanism could possibly generate lightning in storm clouds.

Man's effect on climate. In 1971 the Massachusetts Institute of Technology Press issued a volume entitled *Inadvertent Climate Modification: Report of the Study of Man's Impact on Climate.* Familiarly known as the SMIC report, it was a companion to a 1970 MIT volume *Man's Impact on the Global Environment: Study of Critical Environmental Problems* (the SCEP report). The new book is a summary of a conference planned by Carroll L. Wilson of MIT and held in Sweden during the summer of 1970. Some 30 scientists from 14 countries attended. The discussions considered a wide range of ways by which human activities could affect the climate, including changes in atmospheric composition; release of energy into the atmosphere; land-surface alteration; manipulation of surface and underground waters; weather modification;

and the effects of automobiles and aircraft, particularly supersonic aircraft. The conference made it clear that much still had to be learned in these areas.

A subject of more local—but still important—interest was the effect of large industrialized cities on the climate of the cities themselves and of the regions immediately around them. In 1968 Stanley Changnon of the Illinois State Water Survey reported certain anomalies in the weather records from stations downwind of Chicago and Gary, Ind., particularly in the data from the town of La Porte, Ind. There was considerable debate over possible explanations, but the uncertainties might be settled by a program begun in the vicinity of St. Louis, Mo., during the summer of 1971.

The program, called the Metropolitan Meteorological Experiment or METROMEX, was designed by scientists from four institutions, including the Illinois State Water Survey, to investigate changes in weather caused by urban-industrial effects with particular attention to changes in rain and snow. A dense network of observing stations of many kinds was installed around St. Louis. Starting in 1973, scientists of the Environmental Protection Agency would make detailed measurements of the pollutants in the air over St. Louis. The concentration of contaminants still in the atmosphere downwind of that city was to be measured by chemists from the National Center for Atmospheric Research, who had developed techniques for detecting trace quantities of various substances.

Weather modification. During the spring and summer of 1971, the southern states of the U.S. from Arizona to Florida experienced abnormally dry weather, and the governors of Florida, Texas, Arizona, and Oklahoma requested the federal government to undertake cloud-seeding operations in an attempt to increase rainfall. Each project lasted for one month or longer. In every case, rain did fall, but there appeared to be little concrete evidence to support claims that it fell because of the seeding or was increased by the seeding. Evaluation procedures were inadequate; the operators tried to seed the maximum number of clouds that appeared favorable, and the design of the programs made it virtually impossible to arrive at a satisfactory determination of their effects.

The year's events clearly indicated that the public and their elected representatives had become more aware of the potential value of cloud seeding. Most atmospheric scientists, however, were of the opinion that the technology is not sufficiently advanced to be used in the uncontrolled way adopted during the summer of 1971. Except in a few circumstances, it still had not been adequately demonstrated that cloud seeding will increase precipitation by substantial amounts. In some seeding programs, in fact, precipitation apparently was decreased.

Several important experimental cloud-seeding programs were in progress during the year. Particularly notable were the so-called San Juan Project in Colorado, in which the Bureau of Reclamation was evaluating the effects of seeding on winter snowfalls; a hail modification program being run by the National Center for Atmospheric Research with support from the National Science Foundation; and Project Stormfury, which was concerned with developing techniques for weakening hurricanes.

Considerable controversy arose around one cloud-seeding project when it was discovered that it had taken place near Rapid City, S.D., several hours before torrential rains caused a devastating flood in that city early in June. Scientists claimed that the seeding was done in clouds that were physically separate from the storm that caused the flood and that any rainfall it might have added to the total would have been comparatively light.

The legal, social, and ecological consequences of weather modification were receiving greater attention, particularly in the United States. At the same time, the international aspects of large-scale weather and climate modification were being recognized by many nations. The National Academy of Sciences report on the atmospheric sciences, acknowledging that weather modification technology could be used in war as well as peace, called on the United States "to present for adoption by the United Nations General Assembly a resolution dedicating all weather-modification efforts to peaceful purposes." Several members of Congress, particularly Sen. Claiborne Pell (Dem., R.I.), were concerned about the use of weather modification techniques in the war in Southeast Asia. Pell called for a treaty to outlaw such practices.

Global weather programs. Progress on GARP continued on many fronts. The first global experiment, an attempt to collect detailed observations of the atmosphere and upper layers of the ocean over the entire earth, was scheduled to take place between 1976 and 1980. The data were to be used to develop a better understanding of the atmosphere up to an altitude of 30 km and in constructing a numerical model to forecast the weather some 5 to 10 days in advance.

Beginning in 1967, a series of experiments had been conducted over small oceanic areas. Plans were in progress for a greatly enlarged experiment, during the summer of 1974, over the tropical Atlantic in a zone including parts of Central and South America and Africa and extending from 10° to 20° N. Some 25 countries were contributing ships, airplanes, weather satellites, other equip-

ment, and scientists. The management of the project was in the hands of an international group of scientists headquartered in Bracknell, Eng. This program, called the GARP Atlantic Tropical Experiment, would set the stage for expansion of the research, toward the end of the 1970s, to cover the entire planet.

—Louis J. Battan

Behavioral sciences

Continuing a trend that had been in evidence for several years, behavioral scientists turned their attention more and more toward the application of their special knowledge to the practical problems facing society. Anthropologists, taking stock of their field, placed special stress on problem-solving. At the same time, psychologists figured prominently in widely publicized arguments over the possibility and desirability of behavior control and over the hypothetical existence of genetic differences affecting the intellectual capabilities of various population groups.

Anthropology

The human species is now recognized to be some two million years beyond its other-primate ancestry. Its whole career is the subject matter of anthropology. The species carries with it much of its long history; thus it is possible for paleoanthropology and archaeology to make intelligible to modern man the fragments of prehistory for which they continually search. In recent years, the 3,000,000,000 humans living today, their problems and prospects, have also become a major focus of anthropology.

To understand the basic characteristics of the species requires disciplined study of the rich variations in human types and cultures. This has been the task of anthropology for at least a century and a half, but accumulation of such knowledge is slow. Moreover, until this generation anthropology very largely lacked input from scholars of other than European cultural traditions, a flaw that seriously crippled progress in a discipline where scientists—who are also humans partially blinded by their own cultural heritages—are the main tools of cross-cultural research. The body of disciplined knowledge has grown substantially in the past 20 years, but because analysis, publication, and criticism of new field research take time, anthropologists have still been unable to make the contributions required by a world whose problems can only be solved by its people.

In May 1971 the International Union of Anthropological and Ethnological Sciences embarked on a program to expose, synthesize, and summarize anthropological knowledge at its ninth International Congress, scheduled to be held in Chicago, Aug. 28–Sept. 8, 1973.

In August 1971 anthropologists all over the world were asked both to propose their own individual contributions and to suggest symposia and conferences for the congress. By March 1972 over a thousand responses had been received from 75 different nations. They were studied, collated, and synthesized by the organizing committee, which found that they could all be subsumed in four overlapping sets of major themes.

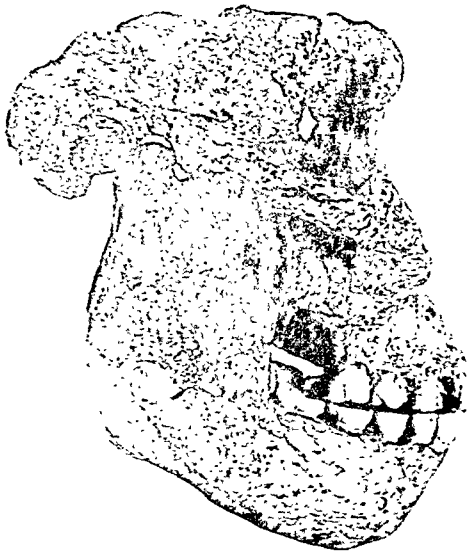
The first two (comprising 60% of the contributions suggested) show the knowledge that we have of the species, the first temporally and developmentally, the second geographically. The other two show the concerns of the disciplines—and particularly how they acquire knowledge—and the intersection of anthropological sciences with problems of the world outside. The whole of anthropology, as it approaches the last quarter of the



Substandard living conditions, as in this slum in Bogotá, Colombia, typify the lot of the urban poor in many areas of the world. Recently, a number of anthropologists completed studies of the urban poor which contradict the idea of a separate culture of poverty. In important areas, notably employment and family life, the values of slum dwellers correspond to those of the majority culture, but behavior differs because of the absence of opportunity to realize their goals.

Courtesy Dr. Thomas Gladwin, University Museum, University of Pennsylvania, and EXPEDITION Magazine

Courtesy, Transvaal Museum



Reconstructed fragmentary skull was recovered from a limestone quarry at Swartkrans, a fossil-rich site in South Africa. This skull differs in several respects from the Paranthropus *fossils found at the same site and has been assigned to the genus* Homo.

century, could be summarized in these terms, if one remembers that there is overlapping at every point.

Nature and development of man. This first set of themes looks at humankind from its beginnings, in all of its interrelated dimensions; 36.8% of suggested contributions are grouped here, and others almost equally appropriate are included in the geographic and methodological groupings.

Body and behavior, the first of three themes under this heading, encompasses the biological problems as they are now seen in three overlapping groups.

• Man and the primates examines human evolution both morphologically and behaviorally, as evidenced by the study of living and fossil genera. The age of the hominid family—going back to the Pliocene and even the Oligocene—requires that the development of humanness be seen in a context far wider than that of the anthropoid apes. Therefore, the search for human ancestry is pushed further back, and our fossils are compared with primates other than apes. Nor can we now tolerate any separation of morphology from behavior. Thus, ethology joins with anatomy and paleontology to provide understanding of human evolution.

• Paleoanthropology: the Pleistocene. As *Homo* developed and differentiated in the Pleistocene, interest shifts from the genus *Homo* to questions concerning the species *Homo sapiens*, and from "behavior" alone to "culture" and "cultures." The evidence shifts from the relatively few human fossils to the important cultural remains. Here, biological or physical anthropology merges with archaeology and prehistory.

• Human differentiation. The richness of evidence from the large post-Pleistocene populations, including the living, permits detailed study of human variability related to both genetic and ecological factors. Emphasis shifts, therefore, to discussion of inheritance and growth within populations and differentiation of groups in different environmental circumstances. Here the simple concept of "race" is falling into disuse. Continental-historic terms such as Africans, Asians, and Europeans are replacing "Negroid," "Mongoloid," and "Caucasoid," and interest in the classification of "races" is giving way to demographic, ecological, developmental, genetic, physiological, and medical studies.

Mind and culture encompasses the development of communications, cognition, and science in evolutionary perspective.

• Language and thought are interests that combine the skills of linguists, psychologists, philosophers, and a variety of anthropologists. Sociolinguistics deals with the dialects of social groups and leads into the problems of education and "applied linguistics." Cross-cultural and intensive studies of cognition involve new problems of conceptual categories as well as nonverbal symbolic behavior. When and how symbolic communication began are questions requiring both ethological perspective and study of the functions of the brain.

• Science, technology, and invention are traditional anthropological interests that have recently claimed public attention in the context of "runaway" technology. Tool making is older than was once thought and is not exclusively human. Recent evidence indicates that deliberate scientific thought was already well developed during the Pleistocene, at least in astronomy and mathematics. Anthropology offers new perspectives for general understanding of this subject, as well as for recently emerging social problems.

• Sociological innovation and change are not confined to recent times, and important evidence of deliberate policy changes among even the smallest and most isolated human societies is being provided by field studies. It is apparent that human societies are rarely passive recipients of change. Any contrary impression may be an obvious example of "colonialist" bias.

Expression in man, also an area of traditional anthropological interest, can now be treated fully

in empirically verifiable developmental and cross-cultural perspectives. The first three overlapping topics under this theme deal with aesthetics broadly considered; the fourth with religious and similar expressions.

- The graphic and plastic arts include all material, forms, and color, two and three-dimensional representations of thought and perception, to which there is affective response.
- The performing arts, music, dance, and theater, are viewed as affective behavior as they recreate human situations to satisfy emotional as well as intellectual needs.
- Folklore includes oral and written literature, seen as a body of information encompassing the study and analysis of myths and legends, fairy tales, riddles, folktales, and creative storytelling, analyzed from the viewpoint of aesthetics, psychology, and anthropology, and in their social and cultural matrix.
- Ritual, cults, and shamanism include studies usually associated with religious behavior; manifestations of a special type of affective responses including supernatural beliefs, worship, ritual, ceremony, and the manipulation of the social and natural world through esoteric means.

Looking at the world spatially. This emphasis has a long tradition in anthropology. Twenty-five percent of all respondents' suggestions are classified here under seven headings. Each subject heading includes an area as a whole plus a particular general problem for which the area is central.

The circumpolar regions, from the icecap through tundra and taiga. Special problem: man's adaptability to new and difficult environments, including the first peopling of, and dispersion throughout, the Americas.

The Pacific rim, from Japan and the northern coasts of mainland Asia through the Aleutians and Alaska and including the mountains south to Tierra del Fuego. Two special problems: (1) maritime anthropology and man's relations to the sea; and (2) communications along a cordillera as compared with cross-relations to the plains on one side and the sea on the other.

Asian-African hot and cold desert and steppe, a belt comprising northern and eastern Africa, the Middle East, and central Asia. Special problem: the relations between sedentary and nomadic ways of life in the context of modernization.

The Indian Ocean areas, including the South Asian plains, the eastern seaboard of southern Africa, Madagascar, and Southeast Asia through Malaysia. Special problem: comparative study of postcolonial "new nations."

China to the Antipodes, including mainland and Oceanic peoples and cultures. The special problem contrasts China as a "mother" culture with island cultures as historic receptors, taking as cases the Philippines and New Guinea.

Europe. Special problem: urbanization as a central historic process.

The Atlantic. The two coastal areas (Afro-European and American) are treated as virtually separate until A.D. 1500, and then (as the special problem) as they are brought together by northern maritime Europeans on both sides of the Atlantic who developed the international plantation economy, moved populations from east to west, and led to the development of a new Afro-American culture.

Professional concerns. It is characteristic of the orientation of anthropology that the smallest number of responses (14%) concerned methodologies and professional problems.

Theoretical perspectives can be divided into three sections, the first two of which deal with

The graveyard of the tiny fishing hamlet Guañape on the coast of Peru illustrates a reality of countless communities around the world in which the graveyard is their most prominent feature. Only seven families remain in Guañape, once a thriving port town.

Courtesy, Dr. Thomas Greaves, University Museum, University of Pennsylvania



major substantive problems: alternative theoretical orientations required for the analysis of differences in economic and sociopolitical development; the anthropology of complex societies; and current theories, methods, and techniques of research.

Data storage and retrieval includes bibliography, museology, cartography, and—what is becoming a major interest—visual-aural anthropology, including, especially, the use of sound motion pictures and television tapes.

The history and future of the anthropological sciences subsumes means of overcoming centrifugal tendencies caused by increasingly specialized knowledge; difficulties of communication across disciplines and across linguistic, cultural, and national boundaries; and problems of training and placing professionals and establishing ethical norms on a worldwide scale.

Social concerns. Some 24.2% of the responses concerned the social uses of anthropological knowledge.

Three interrelated problems that affect the whole of the species, and whose understanding urgently requires the broadest perspective, are: population and technological increase on a limited planet; colonialism, power abuse, and war; and systems of injustice and discrimination.

An area of major concern involves the fates of indigenous and minority peoples, as seen throughout history and today by historians and anthropologists and by the survivors themselves. The possibility and prospects of cultural pluralism in the industrial age is a major theme of the congress.

Among the problems of modern life are three sets of interrelated problems seen in the context of rapid urbanization: mental and physical illness; malnutrition; and drugs and stimulants.

Social improvement through anthropological understanding includes: the study of reproductive and early childhood behavior basic to the family and to community mental health, keeping in mind that child-rearing practices may become more positive and supportive if they are released from restrictions based on mistaken rules of supposedly universal "human nature"; and the need for education based on recognition of cultural and value differences, and of identification of individuals with different local, class, and culture groups, so that supposed "lack of motivation" can be eliminated and children and adults freed to fulfill themselves.

The future of the species as seen in the context of its entire past is an ultimate goal of the sciences of man and a general theme for the congress.

—Sol Tax

See also Feature Article: THE TASADAY—STONE AGE TRIBE OF MINDANAO.

Psychology

The quiet, steady progression of research findings and theoretical understanding in psychology is ordinarily barely visible except to those most deeply involved, and then not in annual segments, but only over several years. During the year, however, several public events, including reviews of the IQ-race argument and statements advocating deliberate behavior control, attracted public vigilance and excitement that would not easily be extinguished.

B. F. Skinner. In his book *Beyond Freedom and Dignity*, B. F. Skinner suggests that since almost all of our major problems involve human behavior, we should turn to the science of behavior for relief. Continuing on our present course, without using a technology of behavior, we will inevitably bypass solutions to these problems, deny the full potential of man, and possibly drive mankind to extinction in the process. Thus he argues that deliberate behavior management is not only desirable but also absolutely essential.

Skinner's primary argument can be summarized easily. Behavior is controlled in any case; the complex relationships that determine behavior encourage what is only an illusion of freedom. And since behavior is already determined, but in most cases by poor and unsystematic environmental arrangements, we should deliberately shape behavior that is desirable to all of us. We should control for the good of man—indeed, for man's survival.

Skinner uses considerable space to demonstrate the varieties of behavior control. He points out that we tend to generalize and to resist any type of control because some forms of it are objectionable. He offers behavior-management procedures that would be agreeable to any subject and suggests ways to institute these procedures piecemeal. Readers are reminded that behavior-management programs do exist. Many have begun in psychotherapy, education, and commerce; they are multiplying, and their coverage and precision are increasing. In many ways Skinner is saying that we should encourage the expansion of behavior-control programs, and we should also consider whether they are based on desirable social policy.

Current psychology has dealt with many issues relating to behavior control, but Skinner widens the debate and strikes at two seemingly fundamental concepts of human nature. In his view, the primary impediments to large-scale employment of behavior technology have nothing to do with knowledge or cost. Rather, it is suggested that the main barriers are existing conceptions of individual freedom and human dignity.

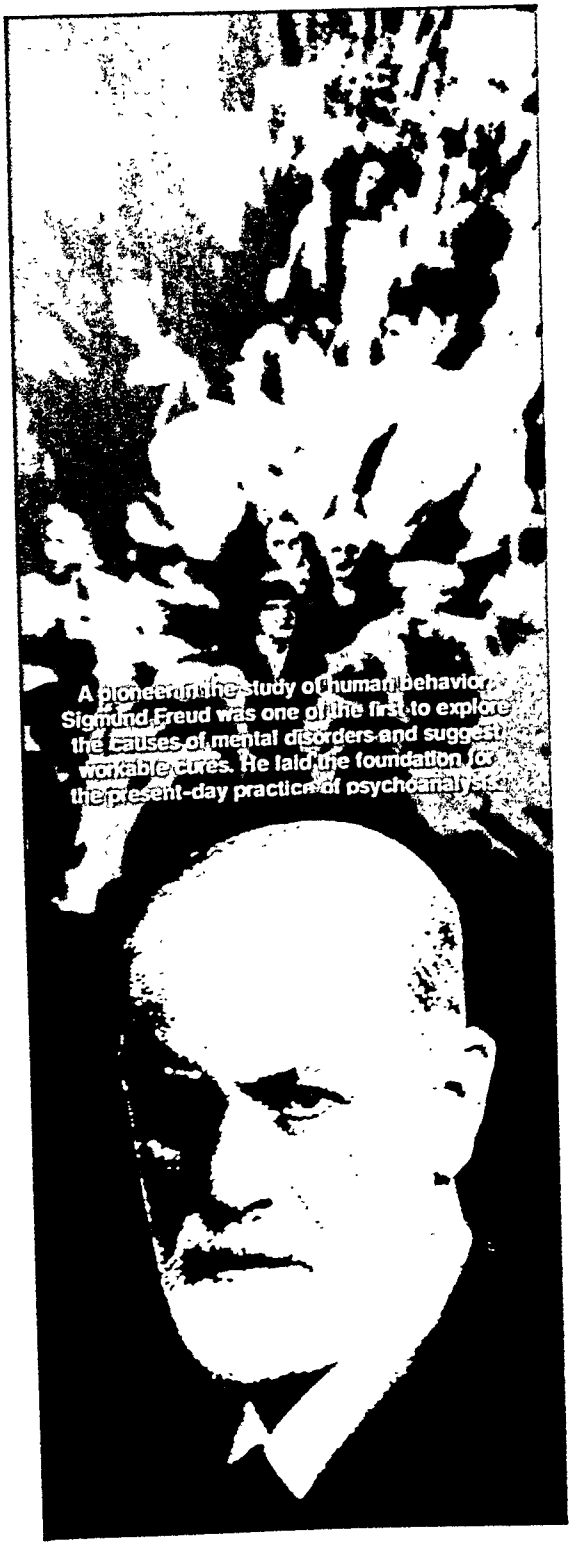
Believers in these conceptions maintain that behavior control would reduce the freedom of any individual, subjugate him to constraints not present now, and, by virtue of considering man as a subject of control, reduce the worth of men. Skinner argues that the "literature of freedom" arose to encourage and justify escape from controls that were seen as oppressive, but that it has grown to regard any form of control as undesirable. Yet, he states, there are alternative kinds of control, involving "positive reinforcement," with which any man would find himself in happy concordance. "The problem," Skinner says, "is to free men not from control, but from certain kinds of control."

Skinner does not urge the immediate adoption of any particular cultural design; rather, he advocates continuous cultural experimentation and piecemeal adoption of those procedures that prove to be successful. The effort "is not to design a world that will be liked by people as they now are but to design one that will be liked by those who live in it." Further, there is no implied distinction between the ruled and ruling classes. A cultural design must answer continuously to the culture itself; those who control are simultaneously those who are controlled.

Kenneth B. Clark. Perhaps even more startling was Kenneth B. Clark's call, in his presidential address to the American Psychological Association, for research into a biochemical means that would prevent persons in power from abusing their power. "A few men in the leadership positions in the industrialized nations of the world now have the power to determine among themselves, through collaboration or competition, the survival or extinction of human civilization . . . . The masses of human beings are now required to live and continue to work on . . . [the] hope . . . that their powerful leaders will . . . use their power wisely and morally." This situation requires the development of precise psychological and social sciences; it has made "psychotechnology" imperative.

Citing what he called "many provocative and suggestive findings from neurophysiological, biochemical, psychopharmacological and psychological research," Clark suggested that "we might be on the threshold of that type of scientific biochemical intervention which could stabilize and make dominant the moral and ethical propensities of man and subordinate, if not eliminate, his negative and primitive behavioral tendencies."

Although Clark's target population and methods differ from those of Skinner, he does call for deliberate behavior control and he implies that much of the essential technology is currently available. Clark anticipated certain objections with a



A pioneer in the study of human behavior, Sigmund Freud was one of the first to explore the causes of mental disorders and suggest workable cures. He laid the foundation for the present-day practice of psychoanalysis.

moral argument. He concluded that moral objections to psychotechnology because it is manipulative and "will take away from man his natural right to make errors—even those errors which perpetrate cruelties and destruction upon other human beings, . . . seem mockingly, pathetically immoral."

Professionals reacted quickly to Clark's address. Researchers in the fields Clark singled out were quick to suggest that his appeal was much too simplistic and fantastic. No one denied that considerable behavioral control was now possible, however, and professionals generally agreed that ongoing research of the type proposed by Clark should continue.

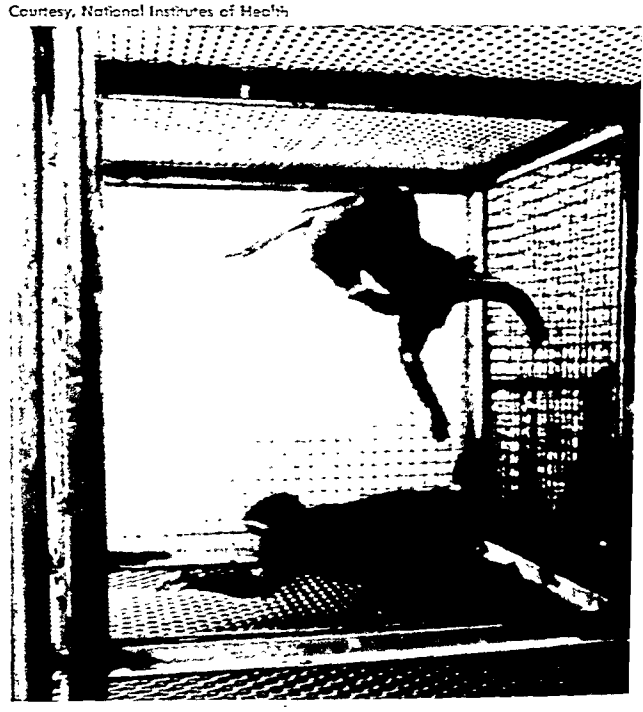
Public reaction was even more interesting. Skinner's book and Clark's speech received immediate worldwide attention. *Time* magazine featured Skinner's work in a cover story. *Beyond Freedom and Dignity* led nonfiction bestseller lists for several months and was nominated to receive the National Book Award. Interest was also evident in high places. Shortly after Clark's speech, Rep. C. Gallagher (Dem., N.J.) asked the U.S. General Accounting Office to examine federal funding to the American Psychological Association to determine whether federal money was being spent to implement Clark's proposal. Vice-Pres. Spiro Agnew spoke of Skinner's and Clark's thinking in an address to the Illinois Farm Bureau, calling it "radical surgery on the national psyche." (*See* Year in Review: SCIENCE, GENERAL.)

IQ again. The ancient heredity-environment controversy was exhumed by A. R. Jensen in 1969, when he analyzed data on heritability of IQ and observed differences between groups. Jensen hypothesized that social class and racial differences were reflections of significant genetic differences. During the year three reviews of the subject appeared: a book, *The IQ Argument*, by H. J. Eysenck of the University of London; an *Atlantic* magazine article by Harvard's R. J. Herrnstein; and a *Science* magazine article by S. Scarr-Salapatek from the University of Minnesota. In addition, *American Psychologist* carried a debate between Jensen and D. O. Hebb of McGill University.

Based on available data, the genetic argument was strong and consistent, but data comparable to that for the white, middle-class population (on which the argument was based) were lacking for lower-class and nonwhite groups. However, in one series of studies, differing heritability coefficients for different racial and social-class groups were obtained by Scarr-Salapatek.

The dilemma, which could be resolved only with large numbers of measurements, was this: because IQ is a trait standardized for a population, defining the population is critical. A population definition rests on increasingly restrictive specifications, particularly those regarding environments. Within a restricted population, the heritability factor must necessarily increase, but, given such restrictions, the meaningfulness and usefulness of the IQ measure as applied over a more generally defined population must decrease. Clearly, more technical expertise was required for public policy decisions on this issue.

Courtesy, National Institutes of Health



Two female monkeys play independently in contrast to males, who prefer contact games. Scientists at the Wisconsin Regional Primate Research Center observed that gender is equal to or more important than environment in determining whether the play time of monkeys involves contact or noncontact sports.

New theory. Experimental and theoretical developments in human verbal learning and in conditioning and animal learning, long the central areas of psychology, have progressed largely without regard to one another. Conditioning research generally followed the elemental, so-called "stimulus-response" format, while human learning theorists postulated hypothetical cognitive processes. During the year two conferences, of researchers in human learning and in conditioning, led to similar theoretical formulations. Since these areas give direction to much of psychology, such convergence would have far-reaching consequences.

A conference on conditioning and learning at North Carolina State University heard suggestions, particularly from W. K. Estes of Rockefeller Uni-

versity, in New York City, for the use of a "coding" event transpiring between experimenter-arranged stimulus events and subject-generated responses. The second conference, sponsored by the U.S. Office of Education at Woods Hole, Mass., was specifically devoted to "Coding Processes in Human Memory."

The notion of a coding event is helpful in both areas. Consider, for example, the problem of selective attention. Some subjects choosing between two complex stimulus arrays will base their choice only upon certain features of the array, while other subjects will choose on the basis of other features. Elemental theories suggesting that all the features have an equal potential for eliciting a response are too simple, while cognitive theories are either ad hoc or vague. A coding event that refers to specific aspects of the stimulus and is determined by experimental treatment and historical variables seems a likely and testable component in the information-processing sequence.

Major differences exist concerning the topography of the coding event, however. The original elaborations emphasized behavior in their discussions of coding as mediating responses. On the other hand, cognitive and perceptual theorists generally referred coding to the nervous system. Many of their theories used the early 1960s discovery, by physiologists D. Hubel and T. N. Wiesel at Harvard, of single neurons in the cerebral cortex that are excited by changes in unusual, single aspects of visual stimuli (angular orientation, direction of movement, size, etc.).

Recently N. Weisstein of Loyola University, Chicago, and J. Bisaha of Mundelein College, also in Chicago, obtained visual masking effects in which the apparent contrast for a second visual item is reduced by prior viewing of another visual item. This suggests an analysis involving groups of neurons. Their work is interesting to psychologists because the more complex the coding, the more a response analysis and a neural analysis converge in function.

—Daniel Johnson

See also Feature Article: THE PSYCHIC BOOM.

Botany

Major trends in plant sciences during 1971–72 provided better understanding of the various interactions between plants and animals and heightened perspective on the control of molecular movement in and between plant cells. The organization of cells continued to seem more and more complex as it was better understood and botanists were learning more about the ways in which this complexity governs the relationships between green plants and their environment. One of the most surprising developments was the establishment of the importance of ion movements in setting up action potentials in plants, movements similar to those long known in the nervous systems of animals.

Recycling of atmospheric ammonia by higher plants. Nitrogen constitutes about four-fifths of the atmosphere but, although it is an important component of the amino acids that make up all proteins, green plants cannot use it directly from the atmosphere and animals must obtain it from higher plants in the form of organic molecules. The process of utilizing atmospheric nitrogen is controlled mainly by a series of microorganisms that occur either free-living in the soil or in the nodules on the roots of legumes, such as clover and soybeans, the plants often grown to enrich the nitrogen content of soil depleted by other plants.

Stoma of a cucumber leaf is flanked by guard cells, which control the movement of water and carbon dioxide between the exterior and interior of the leaf. During the year scientists discovered that the guard cells are open only when they have a high concentration of potassium ions.



Most of the ammonia (ammonium ion) in the atmosphere or in the soil is there as a result of organic decay—the breakdown of proteins and amino acids. In the traditional nitrogen cycle, the ammonia is considered to be oxidized to nitrites by the bacteria *Nitrosomonas* and *Nitrosococcus*; the nitrites are in turn oxidized to nitrates by the bacteria *Nitrobacter*. These nitrates can then be taken in by green plants and used in the synthesis of organic molecules.

In early 1972, however, a group of researchers showed that growing plants could satisfy about 10% of their nitrogen requirements by absorbing ammonia, which is a compound of nitrogen and hydrogen, directly from the atmosphere through the leaves. This discovery might be of considerable importance in explaining the balance between plants and their environment, particularly under polluted conditions where ammonia may be abundant.

Following root growth. Work by J. Waddington of the Canada Agricultural Research Station in Saskatchewan resulted in the development of a periscope for observing the growth of roots. All of the commonly used techniques had involved considerable disturbance to the roots or the application of radioactive traces that constituted potential radiation hazards. In Waddington's method, transparent glass or plastic tubes could be inserted in the soil near a plant and an inverted periscope constructed with one element transmitting light down to the roots and another transferring the image back to a viewing eyepiece. The whole system could be accommodated in a tube about 2.5 cm in diameter and would cause very little disturbance to the plant when left in place over a period of time. The method could permit observations of patterns of root growth far superior to those possible with any previous method and might provide better knowledge of the relationship between roots and the soil, which would be important for agriculture as well as for theoretical botany.

Plant-animal interactions. As the scope of studies into the relationship between green plants and insects and other animals broadened, plants were discovered to employ a surprising variety of methods to ward off predators. Many plants manufacture molecules of alkaloids, cardiac glycosides, cyanide, mustard oils, and the like, which inhibit feeding by most insects. Some of the relatively few insects that are able to feed on these "protected" plants retain these molecules and use them as a defense against their own predators. A familiar example is that of the orange-and-black monarch butterfly (*Danaus plexippus*), which is highly distasteful to birds because it retains cardiac glycosides it took up as a caterpillar from milkweed plants. The viceroy (*Limenitis archippus*) resembles the monarch so closely that it too is avoided by birds, even though it is not distasteful because its larvae did not feed on milkweed.

Some plant defenses were found to be, or were suspected of being, more subtle. Some ferns and gymnosperms, for example, have molecules that resemble ecdysone, the insect molting hormone, which might cause disturbances in the development of the insects that feed on them. Certain bark beetles and bees utilize substances they derive from plants as their own sex attractants. Many of the hairs and spines on plants might constitute almost impenetrable barriers to small insects, and also might regulate water loss from the leaves.

During World War II, in an attempt to discover why bracken fern (*Pteridium aquilinum*) was not eaten by cattle and sheep, it was found that the plant contained substances that inhibit the synthesis of thiamine. Perhaps this also explained why bracken and other ferns are rarely eaten by insects and other herbivores. Recently it was shown that when the leaves of tomato or potato plants are wounded by insect attack, they rapidly accumulate a substance that inhibits digestive enzymes (proteinases). Such wound reactions of plants might eventually be found to discourage insect attack, a role that might have important implications for agriculture.

The meaning of flower colors. Recent observations helped to explain why flowers visited for food by hummingbirds and other birds are most frequently red. The energy consumed by a hummingbird hovering at a flower is some 600 times that used by a bumblebee crawling over a cluster of lilac blossoms. Hummingbirds and other animals with high energy requirements, such as hawkmoths, must largely confine their visits to flowers that produce nectar abundant enough and rich enough in sugar to support them. Insects with lower energy requirements will also visit flowers that produce abundant nectar, but they will not normally move from plant to plant and their visits will not result in cross-pollination. The plant that produces enough nectar to support repeated visits by hummingbirds must, therefore, "protect" its nectar from these insects.

The plant appears to accomplish this in three ways. First, its flowers are generally strong and tubular and the nectar is secreted at the base, so that only an animal with a long tongue or beak can reach it. Second, the flowers are odorless. Birds, like men, orient largely by sight, while insects often orient by odor, especially at a distance. Third, the flowers are often red. Although insects are known to detect wavelengths in the ultraviolet that are not visible to men or birds, red, to them, fades into the

Barbara Panessa, New York University





Scanning electron micrographs of a sundew leaf clearly show the tentacles through which digestion of trapped insects takes place (close-up at right) The sundew may prove valuable in further studies of the role of electrical energy in plant behavior

background of green leaves, as it does to a color-blind person. There are few pure red flowers in Europe, where there are no flower-visiting birds. In contrast, the distribution of red flowers in the Americas, where 84% of the South American species known to be bird-pollinated are red, may well depend on the annual migration of hummingbirds.

Control mechanisms in stomata. One of the most striking developments in botany was the growing understanding of the mechanisms controlling the movement of water and carbon dioxide between the exterior and the interior of leaves. Water and carbon dioxide are the compounds from which organic compounds are built during photosynthesis. A thin cuticle makes leaf and stem surfaces largely impervious to both of these vital molecules. Water must flow continuously from the soil into the roots, upward through the stems, and out through the leaves. Since there is no mechanism for recirculating water, continuation of plant life depends upon the maintenance of this flow. Carbon dioxide, on the other hand, must enter the green parts of the plant directly from the atmosphere. It does so through the same small openings, called stomata (singular: stoma), that permit the escape of water.

Each stoma is flanked with a pair of specialized cells called guard cells, which, instead of being flat and tablet-shaped like the rest of the surface, or epidermal, cells, are sausage-shaped and thickened on ridges along their inner margins. When the guard cells are turgid, or subject to high internal water pressure, the inner margins spring outward in opposition to one another and the stoma is open. When they are flaccid, or the water pressure is low, the inner margins relax and come together. In many plants additional specialized cells, the subsidiary cells, are arranged in small groups of definite position around the guard cells.

Stomata are often very numerous; there are 12,000 per sq cm on tobacco leaves. In some plants they are confined only to the upper or lower surface of a leaf, while in others they are on both. The stomata are connected directly with a honeycomb of air spaces within the leaf that sometimes makes up nearly half of the total volume of the leaf. The air in these spaces is saturated with water evaporated from the damp surfaces of the leaf's interior cells. Within these cells are the chloroplasts in which photosynthesis occurs. For a plant to continue to live, the flow of water from its leaves and the passage of carbon dioxide into the leaves must be regulated. Under drought conditions, the low water pressure in the leaves often causes the stomata to close. This reduces access to carbon dioxide, and photosynthesis may be very limited.

The strides made during the year, however, dealt with influences other than drought on the regulation of the stomata. The stomata of many plant species were known to close regularly in the evening and open in the morning, even when the supply of water to the plant was constant, presumably because of an increase in carbon dioxide concentration around the plant. It was shown that when stomata are open, the guard cells have high concentrations of potassium ion (K^+) and that when they are closed, most of the potassium ions have moved out into the subsidiary cells or into other

cells of the leaf. The changes in concentration were sufficiently large to account for other changes associated with the opening of the stomata. Normal opening and closing of the stomata were found to be possible only when the guard cells were attached to the other cells of the leaf or when they floated in a solution containing potassium ions. In darkness, air containing carbon dioxide apparently inhibits the accumulation of potassium ions in guard cells, and thus the stomata do not open.

The ability of stomata to open and close rapidly in response to environmental stimuli is essential to good plant growth, and botanists were considering possible mechanisms whereby the movement of potassium ions might be controlled. Guard cells in higher plants also clearly can take up ions of potassium with a much greater degree of specificity than had been suspected. The way this specificity is controlled was also expected to be studied further, since the considerable degree of specificity found in the movement of ions from the soil into the plant roots remained one of the unsolved questions of botanical science.

Electrical signals in plants. As early as 1880, it was known that a leaf of Venus's flytrap (*Dionaea muscipula*) conducts "action potentials" when certain specialized hairs protruding from its surface are touched by an insect. Following the passage of two or more action potentials, the two lobes of the leaf fold together rapidly. If the insect is trapped, small glands secrete digestive enzymes that reduce the hapless creature to its biochemical building blocks, which are rapidly absorbed for the nutrition of the plant. These action potentials, which seemed to be very similar in origin and function to those of animal nerve cells, were long regarded by botanists as freaks of evolution, even though similar action potentials were discovered to mediate the rapid closing of leaves of the sensitive plant *Mimosa pudica*. To some botanists, however, it seemed that such specialized behavior could not have arisen de novo in these peculiar plants, so they looked for electrical signals of a less conspicuous nature under more ordinary circumstances. As a result of their investigations, it appeared that action potentials might be widespread in the plant world, communicating information about the state of the plant's cells or about the external environment.

Leaves of Venus's flytrap conduct "action potentials" and close rapidly when hairs on their surfaces are touched by an insect. Scientists are currently studying other factors that stimulate electrical signals in plants as well as the roles played by such signals.



Russ Kinne from Photo Researchers

It was reported, for example, that when pollen lands on the surface of the female part of a lily flower, an action potential passes into the hidden region of the flower where the egg is waiting to be fertilized. The action potential may trigger final stages in the development of the female tissue that aid in the passage of the sperm to the egg and might even aid fertilization itself. In certain families, the female parts of the flower play an active role in securing pollen. The touch of an insect on the stigmatic surface of the female part triggers an action potential that causes the lobes of the stigma to fold around the insect. The insect usually escapes, but any pollen on its body is brushed off and held tightly between the lobes, which form a little chamber within which the pollen develops further. A second action potential then passes to the region of the egg in the ordinary fashion.

When a young seedling, such as that of the garden pea, struggles to emerge from the soil, it is aided by a special sensory system that enables it to judge the depth and compaction of the overlying soil. The detailed mechanism of the system was not understood, but it was clear that when the surface of the stem (technically, of the epicotyl) is rubbed, as by particles of soil, voltage fluctuations that resemble action potentials can be observed almost immediately and continue for some time. A hormone is soon released that causes the plant to develop a stouter stem and keeps the tiny leaves folded over tightly in a bud that will not suffer abrasion as the plant pushes through the soil. When the plant nears the surface, friction between soil particles and the stem diminishes, the voltage fluctuations cease, the release of the hormone decreases, the stem puts on a burst of elongation, the bud unfolds, and the leaves expand in preparation for photosynthesis.

More mysteriously, a variety of spontaneous signals of unknown function were detected when

electrodes were applied to the green parts of such plants as the morning glory, garden pea, and cocklebur. These signals sometimes occurred in trains of variable duration. The individual signals might be very brief and rapid in sequence, or they might be longer and separated by fairly long intervals. Isolated individual signals of more erratic character were observed in mushrooms as well as in green plants.

Scientists were trying to learn more about the factors that trigger electrical activity in plants and about the role of electrical signals in plant behavior. A carnivorous plant might well play an important part in these studies. The sundew *(Drosera)* was found not only to have action potentials like those of animal nerves but also to have receptor potentials resembling those of animal receptor organs. Because this versatile plant has cells that are comparatively easy to see and to impale with electrodes, it was thought to be particularly suitable for detailed comparisons of the electrical activity of plants and animals.

—Peter H. Raven

Chemistry

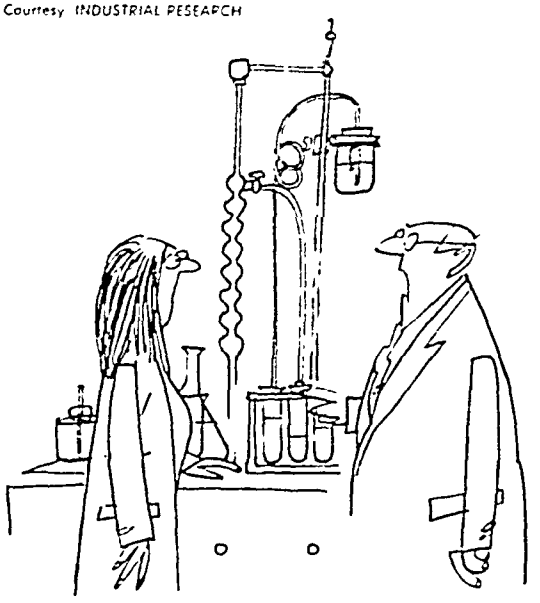
Advances during the year in chemistry ranged from success in limiting the lifetime of plastics to the recording of the two millionth unique chemical structure. Beam collision techniques were used effectively to help discover the nature of chemical reactions, while liquid-liquid chromatography helped determine chemical structures.

Applied chemistry

"Energy Crisis" was added firmly to the list of public concerns during the past year, and chemists and chemical engineers responded by intensifying their efforts to improve the creation of synthetic natural gas from naphtha and coal. They also suggested hydrogen as a universal fuel, supplementing both fossil fuels and nuclear energy. A successful effort at reducing the persistence of pesticide molecules in the biological environment was also reported.

Chemistry in the furnace. About one-third of U.S. energy needs in 1972 were met by natural gas, a remarkable statistic considering that until the end of World War II this fuel was simply flared as a necessary waste in the production of oil. The energy demands of the postwar suburban boom, coupled with the invention of the seamless welded pipeline that made possible long-distance transmission at high pressures, produced natural gas' explosive growth, about 6% a year since 1950.

Courtesy INDUSTRIAL RESEARCH



"We should have a reaction in about 36 hours Call me when it happens"

During the past year, various indications—gas companies cutting back or simply eliminating new orders of gas, for instance—made it evident that shortages of natural gas were developing in the United States. The reasons for the shortage included not only an actual decrease in the supply but also the pricing policies of the Federal Power Commission (FPC) and the apparent reluctance of the gas companies to search out new deposits. There did appear to be ample supplies of natural gas for the next two to three decades if the predictions of the Potential Gas Committee are borne out. The committee estimated proved reserves of natural gas at 260 trillion cu ft (the U.S. now uses about 23 trillion cu ft annually), and potential reserves at 1,178 trillion cu ft. Given the exponential increase in overall energy consumption—a doubling about every 10 years—this meant that the proved reserves would last for 13 years and the potential reserves for 20.

The combination of these limitations on natural gas supplies and a more favorable FPC pricing policy spurred the gas companies into a greater technical effort to make a gas from coal and naphtha (a light hydrocarbon fraction of crude oil) that will be compatible with natural gas. More than a dozen companies recently announced plans to make synthetic natural gas (SNG) from naphtha, while several more planned to make SNG from coal. To the consumer the effect of this will be higher gas prices, perhaps two to three times

Courtesy, ICI Fibres Ltd.



Heterofil bond is formed when a web containing normal fibers and bicomponent fibers, a fiber with a high melting core and a sheath of a low melting polymer, is heated. The resulting fabric is called a melded fabric.

above current levels, although the blending of natural with synthetic will somewhat mitigate the price increase.

For scientists and engineers, the effort to create SNG compatible with natural gas creates intense technical pressures. While synthetic gas is not new —town gas made from coal was the chief heat and light fuel in the 19th century—it is quite something else to make a synthetic product as good in its heating qualities and as free of contaminants as natural gas. Town gas, made by simply heating coal, has a heating capacity of about 500 British Thermal Units (BTUs), while natural gas is about twice that, about 1,000 BTUs.

Work on creating SNG from naphtha was well underway in 1972, spurred largely by the initial efforts of the British Gas Council. The largest venture to be announced by mid-year was a 500 million-cu-ft-per-day plant to be built in New Jersey in 1973 jointly by Texas Eastern Transmission Corp. and Consolidated Natural Gas Co. The effort to create SNG from coal is a bit behind naphtha; most experts predict 1977–80 as the time for commercial coal gasification in the U.S. However, in April 1972, the Continental Oil Co., British Gas Council, and Scottish Gas Council jointly announced plans to upgrade an existing coal gasification facility in Scotland to the point where it will produce a gas with the heating capacity and purity of natural gas.

Natural gas is almost exclusively one hydrocarbon, methane (CH_4), and the successful creation of SNG consists of converting economically a mixture of many hydrocarbons into methane. The problems are particularly difficult for coal: the hydrogen content is too low and must be upgraded; it must be properly pretreated to avoid caking problems that delayed the start-up of one gasification plant this year; and, there are a host of impurities, including sulfur, that must be removed.

The fuel to be gasified—be it coal or naphtha—is reacted under pressure with air and steam. The product is "synthesis gas," a variable mixture of carbon monoxide, hydrogen, methane, carbon dioxide, and sulfur impurities. A properly catalyzed "shift reaction"

$$CO + H_2O \longrightarrow CO_2 + H_2$$

brings hydrogen and carbon monoxide into proper balance for the subsequent methanation reaction,

$$CO + 3H_2 \longrightarrow H_2O + CH_4$$

Methanation, while successful in the laboratory, has not yet been proven commercially. However, it is necessary if several gasification schemes now proposed are to produce useable SNG.

Coal, as suggested earlier, presents some formidable technical problems as a source of SNG. However, technical experts are optimistic that these problems can be resolved. Coal, that is, carbon (C), is gasified when it reacts with steam (H_2O) and air (O_2) at about 1,800° F:

(1) $C + O_2 \longrightarrow CO_2$
(2) $C + H_2O \longrightarrow CO + H_2$
(3) $C + 2H_2 \longrightarrow CH_4$

The heat required for these gasification reactions makes them expensive steps in the coal-to-gas process. Heat is supplied in various ways depending on the process: electrical energy, burning of coal, reaction of carbon monoxide with metal oxides, reaction of lime (CaO) with carbon dioxide.

In addition, coal contains various impurities—a typical chemical formula for coal (Illinois #6) is $C_{11}H_{85}S_2N_{1.5}O_{9.5}$—that must be removed. Sulfur is taken out as hydrogen sulfide, nitrogen as ammonia, and oxygen as water.

In 1972 there were about 60 coal gasification plants operating in Europe (none in the U.S.). All were based on the Lurgi Process, which helped keep Germany supplied with synthetic fuels during World War II. It is questionable, because of caking problems, whether bituminous coals found abundantly in the eastern part of the U.S. are suitable for the Lurgi process. However, at least three U.S. plants using the Lurgi process were announced.

There were several new approaches to coal gasification on the planning boards in 1972. The most advanced, in terms of reaching actual production, was the Institute of Gas Technology's HYGAS Process. In this process, hot hydrogen reacts with a mixture of coal and oil in a hydrogasifier. The methane formed is enriched by a subsequent reaction between carbon monoxide and hydrogen. A HYGAS plant was scheduled in October to start producing about 2 million cu ft per day of synthetic gas from lignite (brown coal) or midwestern coal.

The M. W. Kellogg Company's molten salt process may prove the most versatile, both in the kind of fuels it can gasify (ranging from coal to garbage) and in its ability to handle both caking and noncaking coals. The coal is suspended in molten sodium carbonate, which also catalyzes the formation of methane in the gasification steps. One advantage of the molten salt approach, carried out under pressures of 1,200 pounds per square inch, is that combustion can be separated from the synthesis gas, eliminating the need to remove sulfur, carbon oxides, and other impurities.

Hydrogen as a fuel. While coal gasification neared the production stage, energy experts were also seriously considering another energy source —hydrogen gas. At a national meeting of the American Chemical Society in April 1972, several speakers considered the prospects for a "hydrogen economy" in which hydrogen would be used as a universal fuel, that is, as an alternative to both nuclear power and fossil fuels, natural or synthetic. Hydrogen fuel has several immediate advantages: it can be made from water, burns easily, is transportable through already existing gas pipelines, and, when burned, leaves only one "ash"—water. Moreover, unlike electricity, which must be made on demand, hydrogen gas can be stored.

The first basic step in developing a hydrogen economy is to use nuclear power to break down water, either electrolytically or by thermal cracking—heating to very high temperatures. However, electrolysis of water to hydrogen and oxygen is a relatively expensive and somewhat inefficient process. Direct thermal breakdown would require temperatures higher than fission (but not fusion) reactors could achieve. However, Cesare Marchetti and G. De Beni of the European Atomic Energy Community proposed a four-step process to make hydrogen that involved a series of recycled chemical intermediates in which the highest temperatures reached would be about 1,350 F. Some problems might arise with this, including possible loss of mercury (one of the chemicals involved) to the environment, corrosive intermediate materials, and an overall efficiency about the same or below that of electrolysis.

The architecture of pesticides. The past decades of organic chemistry were marked by the analysis of the structures and subsequent syntheses of often quite complex molecules. By 1972 the emphasis was on coupling the ability to synthesize with the growing knowledge of how chemicals act in living systems, including the human body. The result was molecular architecture; chemicals designed for specific biological applications. One example of molecular architecture of particular satisfaction to environmentalists was provided in the February 1972 issue of *Chemical Technology* by Robert L. Metcalf and his colleagues at the University of Illinois. They designed analogs, or chemically similar materials, to DDT that are reportedly as effective as that insecticide but much more readily broken down by living systems, that is, more biodegradable.

DDT, and its even more stable metabolite DDE, do not break down easily, and this has been blamed for the accumulation of these pesticides in fishes and for the reproductive failures of a variety of birds such as the Bermuda petrel. The basic problem, as Metcalf pointed out, is that both DDT and DDE dissolve much more readily in fat than in water. The consequence is that DDT (or DDE) is poorly excreted and instead accumulates in fatty tissues of fishes, birds, and man. The reason DDT is not broken down in the body to water-soluble products is that enzymes, biological catalysts, cannot attack a certain portion of the DDT molecule. Accordingly, working from clues supplied

by a much more biodegradable, if less effective, pesticide called methoxychlor, Metcalf and his colleagues prepared a host of DDT-like compounds in which the enzyme-resistant portions were replaced by other chemical groupings.

The result, reported Metcalf, was a variety of compounds readily biodegradable but just as effective as DDT. In some cases, these products of molecular architecture were even more effective; for example, one designed compound proved effective against a strain of DDT-resistant houseflies.

—Norman Metzger

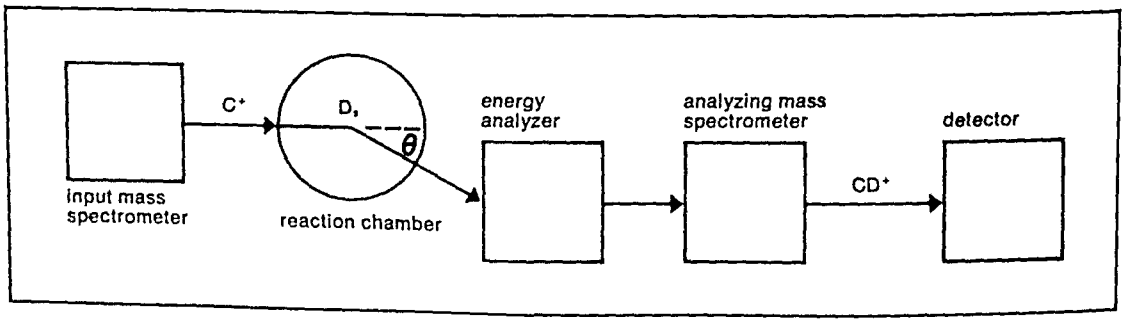
Chemical dynamics

Research in chemical dynamics continued to try to shed light on the questions as to how chemical reactions occur, what forces drive them, and what factors determine their rates. Traditionally, the processes involving chemical change have been studied by mixing reactants in the gas phase or in solution and then monitoring the products produced as a function of time. The energy of the reactants was varied by varying the temperature. In such a system the reactants have a spread of kinetic energies corresponding to their thermal distribution. One is limited in the energy range one can cover, and if solutions are involved the matter may be further complicated by effects of the solvents. In order to avoid some of these complications, chemists began to use the so-called beam techniques, in which a beam of ionic or neutral reactants with a narrow spread in kinetic energy is made to collide with the target gas molecules. In such a reaction one studies the energies, the identity, and the angular distribution of the products resulting from a collision between projectile and target.

Beam collision techniques. A diagram of a spectrometer used for such studies is shown in figure 1. Ions (charged atoms) are produced in the input mass spectrometer by the electron bombardment of a suitable gas. The ions so produced are then retarded or accelerated to a desired energy and focused into a reaction chamber containing D_2. The ionic species (C^+ and CD^+) that come out of the reaction chamber have their energies determined by the energy analyzer and their identity established by the analyzing mass spectrometer. The ions are then detected by a sensitive detector such as an electron multiplier. An ion-molecule reaction is used here to illustrate this technique since ions can be accelerated, decelerated, and focused. Consequently, they are easier to work with than projectiles without a charge. Similar experiments, however, can be and are being carried out for reactions where both target and projectile are neutral.

When ions are produced by electron bombardment, they are frequently electronically excited; that is, their internal electrons are displaced from their most stable positions. Likewise, a similar situation may exist when an ion reacts with a molecule and produces an ionic product. This product may be electronically excited, or its nuclei may be vibrating more violently than normal (vibrational excitation), or the product may be rotating more rapidly than in its lowest rotational energy state (rotational excitation). Quantum mechanics tells us that these states of excitation are characterized by discrete energies called energy levels. In general, the differences between electronic energy levels are larger than the differences between vibrational energy levels, which in turn are larger than the rotational energy level spacings. In a chemical reaction ideally one would like to know the kinetic, electronic, vibrational, and rotational energies of all the species involved in the reaction. This has been accomplished in only a few favorable cases such as the reactions of deuterium atoms with diatomic halogen molecules in which the various states can be determined by the light emitted during the course of reaction.

Figure 1. In the beam techniques for studying chemical changes, ions are produced in the input mass spectrometer, focused into the reaction chamber, and, after coming out, analyzed by various instruments.



A technique was recently developed for determining how many and what electronic states are present in a projectile ion beam produced by electron bombardment. The ion beam is passed through a chamber containing a suitable gas, the pressure of which can be varied in a quantitative manner. By measuring the diminution in intensity of the ion beam as a function of gas pressure, one can determine if the ions are in a single electronically excited state; if there is more than one electronic state, the fractions of various states present can be evaluated. By studying these fractional abundances as a function of the electron bombarding energy one can determine which electronic states are present. If an ion in an electronically excited state makes a sufficient number of collisions with other gas molecules, it loses its excitation energy and goes into its lowest (ground) state. Using this technique, scientists studied a number of ion-molecule reactions with the projectile ions in their ground electronic state; and by comparing the reactions produced by a projectile beam of ions in mixed electronic states, the role of both the ground electronic state and the excited states could be determined. In the near future one can expect application of these techniques to the identification of states of the product ions.

Another more elegant method of state selection that has been used is photoionization. In this technique one irradiates a molecule such as H_2 with a beam of light with a very narrow energy spread but of sufficient energy so that ionization of the molecule occurs. The molecule then can be put into not only a desired vibrational but also into a selected rotational state. This type of refined state selection permits one to investigate the roles that vibrational and rotational energy play in chemical reactions.

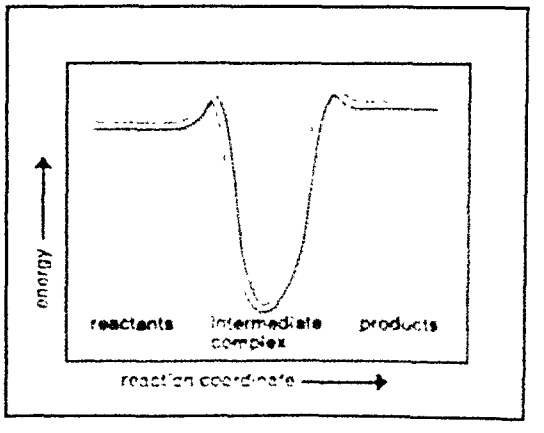
A fascinating development is the observation that beam techniques can readily produce rather large ion clusters that are of sufficient stability so that their properties and reactions can be studied in the gas phase. Several studies were reported on ion clusters as $H^+(H_2O)_n$, $NH_4^+(NH_3)_n$, and others. A number of solvated (containing solvent and solute) clusters of both positive and negative ions were reported. In the case of ammonia clusters as many as 20 ammonia molecules were found associated with the NH_4^+ ion. These clusters are not just academic oddities. Such solvated ions will probably be found to play a significant role in pollution problems and in the nature of structured water in biological systems.

Studies of the reactions of ion clusters are just beginning; and before quantitative studies can be realized the properties of the excited states of such ions will have to be investigated. Probably the most fascinating implications of these studies is that they will permit the bridging between gas phase and solution chemistry. Chemists for a number of decades have been accustomed to assuming the existence of species such as $H^+(H_2O)_n$ in explaining the migration of ions in solutions, rates of reactions, electrical conductivity of ionic solutions, etc. By 1972 it had become possible to examine the various properties of such species on a molecular basis. This will undoubtedly prove to be a fruitful area for the study not only of aqueous solutions but also of solutions of various organic and inorganic systems.

Reactions of three-atom systems. During the past year, investigators continued to report results on the angular and energy distribution for products of relatively simple ion-molecule and neutral-neutral reactions represented by the equation $A + BC \rightarrow AB + C$. Depending on the shape of the angular distribution (the distribution in angle, relative to a specified direction, of the intensity of particles resulting from a reaction), the reaction forms a persistent complex or proceeds by some type of direct mechanism. An example of a complex formation may be a case where A and BC on collision interact with each other for a period of about 10^{-12} seconds and then dissociate into products $AB + C$. An extreme example of a direct mechanism is one in which A on moving past BC picks up B to form AB, leaving C behind without any momentum imparted to it. In such a case A may spend a relatively shorter time (less than 10^{-14} sec) in the region of BC.

Some investigators believed that the condition necessary for persistent complex formation is a potential "well" in the ABC system that is avail-

Figure 2. In a schematic of a potential well, reactants overcome a potential barrier (slight rise at left) before forming intermediate complex at lower energy. Energy barrier at right is surmounted to form final products.



able to the reactants—access is not forbidden by spin, symmetry, or other restrictions. Under such a condition persistent complex formation can be expected if the relative kinetic energy is low enough. Persistent complex formation was observed in sample reactions such as $O_2^- + D_2 \rightarrow DO_2^- + D$; and $C^- - D_2 \rightarrow CD^- + D$. As the projectile kinetic energies are increased in these reactions, a direct mechanism comes into operation.

A schematic potential well, which may represent the situation in an endothermic reaction such as $C^- + D_2 \rightarrow CD^- + D$, is shown in figure 2. In the left-hand side of the diagram, as the projectile approaches the target, it may have to overcome a small potential barrier (the slight rise); but as it gets closer to the target, the potential energy falls strongly. This represents a strong attraction between the reactants, and a complex possibly such as  is formed. The kinetic energy of the projectile has been converted in part to vibrational and rotational energy of the complex. The smaller this energy is relative to the depth of the well the longer the complex lives.

After going through a series of internal oscillations, the system surmounts the barrier on the right-hand side of the figure and the products $CD^- - D$ are formed. The line on the right representing the products is higher than the line on the left that represents the reactants because the reaction is endothermic and requires a certain amount of energy in order to be able to proceed to the final products.

It is clear that much remains to be done before a thorough understanding of these three-atom systems is realized. The role not only of kinetic energy but also of vibrational and rotational energy as driving forces in chemical reactions will have to be investigated.

Future outlook. The immediate future outlook for the area of chemical dynamics is bright except for reduced funding for basic research. With the increased availability of tunable lasers and sensitive, high-resolution optical spectroscopic systems, scientists can expect more work on state selection of reactants and the determination of the states of the reaction products. By irradiating suitable target gases with the proper frequency of light obtained from a laser, one will be able to put a target molecule into a particular desired state. The high-resolution optical spectrometers will permit the analysis of light emitted by the product; and in favorable cases, the electronic, vibrational, and rotational states, as well as the geometry of the product, will be determined. This will lead to a deeper understanding of the role of kinetic, vibrational, and rotational energies as driving forces of chemical reactions.

In the coming years, work on solvated ions in the gas phase is expected to increase our understanding of the properties of these ions and, it is hoped, bring us closer to bridging the gap between gas phase reactions and reactions in solution. The question of persistent complex formation *v.* direct mechanisms in chemical reactions will certainly receive attention from a number of research groups, and we will be getting a clearer understanding of exactly what happens in a binary collision between reactants.

—Walter S. Koski

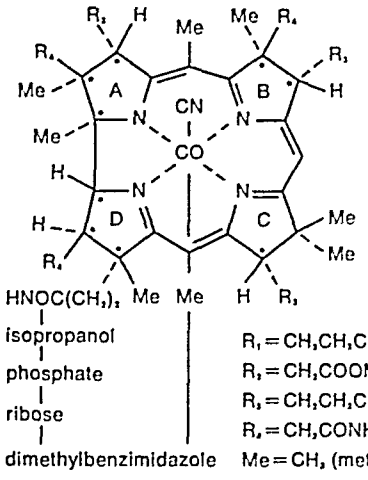
Chemical synthesis

For modern chemical technology and fundamental studies of molecular behavior, pure chemical compounds of defined constitution must be secured. While naturally occurring materials exhibit great diversity, they are often limited in supply and utility. In fact, their number and structural types pale before those of the conceivable atomic combinations of the elements. In the effort to build new chemical structures, and reproduce or modify complex natural products, chemists rely first upon the vast body of chemical theory to guide them in formulating workable synthetic routes, and then upon the array of selective and efficient reagents for performing each of the individual component transformations. The following discussion presents recent examples of the successful application of this basic procedure.

Vitamin B_{12}. A clear indicator of the capability of chemical synthesis is the complexity of structure yielding to the chemist's hand. The synthesis of vitamin B_{12} was announced at an international symposium on the chemistry of natural products held at New Delhi, India, in February 1972. Robert B. Woodward delivered the address describing the culmination of a decade of joint activity between his group at Harvard University and a team at the Swiss Federal Institute of Technology, Zürich, under the direction of Albert Eschenmoser. The focusing of talent and resources by these research teams is probably unparalleled in both quality and magnitude, and in the ingenuity required to achieve the goal.

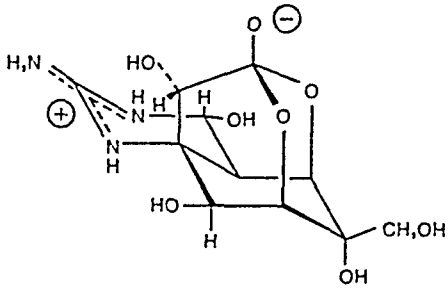
Since the discovery in 1926 that minute quantities of what was later found to be B_{12} are required by liver tissue for the prevention of pernicious anemia, the vitamin yielded to purification (1948) and structure elucidation (1956) only with the greatest difficulty. Vitamin B_{12} (1) is a structural relative of heme, the red blood pigment, and chlorophyll, the green leaf pigment, in that a metal

vitamin B_{12} (1)



$R_1 = CH_2CH_2COOMe$
$R_2 = CH_2COOMe$
$R_3 = CH_2CH_2CONH_2$
$R_4 = CH_2CONH_2$
Me = CH_3 (methyl group)

tetrodotoxin (2)



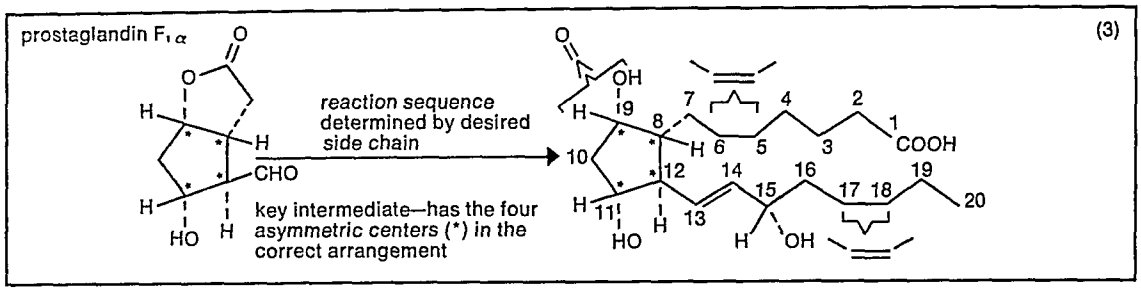
atom (in this instance, cobalt) is embedded within a nearly planar macrocyclic (ring structure of large size) framework of four nitrogen containing rings (A, B, C, and D). The singularity of vitamin B_{12}, and the challenge to synthesis, derive from the presence of nine asymmetric centers on the periphery of this large ring. At the starred sites (1) two different substituents project either above (indicated with solid lines) or below (broken lines) the plane. Only the indicated configuration of substituents at each site corresponds to the natural vitamin.

The synthesis of polypeptides (see *1972 Britannica Yearbook of Science and the Future* CHEMISTRY, *Breakthrough in Chemistry*), because of the repeating amino acid units, could be accomplished automatically with a machine programmed to link the required building blocks. By contrast, the vitamin B_{12} molecule does not have repeating units. Thus, each of the approximately 100 synthetic transformations required individual design. To complete the synthesis a large number of wholly new and ingenious reactions were devised. The broad method of attack involved the construction of two subunits, one comprised of rings A and D, the other of rings B and C. The joining of rings C and D yielded an elongated structure A-D-C-B with many of the necessary features. The joining of A and B required a folded form rather than the extended one preferred by this molecule. Introduction of a metal atom brought the nitrogen atoms into close proximity with the metal, thus bringing rings A and B close enough to be joined by a chemical bond. By following this basic pattern, the researchers synthesized cobyric acid and showed it to be identical with a sample of cobyric acid derived from vitamin B_{12}. Some years earlier K. Bernhauer and his colleagues in Stuttgart, W.Ger., had devised a method for converting cobyric acid to vitamin B_{12}. Consequently, the synthesis was complete.

Aside from the personal satisfaction gained by these scientists on having surmounted their Everest, what is the significance of their achievement? In earlier days, synthesis was considered the ultimate proof that a structure had been correctly deduced. However, X-ray diffraction analysis is now the prime method for proof of structure. Furthermore, the synthetic route is unlikely to be employed for preparing the vitamin in the future since the cost would be prohibitive. Perhaps this new synthesis will make possible the preparation of some modified form of vitamin B_{12} that will be useful in helping to elucidate the biological role played by the vitamin. Also, the stimulus of achieving their goal inspired the scientists to develop a number of highly ingenious synthetic procedures that will have broad utility in other work. Nonetheless, in retrospect, the argument can be made that the return was too small for the expenditure.

Perhaps the great artistry exemplified by this effort is the final best effort of the golden age of synthesis. As one ponders in what manner these artistic expressions will be passed on to succeeding generations, efforts are beginning to develop in the direction of syntheses designed with the aid of computers. Perhaps a computer can be programmed to duplicate and improve on the ingenuity of man in this area.

Tetrodotoxin. Another synthesis of great complexity, described at the New Delhi meeting by Yoshito Kishi and six colleagues of Nagoya University's department of agricultural chemistry, dealt with the elaboration of tetrodotoxin, the poi-



sonous principle of the Japanese puffer fish and one of the most potent nerve poisons known. The unusual assembly of rings into a space-enclosing cage-like structure (2) was derived in part from a simple benzene derivative.

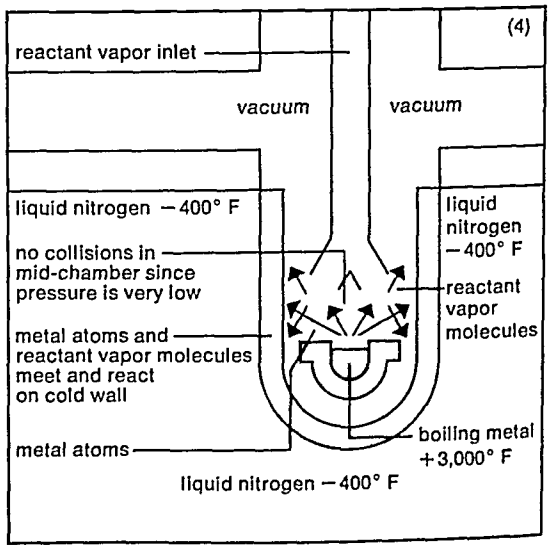
Prostaglandins. The prostaglandins, a family of physiologically active compounds, were becoming available in research quantities through the efforts of E. J. Corey at Harvard University and many pharmaceutical research teams. Interest in these substances, which occur naturally in only tiny amounts, derives mainly from their unique ability to stimulate muscle contraction at dosages of one-billionth of a gram, and the hope that this action can be safely and reliably used to induce labor and abortion. The prostaglandins' diverse influences upon biological functions have also suggested their utility in the treatment of ulcers and asthma, and as stimulants for the heart. Clinical evaluation and research into all aspects of their pharmacological action are intense.

The structures of the six primary prostaglandins are related to that shown for $PGF_{1\alpha}$ in (3). Two other F-series compounds contain *cis* double bonds at carbons 5,6 or 17,18; the three E-series structures contain a ketone function at carbon 9. All these 20 carbon fatty acids have two long carbon chains on opposite sides (indicated by broken and heavy lines at positions 8 and 12) of a small planar ring. Not only must these and the other substituents be in the proper three-dimensional relation to one another, but the absolute configuration of the whole molecule must be only that shown. That is, the fingers of the right hand are related to each other as are those of the left, but the right and left hands are certainly not the same! This subtle mirror image spatial isomerism of many natural substances presents a particular challenge to the synthetic chemist.

The structural similarity of the several naturally occurring prostaglandins suggested to Corey that, rather than design distinct syntheses of each individual family member, an efficient approach would involve construction of a single key "intermediate" having many crucial features common to all. Further simpler transformations of this intermediate would yield all the desired compounds. The success of this plan and further improvements adaptable to large-scale production were reported.

Synthesis from free atoms. A largely neglected area of chemistry was the reactions of atoms. Contrary to popular thought, until recently the chemistry of only a few of the 103 known atoms had been described: hydrogen, nitrogen, oxygen, sulfur, fluorine, chlorine, bromine, and iodine. Chemists generally did not have free atoms for study, but only atoms strongly combined with other atoms (like atoms combined are the elements, unlike atoms combined are compounds). Although in common parlance one makes such statements as water contains oxygen atoms, this statement only means that in principle water can be made from oxygen atoms and hydrogen atoms; there is not even a remote resemblance in chemical behavior between water and free oxygen atoms.

The boiling metal heated within a highly evacuated flask liberates free atoms which strike a cold surface of reactant vapor molecules. The reactant used may be one of many organic or inorganic compounds. New materials incorporating the atoms form in the solid matrix at the wall.



At high temperatures, above 3,000 F, most atoms are available in the free state. They had not been studied in this state for want of a method of mixing them with other substances at low temperature. If the high-temperature atoms are cooled in the absence of other substances, they react with one another vigorously to give the usual comparatively unreactive form of the element. Recently, a method was developed by P. S. Skell and coworkers for mixing high-temperature atoms with low-temperature substances. A schematic diagram (4) shows their basic apparatus, which was used to study the reactions of free atoms of many elements. As instances of the difference between bound and free atoms, carbon in its usual form of graphite or diamond is chemically inert, while carbon atoms react at temperatures of −300° to −400° F with almost any substance. Similarly, platinum metal is valued because it is so inert to corrosion and almost all reagents; in contrast, free platinum atoms will react with simple olefins at low temperatures to make organoplatinum compounds.

A simple principle is that the higher the boiling point of the element, the greater will be the difference in chemical properties between the free atom and the usual form. This is a useful principle because the more strongly atoms are bound together the higher will be the element's boiling point. These new reactions of atoms are broadly applicable, and there is promise that many new compounds will be synthesized by application of the technique of carrying out low-temperature reactions with high-temperature substances.

—Robert A. Davidson and Philip S. Skell

Structural chemistry

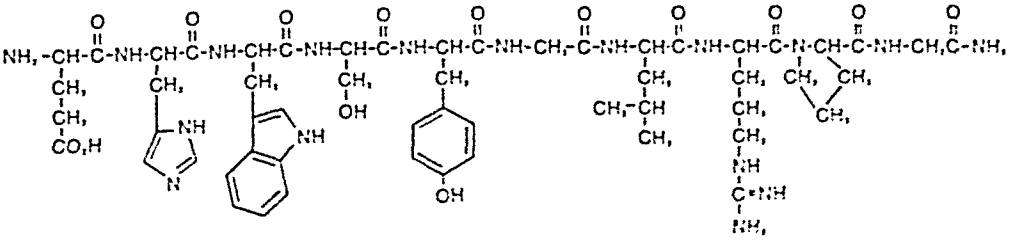
A milestone in chemical structure was reached in 1972. In February *Chemical Abstracts*, published by the American Chemical Society, recorded the two millionth unique chemical structure in its files. The substance was 5-amino-3-chloropyrazinecarboxaldehyde oxime. Since compounds are being added at the rate of 300,000 per year at the present time, the three millionth unique chemical structure should be recorded in 1975.

Structure of atoms. Structural chemistry is concerned not only with the shape and size of molecules and how the shape affects chemical and physical properties but also with the relation of each individual atom in a molecule and how the atoms are bonded together. This latter concern includes the disposition of the electrons and the shape and size of the individual nuclei. For some time it was thought that the nuclei of atoms were spherical, but in 1971 a group of scientists at Oak Ridge (Tenn.) National Laboratory led by Paul H. Stelson found that the nucleus of the uranium-238 atom was actually elongated in the shape of a football. They were able to demonstrate that the long axis of the atom is about 35% longer than the short axis.

For a long time it was thought that the rare gases were completely inert, but in recent years a number of compounds of these rare gases have been described. In 1971 Roy Gordon at Harvard University was able to show that argon forms a diatomic molecule (Ar_2); the bond energy of this molecule, however, is only $1/400$ of the hydrogen molecule (H_2). In addition to this weak binding force, "nonbonded" systems repel each other at short distances. These nonbonding intermolecular forces determine many chemical and physical properties of substances.

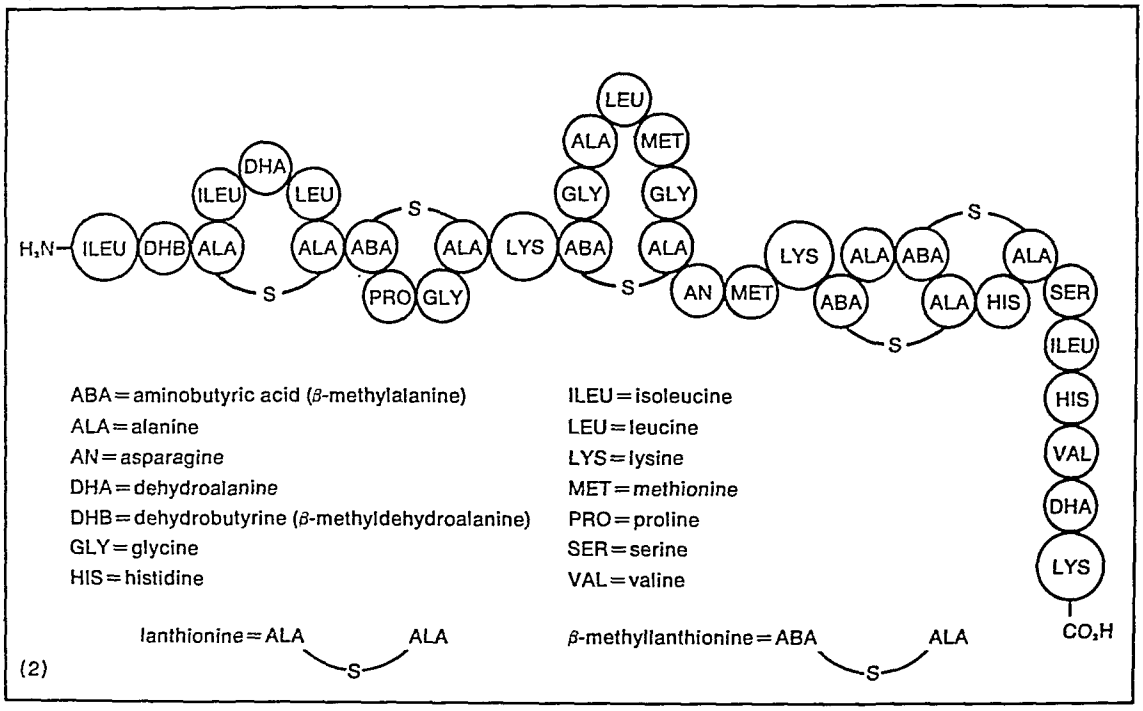
In a related study, Stephen Derenzo at the Lawrence Radiation Laboratory, Berkeley, Calif., was able to use some of these properties to build a liquid xenon radiation detector which proved to be about 10 times more accurate than the conventional gas-filled detectors in pinpointing the position of charged particles and the energy of gamma rays. The basis for this detector is that the liquid xenon has properties favorable for electron avalanche, a snowballing effect that greatly amplifies the small electrical signal produced when radiation interacts with a detector. When the avalanche

the LH-RH/FSH-RH hormone



(1)

the antibiotic nisin



(2)

occurs, a few thousand electrons freed by incident radiation knock loose millions of additional electrons. Because xenon is relatively inert (that is, its outer shell is filled with tightly bound electrons), the electrons, once freed, drift freely in the pure liquid xenon. Very fine positively charged wires criss-crossing the detection chamber pick up these drifting electrons and their electrical signals.

New tools for structural determination. The determination of the structure of a complex molecule is often difficult and time-consuming. The first step is the isolation and purification of the material. A new tool for the isolation of compounds of high molecular weight or of those that are heat-sensitive is liquid-liquid chromatography. Robert B. Woodward of Harvard University, who used liquid-liquid chromatography extensively in his recent synthesis of vitamin B_{12}, predicted that this method would become in the 1970s what gas-liquid chromatography was to chemistry in the 1960s. (In chromatography a flow of solvent or gas causes the components of a mixture to migrate differentially from a narrow starting point.)

If a material can be obtained in a crystalline form, X-ray crystallography has often been the method of choice to determine its structure. If, however, the material can not be crystallized or if the actual structure or conformation in solution or in a mixture is desired, such a technique is not applicable. For example, it has been widely assumed that enzyme structures are the same in crystals and in solution. However, using a spectral chemical probe with the enzyme carboxypeptidase A, Harvard Medical School chemists Jack T. Johansen and Bert L. Vallee were able to show that a derivative of a tyrosine residue does not complex with the active site of the crystals but does complex with the active site in solution. (The active site of an enzyme is that portion that interacts specifically with the substrate.) Furthermore, the specific activity in the solution is 300 times that of the crystalline enzyme.

Another important problem in which X-ray diffraction is of little use is in the location of the very small hydrogen atom in a hydrogen bond, which is extremely important in the alpha helix of the protein structure (a polypeptide chain folded in a spiral similar to the threads of a screw) and base pairing in nucleic acids. Neutron diffraction can determine the position of the hydrogen atom to an accuracy much better than 0.01 Å, while X-ray diffraction can rarely determine the position of the hydrogen atom to better than 0.2 Å (1Å = 10^{-10}m). With such information one can show that in lysine hydrochloride one hydrogen atom of the α-NH_3^+ forms a very strong hydrogen bond with a neighboring carboxyl group so that the barrier of rotation is 7.0 kilogram calories (kgcal)/mole. For com-

parison, the barrier for the amino group, which does not form such a strong hydrogen bond, is only 2.9 kgcal/mole, according to Walter C. Hamilton of the Brookhaven National Laboratory, Upton, N.Y.

A useful tool for examining the shape of noncrystalline large molecules is the transmission electron microscope. Halmet Coppa and Klaus Heinemann, working at the Ames Research Laboratory of the U.S. National Aeronautics and Space Administration, recently improved the resolution of this microscope to about 1 Å from the present limits of 3 Å by use of an angular aperture system.

The molecular formula of a substance can now be determined directly by the use of a high-resolution mass spectrograph that can determine molecular weights accurately within 0.001 of any given molecular weight unit. Because of the structure and natural abundance of various isotopes, the atomic weights of elements are not even integers. For example, if the carbon isotope ^{12}C, is assigned the value 12.00000, then hydrogen, ^{1}H, is 1.00783; nitrogen, ^{14}N, is 14.00307; oxygen, ^{16}O, is 15.99491. With these values one is able to calculate a molecular formula quickly and accurately from a single determination.

Proton nuclear magnetic resonance has been used for some time to determine the structure of small organic molecules. However, with the advent of the new generation of instruments, such as the 220 and 300 MHz high-resolution spectrometers as compared to the usual 60 MHz instruments, it became possible to examine the structure of various large and complex molecules, such as proteins and synthetic polymers with molecular weights in the millions. Similarly, nuclear magnetic resonance (nmr) is capable of looking at the naturally occurring ^{13}C carbon isotope which occurs to the extent of 1.1% together with the very common ^{12}C isotope in organic compounds. By the utilization of the newer, more powerful nmr instruments, together with a Fourier analysis in a computer, very accurate information which allows structural assignment can be obtained.

Another useful new technique is electron X-ray spectroscopy, sometimes called ESCA (electron spectroscopy for chemical analysis). This was pioneered by Kai Siegbahn at the University of Uppsala in Sweden. His technique was to bombard a molecule with X rays to eject the tightly held valence electrons, the energy of which is determined by the effective charge on a particular atom and therefore its chemical environment. This method allows one to look at a large variety of chemical elements directly. For example, since there is a good correlation between the effective charge on a sulfur atom and the energy required to eject an electron from the 2p valence orbit (the orbit of third lowest energy level around a nucleus), Siegbahn was able to use this technique to show that the oxidation of sulfur in a molecule of insulin took place to give the thiosulfonate form rather than the disulfoxide form. The spectra showed two peaks for sulfur atoms rather than the single peak that would have been expected if the symmetrical disulfoxide had been produced.

Structure of inorganic compounds. In the inorganic field two new isotopes of element 105, for which the name hahnium was proposed, were synthesized with a heavy ion linear accelerator by



Courtesy, Drs. T. Baird, E. Grant, J. S. Fowler, and J. L. Hutchison

Electron micrograph shows a carbon fiber produced by propane pyrolysis over nickel. The average direction of the (0002) graphite lattice planes is parallel to the axis of the fiber, i.e., the areas where metal particles are believed to have been (the metal was presumably removed during preparative treatment with concentrated HCl). One recent theory for the formative mechanism of these fibers suggests that atomically dispersed nickel is deposited in each carbon layer, making possible the continual migration of catalytic deposition of carbon some distance away from the actual metal surface.

Albert Ghiorso at Lawrence Radiation Laboratory, Berkeley, Calif. Hahnium-262, which was produced by bombarding berkelium-249 with oxygen-18, has a half-life of about 40 seconds. Hahnium-261, which was produced by bombarding californium-250 with nitrogen-16 or berkelium-249 with oxygen-16, has a half-life of about 1.8 seconds.

Uranium carbonyls, sought unsuccessfully in the 1940s for the separation of uranium isotopes by gaseous diffusion, were successfully prepared at low temperatures by a group of chemists from the University of Florida and Florida State University when a mixture of uranium, carbon monoxide, and argon at 4° K (–269° C) was warmed and then quenched to 4° K. Uranium compounds containing up to six carbonyls (the radical CO) are formed.

Structure of new polypeptides. As the structures of more and more proteins were determined, the structures of many different materials were noted to be strikingly similar. For example, Joseph Kraut of the University of California, San Diego, found that two catalytic enzymes, which evolved independently, have identical arrangements of the peptide chains involved in the catalytic mechanism. The two molecules, chymotrypsin from vertebrates and subpilisin from bacteria, are identical at the catalytic site but have peptide chains folded differently in other parts of the two molecules. Kraut noted; "Nature has twice come up with the same solution to a specific problem in molecular engineering."

In a similar vein, Choh Hao Li of the University of California's Hormone Research Laboratory in San Francisco recently determined the structure of the human hormone, chorionic somatomammotropin (HCS), that is present in the placenta of pregnant women. This hormone bears a remarkable similarity to the human growth hormone (HGH) whose structure his group had determined earlier. The two hormones share the same bifunctional physiological action in that they both promote bodily growth and stimulate mammary development and milk secretion, as well as have similar immunological responses. Both hormones are proteins comprised of 190 amino acids, 160 of which are sequentially identical. In addition, both molecules consist of two loops, one large and one small, formed by a disulfide bridge between the cysteine residues at positions 53 and 164 and positions 180 and 188.

Chemists at Ciba-Geigy, Ltd. in Switzerland reported that the previously published structure for the adrenocorticotropic hormone (ACTH) was incorrect. ACTH, which has 39 amino acids, was reassigned a structure that was later confirmed by the synthesis of the full polypeptide molecule.

A nonsteroidal fertility-regulating compound, a hypothalamic hormone that triggers the release of lutinizing hormone and of the follicle-stimulating hormone from the neighboring pituitary gland, and hence called LH-RH/FSH-RH, was recently isolated and its structure determined (1). The structure appears to be simple enough to permit its synthesis on a commercial scale and suggests that analogs will also be available in the near future.

The peptide antibiotic nisin (2), which is active against malarial parasites, also was isolated and its structure determined. Although nisin consists of only 29 amino acids, that number includes 8 of the less common ones; the peptide also contains five cyclic units that may give the antibiotic the capacity to bind ions. Erhard Gross and John Morell of the U.S. National Institutes of Health, Bethesda, Md., speculated that the two double bonds in the molecule play a key part in nisin's biological activity.

—William J. Bailey

Communications

In charting the growth of the world's population and of the world's telephones over the past 50 years, it becomes quickly apparent that the number of telephones has grown more rapidly than the number of people. While the world's population has approximately doubled since 1921, the number of telephones has grown more than tenfold.

By Jan. 1, 1971, the number of telephones throughout the world had increased to nearly 273 million. And if, as expected, the pattern of growth established over the last decade continued during 1971, nearly 300 million phones should have been in service by the year's end. Also by 1971, 37 countries had more than 500,000 phones. Israel was the latest nation to join this group. Fifteen of the world's cities had more than one million telephones, seven of those within the U.S.

As telephone users, North Americans remained the busiest with each person in the U.S. accounting for 779 calls in 1970, and each Canadian accounting for 739. Sweden ranked third, with 674 telephone conversations for each person during the previous year. Interestingly, Iceland and the Bahamas were not far behind the leaders, with 593 and 512 calls, respectively.

This continuing growth of telephony provided a challenge to scientists and engineers in the field of telecommunications. New ways of transmitting messages had to be invented, and new techniques had to be developed for routing these messages through the complex telephone network to their destination.

Communications services. While the basic telephone was being used by more people than ever in 1971, new services and new uses for it were being added. Perhaps the most spectacular of these was the see-while-you-talk PICTUREPHONE® service, introduced in Pittsburgh during 1970 and in Chicago during 1971. This service permits PICTUREPHONE conversationalists to see and show drawings and objects to each other and, in general, represents a form of communication that is the "next best thing to being there." PICTUREPHONE service also enables the user to dial information from a computer and have it displayed graphically on the screen.

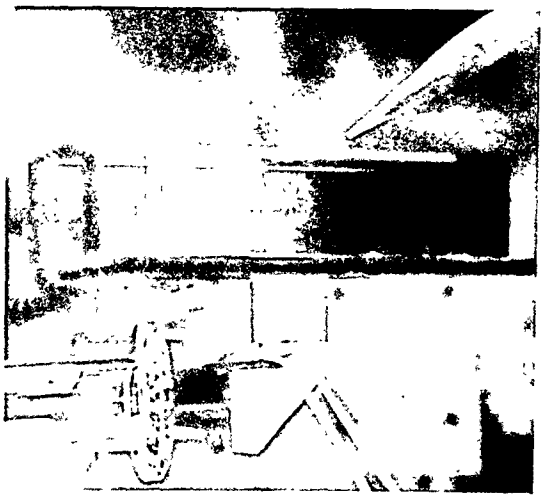
But while a telephone conversation requires about 4,000 Hertz (Hz) of bandwidth for transmission, a PICTUREPHONE signal needs 1,000,000 Hz. Much research was devoted to removing transmission redundancy for areas of the picture that do not change from frame to frame. This would allow the use of a narrower bandwidth, making transmission costs cheaper.

One of the most promising methods for doing this is conditional selective frame replenishment. The concept behind this technique is that when the picture is not changing the only information that must be transmitted to the other screen is just that —"no change." As movement occurs, changing the scene, the particular part of the picture that needs updating is defined and only that area of the picture on the other screen is changed. The amount of frequency bandwidth needed to transmit the no-change condition is quite small, while the bandwidth needed to transmit rapid motion over large areas is quite large—1,000,000 Hz as mentioned earlier. Frame replenishment attempts to average these extremes. The scheme's objective is to process a PICTUREPHONE signal so that it can be transmitted over the equivalent of one-tenth its original bandwidth when the signal is coded in a digital format.

The role of digital coding is important, and digital transmission looms large both in a review of important events in 1971 and in the future of telecommunications. Future systems to carry the world's great variety of communication signals will probably be digital—that is, they will transmit communications as on-off pulses rather than as continuously varying signals.

Digital transmission makes possible the use of another important telecommunication service, digital data. Although digital data transmission service is not new, having been developed in the 1950s, important new advances took place in 1971 that were expected to speed and enlarge its applications. The principal use of digital data is to permit machines—computers, teletypewriters, and

Courtesy, Bell Laboratories



Tiny starlike particle at the center of the photograph is being held aloft by light. An invisible laser beam passing through a lens at the end of the glass tube is bent by the triangular prism to focus on the transparent glass particle from below

telemetering equipment—to communicate with each other. The most efficient means for handling their language—on-off digital signals—is a digital transmission system. The new development achieved during 1971 that would eventually link machines in most cities of the U.S. was a technological breakthrough known as data-undervoice (or DUV). What made DUV so significant and its potential impact so far-reaching was that it could be used on the existing microwave radio relay network, a transmission facility that reaches almost every corner of the U.S. This network in 1972 relayed nearly all television programming and about two-thirds of the long-distance telephone conversations in the U.S. The DUV system, developed at Bell Laboratories, "piggy-backs" digital data signals over the microwave network in frequency bands currently transmitted by the system but below those used for its voice traffic. A field trial of the new DUV system was scheduled for 1972.

DUV's new capability was built around terminal equipment that processes a 1.5 million-bit-per-second (megabit) digital signal so that it can be transmitted over one working channel in the microwave system. In a radio system route with 16 channels, for example, it would be possible to expand digital data service, in steps of 1.5 megabits, from a capacity of 1 channel to 16 1.5-megabit channels, depending on demand for the service.

When transmitting digital data, the error rate of the system is vital. If transmission facilities that carry data distort the signals, the accuracy of the communication will be degraded. The DUV system

was expected to achieve a very low error rate. Even if the radio channel carrying the signal should fade severely enough to trigger the system to switch to a protective, back-up channel, the error rate of the digital signal at the time of the switch is expected to be significantly better than one on-off pulse for every 10 million transmitted. When such fading is not a factor, the performance of DUV is expected to make the error rate practically zero.

Another new communications service that was shown to be practical and came a step closer to realization during 1971 was a high-capacity mobile telecommunications system proposed to the U.S. Federal Communications Commission (FCC) by the American Telephone and Telegraph Company (AT & T) in December 1971. The proposed system represented a radical departure from previous mobile radio telephone concepts. By using a honeycomb pattern of small service areas and reusing a limited number of radio frequencies many times, the new system was designed to make it possible to offer mobile telephone service to many more users, and at the same time offer improvements in cost and quality of service.

Communications devices. The laser, a device capable of emitting coherent light, seemed likely to be the cornerstone of future high-capacity systems to transmit communications. Optical transmission techniques were being studied by researchers to develop high-capacity systems in which telephone conversations, television, digital data, and other signals would be transmitted by means of visible and infrared light. Lasers were expected to provide potent light sources for these systems.

One of the most unusual discoveries during 1971 was made by research scientists who used radiation pressure from a beam of laser light to raise small transparent glass spheres off a glass surface. The researchers found they were able to lift the spheres and hold them aloft for hours in a stable position, a phenomenon never before observed.

In the experiments, a laser beam was focused upward on a tiny glass sphere about 20 microns (about 0.001 in.) in diameter. The researchers found that radiation pressure from the light not only counteracted gravity and raised the particle, but also trapped the glass sphere and prevented it from slipping out of the beam. In the experiment, successfully conducted both in air and in a partial vacuum, the scientists generated a stable optical trap for holding particles, which they termed an "optical bottle."

Their results demonstrated that light photons have momentum as well as energy. Thus, when a laser is focused on a small transparent particle, the force exerted by its light, though extremely small, is sufficient to lift the sphere off the surface and suspend it.

The experiment was not as simple a procedure as it seemed. The sphere was launched by lifting it off a transparent glass plate with the light beam. Initially, however, the radiation pressure was not sufficient to overcome the molecular attraction between the sphere and the glass plate. This attraction, known as Van der Waals force, is about 10,000 times the force of gravity for a 20-micron sphere. For this experiment, the Van der Waals attraction was broken acoustically by vibrating a ceramic cylinder attached to the plate.

When the attraction was broken, the sphere rose in the light beam and came to rest where the upward pressure caused by the laser was balanced by the earth's gravity. In this position, it was held aloft as long as the light was focused on it. By changing the position of the focus, the researchers caused the trapped sphere to move up and down or sideways very precisely.

In the experiment, the new phenomenon of the trapping forces created by the light was also studied by using a second laser focused on the trapped particle from the side. As the power of the second laser was increased, the particle was displaced within the first laser beam until it was finally driven out and fell.

The experiments may provide research scientists with simple, precise methods for manipulating small particles without mechanical support. This capability could be useful in communications research for measuring scattering loss caused by particles in the atmosphere or in other transmission media. These measurements were expected to help communications researchers develop optical transmission systems for the future.

During 1971, the study of lasers for their communications potential demonstrated some new and unanticipated noncommunications applications for these devices. The studies showed that rapid, precise, on-the-spot identification of pollutant gases in the air might be made possible by using a laser-light technique devised at Bell Laboratories. The equipment used for the tests included a fixed-frequency pump laser (in the present case a carbon monoxide laser), a powerful electromagnet used to "tune" the laser beam to a desired light frequency (by changing its magnetic field), and a rotating shutter to interrupt the beam at regular intervals to cause a pulsing in the light emitted.

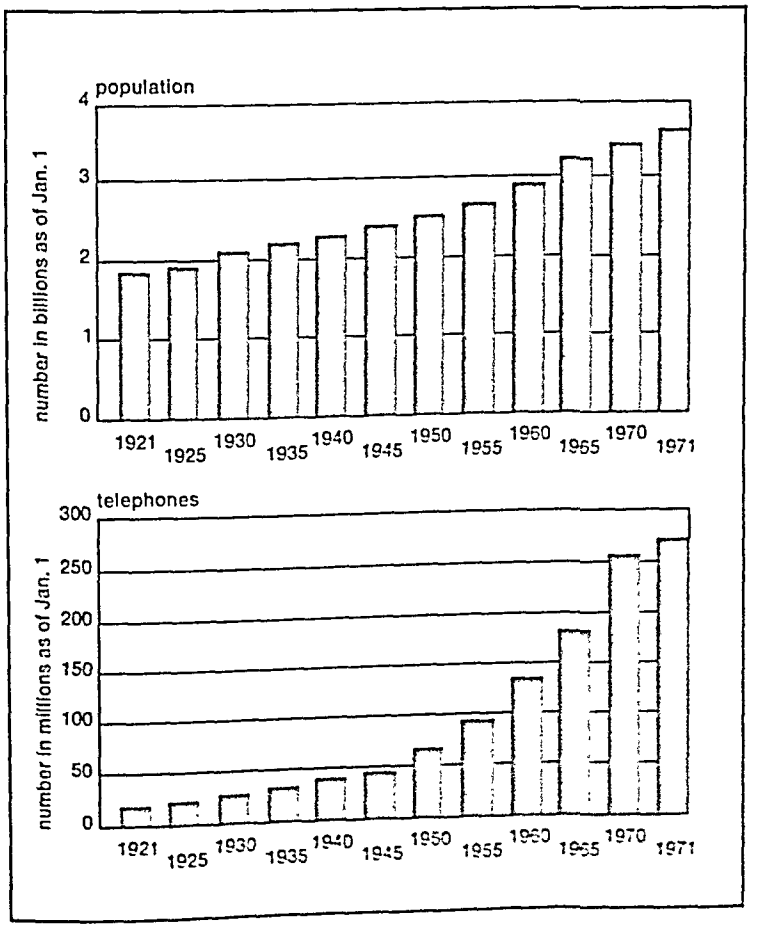
The beam of laser light was directed into an optoacoustic absorption cell containing the air sample suspected of being polluted. The cell contained a sensitive microphone with a cylindrical diaphragm that converted changes in air pressure into electrical energy. In the air samples, each type

of polluting gas can be identified by the specific frequency of light that it absorbs from the laser light (its infrared absorption spectrum). When the gas absorbs the light energy, it turns it into heat. The heat in turn causes the gas pressure to increase, and it is this increase in pressure that is detected by the sensitive microphone referred to above. A common pollutant, nitric oxide, absorbs infrared light at several wavelengths in the region of 5 to 6 microns.

Infrared absorption measurements are helpful for pollution studies because almost all known pollutants have their fundamental absorption bands in the infrared (nonvisible) portion of the spectrum from about 2–15μ. While many gases may be present in an air sample, each separate gas has its own absorption characteristics, and it is possible to find at least one absorption line for a pollutant that is not overlapped by absorption lines from other gases. One problem has been to distinguish between a pollutant and other overlapping gases. Another difficulty has been that pollutant concentrations are as small as one part per million—too small to be measured directly. The new laser technique solves both problems.

International communications. Although international telephone traffic was much smaller than that within nations, international calling was growing in the early 1970s at twice the rate of domestic calls. The international telephone calling rate from the U.S. to other countries continued to grow. In 1969 Americans originated about 20 million international calls and in 1970 about 26 million. Between 1960 and 1970 there was a sevenfold increase.

In 1971 the Intelsat 4 series of satellites was inaugurated with the launch of the first one for the Communications Satellite Corporation in January. A second member of this family was launched in December, followed by the third in January 1972 and the fourth in June. These satellites were designed to provide much-needed relief for overworked channels spanning both the Atlantic and Pacific oceans. Each Intelsat 4 could handle more



Growth in the world's population and number of telephones is compared. The number of telephones jumped sharply after 1955 in contrast to the gradual upward curve of population

than 6,000 telephone conversations, and its functioning could be modified by commands from the ground as new needs arose.

The Soviet Union also added to its satellite communication system during 1971 with a launch of another in the series of Molniya satellites in July. The satellite system in the U.S.S.R. is used for television and telephony.

In the field of submarine cables, considerable activity took place, although none of the systems terminated in the U.S. Ten cable systems were installed during 1971, ranging in length from 64 naut mi (across the English Channel from Great Britain to Belgium) to 825 naut mi (from Canada to Bermuda). They varied in capacity from as few as 60 channels (Okinawa to Taiwan) to as many as 1,840 (Spain to the Canary Islands).

Future outlook. A far-reaching and comprehensive review of the telecommunications field was contained in a report submitted by the National Academy of Engineering (NAE) to the U.S. Department of Housing and Urban Development in June 1971. This report, which summarized the thoughts of many telecommunications planners, discussed four basic future networks: (1) the telephone network for transmitting pictures, voice, and written material between two points; (2) a network, based on existing cable television systems, which can distribute information from central facilities to offices and homes, with a capacity of as many as 30 television channels and a limited call-back capacity for polling or making requests; (3) a broadband communications network carrying up to 30 television channels in both directions that would interconnect major public institutions and large commercial enterprises; (4) a multipurpose city sensing network to collect data on such items as weather, pollution, and traffic.

The NAE report reached the following conclusion: "Many of the cities' problems are caused by high-density living conditions in an era of increasingly rapid change. Communications technology, imaginatively applied, could offset the trend in which the vast majority of Americans today, and more in the future, live on a small percentage of the available land.

"We suggest an exploratory program to examine how broadband communications technology could be applied to business, government, education, health care, and entertainment to stimulate the development of existing small communities, or new communities, in rural areas. As a result, people would have a viable option of settling in either urban or rural America."

—Irwin Welber

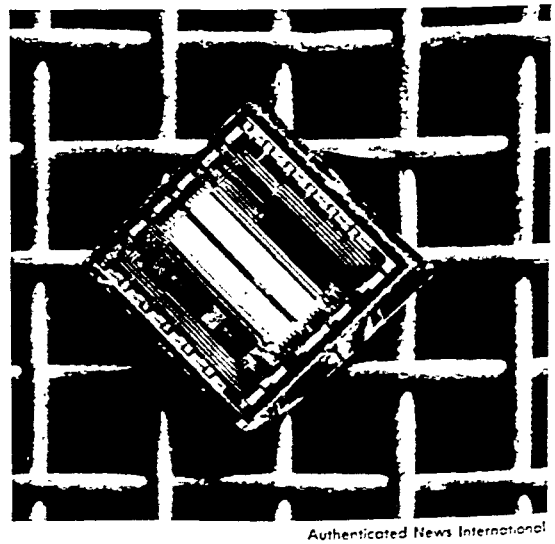
See also Year in Review: ASTRONAUTICS AND SPACE EXPLORATION, *Earth Satellites.*

Computers

When viewed from the outside, the computer field in 1972 still appeared to be vigorous and dominated by a "pioneering" psychology—there were so many new applications, so much new technology, and so many pressing national problems requiring intelligent computer support. From the inside, the field seemed less lusty, more deliberate in its choice of problems, more conservative in its methods, and more perfectionist in its certification of software and hardware products. As organizations have become more dependent on computers, they have become more cost-conscious. Competition for the customer's dollar has increased. Overall, there were enormous economic forces on the computer industry to stabilize, to slow its headlong development, to increase its quality control, and to become more conservative in its methods. But there were also enormous technological forces that mitigated against stability and control. The computer field had not begun to use up its reserves of discoveries in physics and electronics, which spawn new components, new design, and new equipment.

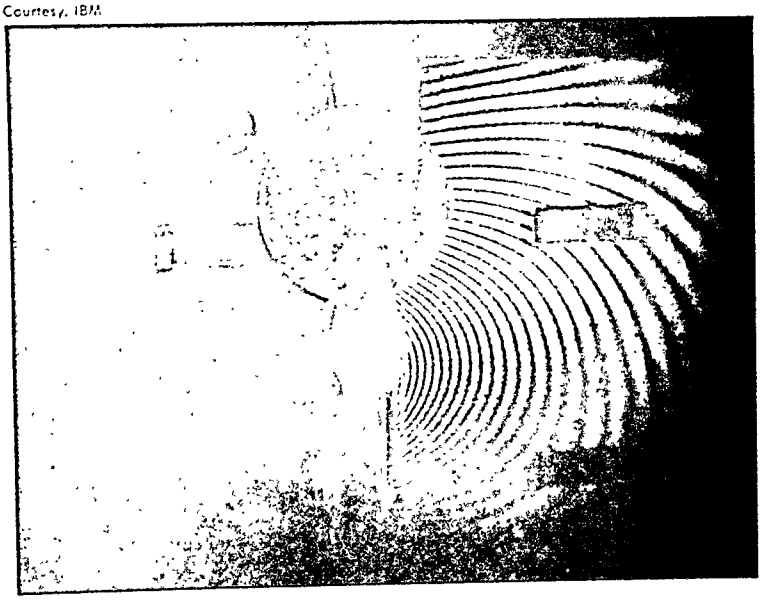
World computer growth. Estimates in 1972 placed the number of installed computers in the United States at about 80,000. However, most of the newly installed computers were in the small or mini category (rental about $1,500 a month or less). The Japanese had about 8,000 computers installed and were engaged in a national effort to computerize their society. It was estimated that they had

Experimental electronic chip, shown here on a common window screen, can store 960 bits of computer information. Microscopic circuits on the chip—called charge-coupled devices—store the information by means of minuscule electric charges.



Authenticated News International

Courtesy, IBM



Double-exposure of a defective card reader part pinpoints areas of stress that caused the part to fail. By using this new technique, scientists can analyze such failures in as little as two hours, a task that previously took as long as two weeks.

earmarked $1 billion for revamping primary and junior-high-school education, automated vehicle control, pollution alarm systems, and automated service industries like supermarkets and banking. The government allocated $24 million to subsidize the Japanese computer industry, and from 1972 to 1975 promised computer manufacturers about $110 million to support their research and development programs. Smaller amounts were set aside for the support of software development.

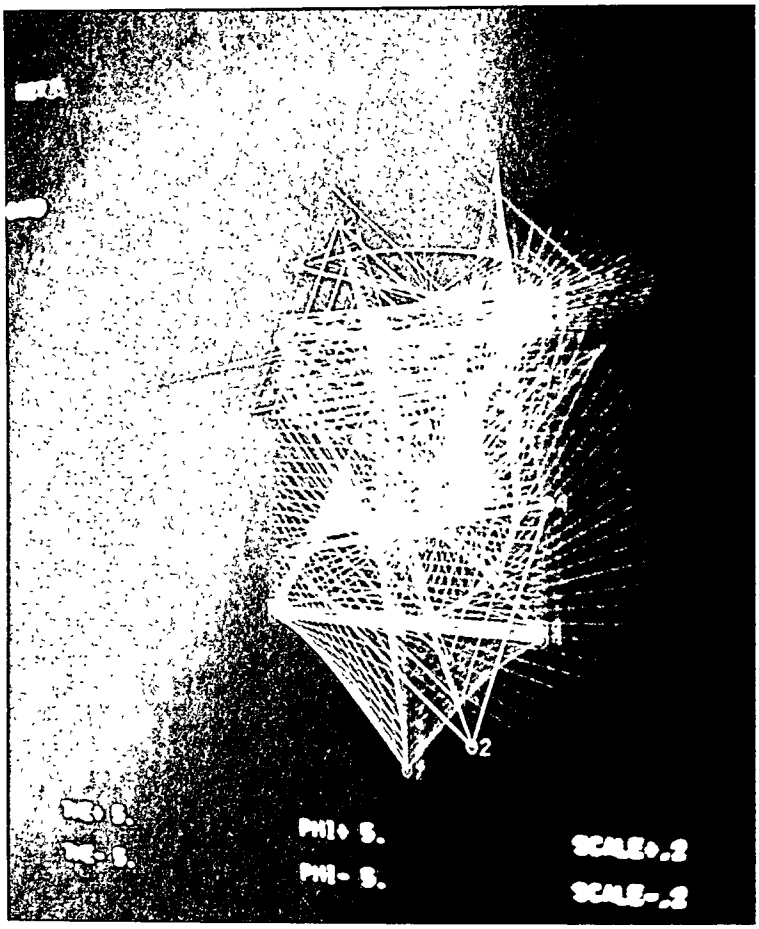
In France there were about 6,500 computers, and, through joint efforts with West German and Dutch firms, the French continued their determined drive to weaken the domination by IBM of computing in Europe. West Germany, which in 1972 had about 8,000 installations, was hoping to reduce IBM's share of the government computing business from 80% to 60%. In Great Britain the government was asked to provide $120 million a year for the support of its computer industry.

The decision of RCA in September to discontinue its computer manufacture and sales was the major business story of the year in the U.S. RCA sustained a $250 million tax loss and laid off 11,000 people. Control Data Corp. took over the support of leased RCA installations. In other business developments IBM delivered more than 10,000 of its System 3 line of small business computers, and the stability of its new System 370 line in its first year already exceeded that of the comparable six-year-old 360 models, even though the 370 had about four times as many components. Digital Equipment Corp. delivered about 13,000 of its diverse minicomputers and continued to be the leading supplier of machines of that size. Overall, in the U.S., the economic slowdown continued to affect the industry: for example, the number of installations in southern California dropped 10% during the year.

Computer technology. Very large computer memories were being supplied to government and industry in 1972. Precision Instrument Co. delivered to the U.S. National Aeronautics and Space Administration a memory consisting of one trillion bits, and a three trillion-bit memory was promised for late 1972. (A bit is the basic information symbol in the binary notation system used by digital computers and is represented by either a closed or open circuit.) In the present decade the cost per bit is expected to fall from 0.01 to 0.00001 cents. However, in 1972 the industry was still operating at the expensive end of the spectrum. Thus, a commercial holographic (laser) memory system of 12 million-bit capacity was being delivered at a cost of 0.01 cents per bit. Commercial magnetic spot (or domain) memories were also available at a cost of about five cents per bit, although a slower and smaller version cost about one cent per bit.

By 1972 the age of large-scale integrated (LSI) circuits had arrived. MOS (metal oxide semiconductor) integrated circuits accounted for about 25% of the computer circuit market. Some of this circuitry allowed minicomputers to achieve addition times of 100 nanoseconds (1 nanosecond = 0.000000001 sec). The first "computer on a chip" was announced by Intel Corp. Such a chip, made of silicon and measuring 1/4 × 3/4 in., contained a 4-bit adder, 48-bit program counter and stack, an address incrementer, an 8-bit instruction register and decoder, control logic, and a repertoire of 45 instructions. A computer developed by Intel con-

Harry Seawell



A graphic design as at the left can be presented and manipulated on a terminal hooked up to a specially programmed computer. The terminal displays mathematical functions and circuit designs. The image can be rotated by pointing a light pen at the area on the terminal labeled "phi"; size changes can be accomplished by pointing the pen at the area labeled "scale."

tained four such chips, a control memory, a 320-bit memory, and a 10-bit shift register.

Optical character recognition (OCR) machines by 1972 were considered standard commercial items. However, their inclusion in general computer operations had still not been attained. A system being designed for the blind used OCR for putting English text into a computer, utilizing a dictionary to map the words into phonemes, passing these to a speech synthesizer, and then expressing the text in audio form. The system was scheduled to be tested on blind students at the University of Connecticut late in 1972.

Supercomputers were in operation during the year. Goodyear's STARAN IV, under optimal conditions, processed up to 500 million instructions per second, though the average performance rate was more like 16 million instructions per second. The STAR computer of Control Data was somewhat slower but still could process about 15 million instructions per second on data streams.

The network of the Advanced Research Projects Agency (ARPA) of the U.S. Department of Defense in 1972 connected 23 centers and was functioning for a growing population of users. The connected computers included PDP-10, PDP-11, Illiac IV, B5500, IBM 360/91. Each node of the network contained a modified Honeywell DDP 516 computer (IMP), which processed (and forwarded) messages. The connecting links were leased telephone lines operating at 50,000 bits per second. The network was equipped to handle both long and short messages as sequences of 1,000-bit packets which are independently propagated. Routing and reformatting of forwarded messages was routinely handled in the IMPs at the nodes.

The network was used by researchers who wished to have access to special programs and/or large data bases at remote sites. One installation used a remote computer to build and test software for a similar computer that it would later take delivery on. The network had a number of one-of-a-kind computer resources that all subscribers might use, such as special very fast computers, very large memories, and specialized software systems.

Other commercial networks existed, including

the extensive CYBERNET of Control Data Corp. and the INFONET of Computer Sciences Corp., but none was as well organized and as flexible a switching network as ARPA. The U.S. National Science Foundation continued to support various university networks aimed at supplying computing power from central machines to smaller ones at high schools and small colleges. A good example of such a network was one operated by the University of California.

There seemed little doubt that network configurations of computers and terminals would be the dominant mode of future computing. Thus, there was enormous activity in the design and manufacture of terminals and minicomputers that could be connected to networks. Their prices ranged from $800 for the teletype up to $20,000 for a graphics terminal. Their variety was bewildering. Some produced hard copy, and some character graphics only; others provided line-drawing capability.

Applications. There seemed to be no slackening in the application of computers to new tasks. At the same time, though it appeared less evident to the casual onlooker, enormous improvement was continually taking place in those applications.

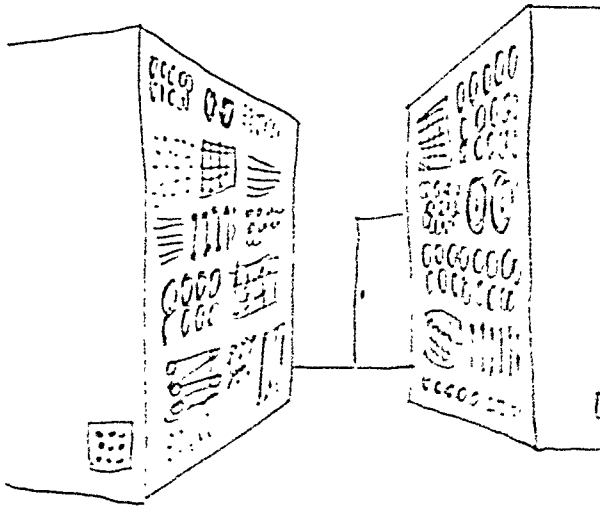
The postal services were prime candidates for computerization. Tests were under way in the Cincinnati, O., post office to sort mail under computer control. A host of problems remained to be solved, and in their solution the postal systems would almost certainly be radically altered. Thus far, the emphasis was on the distribution of mail. However, the sending of mail by optical or electronic means was sure to be actively tried in the next few years.

One of the most successful computer systems was NASDQ, used by stockbrokers. In 1972 it processed about one million calls per day for stock quotations. Few doubted that the automatic stock exchange was near to reality. Many newspapers of medium circulation installed and were using computer-controlled typesetting. Scores of police departments used computer systems for an increasingly sophisticated attack on crime based on the premise that information existing in files can be correlated by computers to narrow the choices that make crime-solving difficult. (*See* Feature Article: CRIME FIGHTERS IN THE LABORATORY.)

Volkswagen installed in its cars a set of sensors whose outputs are connected to one central socket. A computer can be attached to the car through the socket so that a program on the computer can test a number of the critical points in the car. For years many had proposed such a scheme for testing complex devices.

Modeling of complex phenomena is, of course, the area in which the computer is essential. Man is no longer driven by curiosity, but by necessity, to model his society and environment. He has become aware that many of the great forces acting on society are irreversible and that planning—long-range planning—has thus become indispensable. Weather forecasting, in real time, by computers is recognized as an important goal since it has such immediate commercial and social value. But scientists were also beginning to appreciate the need for long-range climate study. Man's handiwork increasingly affects climate, and computer simulations of climatic consequences were increasingly recognized as important contributions to national debates such as those on supersonic transport, the Alaskan pipeline, and urban pollution. An interesting computer simulation of the forces causing the deterioration of Venice is being performed in Italy. Land subsidence, pollution, and floods are taking their toll of that city. What controls will slow this deterioration of an important center of Western culture? So many variables interact, and so many models are possible that the computer is essential for such studies. Similar studies are soon expected

"You know, I'm beginning to feel guilty about the unemployment situation!"



Fort Eee Fern Agency

to be quite common in many U.S. municipalities.

No model provoked more comment than one developed at the Massachusetts Institute of Technology which sought to show that national and international growth of the scale now being sustained would bring irreversible disaster to the world in the next century. The model is international in scope, covers a long time period, and includes a large number of important variables. Its simulation results had a mixed reception. Many outstanding economists publicly derided the approach, the data used, and the conclusions reached. Such has been the fate of most such studies, which have attempted to extrapolate short-term present behavior into the future. It should be noted that simulations can be improved through practice, as witness the enormously improved competence of the election results simulations.

The computer is approaching a combination of speed, memory, size, and cost that allows it to be used in increasingly important control applications. Serious research work was under way to use a computer to signal an undamaged part of a brain to control the performance of motor functions which a damaged part can no longer do. A brain-damaged monkey with one paralyzed arm was taught to flip a switch on a computer which would then transmit signals to its brain to work the paralyzed arm so that it might feed itself.

By putting a scanning video camera and a computer into a car, researchers at Stanford (Calif.) University could study robot-controlled driving. Robots were solving some simple problems, but mostly they worked on the blindly mechanical level indicated by their name. (*See* Feature Article: MECHANICAL SERVANTS FOR MANKIND.)

The future. So much happens in one year in the computer field that it is difficult to sense the future. Still, in 1972 some trends were clear. The computer is accelerating the rate at which knowledge gets distributed and the rate at which our systems for performing large tasks get altered. It seems unlikely that there will be less use in the future of computers for processing data about us and our society. Our security and dignity can only be safeguarded by appropriate legal means (legislation and the courts) and, more importantly, by an increasing understanding and appreciation of computers. These machines are not our masters. We are theirs. In the next few years one of the greatest responsibilities of our education systems is to teach our young that computers, and the tasks they perform, can be bent to serve everyone and on a one-by-one basis, and not just the large organizations whose needs and appetites dominate the uses made of computers today.

—Alan J. Perlis

Earth sciences

The most significant developments during the year were in the history of the ocean basins and in planetary geology. Results of extensive programs over the last decade were yielding a consistent model for the geologic development of planetary bodies of various sizes.

Geology and geochemistry

As part of the Apollo 15 mission, begun July 26, 1971, astronauts David R. Scott and James B. Irwin collected moon rock samples near the foot of Hadley Delta Mountain, which rises 12,000 ft above the Mare Imbrium plain. The lunar rover traveled three miles from the landing site to the edge of Hadley Rille, a sinuous fissure extending for 70 mi. The rille is probably a collapsed lava tube formed during volcanic eruptions long after the formation of Mare Imbrium. Horizontal layering of a dozen successive lava flows is visible on the sides of the rille.

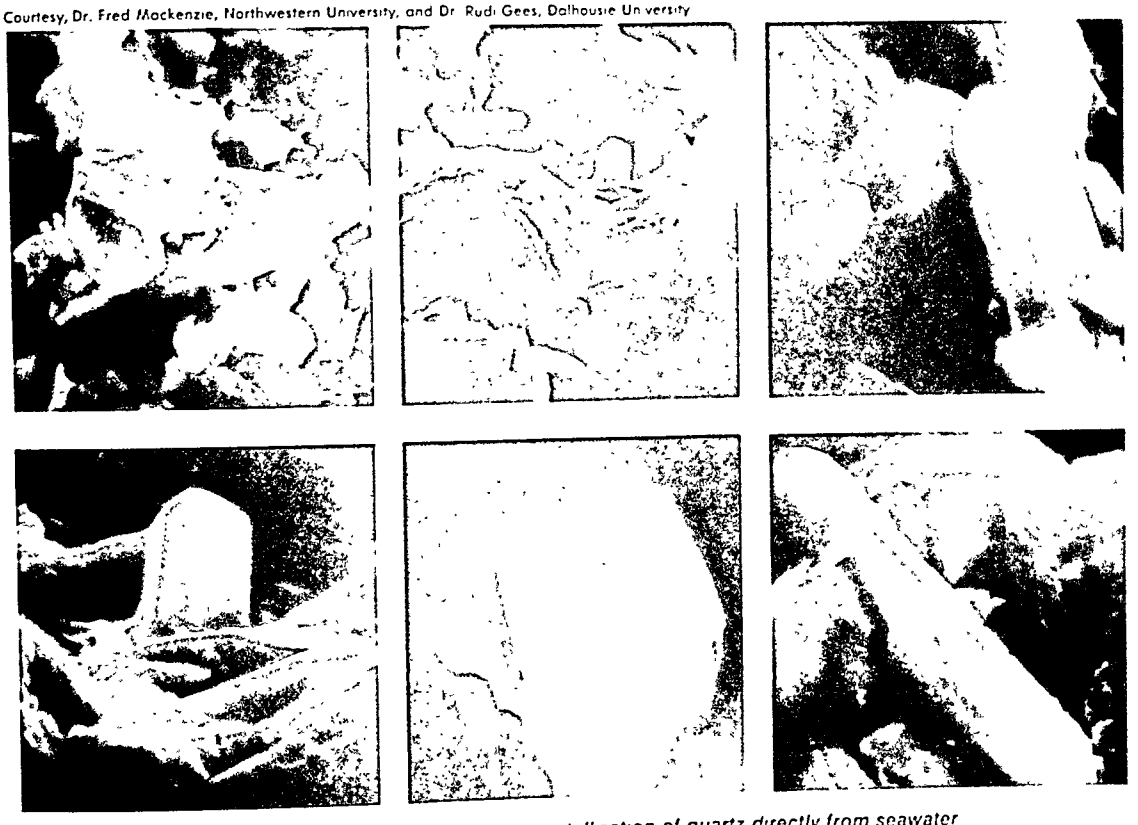
Included in the 171 lb of rock returned to earth was an important sample of anorthosite (composed of over 99% plagioclase with the remainder pyroxene and ilmenite). It is probably a piece of the lunar crust that existed before the formation of Mare Imbrium and was dated at 4,150,000,000 years, the oldest rock yet collected on the moon. The moon, along with the earth and other planets, probably formed by means of gravitational accretion about 4,600,000,000 years ago, while the Mare Imbrium formed about 4,000,000,000 years ago as a result of a meteorite impact on the moon. Lava flows filling the Mare Imbrium at Hadley Rille are 3,300,000,000 years old.

Instrumentation installed at the Apollo 12 and 14 sites sent back information that trace amounts of water vapor are escaping from the lunar interior. Previously, the moon was thought to be devoid of water. The hydrous mineral goethite ($Fe_2O_3 \cdot nH_2O$) was found in small amounts in the Apollo 14 samples from the Fra Mauro region; this was the first evidence of water incorporated in the mineral structure of any lunar sample. The total amount of water on the moon is minuscule, however. There is no atmosphere to produce precipitation and no indication that enough water ever existed on the moon to produce stream erosion.

In June 1971 the United States exchanged three grams of Apollo 11 samples for three grams of Soviet samples obtained from the Sea of Fertility by the unmanned spacecraft Luna 16. This was the first concrete result of the U.S.-Soviet agreement for cooperation in space.

Photographs from the Mariner 9 spacecraft in

Courtesy, Dr. Fred Mackenzie, Northwestern University, and Dr. Rudi Gees, Dalhousie University



A series of scanning electron micrographs depict the crystallization of quartz directly from seawater at room temperature. The first figure is the starting material, ground quartz, which exhibits poor sorting, high angularity, and no evidence of external crystal morphology. The remaining figures show the quartz surfaces after immersion in seawater and illustrate the formation of new crystals.

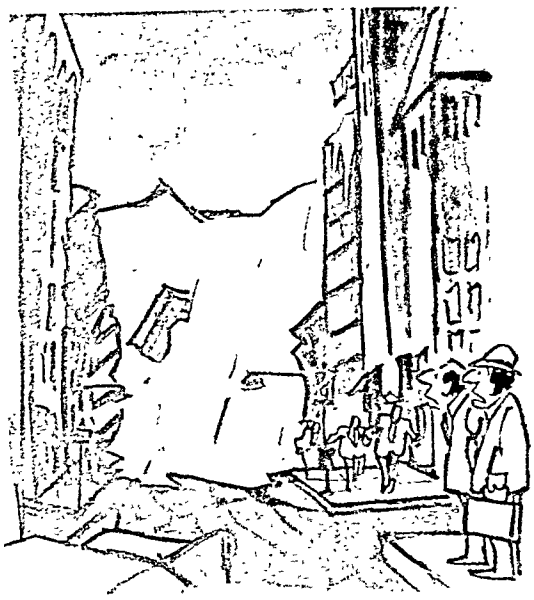
orbit around Mars revealed a probable volcanic vent at Nix Olympica and three probable volcanic craters in the Tharsis region. Mars is intermediate in geologic behavior between the moon and the earth. Its interior has had more differentiation of igneous rocks than the moon, and it has an atmosphere to produce weathering and wind erosion, phenomena present on the earth but absent on the moon. Impact craters are conspicuous on Mars, because erosion and mountain-building processes have not obliterated early craters, as had happened on the earth.

Radar measurements from the earth were beginning to reveal the topography of Venus, which is invisible to direct observation because of the dense cloud cover of that planet. One mountainous region about 200 mi across averages about 2 mi above the general level of Venus. (*See* Year in Review: ASTRONAUTICS AND SPACE EXPLORATION; ASTRONOMY.)

Marine geology. The vessel "Glomar Challenger" completed legs 17, 18, 19, and 20 of the National Science Foundation's Deep Sea Drilling Project, with a total of 37 new holes drilled into the northern Pacific. In leg 20, two drilling records were set at a site 800 mi SE of Tokyo: the "Glomar Challenger's" bit descended through the deepest water yet tested in the drilling project (20,321 ft) and then drilled the greatest rock penetration in the project (1,237 ft). The bottom hole samples were Jurassic rocks over 135 million years old, the oldest yet obtained from the Pacific floor. The findings of the entire project caused a complete rethinking of theories concerning the structure and behavior of rocks beneath the ocean, confirmed continental drift, and revolutionized prospects for long-range mineral exploration.

During the past 125 million years the northern Pacific floor has moved northwestward more than 2,000 mi. Parts of the Pacific that were once under the Equator are now just south of the Aleutian Islands. This motion has not been at a uniform speed, but it came as a total surprise that 70 million to 55 million years ago the motion reversed, so that the Pacific crustal plate moved southward for a time before resuming its northwestward drift. This

Sidney Harris



"They did it again—not a word in the weather report about an ice age."

was the first definite evidence of a complete reversal in motion of a tectonic plate. The reversal might be related to the breaking apart of Australia and Antarctica, which occurred about 65 million years ago. At the present time, the Pacific crust is moving against and downsinking beneath Asia, drifting at the rate of 4 in. per year over the past 10 million years.

The 1970s were designated the International Decade of Ocean Exploration by the UN General Assembly. As part of this effort, the U.S. Geological Survey undertook a six-month cruise to study the sediments and mineral resources beneath the Gulf of Mexico, the Caribbean, and the sea floor adjacent to Liberia, in Africa. The first leg was off the coast of Mexico. Jurassic salt beds seem to underlie the entire Gulf of Mexico and appear to have been formed by a combination of evaporation and restricted circulation as the Gulf was opening up during the beginning of continental drift. Seismic profiles revealed that the sediments along the western margin of the Gulf are sliding toward the deeper portion of the basin, producing folds in the marginal sediments.

The theory of sea-floor spreading implies an upwelling of the suboceanic crust at the site of the Mid-Atlantic Ridge, with a moving of the sea floor away from the ridge at a rate of one to two centimeters a year as new material is brought up. Thus, the axial zone should contain only rocks less than 10 million years old. During the year, however, scientists reported remnant blocks of older rocks in transverse fracture zones left behind as most of the sea floor spread. Ultrabasic (low in silica and high in ferromagnesian materials) igneous rock from St. Paul Rocks is 835 million years old. The crest of the Vema transverse ridge yielded samples of limestone with detrital feldspar and quartz deposited at a time when granitic continental areas were nearby; these probably represent remnant blocks of Jurassic or early Cretaceous sediments deposited as the Atlantic Basin was first spreading open some 120 million years ago.

Scientists at the Scripps Institution of Oceanography, La Jolla, Calif., reported that some of the thickest known ocean sediments in the world are in the Bay of Bengal. Some 54,000 ft of strata have been deposited there after being carried from the Himalayas to the sea by the Ganges River. (*See* Year in Review: MARINE SCIENCES.)

World geologic map. The Commission for the Geological Map of the World continued work, under the direction of the International Geological Congress, to develop a geologic map at scales of 1:10,000,000 (1 in. = 160 mi) and 1:30,000,000 (1 in. = 480 mi). The project involved geological representatives from more than 100 countries. The first parts of the finished map were printed in 1972 for presentation at the 24th International Geological Congress in Montreal in August.

Paleontology. In 1971 William J. Morris discovered remains from a duck-billed dinosaur over 100 ft long in Baja California. The duck-billed dinosaurs were very prominent in the Late Cretaceous about 75 million years ago. Their average length was about 30 ft, although specimens attaining 50 ft were recently found in Asia.

The extinction of the dinosaurs at the end of the Cretaceous has long puzzled paleontologists. Thomas R. Worsley of the University of Washington proposed a link between dinosaur extinction on the land and events in the ocean basins. During the Mesozoic Era (225 million–65 million years ago), excessive volcanism resulted in a warm, cloudy climate especially favorable to the development of large reptiles. The "Glomar Challenger" cores revealed that about 160 million years ago marine plankton that extracted carbon dioxide from the atmosphere evolved. As these flourished, an ocean-wide layer of calcareous sediment, consisting of the tests or outer coverings of the plankton, formed in the oceans, diminishing the greenhouse effect of the atmosphere through removal of carbon dioxide which was incorporated in the plankton tests. Worsley postulated that the resulting worldwide temperature decrease rendered conditions so unhealthy for dinosaurs that they became extinct. (*See* Year in Review: ARCHAEOLOGY.)

Geochemistry and geochronology. Strata with marine fossils associated with very fine-grained quartz (silica) in the form of chert or flint have been known for over a century from many parts of the world. Origin of the silica remains a mystery; such rocks are the only major sediment type that has not been seen forming today somewhere in the earth or in the sea. Geochemical experiments by Fred T. MacKenzie of Northwestern University, Evanston, Ill., and Rudi Gees of Dalhousie University, Halifax, N.S., resulted in overgrowths of silica crystals on finely ground quartz placed in natural seawater from Bermuda. This was the first time identifiable quartz had been formed directly from seawater at surface conditions without aging on amorphous precipitates.

Rubidium-strontium and lead dating of rocks from southwestern Greenland revealed the oldest rock yet discovered on the earth: gneissic granite which crystallized 3,980,000,000 years ago. Previously the oldest known rocks, dated about 3,500,000,000 years ago, were from Minnesota and South Africa. Greenland is a fragment of the ancient continent that ruptured to form the nucleus of North America and Europe as the continents drifted apart. The Greenland sample is considerably younger than the 4,600,000,000 years postulated for the earth-moon system, and its composition shows evidence of a complex earth history of crustal differentiation prior to its formation.

The Precambrian Era, which ended 570 million years ago, comprises the first 85% of the earth's history. A group of scientists from Australia proposed a formal division of the Late Precambrian Erathem, designated the Adelaidean System and defined to range from the beginning of Late Precambrian glaciation in Australia to the beginning of the Cambrian Period (spanning a time roughly 750 million–570 million years ago). This is the first formal subdivision of the Precambrian into periods based on modern dating techniques.

—John M. Dennison

Geophysics

Geophysicists made important contributions to two national policy debates in the U.S. during the year. The Cannikin nuclear test on Amchitka in the Aleutian Islands was hotly disputed, and one of the central points of concern was the possibility that it might trigger a large and damaging earthquake. The second question concerned the ability of seismologists to detect all significant nuclear tests so that a comprehensive test ban treaty could be negotiated without the requirement for on-site inspection. A precise description of the degree of accuracy actually attainable was probed

Courtesy, Dr. D. W. Durney, Imperial College, London, and NATURE Magazine



Pressure shadows and veinlets (light) of symmetrically curved fibrous calcite growths in a pyrite concretion (black) are an example of the redistribution of minerals in nonporous sedimentary rock subjected to stress. This phenomenon was recently explained as arising from the diffusion of ions along grain boundaries

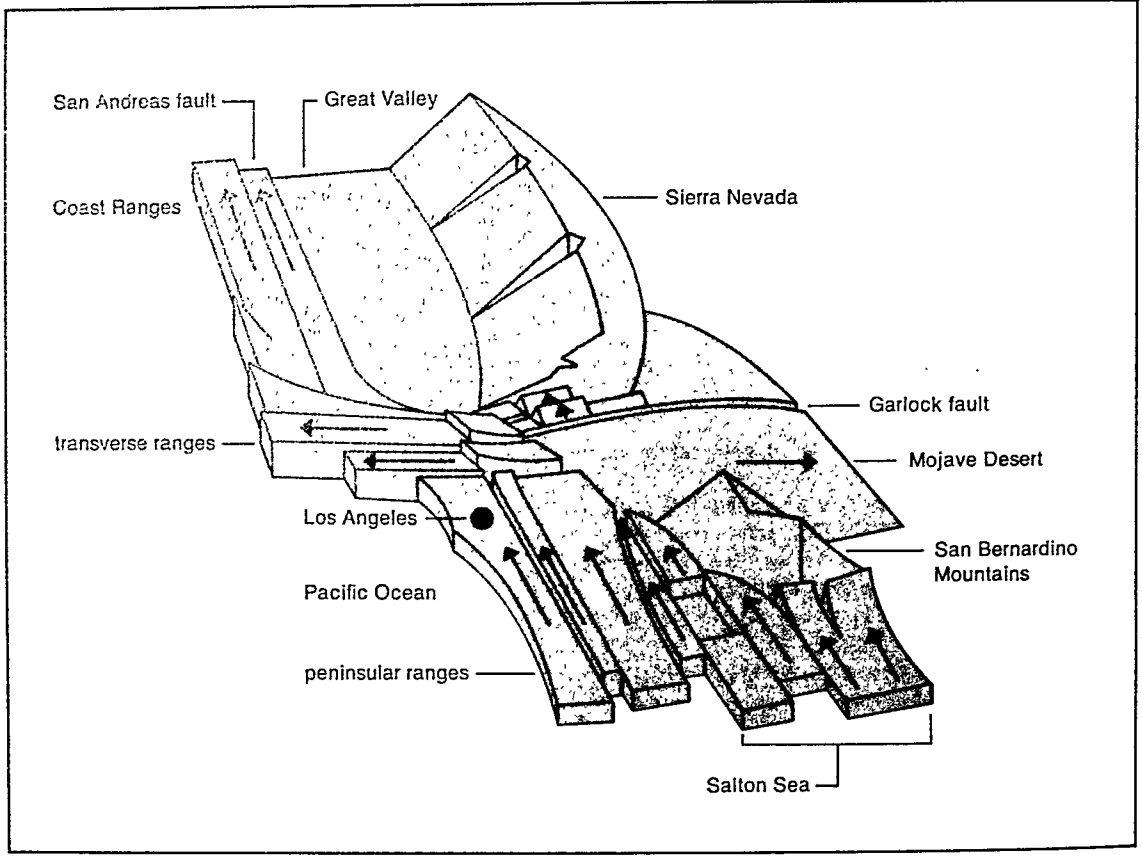
by two symposia and vigorously debated within government circles. Both of these topics were of general interest, since they test the ability of scientists to feed accurate information into the decision-making process in an atmosphere that is not always conducive to scholarly detachment.

Cannikin. Amchitka lies in an island arc structure marking a place where a giant crustal plate plunges back into the earth's mantle along a great fault, capable of producing major earthquakes. The island itself is so remote that even a large earthquake probably would not have caused any significant damage by ground shaking, but there was concern that such an earthquake might trigger a seismic sea wave, or tsunami, that could cause high waves at distant sites around the Pacific Basin.

The distribution of small earthquakes located by special networks of seismograph stations revealed that the great thrust fault in the region of Amchitka passed approximately 30 km (1km = 0.62 mi) below the point of detonation, and studies of ancient shorelines indicated that the island itself was outside the region where large deformations had taken place in past great earthquakes. These observations and the fact that no large tsunamis had been generated in this region in historic time led to the conclusion that the test was not likely to trigger a large, dangerous quake.

The Cannikin nuclear test was detonated on

Adapted from "The San Andreas Fault" by Don L. Anderson, © 1971 by SCIENTIFIC AMERICAN. All rights reserved



Movement of the earth's crust in southern California is generally from southeast to northwest along the San Andreas fault. But at the point where the moving crust encounters the deep roots of the Sierra Nevada, the blocks of crust move west, creating the transverse ranges and a bend in the fault.

Nov. 6, 1971, and the predicted seismologic effects were in agreement with the observations. The test triggered only small earthquakes in the immediate vicinity of the shot. Geophysicists were relieved that their predictions had been borne out. Had knowledge of the earthquake mechanism been more precise, however, it might have been possible to minimize some of the controversy.

Nuclear test detection. Negotiation of a comprehensive nuclear test ban treaty, under discussion since the mid-1950s, has been blocked largely because the major nuclear powers are reluctant to permit on-site inspection. The possibility of using the seismic waves generated by tests to detect treaty violations has been recognized, however, and beginning in 1959 a massive research program, sponsored by the U.S. Department of Defense, was undertaken to develop seismic means for detecting and identifying underground nuclear explosions. More than $300 million was spent on this research.

At the beginning of the program, most seismologists believed the task would be relatively easy, but this proved not to be the case. As the research progressed, it was found that complexities in the structure of the earth distorted seismic signals so that it was difficult to obtain accurate locations for some events. Furthermore, it was not always possible to tell the difference between an explosion and an earthquake. Nevertheless, a dramatic improvement was finally achieved. As the number of seismograph stations in the world increased and more data became available for study, corrections could be made for perturbations in the seismic signals caused by structural anomalies. This, in turn, led to an improved capability to detect and locate nuclear explosions and to distinguish them from earthquakes.

A series of studies initiated by Jack F. Evernden, a seismologist then employed by the Department of Defense, led to one of the most effective techniques for identifying nuclear explosions. The first seismic waves to arrive at a seismograph station pass through the deep interior of the earth,

where they travel in a mode similar to the propagation of sound waves through the air. These are called body waves. Another class of seismic waves, arriving later, travels over the surface of the earth much as water waves travel over the surface of a body of water. The size, or magnitude, of a seismic event can be estimated by measuring the amplitude of either of these classes of waves at a number of distant seismograph stations and correcting the amplitude measurements for distance and other peculiarities along the propagation path.

Through comparison of the waves from many earthquakes and explosions, it was found that explosions tend to radiate surface waves of lower amplitude than earthquakes of comparable size as determined by the amplitude of the body waves. Continued refinement of the corrections needed to make these determinations and improvements in instrumentation led to an almost perfect set of discriminators to identify nuclear events. Problems with smaller events were gradually reduced by the development of larger arrays of very sensitive instruments, which are theoretically capable of detecting all earthquakes and explosions down to approximately magnitude 4 as measured on the Richter scale.

The seismic signals from underground nuclear explosions depend not only on the size of the test but also on the medium in which the device is detonated. In hard, water-saturated rocks, almost all tests of a yield of one kiloton can be detected. In dry, alluvial rocks, nuclear tests yielding 10 kilotons or more might be fired without detection by seismic means. However, when tests are fired in alluvial rocks, they frequently produce characteristic surface fractures or craters that could be observed from satellites. The exact threshold of detection remained a matter of concern, but it was generally conceded that the seismic methods currently available would severely limit the ability of a country to conduct a secret nuclear test program.

Earthquake resistant construction. During the San Fernando, Calif., earthquake on Feb. 9, 1971, an instrument located at the Pacoima Dam measured a ground acceleration of approximately one unit of gravity (G), the highest ever recorded from an earthquake. Engineers and seismologists usually describe ground accelerations as a function of the force of the earth's gravity field. A vertical acceleration of one G would apply a force equal to the weight of an object sitting on the stable surface of the earth. For example, if a 150-lb man was standing at a point that was accelerating at one G, he would feel that his weight had doubled to 300 lb during the upward cycle. If the direction of motion reversed, he would feel as though he had zero weight and was floating through space. If the ground acceleration is greater than one G, objects can be thrown into the air. During great earthquakes rocks have apparently been thrown into the air and come to rest some distance from their original positions. From this, and from some observations of ground failure, seismologists postulated that earthquakes might produce ground accelerations of more than one G, although this had never before been recorded.

The evidence of high accelerations during the San Fernando earthquake, together with the failure of a number of modern structures, indicated that an evaluation of existing building practices was in order. Some engineers believed that the high accelerations measured on Pacoima Dam resulted from unusual local conditions that focused or amplified the seismic waves. However, preliminary results of studies undertaken to determine the nature of this amplification, if any, failed to indicate any local conditions that could account for the Pacoima measurements.

Portion of the San Andreas fault runs almost due east and west a few miles north of Frazier Park, Calif. The hilly region left of the fault line is moving upward with respect to the plain, causing definite offsets in the courses of the two largest streams in the area



This poses a difficult dilemma for engineers and seismologists. If all structures are designed to withstand forces as large as those observed at San Fernando, the cost of construction would be increased substantially. Furthermore, the high accelerations raise serious questions about the safety of some existing structures that were designed in the belief that earthquake forces would not approach one G. On the other hand, accelerations as high as one G are not likely to be experienced by most buildings, even in great earthquakes. Even though the Pacoima Dam observation may not be unique in the sense that such accelerations may be experienced in most earthquakes, the area in which they are experienced and the percentage of buildings subjected to them are likely to be quite small. Eventually, the risk that some structures will be destroyed may have to be accepted if the cost of earthquake-resistant design is to be kept at an acceptable level.

The question of acceptable risk becomes particularly acute for certain critical structures such as nuclear power plants and dams, which have a potential for causing damage far beyond the structures themselves. One possible approach is to identify in advance those regions that might be prone to very large accelerations and to avoid such sites as much as possible. Another is to pay the price of higher costs for buildings located in those areas. It was too early to project all of the implications, but clearly the San Fernando earthquake would have a considerable effect on earthquake-resistant design for many years to come.

Earthquake prediction. One of the most attractive possibilities for reducing the danger from a great earthquake is prediction of the approximate time and location in advance. A program of research in earthquake prediction was proposed in 1965 by a panel headed by Frank Press of the Massachusetts Institute of Technology, and a modest level of formal research was undertaken at that time. In response to the San Fernando earthquake and rising public concern about earthquake hazards, proposals for a greatly expanded program were introduced in Congress.

There are numerous reports of phenomena observed prior to great earthquakes, although many are undoubtedly unreliable. Soviet researchers have discovered changes in the velocity of seismic waves propagating through the epicentral zones prior to the occurrence of some large earthquakes. Changes in the ground level and magnetic field have been reported by researchers in Japan and the Soviet Union, and these may be useful. In the United States there have been a few isolated reports of phenomena that might be precursors. However, the U.S. program has concentrated on achieving a better understanding of the fundamental process in the expectation that, if precursory signals do exist, they will be discovered in this way.

One center for this research is the U.S. Geological Survey's National Center for Earthquake Research located in Menlo Park, Calif. This group has deployed dense networks of seismometers and measured strain and tilt in a region extending south from San Francisco to Parkfield, a distance of approximately 200 km. The research of this group and others clearly demonstrates that the San Andreas Fault, the most likely location of future large earthquakes, is currently moving more or less continuously over part of its length. Presumably, where the fault is continuously creeping, at least a portion of the strain is being released by a nondestructive mechanism. Where the fault is locked, particularly in the section north of San Francisco, it is believed that strain is accumulating and the potential for a great earthquake is increasing.

By determining the accurate locations of very small earthquakes (microearthquakes), 4,000 to 5,000 of which occur each year in the region being studied, it is possible to define a three-dimensional picture of the geometry of the fault zone. Further, studies of historical data suggest that no large earthquakes have occurred in California without being preceded by some microearthquake activity. Although not yet proven, the corollary is probably true. That is, if a given region or length of the fault zone does not presently have any microearthquakes at all, that portion of the fault zone is not likely to produce a great earthquake in the future.

Traditional surveying methods, supplemented by the use of an instrument called the geodolite, which employs a laser beam to measure distances between two points, have been used to track the current deformation of large blocks of the earth's crust in California. These measurements confirm the fact that the portion of California west of the San Andreas is moving northward at a rate of one to two inches per year, and an increase in the density of these measurements is revealing details of the pattern of movement and showing how the rate of movement varies from place to place. The measurements also show the pattern of other complexities of the San Andreas fault system.

New research proposals are based on a major extension of these methods. A combination of surface geologic mapping and microearthquake studies would be used to identify the currently active faults. Once identified, these faults would be repeatedly resurveyed to determine the nature of ongoing deformations. Even if the exact time

of future earthquakes cannot be predicted, the identification of currently active faults, together with an estimate of their potential for producing large earthquakes, could be of practical value.

Plumes. The island of Hawaii is being formed by volcanic activity that is bringing molten rock from a depth of at least 60 km and depositing it on the flanks of great volcanoes. This island is the easternmost and only currently active volcanic island in the Hawaiian chain. Geologists studying the other islands have determined that each has been formed by a similar process.

W. Jason Morgan, associate professor of geological and geophysical sciences at Princeton, suggested a possible mechanism to explain the origin of the islands. He believes they are the result of great vertical upwellings of material, called plumes, rising from deep within the earth in an approximately cylindrical column. According to his theory, the crust of the whole Pacific Ocean is sliding slowly over these fixed plumes at a rate of approximately two centimeters per year, thus accounting for the succession of islands.

—John H. Healy

Hydrology

The recent rapid pace of research in hydrology and related water-resources fields continued during 1971–72. One index of the pace was the large number of national, regional, and international symposia. Prominent among these were meetings on the following subjects: Man-Made Lakes (Nashville, Tenn.); Mathematical Models in Hydrology (Warsaw); Water Balance in Semi-Closed Sea Bays (Moscow); Surface and Groundwater Pollution (Moscow); Hydraulic Research and Its Impact (Paris); Hydrology of Fractured Rocks (Washington, D.C.); and Stochastic Hydraulics (Pittsburgh, Pa.).

Organizational changes. The increased rate of research was matched by changes in the associated institutional structures. In the United States, the past few years witnessed the establishment of the Water Resources Council, the National Water Commission, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Office of Water Resources Research, together with Water Resources Research institutes in each of the 50 states and Puerto Rico. These, and other federal and state agencies, spurred by the increased awareness of local, regional, and national water problems in the U.S., operated generally within the framework of a report issued by the Committee on Water Resources Research in the Office of Science and Technology. This report, "A Ten-Year Program of Federal Water Resources Research," was issued in 1966. Because of the progress and institutional changes since 1966, the program was being revised. The first step in the revision was a survey of water-research programs in the universities.

The International Hydrological Decade (IHD) in 1972 was in its eighth year. At its latest (1971) session, the IHD Coordinating Council stressed the need to complete documents and publications fulfilling its program by the time the Decade ends in 1974. These reports were prepared to guide hydrological research and education in all countries, particularly developing ones. One of the principal benefits of the IHD program to date has been the increase in the number and functions of regional groups dealing with water problems common to

Right, after a 44-mi stretch of Crow Creek in Tennessee was rechanneled for flood control, biologists who visited the area found the stream nearly lifeless and termed it an "ecological disaster." Left, an untouched portion of Crow Creek still provides a home for rainbow trout and wood ducks





Courtesy, Tennessee Game and Fish Commission

two or more countries. In addition to the Nordic Council, which had been established for several years, there was an International Commission for the Hydrology of the Rhine Basin, an international group to study the water balance of the Danube basin, and an international cooperative program to study the water balance of Baltic waters.

While moving vigorously ahead in research and regional cooperation, hydrology was given another twist in its search for identity as a clearly defined scientific discipline. Hydrology's principal international group, the International Association for Scientific Hydrology (IASH), changed its name and broadened the scope of its interests to become the International Association of Hydrological Sciences (IAHS). The new name reflected the concern of hydrologists with engineering, statistical, mathematical, economic, political, and sociological disciplines where these activities affected man's use of the available water resources.

Research efforts. The new name also responded to the increasing concern in many countries for the quality of the environment. This concern particularly focused attention on the need to maintain and improve the quality of atmospheric, surface, and underground waters. Rainfall in Europe, for example, became increasingly corrosive over broader areas between 1956 and 1966. Rain and snow with a pH of 5.5–5.0 fell on parts of the Netherlands, Belgium, eastern England, and the North Sea in 1956. (The pH scale measures acidity and alkalinity, with 7.0 representing pure water at 25° C; lower figures indicate increasing acidity.) By 1966, an area nearly as large received precipitation with a pH of 4.5–4.0—and in spots as low as pH 2.8—while the area receiving a rainfall with a pH of 5.5–5.0 grew to extend from Great Britain on the west to the western border of the Soviet Union on the east, and from southern Norway and Sweden south across West Germany almost to Switzerland. Potentially the effects of the increased pH are multiple and complex, including changing the leaching rates in soils, acidification of lakes and rivers, corrosion of structures, and modification of metabolic systems of organisms. In southern Norway, for example, salmon runs have been eliminated in some streams because the increasing acidity has prevented salmon eggs from developing. Some data indicate that the northeastern United States has been similarly affected.

Increasingly extensive compilations of data show that the pollution of rivers and lakes has continued with little abatement in recent years. Although the problem is common throughout the U.S., it is as yet critical only in selected areas. Among the difficult decisions to be made are those that differentiate between levels of pollution that are "only" undesirable and those that are definitely toxic.

In partial response to this problem, U.S. Pres. Richard M. Nixon and Canadian Prime Minister Pierre Elliott Trudeau signed a joint U.S.-Canadian agreement to clean up the Great Lakes. The treaty, called the Great Lakes Water Quality Agreement, set stringent standards for the quality of the Great Lakes waters and also established a timetable for meeting them. The treaty pinpointed five objectives: to free the waters from substances that enter as a result of human activities and from harmful sludge deposits; to free the waters from floating debris, including oil; to free the waters from undesirable colorations and odors; to free the waters from materials toxic to man or aquatic life; and to free the waters from an excess of nutrients that enter as a result of human activities and result in undesirable growths of weeds and algae.

To provide an improved comprehensive base of hydrological information for the management of the water of Lake Ontario and its basin, the U.S. and Canada launched the International Field Year for the Great Lakes (IFYGL) on March 30, 1972. This program comprised an integrated series of studies and investigations on five major components of the hydrology of Lake Ontario and its basin: the terrestrial water balance, the atmospheric water balance, the heat-energy balance, lake circulation, and the distribution of chemical constituents and life forms. Several governmental agencies and universities on both sides of the border are involved. The IFYGL was expected to accumulate masses of data, some of which would take years to analyze, synthesize, and report. The program was organized, however, to make the actual data available at the earliest possible time through two data-management centers, one in each country.

In a somewhat different category was another proposal to collect large amounts of hydrological data during the last half of 1972. The first U.S. Earth Resources Technology Satellite, ERTS-A, was designed to provide information for several hydrological and water-resources experiments. These included interpretation of ERTS spectral imagery in the preparation of hydrological maps of arid lands; the practicality of using satellites to transmit water data from surface stations to central data-processing facilities; evaluation of hydrological hazards along the Alaska Pipeline corridor; delineation of boundaries of regional wetlands; the evaluation of soil moisture in the Lake Ontario basin; changes in snow cover in the Pacific Northwest; relationships of changes in the quantity of runoff in the Potomac River; and changes in land and water distribution in the Everglades in Florida.

—Leo A. Heindl

Electronics

The epoch-making visits of U.S. Pres. Richard Nixon to the People's Republic of China and to the Soviet Union threw a spotlight on recent advances in electronics technology's oldest branch, telecommunications. China, through its government's choice, had remained isolated from most of the world for a quarter century. But with Nixon's visit it found itself the center of attention of the mass communications media of the world's technologically most advanced nations. To anticipate the demand, the Chinese government contracted with a number of Western firms for facilities and services to cover Nixon's visit.

An Intelsat 4 communications satellite went into service over the Pacific Ocean, taking up traffic that had been carried by the smaller Intelsat 3. Some 850 circuits between 15 earth stations were transferred to the new satellite. A second ground station was installed in Shanghai, supplementing one previously delivered to Peking. The second station also featured Western-made video and voice circuits, microwave terminals, and other equipment capable of handling television, telephone, and teleprinter transmissions, all of which were being expanded and were intended to remain in service for international communications following the visit. International divisions of four U.S. firms provided television coverage to viewers in America and elsewhere on a rotating basis, in accordance with special authorizations by the U.S. Federal Communications Commission (FCC).

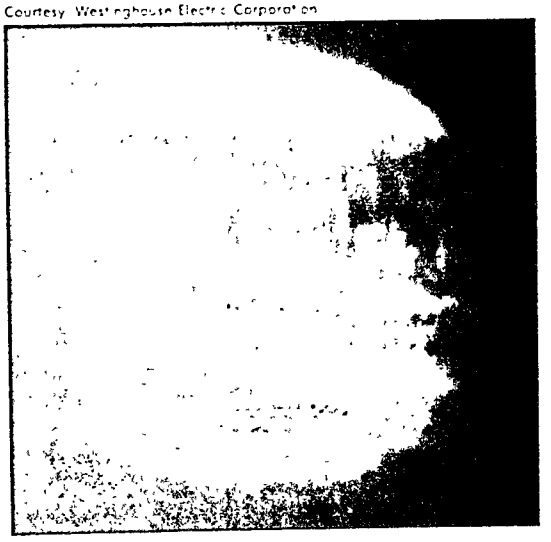
Mobile communications. The FCC also figured importantly in several domestic rulings. One concerned mobile communications, especially for moving automobiles and trains. Such service had been limited to 33 channels totaling about 2 Mega-Hertz (MHz) in bandwidth, around 35, 150, and 450 MHz. This provided a somewhat overloaded system in which the police, fire, taxicab, and other dispatch services in some U.S. metropolitan areas tended to interfere with one another; a move to a higher frequency range, where greater bandwidth (and hence more services) could be accommodated without "crosstalk," had long been indicated. In 1971, the FCC allocated a total of 75 MHz (from 806 to 881 MHz) to mobile communications, opening exciting possibilities for new developments. Among them was a system of particular interest to highly congested areas, such as New York City, in which the mobile radios of several users share a single transmitter, a "community repeater."

In another proposed shared-user technique, computers are used to control a system based on geographical "cells" approximately hexagonal in shape. Three low-power switching units are located in alternate corners of the hexagon and communicate by radiotelephone with mobile units operating within their reach; also several switching units, provided they are sufficiently distant from one another, can use the same frequency, so that a limited band can serve a large number of clients ("frequency reuse"). Selection of the switching unit nearest to the mobile user to be contacted is automated, as is switching to a new frequency when the mobile user moves to an adjacent cell. As the density of users grows, the hexagons can be further subdivided into a more dense honeycomb.

Introduction of such services remained in the future. But some of the individual features were being used on a limited basis in existing systems. For instance, on the new high-speed Metroliner trains between New York City and Washington, D.C., American Telephone and Telegraph Co. (AT & T) as early as 1969 installed pay telephones that automatically switch calls from one radiotelephone channel to another as the train moves from zone to zone.

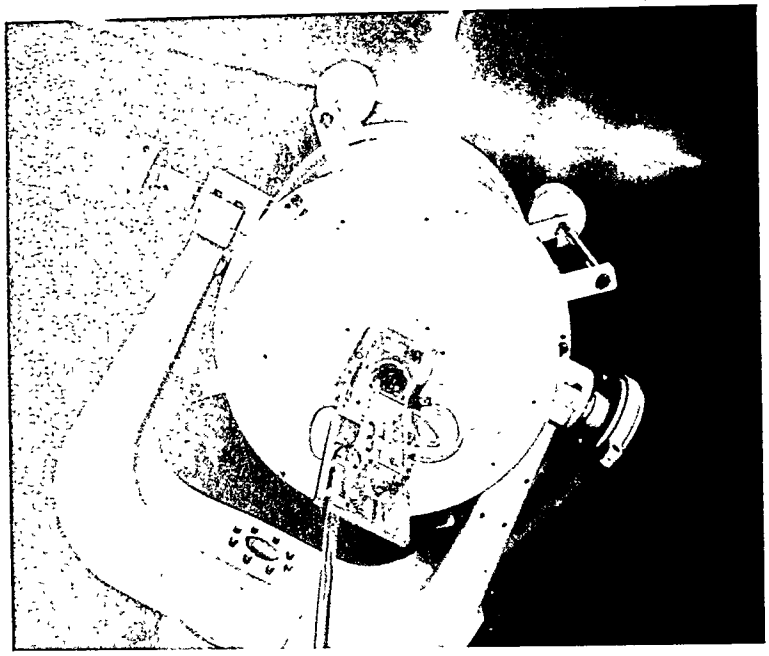
Data transmission. Another important FCC action was the Specialized Carrier Decision, intended to stimulate competition with AT & T's dominant Bell Telephone system in the increasingly important field of computer and other data transmission. Among other things, the decision would provide for the entry of carriers with no interest in the transmission of speech into the lucrative telephone market and force established companies to permit the interconnection of cus-

Courtesy Westinghouse Electric Corporation



Photograph taken by starlight was made with the aid of a small, self-contained, direct-view image intensifier The intensifier brightens an image by converting weak incoming light to electrons which are amplified and reconverted to visible light

Courtesy, GTE Sylvania



Newly developed laser capable of operating five to seven years in a communications satellite is powered by sunlight. Solar energy is collected by a 24-in. mirror and directed into the end of the laser (center). Lenses and mirrors collect and focus rays of the sun, which stimulate material in the laser to produce beams for carrying voice, data, television, and other communications between satellites and earth.

tomer-owned terminal facilities with existing telephone networks. There was widespread skepticism about the effectiveness of stimulating competition by government measures. The skeptics pointed out that previous attempts in that direction had proved only moderately successful, at least from the customer's viewpoint: even when an alternate service was required to avoid monopoly (as for domestic telegraph and communication-satellite services), it often appeared that Bell could have done the job cheaper. Moreover, potential newcomers were said to be interested in competing only for the most profitable long-haul services, which might ultimately result in higher charges for less profitable local services, overcrowding of existing facilities, and the establishment of incompetent firms.

Representatives of new Bell competitors, among whom Microwave Communications Inc. and Data Transmission Co. (Datran) were the most prominent, retorted that none of these charges was true. Datran spent $10 million over the four years since its formation in 1968 to plan and design a network that would ultimately serve 35 cities and cost $400 million to construct—yet the firm was still two years from earning its first dollar; thus, the cost of competing against the giants would be sufficient reason to keep out get-rich-quick operators, and in any case the FCC would not approve carriers who failed to meet stringent financial requirements. As to jeopardy to local services, the revenues from data transmission were expected to increase tenfold during the 1970s, from $500 million to $5 billion a year. Thus, there would be more than enough business for several carriers and no justification for intrastate rate increases based on the contention that the new entrants were siphoning off the most profitable interstate business.

Meanwhile, the Bell system was advancing its own research and development to meet future demand in data communications. Its Canadian associate was experimenting with an entire digital-data network (known as Project 99). Already linking Toronto, Ottawa, and Calgary, the network was slated to be expanded to Halifax in the east and Vancouver in the west, so that it would become a coast-to-coast facility. The economic constraints in communicating with northern Canada are greater than in more densely populated areas, since there are fewer potential customers separated by larger distances. Therefore, a system that would meet their requirements economically would be sure to be viable in the U.S., Western Europe, and Japan.

"The New Rural Society." Thoughtful engineers also looked to electronic communications services to reverse the centuries-old trend of migration from rural areas toward cities. As early as 1962, J. R. Pierce proposed that much of the time now spent in travel, especially to and from work, could be saved by substituting communications for travel through such services as "face-to-face or group-to-group sound and vision, safely encrypted to preclude eavesdropping, documents transmitted by rapid facsimile or by data devices, some control or manipulation at a distance . . . equivalent to

operating a computer, turning the pages of a catalog, or moving from department to department in a store while shopping. With cheap enough communication, students could attend classes by television." Now, a decade later, another U.S. engineer, Peter Goldmark (the inventor of the long-playing record and of electronic video recording, or EVR, for the home), suggested that the trend toward urbanization could be reversed by planning for what he dubbed The New Rural Society, which would imaginatively apply modern communications to make rural life more attractive.

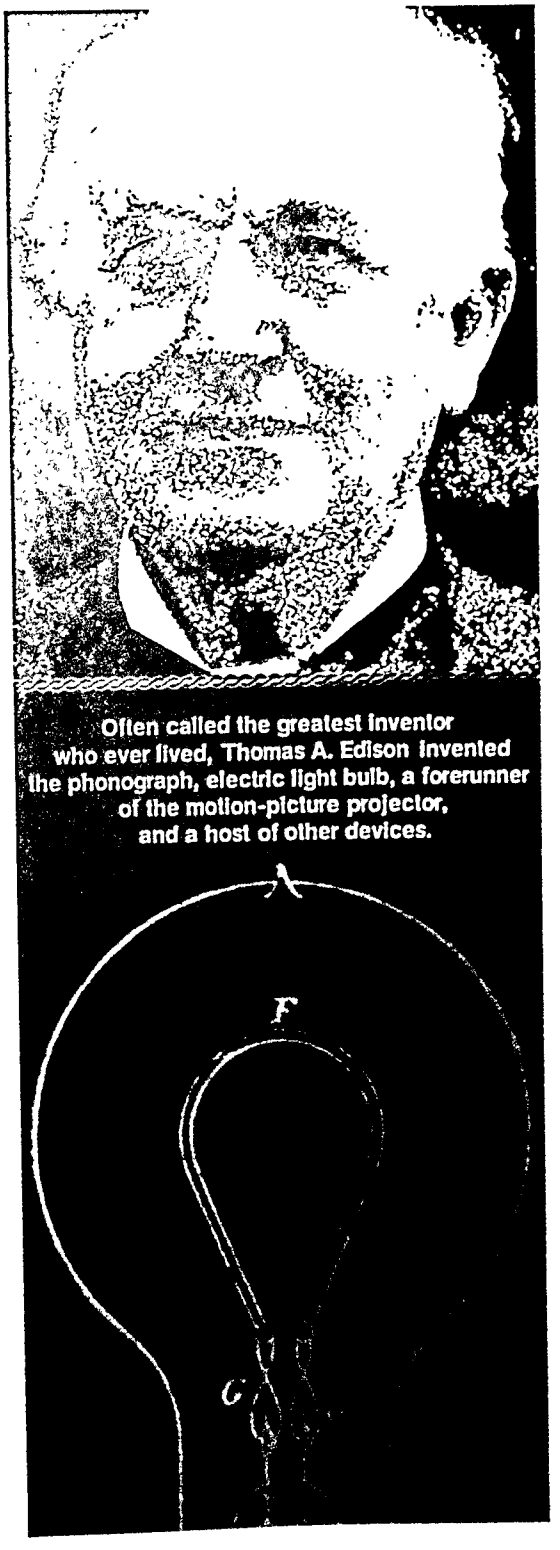
A tentative start toward such a society had already been made in Britain, where the government was undertaking a study of the feasibility of dispersing some of its offices out of London. The study was directed toward maximizing the fiscal and social benefits and minimizing what was termed "communications damage" arising from the absence of face-to-face contacts. An interesting approach to the problems involved was to adjust the solution to prescribed amounts of funds available: how much could be accomplished by telecommunications "packages" costing the same as normal telephone services (*T*), four times that amount (4*T*), and sixteen times (16*T*)? Preliminary estimates showed that 4*T* could provide loudspeaking, audio conferences, and transmission of documents. Going to 16*T* would provide two-way television communications of standard broadcast quality. The next step would be to classify existing face-to-face contacts into those which could be carried out by phone, those which would require a 4*T* system, those which would require 16*T*, and those which would still have to be face to face.

Similar planning on an even more ambitious scale was taking place in the U.S., where systems engineers talked about integrating energy flow, waste flow, information flow, and "people" flow into a single, optimized system in which information flow would become a viable alternative to moving people and things and to the consumption of energy. Bell Laboratories announced that it had evolved a method of video conferencing in which two groups of nine conferees each could meet in two separate locations. Three unattended cameras in each room provide uninterrupted coverage without operators or other technicians.

In summary, electronics developments during the past year highlighted an emerging characteristic: a stage at which "hardware" innovations were less prominent than methods of applying them in novel ways that promised to increase communications between city and country and among the nations of the world.

See also Year in Review: COMMUNICATIONS.

—Charles Süsskind



Often called the greatest inventor who ever lived, Thomas A. Edison invented the phonograph, electric light bulb, a forerunner of the motion-picture projector, and a host of other devices.

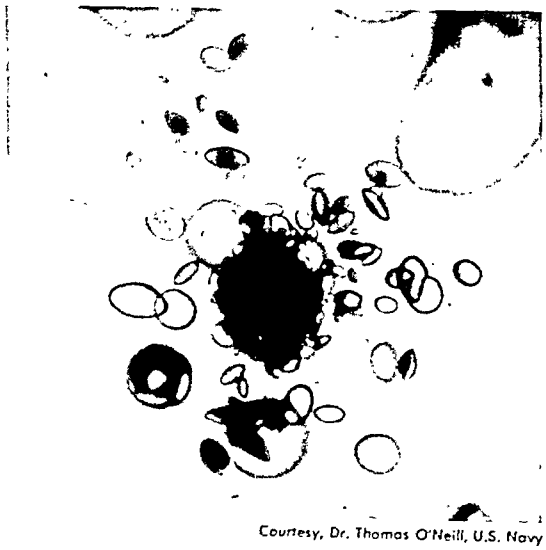
Environmental sciences

The environmental movement, launched with spectacular bravado and fueled by intense popular enthusiasm, was brought down to earth during the year. Dreams of easy solutions had drifted away. In their place were tough and complex political choices, economic analyses, lawsuits, legislation, technological development, and scientific research.

Challenge to growth. The change was graphically illustrated by the appearance of several widely discussed treatises on environmental dilemmas. Two of them, based on a series of computer models of the whole world, made some startlingly gloomy predictions, given current trends in development, environmental degradation, and population growth.

One, *World Dynamics*, was written by Jay W. Forrester, a Massachusetts Institute of Technology engineering professor and pioneer in systems analysis. A similar and more widely publicized book, *The Limits to Growth*, was based on a study sponsored by the Club of Rome and directed by another MIT professor, Dennis L. Meadows. "If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged," it warned, "the limits to growth on this planet will be reached sometime within the next 100 years." It stated, ominously, that the "most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity." *The Limits to Growth* added, however, that man can successfully opt for a state of "equilibrium" by stabilizing population and capital investment.

Oil-eating bacteria (light globules) devour drops of oil in a test flask. Laboratory tests have identified 62 species of bacteria that eat oil, and scientists envision a day when freeze-dried bacteria can be stockpiled for use on oil spills.



Courtesy, Dr. Thomas O'Neill, U.S. Navy

Concepts and conclusions in *World Dynamics* and *The Limits to Growth* were challenged by a number of experts. Nevertheless, the books raised the level of debate on the complex issues involved, and many who had dismissed ecological warnings as a bird watchers' fad were being forced to reexamine their ideas. (*See* Year in Review: SCIENCE, GENERAL.)

There were other impressive challenges to unharnessed growth and inadequate environmental protection. A long report entitled "A Blueprint for Survival," published in the January 1972 issue of the British magazine *Ecologist*, warned of the "breakdown of society and of the life support systems on this planet." The report was endorsed by 33 of the United Kingdom's most prestigious scientists. In March 1972 the Commission on Population Growth and the American Future, established two years earlier by the U.S. Congress, released its report. The commission concluded that "no substantial benefits would result from continued growth of the nation's population" and called for a federal population-control policy.

Further thrust was added to the environmental movement by Barry Commoner, a biologist and director of Washington University's Center for the Biology of Natural Systems, with his book *The Closing Circle*. In it, Commoner describes in detail how technological change in many industries—particularly during the post-World War II period—has centered on processes that increase pollution and that use a growing amount of electric power. He argues that there has been no compensating increase in the real value of products and services.

Environmental warnings and remedial activities were not unopposed, however. Critics challenged pollution control standards as unnecessarily strict, stressed the high costs to the public, and cited companies that had been forced to close down and jobs that had been lost. The running debate only served to emphasize how little man really knows about pollutants and health, about practical scientific and economic techniques of environmental protection, about the effect of controls on the economy and employment, and about the ramifications of slowing or stopping growth.

Pollution and health. A joint study summarizing the known effects of environmental pollutants on health was issued in January 1972 by the U.S. Department of Health, Education, and Welfare (HEW) and the Environmental Protection Agency (EPA). Among the findings:

Courtesy, U.S. Department of Agriculture



Reesimermis nielseni *nematode coiled inside the thorax of a southern house mosquito kills its host as it emerges to molt, mate, and reproduce. Nematodes have provided good mosquito control in selected areas around the world with fresh, unpolluted water.*

• "Pollution control should diminish the frequency and severity of acute respiratory disease, acute gastroenteric disease, and chemical intoxications of the central nervous system. Environmental aggravation of existing heart and lung diseases should also be substantially reduced."

• Cancer studies demonstrate that "there are striking differences in cancer incidence from place to place in the world . . . and when persons migrate, they appear to adopt the propensity for cancer which is characteristic of their new home." Also, studies of workers in some occupations reveal a number of substances that produce cancers, and cancers have been induced in test animals by the application of many substances. Thus, the study says, there is "strong evidence that environmental factors have a significant role in cancer production."

• Although cigarette smoking explains about 90% of chronic bronchitis and pulmonary emphysema, air pollution is associated with a "demonstrable excess" of chronic respiratory disease. The culprits implicated are sulfur oxides, nitrogen oxides, and particulates.

• "Atmospheric sulfur oxides, particulates and photochemical oxidants aggravate the frequency and severity of asthma symptoms in persons with this disease. . . . Ambient air pollutants have been associated with a significantly increased frequency of acute respiratory disease."

• "Decreased lung function due to air pollution and increased sodium intake from polluted waters can put a strain on the heart and cause exacerbation of cardiovascular disease." There are also suspicions that the carbon monoxide emitted by cars is linked with heart disease.

Concern also mounted over the high incidence of lead poisoning—in some cases leading to mental retardation—among urban children. In addition to the traditional villain, chipping lead-based paint, increasing blame was attached to the toxic exhausts of automobiles burning leaded gasoline. "Some 400,000 inner city children are believed to be suffering from high blood lead levels," said a federal interagency report, "Our Urban Environment," in September 1971.

Significantly, the HEW-EPA study was filled with warnings about man's ignorance of the health effects of pollutants and the need for further research. "The causes of our three major killers —heart disease, cancer, and stroke—have not been identified," the study noted. Without more knowledge, the effect of pollution on these diseases cannot be assessed. The continued introduction and wide distribution of thousands of chemical and physical substances of unknown environmental and health impact constitutes a "hazard of serious proportions." There is need for a more sophisticated, systematic screening of agents entering the environment and for assessment of their "potential harm."

Clean air standards. The battle over clean air standards in the U.S. began to take shape as each state drew up a plan to implement the strict provisions of the Clean Air Act Amendments of 1970. These implementation plans were sent to EPA for approval. Under Delaware's plan, for example, Delmarva Power & Light Co. would be required to reduce sulfur dioxide emissions at a plant in Delaware City. The company filed an appeal, whereupon EPA issued a federal notice of violation, making Delmarva the first company so cited under the 1970 law.

Congress had warned that many cities would have to enforce drastic curbs on automobiles in order to attain the air quality standards required for 1975, but the proposed state plans were generally timid on that score. In the District of Columbia, the City Council did propose a $1 per day downtown parking tax on commuters as one way to help meet the standards—as well as to raise

revenues. Lusty opposition from a number of business organizations at the council's hearings suggested that it would be a stouthearted local government that would undertake to tell America's spoiled drivers they could not go where they wanted when they wanted. It remained to be seen whether EPA could provide the necessary muscle.

Some encouragement came from Italy where, after a week-long experiment with free bus and streetcar service had brought a dramatic decline in traffic on congested streets, authorities in Rome announced in April 1972 that the free service would be made permanent during rush hours. They added that cars would be banned in stages from the two-square-mile historic and business center of the city. Though traffic problems had sparked the move, the ecological potential for other cities did not go unnoticed.

As challenges to the uncurtailed use of autos increased, so did interest in an important alternative—rapid mass transit. Pressure rose to increase federal financial aid for mass transit systems. Chief target was the enormous Highway Trust Fund, set up in 1956 as the source of federal aid to the states for highway purposes.

Meanwhile, auto manufacturers, insisting they could not produce cars for the 1975 model year that would meet federal emissions standards for carbon monoxide and hydrocarbons, applied for the maximum one-year extension of the deadline to 1976. The major companies continued work on catalytic mufflers or afterburners, designed to cause more complete combustion of pollutants that now escape into the air. One problem was that, as more of the other pollutants are burned up, increasing amounts of nitrogen oxides are formed. Another is that the lead from leaded gasoline chokes the mufflers. The auto industry asked for assurances that lead-free or low-lead gasoline would be available in time for the 1975 models, and on Feb. 23, 1972, EPA took the first step to require that it be sold by refiners and large gas stations.

The auto makers also claimed that cars with pollution-control devices would be expensive, costly to operate, and less responsive than current models. Environmentalists tended to be skeptical about the figures cited, but many of the drawbacks were real enough and served to reinforce the widely held belief that much more drastic measures would be necessary. Auto manufacturers would have to wrench themselves away from the internal-combustion engine or the public would have to wrench itself away from the automobile.

Hundreds of firms around the world were accelerating efforts to develop "clean" cars. Major candidates were cars driven by a gas turbine, by steam, by electricity, by natural gas, by liquefied petroleum gas, or by hybrid engines that would permit the driver to shift from one fuel to another, depending on the circumstances. A gas turbine car made by Williams Research Corp. began undergoing extensive tests in New York City in February 1972. The manufacturer of Mercedes-Benz, which already mass-produced diesel-engine cars with lower emissions, tested a city bus that ran on natural gas. In January a steam-driven bus began experimental operations in the Oakland-Berkeley area of California.

There were several major air pollution episodes during the year, including one in east central New Jersey in September 1971 and another in Birmingham, Ala., two months later. In Birmingham, EPA invoked the emergency provisions of the Clean Air Act for the first time, leading a federal judge to order a two-day shutdown of 23 large industrial plants. EPA sought funds in its fiscal 1973 budget to develop analytical models of urban areas to show the relationships between pollution emissions, atmospheric conditions, and the ambient air quality. In a taste of things to come, Litton Industries was developing an experimental computerized air pollution monitoring system for Los Angeles County.

The unclean waters. The U.S. Congress, in effect, conceded failure in the nation's efforts to clean up its waters by moving to completely revamp the basic federal water pollution control law. Proposed legislation would depart from the existing system under which states specify the uses to be made of a body of water, decide what pollutants would be compatible with those uses, and prescribe necessary control measures. Bills passed by both the U.S. Senate and House of Representatives would rely chiefly on a permit program setting effluent limits for specific sources of pollution.

In other respects, however, the Senate and House bills were so divergent that many despaired of any possibility for effective agreement. Among the major differences was the Senate bill's requirement that all pollutant discharges be eliminated by 1981 except when this could not be done "at reasonable cost." The aim was to make all waters clean enough to swim in. The House bill was more lenient.

Major emphasis in water-pollution control continued to be placed on municipal waste-treatment plants and on modifications and processes to remove higher percentages of pollutants. Pointing out that research along these lines "has failed to provide a single significant technological innovation" (in the words of a Ralph Nader group study), many environmentalists were urging that more attention be paid to "closed systems" involving the benign disposal or recycling of sludge and other water wastes as fertilizer, through "spray

irrigation" and by filtering the wastes through the ground.

In another controversy involving water pollution, confusion over washday detergents reached new peaks. After phosphates had been implicated in the "death" of lakes and streams, more and more jurisdictions were implementing bans on the sale of high-phosphate detergents. The detergent industry, meanwhile, came up with some highly effective cleaning agents to use as substitutes: nitrilotriacetic acid, or NTA, and caustic soda.

Just as manufacturers were phasing out phosphates, however, studies began to raise the suspicion that NTA and caustic soda were potentially dangerous to humans and perhaps to their environment as well. The industry voluntarily stopped using NTA. Then, in September 1971, the federal government did an about-face and suggested that housewives return to detergents with phosphates as the lesser of two evils. Housewives were understandably perplexed, and some environmentalists suggested a return to soap.

Solid wastes. Governments and industries continued to grapple on a more or less piecemeal basis with the myriad problems of solid waste disposal and recycling. Much attention was focused on the use of municipal solid wastes to produce energy. In one of a number of demonstration projects, the Union Electric Co. in St. Louis, Mo., planned to grind up refuse, mix it with pulverized coal, and use the mixture to fire a boiler and generate electricity.

"The United States pays over $3 billion to dispose of the solid waste residue of our affluent society," Richard C. Bailie, professor of chemical engineering at West Virginia University, told the annual meeting of the American Association for the Advancement of Science in December 1971. "This residue has a heating value equivalent to 300,000 tons of coal a day with a sulfur content of 0.2 to 0.3%. Our cities are literally being buried under the thing they desperately need—low-sulfur fuel." He added that processes have been developed that offer the promise of effectively using



Psychologist John Calhoun stands among some of the 2,200 mice bred in a physically optimal environment. As the population, which started with four pairs, increased, the mice began to suffer from a "lack of psychological space." Aberrant behavior, homosexuality, anxiety, and aggression increased, while reproduction and the capacity for reproduction decreased. As the members of this colony die, there will be no replacements for them. From experiments such as this, behavioral scientists believe they can extrapolate insights into such human conditions as urban crowding

refuse for at least a fraction of the nation's energy needs. Along the same lines, Hinrich L. Bohn of the University of Arizona, in the December 1971 issue of *Environment* magazine, said that the organic wastes of animal feedlots, which pose an enormous disposal (and water pollution) problem, could be converted to methane gas for a large new fuel supply.

Marketing of recycled paper continued to rise. In an experimental project, the city of Franklin, O., was selling not only recycled paper but also steel cans and other metals to private industry—all of them from the plant that handled the city's solid wastes. Soon it expected to sell recycled glass and aluminum cans as well.

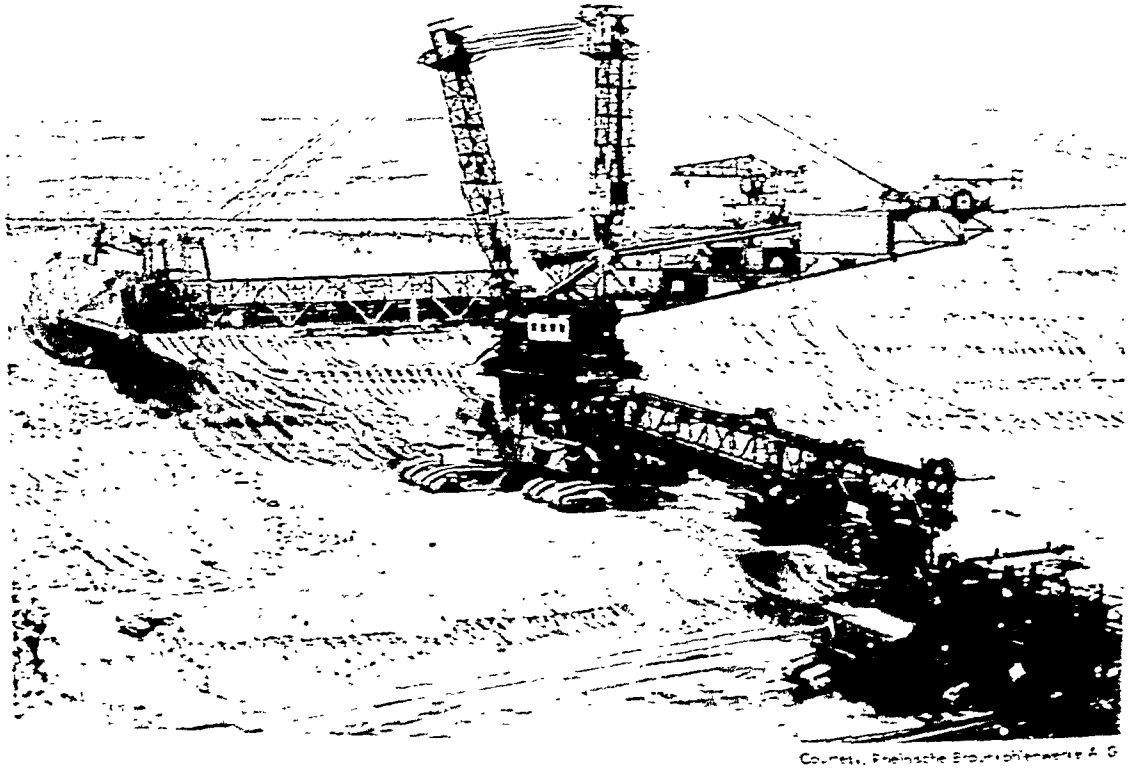
Work continued during the year on various methods for using solid wastes for paving roads. A street in Omaha, Neb., was paved with "glasphalt," made from crushed bottles. The federal government was working on an experimental paving material comprising reclaimed rubber, bottles, garbage, lime, fly ash from incinerators, and calcium sulfate, a steel-processing waste. Michael D. Piburn of Rutgers University suggested in the April 1972 issue of *Natural History* magazine that glass from used bottles be converted back to sand to rebuild eroded beaches.

On the economic and political front, a number of court fights were being waged over statutes requiring deposits on drink containers. In December 1971 a county judge upheld the validity of the first such law, a Bowie, Md., ordinance requiring a five-cent deposit on all beer and soft-drink containers, but the ordinance was not expected to be enforced until further court challenges were settled.

The pesticide controversy. Environmentalists had long urged the adoption of biological or "integrated pest control" techniques in place of chemical pesticides. These techniques include the use of natural predators, pest diseases, sterilization, sex attractants, and genetic manipulation—sometimes in combination with a judicious use of chemicals. In his third environmental message, on Feb. 8, 1972, Pres. Richard Nixon said he was directing half a dozen federal agencies to "launch a large-scale integrated pest management research and development program."

Lengthy EPA hearings and court appeals had not laid to rest the thorny question of DDT use.

A bucket wheel excavator with a digging capacity of 130,000 cu yd per day exposes a layer of lignite during the course of strip mining operations in West Germany. The machine selectively strips off and saves the top layer of fertile loam, which is used for later reclamation.



Despite the imposition of some restrictions, it was still being applied in large quantities by U.S. farmers. EPA announced its intention to ban all use of DDT, but the pesticide industry made an administrative appeal that resulted in the hearings. A federal court declined to suspend sales of DDT pending resolution of the issue. A decision was expected from EPA in the near future, but it was likely to lead to further court challenges. Efforts to ban aldrin and dieldrin—other long-lived chemicals—were going through the same process.

A special advisory panel reported to EPA in September 1971 that even a complete ban on DDT in the U.S. would not solve the problem because of heavy worldwide use and dissemination, but it recommended early curtailment, with a goal of "virtual elimination." Meanwhile, agricultural expert Norman Borlaug, winner of the 1970 Nobel Peace Prize, told a UN meeting in Rome in November 1971 that DDT was indispensable for health and agriculture. Borlaug himself was sharply criticized in return.

With DDT and other persistent pesticides under fire, many were turning to toxic but short-lived chemicals. One widely used pesticide recommended as a safe substitute was carbaryl, sold as Sevin. Some scientists feared carbaryl might turn out to be hazardous, however. It was also one of the many pesticides that are highly toxic to bees. It was an irony of pesticide use that, under federal law, the U.S. Department of Agriculture paid out millions of dollars in indemnities to beekeepers for honeybees lost as a result of nearby spraying, as well as to dairy farmers and manufacturers for milk products removed from the market because they contain excessive residues of approved pesticides.

The energy crisis, continued. Long-range energy-environment problems were the subject of intensive study. On several occasions during the year, President Nixon called for a major effort to find new sources of abundant, nonpolluting energy. The administration requested increased funds in fiscal 1973 for research on a variety of potential sources, some of which had received relatively little attention—liquid metal fast breeder nuclear reactors, controlled thermonuclear fusion, coal gasification, solar energy, magnetohydrodynamics, and geothermal power.

Energy problems were exacerbated by the very real shortage of nonpolluting natural gas, the environmental damage caused by strip mining coal, the shortage of low-sulfur coal in many areas, the constant threat of oil spills, and the potential hazards of radiation or nuclear accident.

The federal government was seeking to encourage increased exploration and production of offshore oil and gas, but it received a major setback in December 1971 when a federal judge enjoined the Department of the Interior from selling oil and gas leases in the Gulf of Mexico. Citing the National Environmental Policy Act, which requires preparation of a comprehensive "environmental impact statement" for all federally funded projects, environmentalists argued—and the court agreed—that Interior had not adequately considered alternatives in the search for energy. A complete study was expected to take months. Meanwhile, environmentalists were poised to fight drilling off the East Coast, which was still in the talking stage.

Conservation and citizens' groups won a dramatic legal victory in their challenge of the Atomic Energy Commission's procedures for considering environmental factors before licensing nuclear plants. In a case involving the Calvert Cliffs plant in Maryland, a federal court ordered the AEC to revise its rules, and some power plant construction was delayed. Pending were complex challenges of safety and radiation requirements, as well as industry's ability to deal with thermal pollution.

The long-delayed trans-Alaska oil pipeline project was approved by the Department of the Interior, although the impact statement admitted the probability of environmental damage. Actual construction was awaiting action by the courts. Held up, at least temporarily, because of inadequate impact statements were some major highway construction projects and a number of large dam and canal projects, such as the Tennessee-Tombigbee Waterway in Alabama and Mississippi and the Gillham Dam and reservoir in Arkansas. (See Year in Review: FUEL AND POWER.)

Swan courtesy INDUSTRIAL RESEARCH



"So far, the only really effective smog filter we've found is the human lung."

Courtesy, Royal Aircraft Establishment



A stained-glass window is a target at the end of the "Blunderbuss," a device designed by British scientists to simulate the sonic booms of the Concorde supersonic transport plane. Preliminary tests indicated that the booms would not affect soundly constructed buildings.

The Stockholm conference. After four years of intensive preparation, the first United Nations Conference on the Human Environment was held in Stockholm in June 1972. Advisory in nature, and with no real power to enforce its recommendations, it nevertheless served to dramatize the growing worldwide awareness of environmental problems.

The conference was attended by delegates from 114 nations, representing some 90% of the world's population. The Soviet Union and its closest allies absented themselves to protest the exclusion of East Germany from full participation, but it was expected that even they would join in support of the conference's aims. These were set forth in 26 principles, embodied in a "Declaration on the Human Environment" which would be submitted to the UN General Assembly for ratification. Also approved were a 200-point "action program" and a recommendation to establish international machinery for coordinating environmental efforts.

The conferees were by no means in total agreement. The developed and less developed countries disagreed on priorities. China objected strongly to the "principle" urging destruction of all nuclear weapons, and there was acrimonious debate on such political matters as the Indochinese war. Despite their political differences, however, the conferees did express a basic unanimity on the need to protect the global environment. It would be a good while before anyone could assess the real effect of the conference, but unquestionably it had forced many nations to begin giving serious attention to their environmental problems.

—Rice Odell

See also Feature Articles: SPECIES IN PERIL; THE NOTORIOUS TRIO: MERCURY, LEAD, AND CADMIUM.

Foods and nutrition

About 25% of the world's total 2,000,000,000-ton food supply is of animal origin—milk, meat, and eggs. To obtain this amount of food from domestic animals, as much food is needed for them in the form of cereals, legumes, and other feedstuffs, as is consumed by humans. Thus, if one counts this as part of the food used to feed mankind, the 1971–72 total is larger than ever before, amounting to roughly 4,000,000,000 tons. This means that there is about one ton of food for every person on earth.

However, there is still a precarious balance between the world's food supply and its population. Millions of persons still do not have enough food

or the right kinds of it. Though at present there is theoretically enough food for all, starving and hungry populations can make little or no use of these supplies due to factors largely beyond their own control, such as disease, famine due to drought or insects, war and unfriendly politics, bad social and health standards, ignorance, and infirmities of old age. Bad economic conditions, infertile land, lack of transportation and storage facilities, and overpopulation are also involved.

In the United States approximately $125 billion were spent on food in 1972, with nearly a third of this being spent for meals outside the home. Foods at no cost or at reduced prices were offered to approximately 15 million persons in the U.S. (or about 7% of the population) by means of commodity food programs or food stamps.

More than 40 million school children (about 80% of the total) were offered school food services throughout the year in 90,000 schools. About 60% of these received federal assistance, including funds for eight million children who received free or reduced-price school meals. The experimental school breakfast program continued to grow, with a budget of more than $25 million a year.

In spite of this important government aid, which exists in many countries, malnutrition continued to be a serious problem in the U.S. and throughout the world. Malnutrition in most of the so-called developed and industrialized countries occurs in such forms as obesity, anemia, decayed and weak teeth, diet-related heart disease and diabetes, alcoholism, and borderline nutrient deficiencies. In the developing, less-industrialized countries malnutrition is often more direct, showing up in the form of simple food shortages with resulting deficiencies of protein, energy, vitamins, and minerals. Overeating of the wrong kinds of food was a problem everywhere.

Preliminary estimates of the dollar costs of malnutrition (including all direct and indirect costs) in the U.S. and countries with similar nutrition problems were placed at approximately $1.5 billion per 10 million population (for a total of about $30 billion in the U.S. per year). This amounted to nearly half of all the nation's medical, dental, and health costs, and about a fourth of all food costs.

Food consumption patterns in the U.S. Typical of citizens in most modern countries, an average individual in the U.S. normally eats a varied diet based on cereal products, fruit and vegetables, milk and milk products, and meat and legumes. In the U.S. the consumption of red meat and poultry was steadily increasing while milk consumption dropped considerably. Of great significance nutritionally was that the consumption of concentrated energy sources (sugars, alcohol, and pure fats) continued at record high levels. In 1971 more than one-third of the U.S. intake of calories came from these sources, which are completely devoid of most other important nutrients such as protein, minerals, and B vitamins.

A detailed breakdown of the 1971 per capita availability (before cooking) of food in the U.S., based on U.S. Department of Agriculture figures, appears in the Table. The amounts are given on a



Navaho nutrition aides prepare a breakfast using USDA-donated foods. A recent agreement giving the Navahos control of the distribution program was expected to achieve a more equitable division of the food among the 83,000 needy individuals

Pounds of available food commodities per capita on a fresh basis	Average 1957-59	1971
Meats (carcass weight, including bone and fat)	156.6	192.0
Beef	82.1	113.3
Veal	7.1	2.7
Lamb and mutton	4.4	3.2
Pork (not including lard)	63.0	72.8
Fish (edible weight)	10.5	11.2
Poultry		
Eggs (pounds, at rate of 8 eggs/pound)	44.5	40.4
Chicken (ready to cook)	27.5	41.6
Turkey (ready to cook)	6.0	8.6
Dairy products		
Cheese	7.9	12.2
Condensed and evaporated milk	14.8	6.8
Fluid milk and cream*	337.0	258.0
Ice cream	18.4	17.7
Fats and oils		
Butter	8.2	5.0
Margarine	8.9	11.1
Lard	9.3	4.4
Shortening	11.4	17.0
Other edible fats and oils	10.8	18.6
Fruits		
Fresh		
Citrus	34.0	29.2
Apples (commercial)	21.0	16.8
Others (excluding melons)	40.5	35.0
Processed		
Canned fruit	22.4	22.4
Canned juice	13.5	14.9
Frozen (including juices)	8.6	10.4
Dried	3.3	2.9
Vegetables		
Fresh (commercial)	104.1	97.3
Canned (excluding potatoes)	43.3	51.3
Frozen (excluding potatoes)	6.6	9.1
Potatoes (fresh equivalent)	106.9	120.9
Sweet potatoes (fresh equivalent)	8.3	5.1
Grains		
Cornmeal and flour	7.4	7.4
Corn syrup	9.4	16.6
Corn sugar	3.6	5.0
Wheat flour (including whole)	120.0	111.0
Wheat cereals	2.8	2.9
Rice, milled	5.4	7.6
Other		
Coffee (green beans)	15.7	13.6
Tea	0.6	0.8
Cocoa beans	3.5	3.9
Peanuts (shelled)	4.6	5.9
Dry edible beans	7.7	6.0
Melons	25.1	21.7
White sugar, refined	96.1	102.0
Total pounds	1,386.2	1,364.3

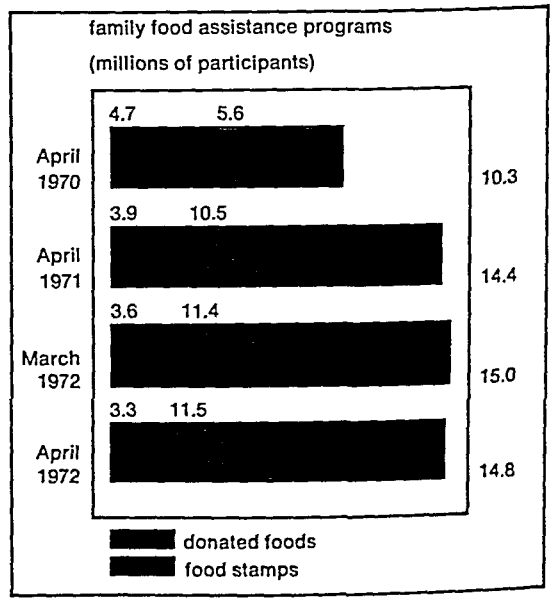
*Fluid milk equivalent (including dried milk).

fresh basis, thereby including the water content, which ranges from 60 to 90% for most fresh foods. These figures are compared with 1957–59 averages, and show such trends as a decline in availability of milk and an increase in meat.

Food science and technology. Probably more than in any previous year, in 1972 the influence of the consumer greatly affected the types of foods made available to the public by the food industry. Of special interest in this connection in the U.S. were the proposals for voluntary labeling of food products by the Food and Drug Administration (FDA). Under these proposals, made as a result of requests of various concerned groups, much more nutritional information about a product could be obtained from the product label (information on the amount of calories, protein, and fat per serving). Detailed information about major vitamins and minerals would also be given if present proposals are approved.

There were many important food technological advances during the past year. Among them was the discovery of many new uses for "texturized proteins" made from soybeans. These products, of lower cost than meat (as low as 30 cents per pound), were added to ground beef or meat-loaf products, for example, in order to raise the levels of protein and decrease costs. They were also used to make imitation meat products, a development that nutritional scientists were studying because the texturized proteins contain very few vitamins and minerals and thus do not provide full nutritive value.

Work continued on the improvement of low-cost vegetable protein sources for human use, includ-



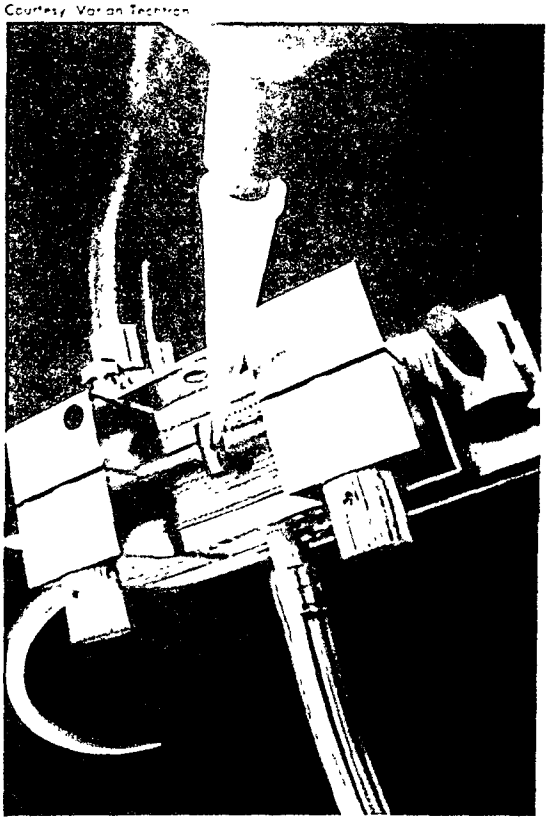
ing those from soybeans, plant leaves, beans, rice, sunflower meal, and rapeseed. Packaging and manufacturing advances resulted in many new products, such as frozen orange slices, frozen meat and cheese specialties, dehydrated batter mixes, frozen ethnic food, dry sauces, new canned foods, specialized "health food" products (many of which are now marketed in large supermarkets), new desserts, and hundreds of other new commercial convenient food items.

The growth of commercial and public food service organizations in the United States was phenomenal, and by 1971 had become a more than $40 billion business. Several private companies produced over 100 million meals per year, and some authorities predicted that within a few years more than half the meals consumed by the American public would be prepared outside the home. Commercial food services for retirement homes and day-care centers in the U.S. were growing at a particularly rapid rate.

The safety of food additives was given more than the usual attention by government agencies in 1972. In the U.S. an entirely new appraisal was being given to those additives designated as "generally recognized as safe," specifically artificial colors and sweetners. The presence of unintentional additives in food, such as synthetic diethylstilbestrol, which is fed currently to most all commercial beef cattle (and which does not remain in meat if removed from the food of the cattle one week before slaughter), and of pesticide residues from treatment of farm crops and animals were under investigation. The widespread publication by the FDA of the legal limitations of "filth" in human foods (such as hair, rodent fecal matter, insects, and worms) attracted much comment from consumers and the food industry alike.

Nutritional advances. Basic discoveries in nutrition continued to be made on a very broad front. The trace mineral field continued to be productive. During the past year Klaus Schwarz of the Veterans Administration Hospital at Long Beach, Calif., confirmed that rats require the element tin in their diet and also demonstrated that fluoride deficiency in rats caused a 20% depression in growth. The latter finding, if confirmed, would be a great impetus to the cause of fluoridation of water supplies. Edith Carlisle of the University of California at Los Angeles announced that silicon, the common ingredient of sand, was a dietary essential for the rat.

Also, in the nutrition area, the rapidly growing interest of all citizens in the environment and in the seeming lack of real concern of the food manufacturing and retailing interests in nutrition resulted in much growth of the new "natural" foods movement. Natural-food stores and restaurants expanded at a rapid rate in most large cities, especially around colleges and universities.



Courtesy Varian Technique

Newly developed carbon rod work head is used with an atomic absorption spectrophotometer to determine the metal content of food additives. The sample is syringed into the rod, dried, ashed, and atomized for analysis of any or all of 60 metals that might be present.

Nutritionists applauded the increased concern in developing better eating habits but were troubled over many false and misleading claims made about foods and food supplements and about the unnecessarily high prices paid for these foods. Adherents of health diets generally consumed food of high nutritional value, but in some cases food extremists and fanatics ate nutritionally poor diets for long periods of time. An example was the "seventh stage" of the so-called Zen macrobiotic diet (consisting chiefly of brown rice and a few vegetables), which can result in severe nutritional problems.

In December 1971, the White House Conference on Aging recognized the importance of nutrition in a properly fed aging society by calling for increased research on nutritional problems of the aged. Especially important was the resolution that "the Federal Government assume the responsibility for making adequate nutrition available to all elderly

persons of the U.S. and its possessions." Means of doing this, such as by food stamp programs, improved nutrition education, improved food facilities, and availability of food services, and by providing adequate income and housing were spelled out in some detail.

About 10,000 research papers were published in 1972 in the food and nutrition field. Among the areas of most active research were nutrition and behavior, vitamin and mineral metabolism, nutrition as it relates to blood lipids, disease and nutrition interrelationships, measurement of the biological value of new foods for man, psychological aspects of weight control, effects of high sucrose intakes, vitamin D chemistry, and the effect of drugs and alcohol on nutrient levels in the body.

The future. Since our most urgent need in the food and nutrition area is the combating of human suffering caused by malnutrition, nutritionists hope that the future will bring a much greater concern about this problem from national leaders, international health agencies, and the food industry. Though the development of technological improvements and the uncovering of basic knowledge in the field is extremely important, these alone are not sufficient to feed the hungry millions. New and attractive low-cost food sources will need to be developed and new educational programs established, the combination of which (with improved economic conditions) is essential if an effective start is to be made in the prevention of malnutrition.

—George M. Briggs

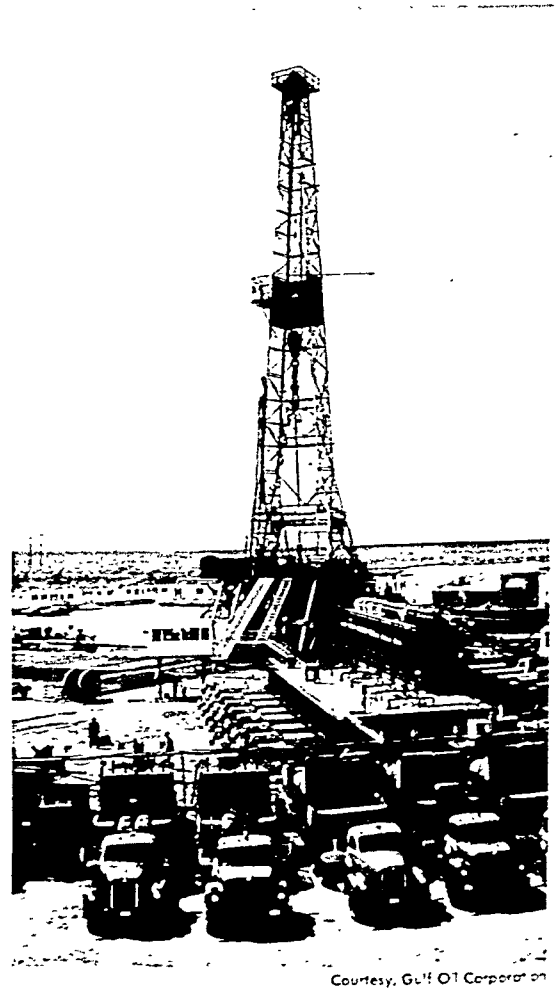
See also Feature article: NUTRITION AND THE AMERICAN DIET.

Fuel and power

Fuel and power matters claimed a growing share of attention during 1971 from political leaders, scientists, environmentalists, and the general public in the United States and the other industrially advanced countries. Adequate supplies of fuels are essential to these complex, highly developed societies because energy is involved in the full range of problems confronting them. These include national economic growth, depletion of resources, security of supply, environmental protection and ecological degradation, conservation and recycling of materials, and changes in living standards and life styles.

Prime evidence of this growing concern was the unprecedented energy message of June 4, 1971, by U.S. Pres. Richard Nixon in which he established national energy goals and outlined a broad range of policies to deal with the nation's growing energy demands and overcome the supply and environmental problems. Nixon stated, "A sufficient supply of clean energy is essential if we are to sustain healthy economic growth and improve the quality of our national life." He noted that existing domestic energy sources and technologies are not sufficient to meet future requirements within acceptable environmental standards and costs. Therefore, Nixon committed the U.S. to a "clean energy" policy and ordered accelerated programs of research and development of three priority technologies—sulfur oxide emissions control, the fast breeder nuclear power reactor, and coal gasification. He also noted the need for greater research and development efforts in nuclear fusion, solar energy, underground electric power transmission, magnetohydrodynamics, and other technologies.

Drilling rig in west Texas was used to conduct tests of a new technique, abrasive jet drilling. The tests demonstrated drilling rates 4 to 20 times faster with substantially longer bit life when compared with conventional rotary drilling.



Courtesy, Gulf Oil Corporation

Secretary of the Interior Rogers C. B. Morton announced on July 15, 1971, the essential elements of a proposed national energy policy that was consistent with and supportive of the president's message. These policy elements set forth the objectives, responsibilities, and roles of private enterprise and of local, state, and federal governments in bringing about a more acceptable balance among national energy objectives.

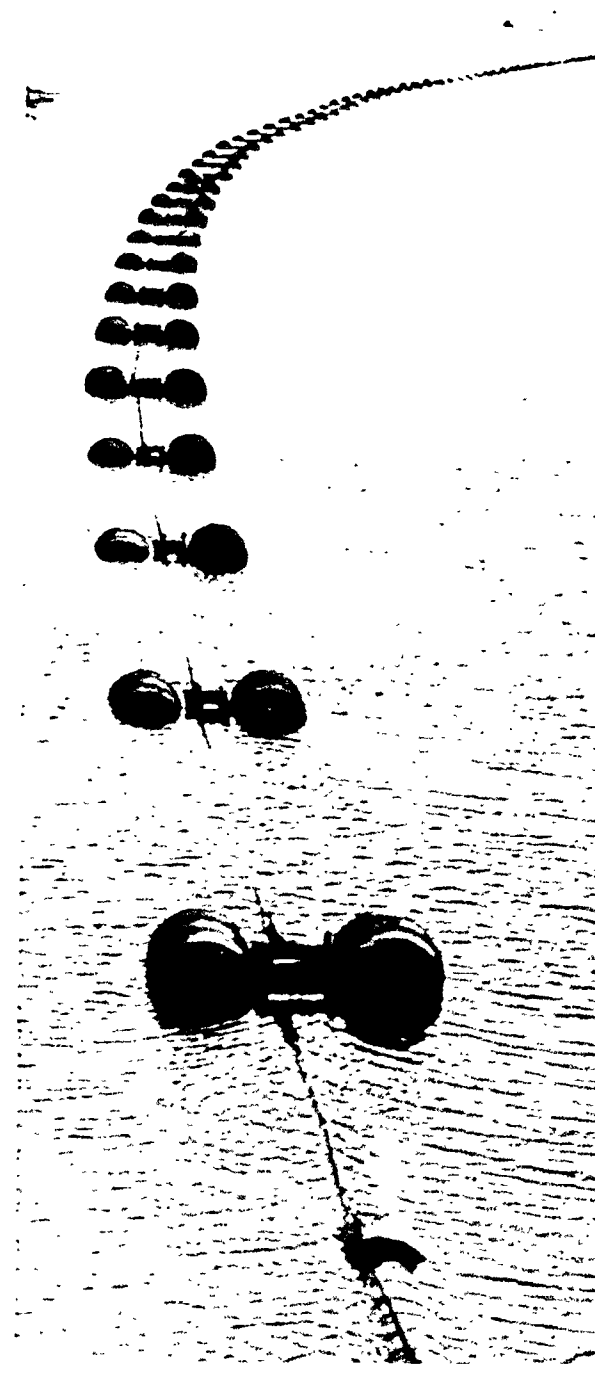
Despite the slowdown of general economic activity during 1971, fuel and power consumption registered healthy gains. In the U.S., energy consumption increased by 2.3% over that of 1970. At the same time, energy demand in all the non-Communist nations was estimated to have increased by more than 5%. Most of the increased consumption occurred in the U.S., Western Europe, Japan, and the other more industrialized and affluent countries.

The less developed countries continued as the principal sources of fuel supplies. Western Europe remained dependent on the oil-rich countries of the Middle East and Africa for nearly two-thirds of its total fuel needs, while Japan obtained about 70% of its fuels from those sources; the U.S. received about 25% of its petroleum requirements from foreign countries, but mostly from Western Hemisphere sources.

As a result of the continuing growth in the demand for fuels in the major consuming nations, the oil-producing and exporting countries were successful in further modifying the terms of concession agreements held by Western oil companies operating in their territories. The exporting countries greatly increased their share of revenues and imposed more stringent controls on the concessionaires. During 1971, oil payments to governments of the oil-producing states in the Persian Gulf and African areas increased by approximately 30 to 40% in accordance with the five-year settlements of early 1971 negotiated in Teheran and Tripoli between oil operators and the Organization of Petroleum Exporting Countries (OPEC). Despite this increase the oil-producing countries pressed new demands for increased revenues and for local government participation in the ownership of the oil companies operating in their territories. These actions seem likely to lead to a greater control of oil exports by the producing countries and further sharp increases in oil prices in the major consuming nations.

One of the most significant steps in nuclear power development in recent years was the announcement on Jan. 14, 1972, by U.S. Atomic Energy Commission (AEC) chairman James R. Schlesinger that the nation's first large-scale nuclear fast breeder electric power plant would be

Novosti from Soviet



constructed in Tennessee. Since the beginning of the nuclear age, scientists have recognized the need for fast breeder reactors. Such a plant will produce more fissionable fuel than it consumes, in contrast to presently developed nuclear plants that consume approximately twice as much fuel as they produce. President Nixon stated in his energy message that "Our best hope today for meeting the Nation's growing demand for economical clean energy lies with the fast breeder reactor." Not until 1972 had the breeder program progressed enough to warrant a large-scale demonstration plant.

During 1971, environmental concerns remained a major issue in the U.S. and other highly industrialized countries. New environmental protection regulations and measures taken to control pollution increasingly influenced the fuel and power industries, placing constraints on traditional methods of producing, processing, transporting, and using fuels and power.

Scientists in 1972 generally recognized that no fuels or forms of energy were entirely "clean" within existing technologies and that "zero pollution" was not a realistic expectation. The production and use of energy involved many activities that inherently affected the environment adversely, and current technologies were simply not capable of providing the ultimate environmental protection desired. Nevertheless, acceptable pollution limits could be attained through improvements in the production and consumption of fuels. Such improvements would result in an increase in the cost of power to the consumer. Thus, the consumer's need for reliable supplies of adequate and reasonably priced energy had to be balanced with attainable and affordable environmental quality objectives.

As a result of a federal appeals court decision in the Calvert Cliffs (Md.) nuclear power plant case, a decision critical of the plant's environmental protection policies, the AEC issued drastically revised rules for assessing the total environmental impact of nuclear power stations. The AEC assumed full responsibility for evaluating all environmental effects from the nuclear plants and all alternatives for producing electric power prior to issuance of construction permits and operating licenses.

Prior to this decision, the AEC had placed most consideration on radiological effects and had relied on other state and federal agencies for advice on other environmental matters. The new regulations were expected to delay licensing of nuclear plants under construction by as much as one to two years.

Other significant developments affecting fuel and power in the year under review included: (1) world petroleum consumption reached record highs, but a general slowdown in economic expansion limited the gain to about half that of recent years; (2) new large oil discoveries in the North Sea confirmed that area as a major oil province; (3) the discovery of natural gas off Nova Scotia was the first commercial hydrocarbon discovery along the east coast of the North American continental shelf; (4) U.S. crude oil production in 1971 declined for the first time since 1961; (5) international shipments of liquefied natural gas (LNG) expanded rapidly as the U.S. and other highly industrialized countries sought new gas sources; (6) despite a slowdown in gas demand in 1971, the natural gas supply situation in the U.S. continued to worsen; (7) U.S. coal production in 1971 declined by 7% as a result of a six-week labor strike; (8) the number of fatalities and their frequency rate in U.S. bituminous coal mines were at an all-time low in 1971; (9) world electricity demand continued to pace energy demand at an extraordinary rate; and (10) there was a continued strong upsurge throughout the world in new orders for nuclear electric power generation units.

Engineers weld sections of the Yakutsk-Pavrovsk gas pipeline in the Soviet Union, the northernmost pipeline of its kind in the world. A 148-km (92 mi) sector of the snakelike structure rests on special pile supports aboveground.



Tass from Sovfoto

Petroleum and natural gas

Throughout 1971 and early 1972, the world petroleum and natural gas industry was confronted with lower growth rates, new economic and political initiatives by the large oil-exporting countries, growing environmental constraints, and greater challenges to develop resources in difficult operating regions so as to diversify supply sources. In the U.S., domestic oil production declined, petroleum product and natural gas demand growth rates slowed sharply, oil and gas prices increased, and environmental constraints increasingly deterred and restricted petroleum exploration and development activities.

Worldwide oil production averaged almost 48 million bbl daily in 1971, only about 5.4% more than that of 1970 and considerably less than the average growth rate over the past decade of nearly 8%. Crude oil production in the U.S. fell in 1971 by about 1% to a little more than 9.5 million bbl per day. Even so, the U.S. continued as the world leader in crude oil production, although its share of the world total steadily declined from 32% in 1961 to 20% in 1971. The Soviet Union followed as the second largest producer, accounting for about 16% of world supply. Iran and Saudi Arabia ranked third and fourth, respectively.

U.S. consumption of petroleum products averaged just under 15 million bbl daily, an increase of only 2.4% over that of 1970. Consumption in the rest of the world of about 33 million bbl daily was only 5.3% higher than the previous year. These gains were only about half the annual growth rates of recent years. The lower rates of gain in 1971 were attributed to a general slowdown in world economic expansion and to milder weather in the major consuming areas throughout 1971.

In concerted and individual actions the major oil-exporting nations of the world exerted economic and political pressures to obtain greater benefits and control over oil concessionaires operating in their territories. Most negotiations were conducted under the auspices of the Organization of Petroleum Exporting Countries (OPEC), an 11-nation group comprising 6 Persian Gulf area states plus Indonesia, Nigeria, Algeria, Libya, and Venezuela. OPEC controls approximately 90% of the world's oil reserves and exports. .

The international oil and gas industry continued exploration efforts throughout the world and succeeded in finding or extending new reserves. The discovery of three potentially large oil fields in the British sector of the North Sea confirmed this area as a major oil province. The first production from large oil fields in the Norwegian sector of the North Sea was initiated in August 1971. Estimates by industry sources indicated that in 1972 known oil reserves were sufficient to support production of one million barrels daily from the North Sea. The major impediment to development was the lack of adequate drilling equipment to operate in the turbulent sea and drill in water depths up to 400 ft.

Other notable exploration successes were registered in offshore Indonesia, where oil production began in 1971. Large new gas reserves were discovered in the Canadian Arctic. The first commercial discovery off the east coast of North America was the announced natural gas find on Sable Island off Nova Scotia. An oil find in the Mediterranean near Spain, a large new oil discovery in Egypt, another giant oil field found in Saudi Arabia, and more new discoveries in Ecuador were among the more significant events of 1971.

The U.S. petroleum industry waged a losing battle in its efforts to expand domestic producing capacity to meet rising demands. Although domestic production neared capacity, 1971 crude oil production actually declined below that of 1970 by 90,000 bbl per day to an average of 9,545,000 bbl daily. Environmental considerations continued significantly to forestall development of oil and gas resources in the most oil-rich regions of the U.S.—Alaska and the outer continental shelf.

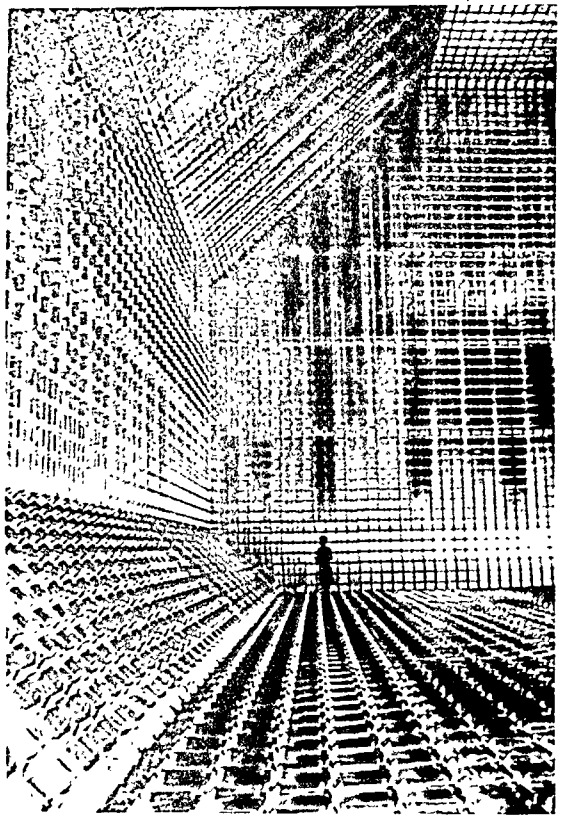
Construction of the trans-Alaska pipeline remained at a standstill as efforts to resolve environmental objections continued. The U.S. Congress passed a bill settling Alaskan native claims, thereby resolving one major problem. As a prerequisite for obtaining a permit for construction of the pipeline, the U.S. Department of the Interior prepared and filed an environmental impact statement for a federal court, in compliance with the National Environmental Policy Act of 1970. Environmental groups were expected to appeal any decisions that would allow issuance of the permit.

A general lease sale of federal outer continental shelf lands offshore of Louisiana, scheduled for Dec. 21, 1971, was cancelled because of court injunctions against the sale obtained through the efforts of three environmental groups. They argued successfully that the required environmental statement was inadequate in its consideration of alternate energy sources.

As a result of these conditions, the U.S. was expected to increase its reliance on foreign oil imports. In 1972 these already provided 25% of the required supply.

Marketed production of natural gas throughout the world amounted to an estimated 40 trillion cu ft in 1971. U.S. production accounted for 57% of this total. Based on gross withdrawals, the world marketed production of natural gas amounted to about

Courtesy, Gazocean



Stainless-steel tank in the hold of the tanker "Descartes" is one of six in ship, which can transport 1,100,000,000 cu ft of liquid natural gas at −259° F. Experts predicted that by 1976 such tankers would be bringing natural gas to the U.S. from such remote areas as Siberia.

70% of producing capacity. The major supply centers were remote from large consuming countries, and inadequate transportation facilities precluded the full utilization of this clean fuel. Few industrial nations had adequate indigenous gas supplies and thus were net importers of natural gas. Pipelines transported most of the gas sold across national boundaries, but LNG continued to grow rapidly as a means of processing and transporting gas in international trade. During 1971, LNG plants were operating in Algeria, Libya, and Alaska, and ten special tankers regularly delivered LNG to European, Japanese, and U.S. markets. The international shipments of LNG in 1971 amounted to 250,000,000,000 cu ft.

In 1971, the U.S. demand for dry natural gas was about 22.1 trillion cu ft, accounting for one-third of the nation's total gross energy consumption. The 1971 demand was only 3.4% more than that of 1970 and was considerably less than the average annual growth rate of 5.8% during the period from 1961 to 1971. Milder weather, a slowdown in the general economy, and limited availability of new gas supplies for some markets were responsible for the sharp decline.

Despite the slowdown in gas demand in 1971, the domestic natural gas supply situation in the U.S. continued to worsen. Consumption continued to exceed the replacement of new gas reserves. Paradoxically, it was reliably estimated that there were large natural gas resources remaining to be discovered and developed in the U.S. According to producers and developers of gas resources, they would remain undiscovered because regulated wellhead prices of gas were inadequate to attract the risk capital necessary for increased natural gas exploration and producing ventures. In an attempt to alleviate this situation the U.S. Federal Power Commission (FPC), the regulator of prices in interstate gas markets, changed its area wellhead pricing rules and took other steps that increased average domestic wellhead prices by 8.4% in 1970 and 6.6% in 1971. But even with the FPC action many producing, gas transmission, and distribution companies maintained that greater price increases were needed.

Expanded domestic natural gas development appeared to be essential to fulfill the expected rising demands of the mid- and late 1970s. If economic incentives prove inadequate, more gas shortages are expected to occur. Alternate sources of supply, such as overland imports from Canada, LNG, and synthetic gas from coal or oil, were not considered adequate supplements to meet fuel demands for gas in the near future.

Nevertheless, the use of synthetic gas as a high-cost supplementary gas supply was growing. Plans were announced for the proposed construction of approximately 20 plants for the conversion of coal, naphtha, and other hydrocarbons to gaseous fuels. The chief detriments to synthetic gas development were that conversion technologies were not perfected and the cost of such gas was very high.

Coal

Coal continued to be a major energy source in 1971, with worldwide production and demand estimated to be slightly in excess of 3,000,000,000 tons. Production was centered in eight countries that accounted for more than 80% of the total output. These included the Soviet Union, the U.S., China, East and West Germany, Poland, the United Kingdom, and Czechoslovakia. The U.S. continued to account for about one-fifth of the total output.

Production of bituminous coal and lignite in the U.S. reached only 560 million tons in 1971, 7% less

than that of 1970. The decline was the result of a six-week strike that shut down most of the U.S. coal industry in the fall. Despite the strike, domestic coal consumption of about 504 million tons was off by only 2.5% from 1970. Coal's most important market, electric power generation, actually increased consumption by about 3.3% to 331 million tons. U.S. coal exports were affected by the strike and by a general slackening of world economic activity. Coal and coke exports declined to an estimated 59 million tons, valued at about $950 million.

Coal in 1972 was the most abundant fossil fuel resource in the U.S., with reserves adequate for centuries at current levels of consumption; however, its combustion was the major source of air pollution from stationary sources. It was essential that new or improved technologies be developed for removal of sulfur dioxide and other pollutants either prior to or after combustion so that coal could make its proper and necessary contribution to future energy needs. Technologies for the removal of sulfur and other harmful contaminants from stack gases, and conversion processes for producing clean synthetic gases or liquids from coal were known but had to be made more efficient and less costly. In his energy message, President Nixon recognized this urgent need and announced high-priority programs and increased funding for research to speed up the time when those technologies become a commercial reality.

The U.S. Bureau of Mines greatly expanded its coal mine inspection and enforcement activities, and the coal industry made considerable progress in complying with the Coal Mine Health and Safety Act of 1969. The number of fatalities and their frequency rate in bituminous coal mines reached an all-time low in 1971. Although there were 177 fatal injuries, this was 78 less than in 1970. The frequency rate of fatal injuries in 1971 was 0.76 per million manhours, a drop of 27% from that of 1970. In addition, four miners lost their lives in anthracite coal and mine accidents in 1971.

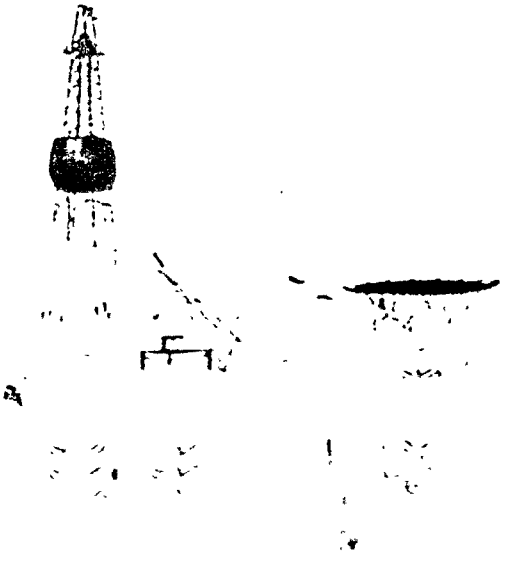
Electric power

World demand for electrical energy continued to grow at an extraordinary rate, nearly double that of energy as a whole. It was estimated that world electricity consumption reached 5 trillion kw-hr in 1971. The U.S. led all nations in power consumption, accounting for more than one-third of the total. In 1971, net electricity generation by the U.S. electric utility industry was an estimated 1,610,000,000,000 kw-hr, a gain of 5.4% over the 1970 output.

Electricity is a secondary form of energy that requires the conversion of a primary source into power by a generation process. In 1972, about 82% of the electricity in the U.S. was generated in fossil-fueled thermal plants; 16% was from falling water in hydroelectric plants; and only about 2% was from nuclear power plants. Insignificant quantities were

Oil drilling rig stands in the North Sea, where potentially large oil fields were recently discovered. In 1971 production began from wells in the Norwegian sector of the sea in spite of difficulties presented by considerable turbulence and by water depths of 400 ft

Courtesy, Standard Oil Co. (N.J.)



generated from geothermal steam, wind, solar, and tidal energy sources. The thermal conversion (of heat energy into electric power) was costly in terms of primary fuels because it was accompanied by a great loss of heat energy. The thermal efficiency of the best power plants in 1972 was only about 40%.

The types of nuclear power plants in use or under construction utilized only 1 to 2% of the thermal energy released from the nuclear fuel. This figure was not expected to improve materially until the so-called fast breeder reactors became a reality. Fast breeder reactors are technically feasible concepts. When perfected for commercial use, each reactor will be capable of producing enough excess fissionable fuel in a period of 7 to 10 years to sustain itself and also fuel another reactor of similar size. In his energy message, Nixon increased the funding for the AEC program to demonstrate the commercial feasibility of a fast breeder reactor by 1980. To achieve this goal, AEC chairman James R. Schlesinger announced on Jan. 14, 1972, a joint industry-government plan to build the nation's first fast breeder prototype power plant.

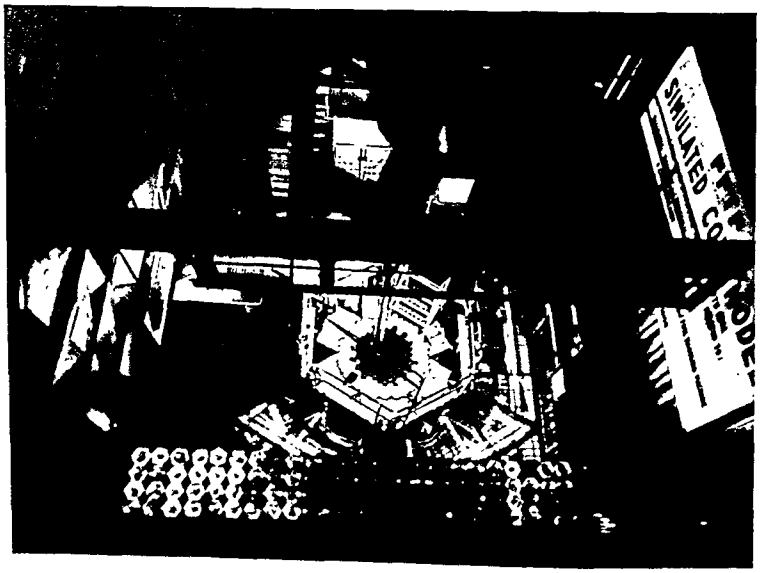
The breeder demonstration plant was to be built at a site to be selected in Tennessee and would be operated by the publicly owned Tennessee Valley Authority (TVA). The AEC and Commonwealth Edison Co. of Chicago were to manage the project. The U.S. government was to provide $200 million of the anticipated total cost of about $500 million for the plant, the rest to be paid by the major U.S. electric utility companies, which by mid-1972 had pledged $240 million for the project. Construction was expected to begin in early 1973.

Despite the small contribution of nuclear power plants to electricity output to date, the expected growth in nuclear generation was the most important change anticipated in the history of thermal power generation. Assuming that expectations are realized in the construction of reactors of the light water and high-temperature gas types and in the development of fast breeders, nuclear power will become the predominant method of electricity generation before the end of the century. A long-range project that could lead to the production of vast amounts of electric power is the effort to achieve controlled nuclear fusion. (*See* Feature Article: NUCLEAR FUSION, POWER SOURCE OF THE FUTURE?)

At the end of 1971, there were 23 nuclear units having a total generating capacity of 10,000 Mw in commercial operation in the U.S. An additional 54 units were being built, and orders had been placed for 52 more units. All of these units added up to a total generating capacity of 107,000 Mw, or about one-third of the present U.S. generating capacity. The total nuclear capacity and planned construction in all countries outside the U.S. was approximately equivalent to that of the U.S.

Outlook

The outlook for fuels and power in 1973 is that it will continue to be of major concern and command high-priority attention from the leaders of the world's industrial nations. The matters of greatest interest will involve the reliability and security of fuel supplies, especially those involving petroleum sources; the resolution of environmental and eco-



Courtesy, Battelle-Northwest Photography

Mock-up shows the Fast Flux Test Facility, an experimental liquid-metal fast-breeder reactor being built in Richland, Wash. Present projections indicate an exhaustion of fossil fuel reserves within several generations; thus, alternate energy sources must be developed. The fast-breeder reactor, when perfected, will be able to provide an essentially inexhaustible, economic supply of energy.

logical conflicts arising from fuels and power production and usage; and the technological achievements or progress that may ensue from the greatly expanded research and development efforts that have been announced or initiated.

Among the most probable specific developments that can be expected to occur in 1973 are the following: (1) total world energy demand growth rates will rebound in response to improved general economic conditions in the major industrialized countries; (2) U.S. domestic petroleum and natural gas production rates will increase to new highs as demands resume higher growth rates; (3) governmental actions to conform to more strict environmental constraints on fuels and power generation will be implemented, especially in relation to air pollution standards, leasing of federal lands for mineral fuel development, and nuclear plant operations; (4) the environmental review prescribed by the new AEC regulations will delay by one to two years the start of operations of nuclear power plants under construction in the U.S.; (5) the U.S. will begin construction of its first fast breeder nuclear demonstration plant, its most important recent step in the development of nuclear reactor technology; and (6) the first substantial results of expanded research to develop coal conversion technologies should be reported.

—James A. West

Honors

The following major scientific honors were awarded during the period from July 1, 1971, through June 30, 1972.

Aeronautics and astronautics

Robert J. Collier Trophy. Established in 1912 by the Aero Club of America and presented annually by the National Aeronautic Association, the Collier Award is given in recognition of great achievement in aeronautics or astronautics in America. The 1971 trophy was awarded to the three Apollo 15 astronauts, David R. Scott and James B. Irwin of the team that explored the moon's surface, and Alfred M. Worden, pilot of the command module. A fourth co-recipient was Robert R. Gilruth, director of the Manned Spacecraft Center at Houston, Tex.

Langley Medal. In 1908 the Smithsonian Institution established the Langley Medal in memory of Samuel Pierpont Langley, an early pioneer in the physics of flight and secretary of the Smithsonian from 1887 until 1906, for the purpose of honoring a scientist who had conducted especially meritorious investigations in connection with the sciences of aeronautics and astronautics. Previously awarded only 11 times, the honor in 1971 went to Samuel C. Phillips of the United States Air Force, who was chosen for his outstanding contributions as director of the National Aeronautics and Space Administration's (NASA's) Apollo manned spacecraft program from 1964 through 1969.

Astronomy

Helen B. Warner Prize. The American Astronomical Society each year presents the Helen B. Warner Prize in recognition of a significant contribution to astronomy made during the preceding five years by an astronomer under the age of 35. The 1971 award was presented to Kenneth Kellermann, a radio astronomer at the National Radio Astronomy Observatory, Charlottesville, Va. Kellermann was honored for his interpretation of the evolution of radio sources, and for his work on high-resolution radio interferometry and on radio emission from planets and stars.

Henryk Arctowski Medal. An award for studies of solar activity, the Henryk Arctowski Medal is bestowed approximately every three years by the National Academy of Sciences and consists of a gold medal and honorarium of $5,000. The 1972 recipient of the award was Francis S. Johnson, director of the Southwest Center for Advanced Studies at the University of Texas at Dallas. Johnson was cited for his pioneering work in the physics of high atmosphere and space. Especially noted was his description of how atmospheric transport processes regulate their response to changes in solar activity as well as to changes in season.

James Craig Watson Medal. The National Academy of Sciences presents approximately every three years the James Craig Watson award, consisting of a gold medal and a $2,000 honorarium for achievements in astronomical research. The 1972 medal was presented to André Deprit, a National Research Council postdoctoral resident research associate at the NASA Goddard Space Flight Center, Greenbelt, Md., for his adaptation of modern computing machinery to algebraic rather than arithmetical operations. His work solved in general terms a problem of lunar theory that concerns the motion of the moon around the earth as affected by the gravitational force of the sun.

Kepler Gold Medal. Co-sponsored by the geology and geography section of the American Association for the Advancement of Science and the Meteoritical Society, the Kepler Gold Medal awards for 1971 were presented in honor of the 400th anniversary of the birth of Johannes Kepler, the German mathematician and astronomer. Six scientists received the gold medal and certificate for

their outstanding contributions to the understanding of the origin of the solar system and the planets: (1) Hannes Alfvén (see *Franklin Medal*, below), visiting professor at the University of California, San Diego, who was cited for past work in the development of magnetohydrodynamics, and recent studies of the role plasmas played in the evolution of the planets. (2) Gerard Kuiper, professor of astronomy and director of the Lunar and Planetary Laboratory at the University of Arizona, who was honored as one of the few 20th-century scientists credited with creating the new discipline of planetary science. Kuiper discovered the atmosphere on Titan, a satellite of Saturn (1944); measured the CO_2 atmosphere of Mars; and conducted research on the meteorology of Jupiter. (3) Harold Urey, a professor at the University of California, San Diego, who was cited in particular for his work on the general formulation of the problem of the origin of the planets.

Also receiving the award were: (4) Fred Whipple, director of the Smithsonian Astrophysical Observatory, for his leadership of the observatory and of the High Altitude Rocket Research Panel in 1946, and for his research into the role of meteors and comets in the evolution of the solar system; (5) E. J. Öpik, of the Armagh Observatory in Northern Ireland, in recognition of his study of the interaction of meteorites and the atmosphere, hypersonic collisions in the solar system, the role of dust grains in planetary and interstellar space, the applications of terrestrial physics to the elucidation of the nature of the surfaces and atmospheres of the planets, and the way in which changes in the sun's atmosphere can influence the climate; (6) Boris Levin of the U.S.S.R. Academy of Sciences, for his work as an astronomer, solar-system astrophysicist, and cosmochemist, with the ability to reach beyond the boundaries of the discipline in which he was trained to achieve an understanding of the origin of the planets. Levin's major research covered meteors and the preatmospheric nature of interplanetary particles, comets, and asteroids; the physical and orbital properties of meteorites; and the structure, thermal history, and surface evolution of the moon.

Biology

Institute of Life Prize. Made possible by a donation from the French electricity system, the Institute of Life Prize consists of a $50,000 monetary award which is to be given to a scientist for outstanding contributions to the life sciences. The first prize, presented in 1972, was received by René Dubos, retired microbiologist of Rockefeller University in New York City, who was cited for his work concerning environmental problems. Dubos was quoted as having pledged to use the prize money for furthering his commitment to finding out "what human environment really means."

Louisa Gross Horwitz Prize. Established in 1967 by the College of Physicians and Surgeons of New York, the Louisa Gross Horwitz Prize is administered by Columbia University and is awarded annually to recognize outstanding basic research in biology or biochemistry. The 1971 prize of $25,000 was awarded to Hugh E. Huxley, a fellow of Churchill College, Cambridge University, who was cited for his studies that revealed the chemical mechanism of muscle contraction. Huxley's "sliding filament hypothesis" proposed that thick and thin filaments, sliding past one another, could form bridges that provide the basis for the weight-bearing capacity of contracting muscles.

U.S. Steel Foundation Award in Molecular Biology. Administered by the National Academy of Sciences, the U.S. Steel Foundation Award may be given annually for a recent discovery in molecular biology by a young scientist. The 1972 award with its honorarium of $5,000 was presented to Howard M. Temin, Wisconsin Alumni Research Foundation Professor of Cancer Research at the University of Wisconsin McArdle Laboratory for Cancer Research in Madison, Wis. Temin was cited for his work in the experimental demonstration that showed some cancer viruses transfer genetic information by a reverse process. This demonstration contradicted the older theory that the transference is only a one-way process, and could lead to a greater understanding of the mechanisms that cause cancer.

Chemistry

ACS Award in Pure Chemistry. Sponsored by Alpha Chi Sigma Fraternity, the $2,000 American Chemical Society's Award in Pure Chemistry is given to recognize and encourage fundamental research in pure chemistry carried out by a U.S. or Canadian citizen. The 1972 award was received by Roy Gerald Gordon, professor of chemistry at Harvard University, who was cited for his many contributions to the field of theoretical chemistry. Gordon has advanced numerous new approaches in quantum mechanics, statistical mechanics, scattering theory, and spectroscopy in order to secure new information concerning the shapes and strengths of intermolecular forces.

Beilby Medal. Representing the Royal Institute of Chemistry, the Society of Chemical Industry, and the Institute of Medals, the Sir George Beilby Memorial Fund administrators made an award of the medal and £100 prize from the fund in 1971.

Courtesy, Harvard University News Office



George Kistiakowsky

That year's recipient was John Howard Purnell, dean of the Faculty of Science at the University College of Swansea, Wales, for his research in physical chemistry, pertaining particularly to his studies of hydrocarbon pyrolysis, and to the application and development of gas chromatography. Purnell and his associates extended certain findings of their prior academic studies of alkane systems to problems connected with industrial hydrocarbon cracking processes and olefin production. Purnell pioneered in the application of the gas chromatographic method to the measuring of physical properties of molecules, and in the study of solution and liquid surface thermodynamics.

Garvan Medal. The American Chemical Society presents each year the Garvan Medal, an award established in 1936 and consisting of a gold medal and a $2,000 honorarium, to a U.S. woman chemist selected for her distinguished service to chemistry. The 1972 winner of the award was Jeanne M. Shreeve, professor of chemistry at the University of Idaho, for her contributions to the fundamental understanding of the behavior of inorganic fluorine compounds, and to the synthesis of important new fluorochemicals. Among Shreeve's earlier research accomplishments were the discovery of the compound perfluorourea, an oxidizer ingredient, and new methods of synthesizing several important compounds including chlorodifluoroamine and difluorodiazine, both used to synthesize rocket oxidizers.

Nobel Prize for Chemistry. The Swedish Royal Academy of Sciences chose Gerhard Herzberg of Ottawa, Ont., as the recipient of the 1971 Nobel Prize for Chemistry. Herzberg, a retired scientist at the National Research Council of Canada, was cited for his contributions to the knowledge of electronic structure and geometry of molecules, particularly fragments of molecules, known as free radicals. The physicist's laboratory was also cited as the foremost molecular spectroscopy center in the world. Herzberg's synthesizing of numerous techniques and theories, which led to the uncovering of structures and characteristics of diatomic and polytomic molecules and of classic free radicals (methyl [CH_3] and methylene [CH_2]), contributed greatly to the development of chemistry.

Priestley Medal. The American Chemical Society's Priestley Medal, established in 1922 and considered the highest honor in American chemistry, is bestowed in recognition of distinguished services to chemistry. The 1972 recipient was George Kistiakowsky, associated with Harvard University for more than 40 years. An authority on explosives, shock waves, thermodynamics, and rates of chemical reactions, he was cited for his more than three decades of service to the U.S. government. Kistiakowsky was head of the explosives division of the National Defense Research Committee (1940), chief of the explosives division of the Los Alamos Scientific Laboratory (1944), and a member of the Science Advisory Board of the Air Force until 1957. From 1959 through 1961 he was science adviser to U.S. Pres. Dwight D. Eisenhower and then served (1962–68) as first chairman of the National Academy of Sciences Committee on Science and Public Policy. From 1965–69 he was vice-president of the Academy.

UPI Compix



Gerhard Herzberg

Wide World



Earl W. Sutherland, Jr.

S. Yoder, Jr., a petrologist and first director of the Geophysical Laboratory of the Carnegie Institution of Washington, D.C., who was cited for developing an apparatus that enabled scientists to investigate a wide range of phenomena within the earth's crust. Yoder's investigations dealt with the properties of minerals and rocks, synthetic and natural, at high pressures and temperatures.

Charles P. Daly Medal. The American Geographical Society of New York intermittently presents the Charles P. Daly Medal for valuable or distinguished geographic services or labors. In 1971 the award was made to Gilbert Fowler White, professor of geography and director of the Institute of Behavioral Science at the University of Colorado. Research, administration, and public service all figured in White's career.

In research three fields were of interest to him: arid lands, water resource allocation, and natural hazards. White's public service covered membership on the National Resources Planning Board and work in the United States Bureau of the Budget. He was president of Haverford College, in Pennsylvania for ten years (1946–55) and served as chairman of the American Friends Service Committee from 1963 until 1969.

Cottrell Award. Established by the Research-Cottrell Inc., the $5,000 Cottrell Award is to be given annually for outstanding scientific or technical achievement in improving the environment or controlling pollution. First awarded in 1972, it was presented to Arie J. Haagen-Smit, emeritus professor of bio-organic chemistry of the California Institute of Technology, who was cited for his highly innovative studies on the formation of smog, and for his untiring efforts to shape the air pollution control policies of the nation. Haagen-Smit began his studies in the 1940s (long before pollution became a household word) when he undertook the examination of the chemical composition of the polluted atmosphere and its effects on plant life in the Los Angeles basin.

International Meteorological Organization Prize. The World Meteorological Organization's 16th prize was awarded in 1971 to Jule G. Charney, professor of meteorology at Massachusetts Institute of Technology. Charney was cited for his "outstanding contribution to dynamical meteorology, his furtherance of research especially in numerical methods of weather prediction, and his services to the cause of international cooperation in the science of the atmosphere."

Massey Medal. The Royal Canadian Geographical Society annually presents the Massey Medal, established in 1959, for recognition of outstanding personal achievement in the exploration, development, or description of the geography of Canada. The 1972 silver medal was presented to Isobel Moira Dunbar, geographer with the Canadian Defense Research Board, for her work on Arctic ice studies. Dunbar contributed important new knowledge on ice distribution and the interpretation of ice in photographs, including both satellite and infrared photography.

Medical sciences

Albert Lasker Medical Research Awards. The Albert and Mary Lasker Foundation each year presents a number of prizes for medical research. The 1971 Albert Lasker Clinical Research Award with its $10,000 honorarium was given to Edward D. Freis, senior medical investigator at the Veterans Administration Hospital in Washington, D.C. Fries was honored for a five-year study demonstrating that moderately high blood pressure, though producing no symptoms, could be still dangerous and that proper treatment could reduce greatly the high risk of stroke and heart failure.

Three recipients of the Albert Lasker Basic Medical Research Award shared the $10,000 prize: Seymour Benzer of California Institute of Technology, Sydney Brenner of the University of Cambridge in England, and Charles Yanofsky of Stanford (Calif.) University. The three geneticists pioneered in demonstrating that inherited characteristics in all living things are coded molecule by molecule along strands of deoxyribonucleic acid (DNA) and that messages are "read" to produce specific protein molecules.

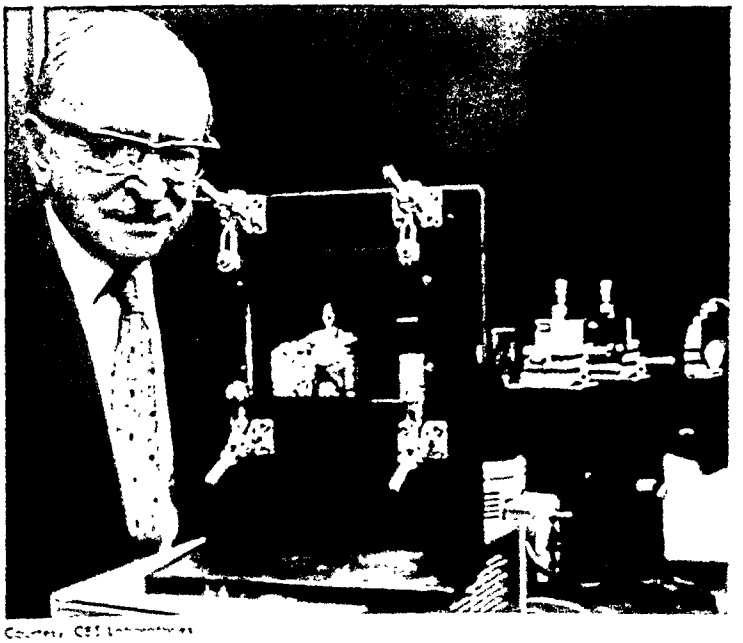
NAMH Research Achievement Award. Established by the National Association of Mental Health, the Research Achievement Award was to be presented annually at the beginning of May, National Mental Health Month. Chosen in 1972 for the first $10,000 award was Seymour Kety, a psychiatrist at Harvard University. Kety was cited for his contributions to the development of pharmaceutical approaches to the control of various types of mental illnesses, especially schizophrenia.

Nobel Prize for Physiology or Medicine. The Swedish Royal Caroline Medico-Chirurgical Institute awarded the 1971 Nobel Prize for Physiology or Medicine, amounting to $90,000, to Earl W. Sutherland, Jr., professor of physiology at Vanderbilt University, Nashville, Tenn. He was honored for his discoveries concerning the mechanisms of the action of hormones, chemical substances secreted by the glands and which influence the activities of various cells, tissues, and organs.

Sutherland's research led to the discovery of cyclic adenosine monophosphate, or cyclic AMP. This intermediary chemical substance proved to play an important role in the mechanisms by which hormones exert their control over various metabolic activities throughout the human body. A later discovery by Sutherland showed that the substances also occurred in bacteria, which opened the door on a whole new biological perspective.

Procter Medal. The Philadelphia Drug Exchange sponsors the Procter Medal, which is given in recognition of outstanding achievement that has benefited the health of the public and advanced the progress of the health professions in the pharmaceutical industry. The 1972 medal was bestowed upon Maurice R. Hilleman, director of virus and cell research for the Merck Institute for Therapeutic Research. Hilleman was honored for his contributions in the fields of etiological discovery, classification, laboratory diagnostics, epidemiology, public health, and clinical evaluation.

Dennis Gabor



Jay Scarpetti, courtesy, Polaroid Corporation



Edwin H. Land

Physics

Albert Einstein Award. Administered by the Lewis and Rosa Strauss Memorial Fund, the Albert Einstein Award is presented approximately every two years for achievement in the mathematical and physical sciences. The 1972 award of a gold medal and $5,000 honorarium was given to Eugene Paul Wigner of Princeton University for his outstanding contribution to the physical sciences.

Wigner, a co-winner of the 1963 Nobel Prize for Physics, was awarded also in 1972 the George Gamow Memorial Lectureship Award presented by the University of Colorado, in recognition for his contributions to the development of physics and to the elucidation of its fundamental concepts.

Enrico Fermi Award. The U.S. Atomic Energy Commission presents annually the $25,000 Enrico Fermi Award in recognition of outstanding scientific or technical achievement related to the development, use, or control of nuclear energy, and to stimulate creative work in the development and application of nuclear science. The 1972 award was made to two of the world's leading medical experts on radiation: Stafford L. Warren, emeritus vice-chancellor of health sciences at the University of California at Los Angeles, and Shields Warren, emeritus professor of pathology at Harvard Medical School. The Warrens (unrelated) were cited for having helped make possible the early development of atomic energy so as to assure the protection of man and the environment.

Franklin Medal. The Franklin Institute of Philadelphia presents its highest award, the Franklin Medal, annually for recognition of those workers in physical science or technology whose efforts have done most to advance a knowledge of physical science or its application. The 1971 award was presented to Hannes Alfvén of the department of applied physics and information at the University of California, San Diego. Alfvén was cited for his pioneer work in establishing the field of magnetohydrodynamics and his many revolutionary contributions in that field to plasma physics, space physics, and astrophysics.

Ernest O. Lawrence Memorial Award. The U.S. Atomic Energy Commission in 1959 established the annual Ernest O. Lawrence Memorial Award to recognize five young scientists who have made recent, especially meritorious contributions to the development, use, or control of nuclear energy in areas of all the sciences relating to nuclear energy, including medicine and engineering. The 1972 awards, consisting of a gold medal and $5,000, were made to: (1) Charles C. Cremer, group leader of the theoretical design division of the Los Alamos (N.M.) Scientific Laboratory; (2) Sidney D. Drell, deputy director and executive head of theoretical physics at the Stanford (Calif.) University Linear Accelerator Center; (3) Paul F. Zweifel, professor of physics and nuclear engineering at Virginia Polytechnic Institute; (4) Marvin Goldman, radiobiologist at the University of California at Davis; and (5) David A. Shirley, chairman of the chemistry department at the University of California at Berkeley.

Cremer was honored for his contributions to the development of weapons design codes; Drell for his theoretical investigations of the range of validity of quantum electrodynamics; and Zweifel for his contributions to the slowing down and thermalizing of neutrons, important to the design and develop-

ment of water-moderated reactors. Goldman was recognized for his contributions as a radiobiologist, and Shirley was cited for his contributions to the understanding of the chemical nature of matter by his studies of the interactions of the nucleus with its electronic environment.

Nobel Prize for Physics. The Royal Swedish Academy of Sciences designated Dennis Gabor, Hungarian-born British scientist, as recipient of the 1971 Nobel Prize for Physics. He received the more than $87,000 award for founding the applied science of holography, a lensless, three-dimensional imagery system. Gabor, emeritus professor of applied electron physics at Imperial College of Science and Technology in London, and a staff scientist at the CBS Laboratories in Stamford, Conn., was an inventor with more than 100 patents, many of them relating to his work in holography.

Gabor began working on his optical system in the late 1940s as he searched for a way to improve the resolution of electron microscopes so that scientists could "see" a single atom. He named his new type of photography hologram for the Greek words *holos* (whole) and *gramma* (letter or message). With the development of laser light, holography became increasingly useful to researchers.

Science Journalism

Howard W. Blakeslee Awards. The American Heart Association presents its annual Blakeslee Awards, named in honor of an Associated Press science editor and founder of the National Association of Science Writers, for outstanding reporting on diseases of the heart and blood vessels. The 1971 awards, consisting of a citation and $500, were made to three reporters and two television stations. The reporters were Jane E. Brody of the *New York Times;* Harold J. Eager of the *Sunday News,* Lancaster, Pa.; and Rachel MacKenzie of *New Yorker* magazine. The TV stations were WHDH-TV of Boston, and WTAR-TV of Norfolk, Va.

James T. Grady Award. The American Chemical Society presents annually the James T. Grady Award for Interpreting Chemistry for the Public, with its $2,000 cash prize and a gold medal, to recognize, encourage, and stimulate outstanding reporting directly to the public, which materially increases the public's knowledge and understanding of chemistry, chemical engineering, and related fields. The 1972 award was given to Dan Q. Posin, professor of physical science and chairman of the department of interdisciplinary sciences at San Francisco State College. Posin authored a number of popular science books, including a biography, *Mendeleyev: The Story of a Great Scientist* (1948), and also wrote for newspapers. A noted television and radio personality, he has produced two TV series: "What's New" and "Dr. Posin's Universe."

Kalinga Prize. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) annually presents its Kalinga Prize, named for an ancient Indian empire of 2,000 years ago renowned for its policies of peace, for particular merit in the popularization of science in writing. In 1971 UNESCO made the award with its $2,400 stipend to Margaret Mead, the anthropologist, for her writing covering her life's work with the primitive cultures of the South Pacific.

Miscellaneous

Founders Medal. The National Academy of Engineering annually presents the Founders Medal, established in 1965, to honor outstanding contributions by an engineer both to his profession and to society. The 1972 recipient of the medal was Edwin H. Land, president and director of Polaroid Corp., who was cited for his development of cameras, films, and processes for instant photography, and for his invention of synthetic polarizers for light. During the 1940s Land worked on the idea of a hand-held camera that would use apparently dry film and would give a picture instantly. In 1947 he demonstrated the Polaroid Land camera, which became available a year later. One-step color photography followed some ten years afterward.

E. Harris Harbison Award for Gifted Teaching. The Danforth Foundation annually presents the E. Harris Harbison Award for Gifted Teaching, estab-

Howard M. Temin



lished in the early 1960s, to an outstanding teacher who has taught for at least five years in an accredited U.S. junior college, college, or university. The 1971 recipient of the $10,000 award, was John G. King, professor of physics at Massachusetts Institute of Technology. King, a leader in educational innovation and reform, was cited for his introduction of numerous new methods of teaching into his undergraduate classes, including approaches to concentrated study and "corridor labs."

Hoover Medal. The American Society of Mechanical Engineers, with several other professional engineering groups, presents the Hoover Medal, named for its first recipient, former U.S. Pres. Herbert Hoover, in recognition of outstanding engineers who have performed distinguished public service. The 1972 medal was given to Luis A. Ferre, an engineer and governor of Puerto Rico, who was cited for exemplifying an engineer-humanist's achievements in enriching the life of a people.

Information science and technology

In this era of rapidly expanding knowledge people must be selective in what they hear and read, and must rely more and more on systems that will store this information until it is needed. The problem is particularly acute for scientists and other specialists who have to locate specific information to carry on their work. Information science and technology is concerned with devising means for providing more efficient access to documents and improving the dissemination of information. To accomplish these tasks it is necessary to gather together large quantities of raw information and to process them into a form that is more easily transferable and usable. When these processing procedures are integrated into an efficiently functioning unit, the result is called an information system.

Since the information problem is worldwide, devising such systems was a matter of concern to most nations, as well as to many private organizations. Many countries and organizations provided support during the year for the development of information systems.

Coordinating information services. The Congress of the United States in July 1970 created the National Commission on Libraries and Information Science (NCLIS) as an independent agency within the executive branch of the government. In establishing NCLIS, Congress responded to the need for improving information services and for alleviating some of the problems faced by libraries throughout the country. During 1970–71 NCLIS spent most of its energies getting organized. In 1972, however, it undertook its first major study effort, which was to take the form of an overview of significant research affecting the library and information worlds. This study was designed to provide a proper base from which to plan future operations. In addition, NCLIS was expected to help coordinate the information activities of various federal and state agencies.

In the United Kingdom, the Office of Scientific and Technical Information (OSTI) supported various research studies and assessments of library and information needs. These included studies of the uses made by chemists of scientific news periodicals, of the design of library buildings and facilities, and of ways to promote the improvement of public library services.

In Canada, an Office of Library Coordination was organized by the Council of Ontario Universities to develop a wide range of cooperative activities among the provincially assisted university libraries in Ontario. This office was the result of several years of planning. Its aim was to provide a means for achieving close cooperation among the participating public libraries in order to provide better service to students, faculty, and staff.

Many other countries established similar national and regional centers for coordinating the collection and dissemination of scientific and technical information. Clearly, information was being recognized as a national resource, and efforts were being made to control and use it as efficiently as possible.

A world science information system. The exchange of information does not stop at national borders, and scientists of different countries have long cooperated in sharing knowledge and seeking the solutions to significant social problems. All of this has been done on a more or less informal basis, and a need exists for a more organized and equitable procedure for coordinating scientific studies and information.

In 1970 studies of the possibility of establishing a world science information system (code-named UNISIST) were begun. In the ensuing two years much progress was made. In October 1971, a UNISIST conference was convened in Paris under the sponsorship of the International Council of Scientific Unions and the United Nations Educational, Scientific and Cultural Organization (UNESCO). The conference was attended by 240 delegates representing 83 member and affiliated nations of UNESCO plus observers sent by many intergovernmental and nongovernmental organizations. On completing its discussions, the conference adopted a broad resolution supporting the creation of UNISIST and laid the foundation for a

voluntary world scientific and technical information system to help scientists and engineers gain access to the more than two million articles published annually in approximately 70,000 specialized journals. The plan called for the development of interconnected automated information systems. Thus, a center in Africa would be able to process on its computer information stored on tapes that had been produced in Europe or North America and immediately tell a researcher what material had been published in his field.

Many practical problems remained to be solved, but funds were allocated and plans for implementation were being prepared. Final approval still had to be given by the UNESCO General Conference, scheduled to meet late in 1972.

Library automation. One of the great contributions to information science and the dissemination of information was the MARC project (machine-readable cataloging) of the U.S. Library of Congress. This project recorded on computer tape bibliographic information for most current English-language books. Although the value of this project was recognized, not all libraries had access to the computer services necessary to process and retrieve MARC records. In 1972, however, the MARC-Oklahoma Data Base Storage and Retrieval Project went into operation. On request, it searched the complete MARC data base and provided individual libraries with bibliographic and cataloging data on only those books that they had acquired. Thus, smaller libraries were able to take advantage of the savings in time and money that computer processing of library records could provide.

MARC tapes were also being supplied to other countries. The Ontario College Bibliocentre in Canada was evaluating the benefits to be gained by using the tapes to provide a centralized and computerized selection, acquisition, processing, and cataloging service for 20 community libraries.

With the MARC program successfully underway, the Library of Congress began a new project called "Cataloging in Publication." Actually, the basic idea is not new; an experimental project called "Cataloging-in-Source" was undertaken in 1958–60. The results of this experiment demonstrated that although it was possible for the Library of Congress to catalog some books from page proofs before publication, the costs and the disruption of publishing schedules outweighed the benefits. But in 1972, as a result of new techniques, the project was revived.

The goal of "Cataloging in Publication" was to incorporate cataloging data, of the kind now found on library catalog cards, in the printed book at the time of publication. Catalogers at the Library of Congress would receive galley proofs of books from the publishers. They would then prepare cataloging information, including Library of Congress call numbers and Dewey classification numbers, and the publisher would incorporate the complete cataloging data in the book. This new service was expected not only to save processing costs for individual libraries but also to provide faster service for library users and even allow small private libraries and book collectors to arrange their holdings more efficiently.

Information dissemination systems. Since scientists generally are most in need of timely information, many of the professional scientific societies have responded by creating specialized information systems. Such systems exist in physics, chemistry, engineering, psychology, education, and medicine. During the year these systems expanded their services and new ones were being formed. The American Geological Institute approved the concept for a geosciences information system that was expected to lead to a more structured pattern of services for the Institute's 17 member societies.

The National Library of Medicine in 1972 introduced a new service called MEDLINE. Previously, hospitals, medical schools, medical libraries, and related research institutes had access to medical literature through an automated system called MEDLARS (Medical Literature Analysis and Retrieval System). In using MEDLARS, a physician or researcher would generally write or telephone a request for a search on a given topic to the National Library of Medicine in Washington. A week or longer would lapse before he would receive the results. Now, through MEDLINE, each user installation would have its own computer terminal connected to a centralized data processing system and would be able to search a large body of the more frequently used medical literature and receive listings of relevant citations in minutes.

The social sciences were also striving to improve access to the literature in their fields. One important study, completed late in 1971, was the compilation of an international registry of *Data Bases in the Social and Behavioral Sciences* under the auspices of the City University of New York Graduate Division. This effort was directed toward helping individual scientists locate files of relevant information outside their immediate specialty.

Frequently, after information dissemination procedures have been proven to be of value in the sciences, they are applied to other more general fields. For example, the Federal Bureau of Investigation (FBI) began operating a computer-based National Crime Information Center (NCIC) in 1967. By 1972 the Center stored more than three million records containing information about wanted

persons, stolen vehicles, license plates, and other property. Rigid safeguards were employed to insure the security and confidentiality of these files. The system was being expanded into a nationwide network and was expected to reduce the number of duplicate records now stored in local, state, and other federal agencies and thus save time, money, and manpower. But more importantly, it was hoped that the NCIC would result in more effective law enforcement.

The U.S. Postal Service was also undertaking an extensive automation project, known as the Letter Mail Code Sorting System (LMCSS). The old manual letter-sorting system required postal personnel to read each first-class envelope up to seven times before delivering it to the recipient. Using LMCSS, one would have to scan a letter manually only once, at which time the name and address would be recorded on the envelope in a code that a computer could read. After being coded, letters would be conveyed directly to a letter-sorting machine which would automatically sort them into a storage bin that represents a specified destination. When a letter reaches the post office at its destination, the code would again be used to sort the letters automatically by street and address into the sequence followed by the carrier as he makes his rounds. When fully operational, this system was expected to enable the post office to deliver more than 95% of all first-class mail within two days.

—Harold Borko

See also Year in Review: COMPUTERS.

Marine sciences

Increasing evidence of pollution, even in the deep oceans, was a source of continuing concern to oceanographers during the year. Government support of marine studies continued, and marine scientists obtained valuable data from these programs and also as a by-product of space exploration.

Pollution and ecology. The year was an active one on the ecology and pollution fronts. Delaware acted to protect its coastal wetlands. According to Gov. Russell W. Peterson, the people of Delaware "made a choice, and that was to use our valuable bay and coastal areas for recreation and tourism instead of for another purpose for which they are admirably suited, industrial growth." Connecticut's program to save its wetlands was also making progress. Pres. Richard Nixon proposed a wetlands protection measure as part of a general land-use planning proposition that would give priority to coastal areas. A thorough mapping of coastal wetlands was also planned.

Following six years of study, Canada and the United States signed a Great Lakes Water Quality Agreement to highlight an International Field Year for the Great Lakes. The agreement called for a dramatic reduction in the pollution of Lake Erie, Lake Ontario, and the international portion of the St. Lawrence Seaway. With the hope that their initiative would serve as a precedent for worldwide action at the United Nations Conference on the Human Environment in Stockholm in June 1972, 12 European nations signed a voluntary pact on Feb. 14, 1972, at Oslo, Nor., to bar dumping of harmful substances in a wide area of the Atlantic Ocean. The pact would take effect as soon as it was ratified by seven of the signatories.

Scientists were gathering the basic data on many aspects of the dispersion, removal, and recycling of pollutants by rivers, the atmosphere, and the oceans. At the annual meeting of the American Geophysical Union, V. J. Linnenbom and his colleagues reported that the Northern Hemisphere oceans contribute 60,000,000,000 kg of carbon monoxide gas to the atmosphere per year. If the Southern Hemisphere oceans contribute a comparable amount, the total is 140,000,000,000 kg per year, or about 60% of that produced by mankind's activities. Carbon monoxide is removed from the atmosphere in various ways, but these figures are important for a full understanding of the air pollution problem.

At the same meeting, R. A. Carr and J. D. Gassaway described the distribution of mercury in the oceans. Typical open ocean values range from 10 to 60 nanograms per liter (1 nanogram = 0.000,000,001 grams). Sea ice is a reservoir for mercury in the geochemical cycle. Other scientists reported on hydrocarbons in the ocean and their effects on estuaries, on mercury in the Columbia River, and on fluorides in Chesapeake Bay.

E. J. Carpenter and K. L. Smith, Jr., described finding about 3,500 plastic particles per square kilometer of surface in the Sargasso Sea. These particles could be the source of the polychlorinated biphenyls found recently in marine organisms. For example, DDT and polychlorinated biphenyls had been discovered in specimens of plant and animal life throughout the Atlantic Ocean by Woods Hole (Mass.) Oceanographic Institution ships. The full effects on the ocean environment of relatively indestructable plastic pellets, and the polychlorinated biphenyls that leach out of them, had yet to be assessed, however.

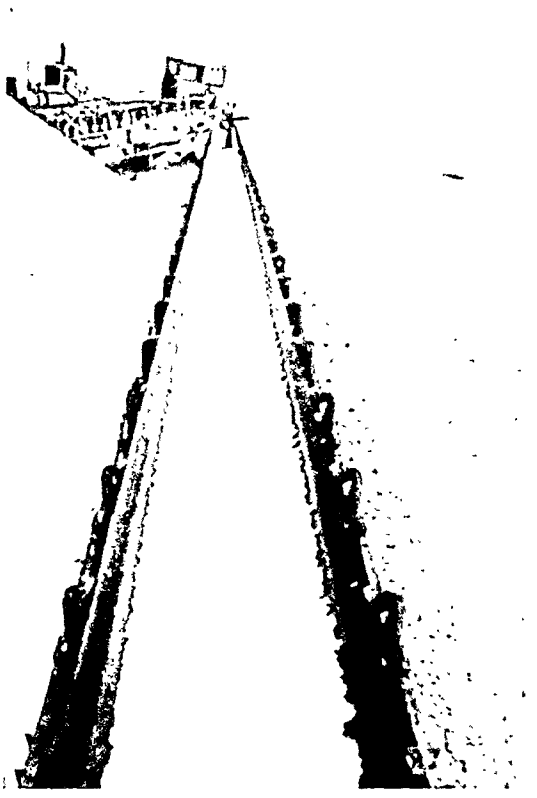
Oil, oil spills, cleanup techniques, and the effects of oil on marine life were the subjects of hundreds of studies and papers. At the Offshore Technology Conference in May 1972, for example, 28 papers were devoted to this problem. Ways to prevent

spills, to contain spills that have occurred, to clean them up, and to predict their movement were described.

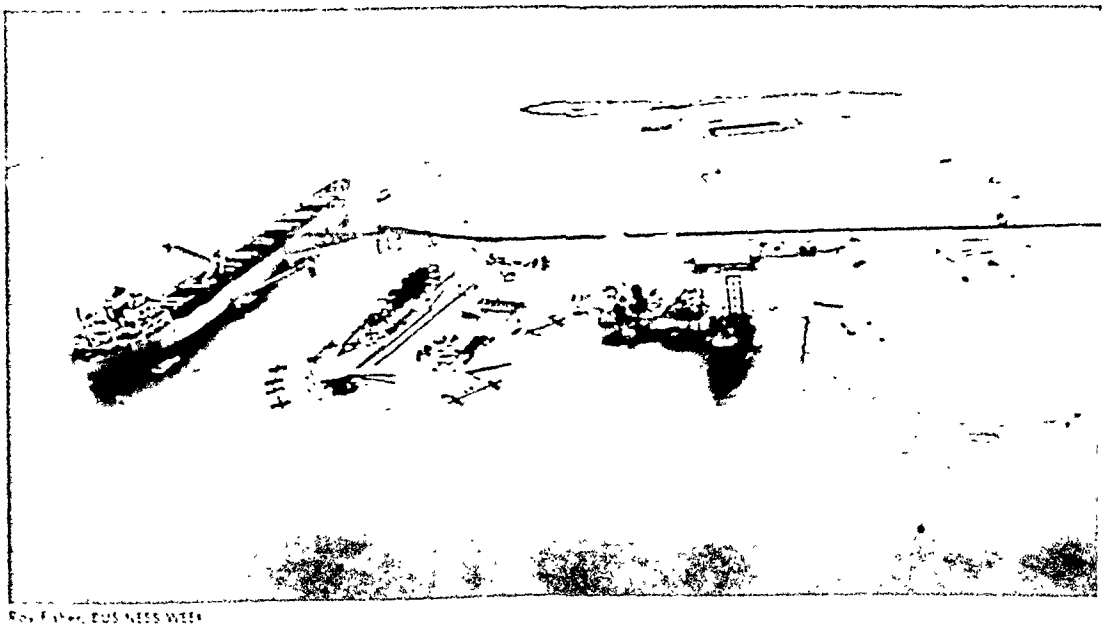
Most of the oil in the marine environment comes from the thousands of ships that clean their fuel tanks by steam and hot water and pump the resulting mixture overboard. The NATO countries agreed to end this practice in the near future but, in general, the outlook for stopping this source of pollution was not bright. The laws that provide penalties against ships discharging their wastes in this way are almost impossible to enforce. The breakup of a ship and the failure of an oil-drilling rig are dramatic examples of oil pollution, but their effects are really small compared with the cumulative results of such everyday practices.

Another practice with similar cumulative effects was identified as the source of 50% of the oil in Long Island Sound. When oil in an automobile is changed, the used oil, which was once collected and reclaimed, is now more often than not poured down a sewer. Oil disposed of in this way in any community near the Sound eventually ends up polluting its waters.

A more encouraging report came from Great Britain. The January 1972 *Marine Pollution Bulletin* reported changes in bird populations on the Thames River since it was cleaned up. Previously, the river had been virtually devoid of life except for hardy scavenging gulls. Now fish are found up-

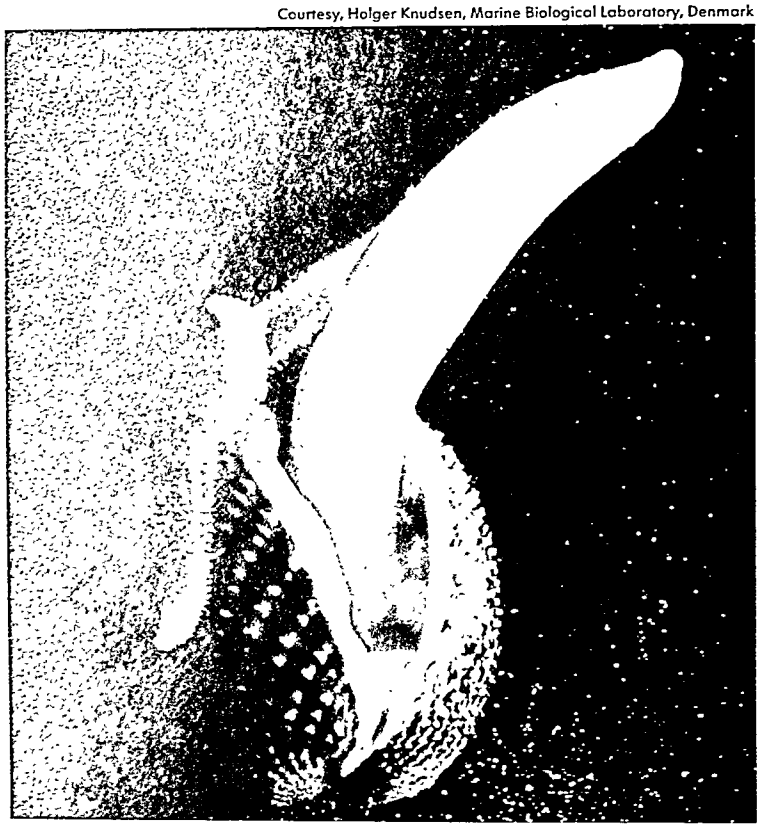


Aragonite, an unusually fine, pure form of limestone, is pumped from an ocean-bed site near the Bahamas and moved by conveyor (above) to a ship for delivery to customers (below) The high purity and uniformity of aragonite make it valuable for cement and glass making



Roy Fisher, BUSINESS WEEK

Courtesy, Holger Knudsen, Marine Biological Laboratory, Denmark



Sea creatures that normally move slowly exhibit lively responses when under attack. The cockle Cardium echinatum, *when touched by the sea star* Asterias rubens, *opens its shell, thrusts out its tubular foot, and, pushing violently against the substrate on which it is resting, jumps as much as 10 cm. It continues this maneuver until the predator is dislodged.*

stream as far as the environs of London and large numbers of migratory birds have returned. (*See* Year in Review: ENVIRONMENTAL SCIENCES.)

Expanding data and improved theories. Better data require improved theories to explain them. Improved theories require better data to check them out. The interaction of theory and data was underlined during the year in studies of the constancy of ionic proportions, continental drift, and the tides.

The theory that the major positively and negatively charged ions are in constant proportion in seawater goes back to a study of water samples collected by the "Challenger" oceanographic expedition of 1872–76 and analyzed in 1884 by C. D. Dittmar. As quantitative chemical analysis techniques became more exact, this concept was tested with ever increasing accuracy, sometimes with results that suggested it was not exactly true. R. C. Mangelsdorf, Jr., and T. R. S. Wilson reported on a study of 345 water samples from the Pacific Ocean along 150° W from 63° S to 54° N. Samples were compared with standards established from samples taken from the Sargasso Sea. No significant variations were found in the ratios of K^+ and Mg^{++} to Na^+, but Ca^{++} to Na^+ varied markedly and systematically, with the bottom water having more Ca^{++} relative to surface waters.

With the acceptance of the theory of continental drift, the questions of "which way" and "when" began to arise. After studying data obtained from the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) project and other data, W. C. Pittman III tentatively modeled the evolution of the North and South Atlantic. According to this model, Africa and North America began to drift apart 180 million to 200 million years ago. Africa and South America began to drift apart 139 million years ago, while Eurasia and North America started to separate only 80 million years ago.

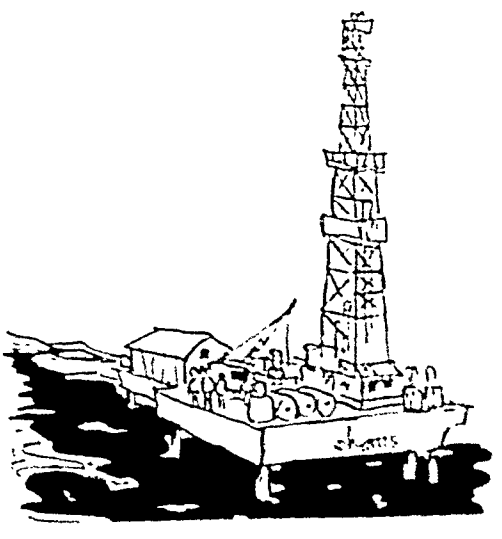
In 1921 A. T. Doodson published an important analysis of the harmonics of the tides. It took 50 years before better astronomical data became available, but during the year D. E. Cartwright and R. H. Taylor of the National Institute of Oceanography of Great Britain published new computations of the tide-generating potential. As a sign of the times, the basic tables were given in the form of a computer printout. These improved tables were needed for many scientific studies, such as that of Walter Munk and his co-workers, who were working on the problem of the global tides by measuring them in the transition zone between coastal and deep-sea waters.

Status of oceanographic programs. In the United States, support for oceanographic research appeared to be holding its own or increasing slightly. The Navy's budget for such research totaled $204 million, compared with $200 million a year earlier, while the National Oceanic and Atmospheric Administration (NOAA) program was increased by almost 20%. Through the National Science Foundation, the United States was helping to support the International Decade of Ocean Exploration (IDOE). The NSF was also suporting a program called Research Applied to National Needs (RANN). Many programs in marine science met the RANN criteria, but it was understood that only $12 million was available for environmental studies and that $300 million to $400 million in proposals had already been submitted.

The IDOE program, recently described by E. M. Davin and F. D. Jennings, involved more than 30 countries in multidisciplinary ocean research programs in the areas of environmental quality, environmental forecasting, and seabed assessment. Other currently active programs included the Mid Ocean Dynamic Experiment (MODE) and a study of how the tectonic plate originating at the mid-Pacific rise moves and is consumed in the Peruvian trench, which encompassed the fields of marine geology, continental drift, and plate tectonics.

The shortage of students entering engineering, including ocean engineering, continued, probably because of the current high unemployment rate in the field. Mrs. Betty Vetter of the Scientific Manpower Commission predicted that there would be a shortage of engineers by 1980. It appeared that overreaction to what was almost certainly a temporary situation might preclude a promising career for many young people.

Sidney Harris, BULLETIN OF THE ATOMIC SCIENTISTS



"Look at the bright side—employment for thousands trying to clean it up."

Space technology and marine science. The U.S. deep space probe Pioneer 10, launched on March 2, 1972, carried a message that, in a million years or so, might reach intelligent life on some other planet outside our solar system. The message was designed to tell its recipients the location of our star, the sun, to within one star in one thousand, the location of earth in our solar system, what men and women look like and how big they are. It will not, however, tell them that life on the earth is possible because of its oceans, continents, and atmosphere or that life started in the oceans. Carl Sagan, Linda Sagan, and Frank Drake, who devised the message, conceded that "it can be improved upon" and expressed the hope that future spacecraft sent beyond our solar system would carry more detailed messages.

The National Aeronautics and Space Administration (NASA) was developing an Earth Resources Program with numerous marine science applications. To test instruments for possible use on either unmanned or manned spacecraft, NASA flew prototype instruments on aircraft and installed them on platforms. Results of the experiments were described in the first through the fourth annual Earth Resources Program Reviews, published by the Manned Spacecraft Center in Houston, Tex.

These studies reached fruition in the instrumentation of the unmanned Earth Resources Technology Satellite (ERTS), launched in mid-1972. ERTS was planned as the first of many systems designed to study the earth from space with agricultural, geologic, land management, marine resource, oceanographic, and meteorological implications. For marine science, it would provide valuable photographic and other data on coastlines and coastal wetlands that were expected to become available during late 1972 and 1973.

The projected manned orbiting space platform Skylab, along with many other experiments, would carry an Earth Resources Experiment Package consisting of S190, a multispherical photographic facility; S191, an infrared spectrometer; S192, a multispectral scanner; S193, a microwave system; and S194, a radiometer. Skylab was scheduled for launch in May 1973, and would be manned during three periods extending through December 1973.

Of particular interest was S193, a combination scanning pencil beam passive microwave-active radar and radar altimeter. The scanning pencil beam passive microwave-active radar would measure the natural and backscattered radiation

from the sea surface at 13.3 GHz (1 gigaHertz = 1,000,000,000 Hertz) over a wide swath to each side of the satellite. Using measurements of this type made from aircraft, it has been demonstrated that winds over the ocean surface can be inferred from these data, while L. M. Druyan showed that the surface atmospheric pressure can be determined from the winds and a few scattered ship reports. These data combined with the infrared atmospheric sounding techniques developed for the Nimbus meteorological satellite should provide greatly improved weather and wave forecasts, especially for the Southern Hemisphere.

R. K. Moore and W. Pierson used the results of studies of the data obtained by the aircraft program and available meteorological and oceanographic theories to predict the usefulness of the data to be obtained by the radar-radiometer mode of S193. They found that the data should provide ideal information on the synoptic-scale (as opposed to local) winds in the planetary boundary layer of the atmosphere.

The altimeter mode of S193 can measure the distance between the spacecraft and the surface of the ocean to within a few meters. Though it may seem strange to laymen, the oceanographers do not know where the surface of the ocean is relative to the center of the earth. The gravity field of the earth is warped because of inhomogeneities of mass in the upper mantle which cause the surface of the ocean to vary by tens of meters from the oblate spheroid that represents an approximation to the shape of the earth. The oceans are not level, and even a level stretch of ocean has bumps and hollows in it.

—Willard Pierson

See also Year in Review: ASTRONAUTICS AND SPACE EXPLORATION, *Earth Satellites.*

Mathematics

Geometry is a branch of mathematics for which a brief definition seems impossible. It is varied and broad. Elements of what most mathematicians would consider to be geometry appear in most areas of modern mathematics, and geometry in its own right is a subject of enormous scope. The most inclusive definition, given by Felix Klein in 1872 and known as the *Erlanger Programm*, states that geometry (roughly) is the study of symmetries of certain structures on sets. By making the structures more and more specialized and detailed, various geometries and subgeometries arise, to be studied in turn. On the other hand, one can specify the symmetries in an abstract manner (they will form a group), proceeding then to study those structures which admit the given group as a group of symmetries. The symmetries are known in general as isomorphism of the structure.

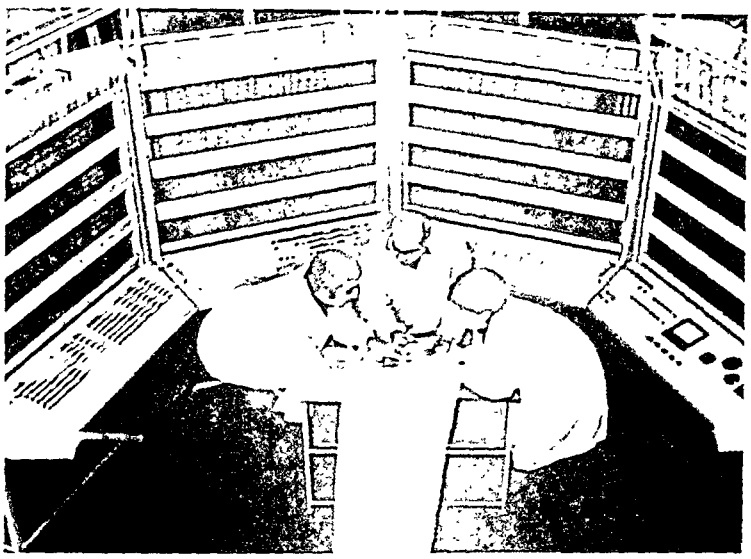
The *Erlanger Programm* is highly successful, even though it does not include all the topics that might be called geometry. In each specialized geometry of the *Erlanger Programm*, there are many questions to consider that are appropriate only to that geometry, but it is generally agreed that a question is "geometrically meaningful" only if it is formulated in a manner harmonious with the symmetries of the geometry being examined.

For example, Euclidean (plane) geometry studies a set called the plane whose elements are called points. The Euclidean structure allows measurement of distances and angles. The symmetries of the Euclidean structure are called congruences. Although several severe crises arose in the 19th century affecting the foundations of Euclidean geometry, they were resolved satisfactorily by 1930 through definitive treatments of the foundations by David Hilbert and his followers. There is little, if any, research of importance being done now in Euclidean geometry, and current trends in education de-emphasize Euclidean geometry in favor of set-theoretic and topological concepts.

Current research in geometry covers too broad an area to be surveyed in a short article. For this reason, this discussion will not deal with algebraic geometry, finite geometries, and coordinatization, all of which are now considered parts of abstract algebra. Of the remaining areas of geometry, the one closest to classical problems is differential geometry, which is the study of geometry by methods of the infinitesimal calculus. Thus, the subject is no older than differential calculus itself, about 300 years. But differential geometry is rooted in the study of the bending and twisting of curves and surfaces, and interest in such problems antedates the discovery of the calculus.

Differentiable manifolds. At present, the main effort in differential geometry is directed toward the study of differentiable manifolds and various structures they can carry. Differentiable manifolds are topological spaces; that is, they are sets of points with certain distinguished subsets called open sets (or neighborhoods), two points in an open set being considered in some sense to be "nearby." Furthermore, differentiable manifolds are topological manifolds. Each point of a differentiable manifold is contained in an open set that is required to be homeomorphic (the name for isomorphisms in the topological setting) to an open set in a Euclidean space, and two distinct points can be enclosed in disjoint open sets (Hausdorff property). The special open sets so singled out on the manifold are called coordinate domains, and

Novosti from Sovfoto



Scientists at the Applied Mathematics Institute of Tbilisi State University in the U S S R make calculations on an advanced computer Soviet-bloc countries are buying computers from U S and West European manufacturers, but their goal is self-sufficiency By 1975 the U S S R hopes to be producing 12,000 to 15,000 third-generation computers annually These will equip a network of 4,000 computer centers set up to monitor a predicted national economic growth rate of 37 to 40%.

the homeomorphic correspondences to Euclidean open sets are called local coordinates.

A topological manifold is covered with coordinate domains in a way resembling an often-repaired automobile inner tube covered with patches. When two of these patches overlap, the open set were they intersect is described by two sets of local coordinates. The topological manifold is a differentiable manifold if the changes of local coordinates from one system to another always have continuous partial derivatives of sufficiently high order. Thus, the manifold will be composed of a certain number of connected pieces, and the dimension of the Euclidean space furnishing the local coordinates will be the same everywhere on a given piece; it is called the dimension of (that piece of) the manifold.

A differentiable manifold is therefore a generalization of the Euclidean space of coordinates. Viewed as a whole, a manifold is a contorted and twisted object, but in the small, thanks to the coordinate patches, it looks like a piece of Euclidean space. Thus, it has an infinitesimal linear structure. The manifold has tangent vectors (corresponding to vectors in a Euclidean space), but they are fixed at a base point and cannot be shifted around without an additional structure, called an affine connection. All tangent vectors with a given base point form a vector space, called the tangent space of the manifold at the point. All the tangent spaces fit together into a new differentiable manifold called the tangent manifold of the original; this has twice the dimension of the original.

If one picks out a tangent vector at each point of the manifold in such a way that the chosen vector varies smoothly as the base point varies, a vector field is obtained. If one supposes the tangent vectors to be hairs, then making the vector fields smooth corresponds to combing the hair down so that there are no cowlicks, whirls, nor, generally, any singularities. On a torus, a differentiable manifold that can be visualized as the surface of an inner tube, many smooth vector fields exist, while on a two-dimensional sphere no smooth vector field can be found.

The first explanation of this came from L. E. J. Brouwer, who used homology theory (a branch of algebraic topology) to examine vector fields on spheres. In 1927, H. Hopf gave a more inclusive explanation. He supposed that the vector field was smooth except at a finite set of points (singularities) and assigned to each of them an integer—the index—which measured its failure to be smoothable. Hopf showed that the sum of all the indexes at all the singularities was a number depending only on the topological nature of the manifold and not upon the particular vector field considered. He calculated this sum, finding its value to be a topological invariant, the Euler characteristic of the manifold. The Euler characteristic of a two-dimensional sphere is 2, and so there must be at least two singularities of index 1 or a singularity of higher index. If there are no singularities, the Euler characteristic of the manifold must be 0; conversely, the manifold has a smooth tangent vector field with no singularities if the characteristic is 0 (for example, the torus).

Recently, M. F. Atiyah and J. L. Dupont generalized Hopf's results. They considered a finite number, r, of smooth tangent vector fields on a differentiable manifold of dimension greater than r. A point is singular if these vector fields fail to

span an r-dimensional vector subspace of the tangent space. Atiyah and Dupont supposed the singularities to occur at a finite number of isolated points and assigned to each an index, which was no longer an integer but an element of a homotopy group. Summing the indexes over all the singularities, they obtain an element of a homotopy group and the vanishing of this element is a necessary and sufficient condition for r vector fields to exist with no singularities.

Besides homotopy theory, other tools from algebraic topology are used, specifically K-theory. This invention of A. Grothendieck's plays an exceedingly important role in current research in topology and is beginning to be used in various parts of differential geometry.

If instead of r tangent vector fields one considers the r-dimensional plane they are to span in each tangent space, the notion of a distribution is obtained. Specifically, a distribution of r-planes on a differentiable manifold selects an r-dimensional subspace from each of the tangent spaces and does so in a smooth fashion from point to point. A distribution of r-planes is called a foliation if the manifold can be filled up with disjoint r-dimensional submanifolds, each of which is tangent to the selected r-plane at each of its points. As a consequence of Hopf's theorem, the two-dimensional sphere can have no foliation by 1-planes. The three-dimensional sphere has a foliation by 2-planes, discovered by G. Reeb. Recently, A. Durfee and I. Tamura discovered a way to foliate any odd-dimensional sphere by planes of one dimension lower (codimension-one). H. Blain Lawson, Jr., and Durfee showed how to obtain codimension-one foliations on a large set of manifolds that are, from the viewpoint of algebraic topology, not too complicated. They obtain obstructions to finding such foliations involving integral 2-torsion of the homology.

Status of the discipline. Differential geometry is currently vigorous and growing. There is a wide variety of current research that makes contact with other fields of mathematics, including topology, ordinary and partial differential equations, and algebraic geometry. The benefits flow in both directions across the interfaces, and differential geometry has contributed its full share to the globalization of analysis that has occurred since World War II. As a course in university instruction, differential geometry remains important; for example, the place of geometry in the undergraduate curriculum was recently the subject of a symposium conducted by the Ohio Section of the Mathematical Association of America.

The methods of Élie Cartan (1869–1951), the most profound and original geometer of the 20th century, are beginning to be widely understood, thanks mainly to the unflagging efforts of S. S. Chern, who spent more than three decades explaining and extending Cartan's work, while himself contributing a substantial share of the original work in differential geometry in that time. Early resistance to Cartan's ideas arose in part from his use of infinitesimals, banished from mathematics in the 19th century. The introduction of the notion of fiber bundles in the early 1940s allowed an alternate description of Cartan's ideas within an acceptable context and led to the discovery by Chern of characteristic classes, which now play a prominent role in differential geometry and algebraic topology.

It is interesting to speculate about the subsequent development of differential geometry if in 1940 geometers had been in possession of A. Robinson's nonstandard analysis (1960), which shows how infinitesimals can be restored to mathematical legitimacy in a perfectly rigorous way. The time is ripe for an exposition of Cartan's work based on nonstandard analysis, and students of geometry are hopeful that one will come within the next ten years. One omen for this is the appearance this year of a rigorous beginning calculus book written by H. J. Keisler and based entirely on Robinson's methods.

—Nathaniel Grossman

Medicine

Significant developments in medicine in the past year are presented below under the title *General Medicine*. The section is followed by a more detailed look at six areas in which there were special developments or accomplishments in the same period. The six are *Paramedical Personnel, Alcoholism, Psychiatry, Death and Dying, Dentistry,* and *Venereal Disease.*

General medicine

The physician and the delivery of health care continued to come under closer public scrutiny in the U.S. and throughout the rest of the world, with the possible exceptions of the Republic of China and the Soviet Union. The private practice of medicine, so long a cherished tradition by physician as well as patient was under heavy fire for its failure to provide a system of equal health care to all people in the United States. Instead of just coming from the impoverished blacks and browns in urban ghettos, serious questioning of the American medical system was beginning to come from middle class white families, who were finding more and more

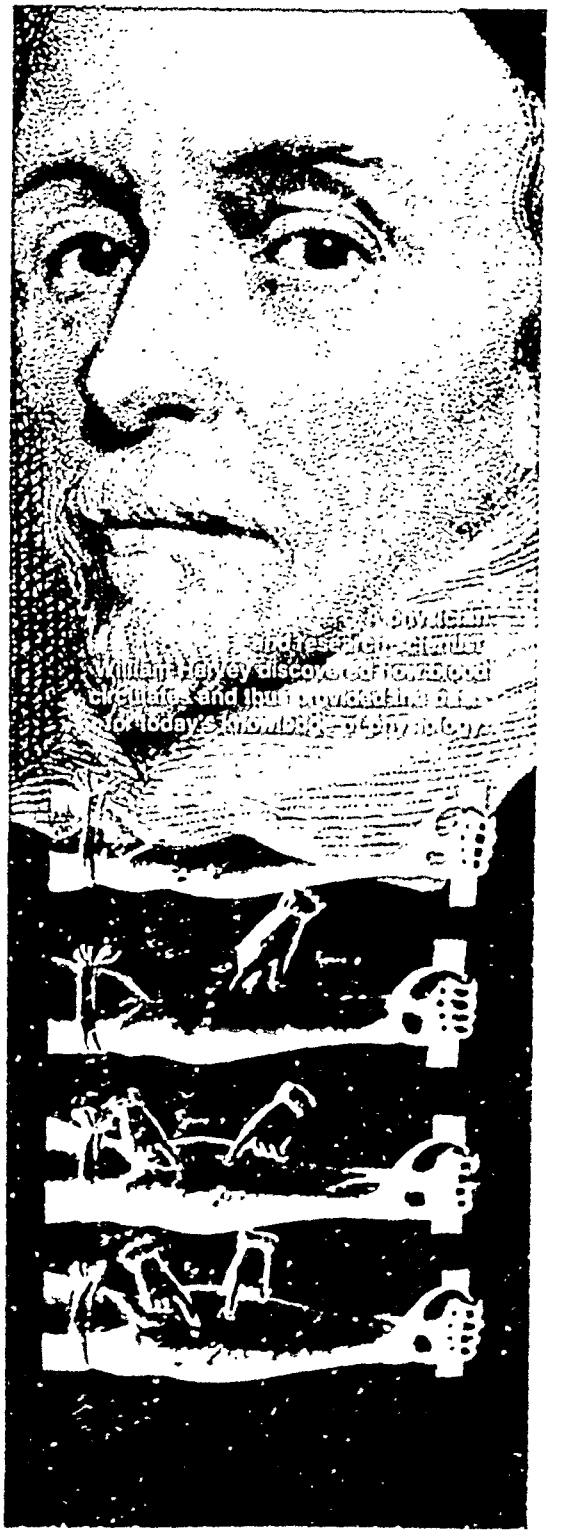
that health care in the U.S., as good as it was, was simply not sufficiently available. The high and continuously rising cost of medical care was not the sole consideration. The distribution of health services—hospitals, clinics, physicians' private offices—was of equal concern. Physicians not only were fleeing urban America along with middle class whites but tended to establish their private practices in areas where climate and lifestyle were more ideal. California, the southwest, northwest, and Florida were the most popular locations for physicians, both young and old. This left situations in other areas of the country that had even people with the ability to pay for private medical attention unable to find physicians, especially pediatricians, general practitioners, and internists, who could take on new cases.

Other areas in the health care delivery system were locked in struggles. One such battle related to the efficacy of various drugs in preventing death from blockage of the coronary arteries (arteriosclerosis). Blockage of the coronary artery was accounting for 80% of the deaths from heart disease in American males and in 1972 was ranked as the first cause of disability or death in the U.S. A number of drugs had been found to lower blood cholesterol. Over 8,000 U.S. men were participating in a current study of the National Heart and Lung Institute attempting to find the most effective agent. The subjects, ranging in age from 30 to 64, had one thing in common: each had suffered a previous myocardial infarction (heart attack). Final results would not be known until 1974, but medical science already was embroiled in debate, arguing: (1) whether cholesterol was really the key factor to be controlled, (2) whether drugs were superior to prevention via exercise and diet, and (3) whether a massive study of men whose hearts were already "sick" would be valuable to the healthy.

In the interim, clinical investigators in both Scotland and Newcastle-upon-Tyne, Eng., reported that one of the drugs being tested in the U.S., clofibrate, was associated with fewer heart attacks when used by a group of men who suffered previously only from angina—"chronic chest pain" that is related to the oxygen starvation occurring in the heart as arteriosclerosis builds its barriers. The studies were considered the best evidence yet that medicine may find an effective chemical weapon against heart disease.

Another study, conducted in the southern U.S., showed that hard-working black and white sharecroppers had an extremely low incidence of heart disease even though they had high levels of cholesterol and a high incidence of cardiovascular abnormalities.

continued on page 270



Acupuncture

On April 21, 1972, at Weiss Memorial Hospital in Chicago, Dr. Wei Chi Liu performed a tonsilectomy on a 31-year-old male nurse, Gary Chinn. What distinguished the otherwise commonplace operation was the absence of any of the anesthetics ordinarily used in Western medicine. Instead, the patient was anesthetized by acupuncture, the age-old Chinese practice in which needles are inserted at specified points in the body.

Gary Chinn's tonsilectomy was one of several surgical procedures using acupuncture anesthesia that took place in U.S. hospitals in mid-1972. Only a year or two earlier, American medical men had regarded acupuncture (if they regarded it at all) as a quaint cultural survival, but by 1972 it was the subject of intense interest and study.

The scene for this change had been set in the political arena, as China and the U.S. made tentative advances toward normalizing their relations and Americans were admitted to China for the first time in more than 20 years. Pres. Richard Nixon's much-publicized trip to Peking gave rise to a fad for things Chinese. More to the point, U.S. doctors returned from China with reports of having witnessed major operations in which only slender, vibrating needles were used to deaden pain. The patients remained conscious and were able to converse with the surgeons. They said they felt no pain, although sometimes they could feel their organs being manipulated. In some cases, they sipped tea or ate pieces of orange while the operation was proceeding.

The use of acupuncture as an anesthetic during surgery was relatively new, but acupuncture had been practiced as a form of curative medicine for some 3,000 years. Legend has it that acupuncture originated when an ancient emperor observed that soldiers struck by arrows sometimes obtained relief from ailments in other parts of their bodies. In time, a body of philosophical concepts grew up around it, involving the ideas of yin and yang, the active and passive principles of the universe.

In traditional acupuncture, the body is divided by 12 meridians, the pathways of the body's vital energies. Disease is seen as an imbalance in these energies, and the imbalance is corrected by inserting needles at one or several of 365 points on the head, trunk, and extremities. The practitioner is guided by elaborate charts, the oldest known of which is a bronze model of about A.D. 860. The needles may be of different metals, each with a special significance, although today stainless steel needles are most frequently used. They may be inserted only a short distance or deeply into the body, and sometimes they are rotated or vibrated. Since the points for insertion are based on the meridians, they may bear no visible relationship to the illness being treated.



A deaf child receives acupuncture treatment at the School for the Deaf No. 3 in Peking. The cure is said to last approximately one year.

Stern from Black Star



Chinese surgeons operate on the spinal column of a 20-year-old man anesthetized by acupuncture. The five silver needles inserted into his ear, neck, and hand are periodically vibrated by a six-volt electric current

Cures and remissions of many diseases have been claimed for acupuncture, but Western science has no explanation of why—or even whether—it works. Skeptical doctors have postulated a placebo effect—the patient is cured because he believes the cure will work—and note that many of the ailments for which acupuncture seems to succeed have a large psychosomatic component. Others, while discounting yin and yang, believe that the ancient Chinese doctors stumbled into something that works, just as herbalists, by trial and error, built up a pharmacopoeia of folk medicines, many of which have real therapeutic value. The most likely interpretation is that the needles in some way affect the nervous system. One theory is that acupuncture's anesthetic effects result when the sensations caused by the needles block "gateways" in the spinal cord and thalamus through which painful sensations reach the brain.

Europeans have long shown some interest in acupuncture. It reached France via Indochina, and a number of French doctors who practice *acuponcteur* claim it has helped patients who failed to benefit from conventional treatment. The Soviet Union is said to have it under study. In the United States, however, it has been confined largely to Chinese communities.

Even in China, acupuncture was falling into official disfavor prior to the Communist revolution. Mao Tse-tung, however, encouraged a combination of traditional and modern medicine and, following his dicta, traditional practitioners and doctors trained in the Western mode began working together. The trend gained momentum during the Cultural Revolution, when doctors from the cities were sent to work in the countryside. Today, Chinese doctors claim their practice includes the best of both worlds. (See Feature Article: SCIENCE IN CHINA.)

It is acupuncture as an anesthetic that has received the most publicity in the West. Partly this is because it is spectacular. Further, although Western anesthesiology is highly developed, a certain small percentage of patients suffer severe reactions or even die from the effects of chemical anesthetics. If acupuncture could be substituted, medicine would have gained a valuable tool.

This does not appear to be in the immediate future, however. The haste with which Western doctors are studying acupuncture stems partly from the fear that, unless the medical profession takes a credible stand one way or the other, it may become a fad and fall into the hands of quacks. Samuel Heller, head of the New York State Board of Medicine, predicts that it will be two to five years before any final judgment can be made. Chinese doctors themselves warn that acupuncture anesthesia is not always suitable and that, even when it is used, it must sometimes be supplemented by chemical anesthetics. Nevertheless, as of 1972 it appeared that acupuncture had emerged from the medical shadows.

break alone. The highly contagious smallpox virus spread quickly to Iran and Pakistan. A Yugoslav Muslim carried the disease back from a religious pilgrimage; a Yugoslav worker imported it into West Germany; and public health officials frantically established mass vaccination programs as modern transportation threatened to send the disease across all of Europe. By spring the outbreak appeared under control and the World Health Organization continued to predict eradication of smallpox by 1976—some 170 years after Edward Jenner introduced his "cowpox" vaccine.

The U.S. Public Health Service (PHS), meanwhile, recommended that compulsory vaccination for smallpox be dropped from the health codes of all states. The infrequent but serious reactions to the vaccine that occurred were a greater risk at this time than smallpox itself, the PHS said. The last U.S. case of the disease was recorded in 1949.

The epidemics of concern to U.S. health planners were venereal disease (see *Venereal Disease*, below) and drug abuse. In a historic and controversial decision, the PHS recommended that private and clinic physicians alike begin routinely testing women patients for gonorrhea. An estimated 650,000 U.S. women were asymptomatic carriers among the 2,250,000 persons who contracted the disease each year. A simple, self-contained test kit for *gonococci* was made available to private practitioners, who were already detecting four of every five VD cases in the nation.

Resolving drug abuse problems. Drug abuse was a no less widespread but quite different problem. While considerable federal attention was focused on such "hard drugs" as cocaine and heroin—there were an estimated 650,000 U.S. heroin addicts spending $2 billion yearly to maintain their habit—the prime method of treatment came under fire. Methadone was dispensed by 450 clinics nationwide as a chemical blocker and antagonist of heroin. It was found that some clinics were not requiring the addicts to consume their methadone during their visits, allowing the drug (which produces a mild "high" of its own) to be sold elsewhere to drug abusers. Several persons, many of them children, died of methadone overdoses. More stringent dispensary methods were instituted as the pharmaceutical industry announced a stepped-up campaign to develop a safer narcotic antagonist, perhaps one that would also replace morphine and other strongly addicting substances used in medical practice to lessen extreme pain.

Federal controls were initiated to reduce amphetamine abuse. Overprescription of these drugs by well-meaning doctors and overproduction by drug firms were spotlighted as the leading causes of this kind of abuse as well as of the skyrocketing barbiturate problem. In 1972, U.S. suppliers were being asked to reduce their amphetamine production by about 80%. At the same time, physicians' organizations were urging members to confine their prescriptions of such drugs to those situations where another, safer agent could not do the job, such as narcolepsy (sleep epilepsy) and severe hyperkinesis in children.



Dave Davis, MEDICAL WORLD NEWS

Blood gases in a premature baby are monitored by an experimental electric microsensor introduced through the umbilical artery into the infant's aorta. University of Arizona pediatrician Thomas Harris and a California firm designed the oxygen-measuring electrode in an effort to avoid missing the signs of distress not detected when blood-gas samples are taken only periodically.

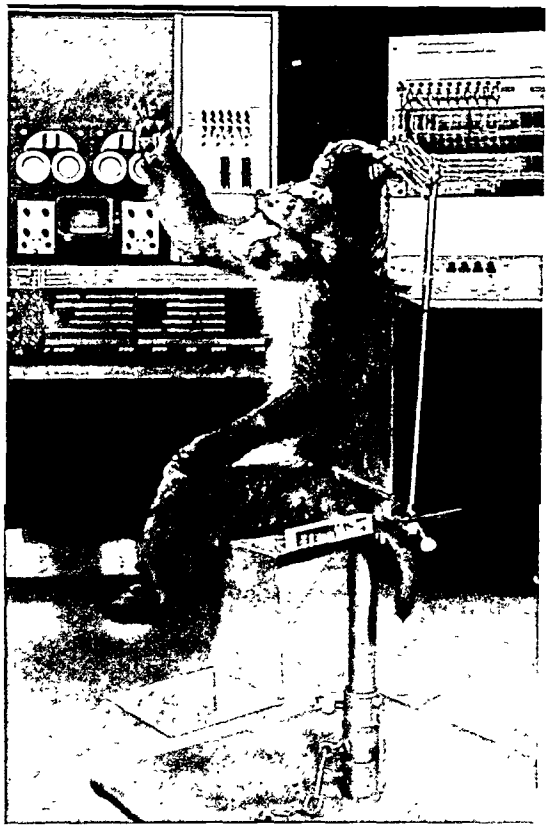
A study commissioned by the National Commission on Marihuana and Drug Abuse showed that 24 million Americans have tried marijuana at least once. Of these, 8.4 million became regular users. The commission's chief recommendations in its marijuana report were two: a national policy of discouragement of marijuana use and the decriminalization of marijuana in cases involving use of the drug in the privacy of the home or use in an obvious social situation. The commission recommended continuation of strong penalties for the sale of large amounts of marijuana for profit (as opposed to the sale of one marijuana cigarette to a friend at cost). It also recommended, in keeping with its intent to keep the marijuana problem out of the overloaded criminal justice system, that the contraband theory in law be applied to public possession cases made by law enforcement officers. This would mean that a policeman could seize marijuana from a person in a public place without having to arrest him. The growing of marijuana in a flower box or elsewhere would still be considered a criminal action under the commission's recommendations.

The 13 commissioners, including eminent physicians, psychiatrists, and lawyers, were impressed in their year's study of marijuana use in the U.S. and throughout the world with the fact that incarceration for marijuana offenses may cause far more serious physical and emotional harm to an individual than smoking marijuana. The commission urged that studies of the long-range effects of marijuana use on the body be started immediately. It deplored the lack of such scientific information. At the same time, the commission had to take into consideration the overwhelming evidence from scientific and social inquiry that showed marijuana used in moderation has no serious ill effects on the body or mind.

Within a few months after the commission's report was released, bills were introduced in Congress and in a number of state legislatures to reduce penalties for marijuana use and possession along lines suggested by the commission report. Penalties for simple possession (one ounce or less) of marijuana ranged from seven days in Nebraska to life imprisonment in Texas. The commission was to review its marijuana recommendations in its second report on drug abuse in general due in March 1973.

Organized medicine. The public and private lives of doctors were becoming increasingly stressful by the threat of massive changes. National health insurance, stalled in Congress until after the 1972 presidential elections, would surely change the method by which the patient paid his bills. But for the doctor it would mean much more:

Courtesy, Lawrence B. Pinneo, Stanford Research Institute



A monkey moves its paralyzed right arm by means of a Programmed Brain Stimulator, a computer that sequentially fires electrodes implanted in the brain stem. Such a device may eventually enable persons paralyzed by brain damage to regain use of their limbs.

audits of his practice procedures, paperwork, and the real possibility that he would no longer control the level of his fees. For these and many other reasons, in recent months U.S. doctors had begun to talk of unionization.

Some physicians preferred to call their organizations guilds or merely associations, but the difference between the new organizations of that title and those that said they were unions seemed purely semantic. All were striving for a "new professionalism" and a collective voice in the socioeconomic struggles ahead. In March 1972, 30 doctors formed the Nevada Physicians Union and became affiliated with a local of the AFL-CIO. In March, over 100 private practitioners met in San Antonio, Tex., to form the American Physicians Union. In April, over 600 San Francisco area physicians formed the Union of American Physicians. Still small and unorganized, the trend to physicians' unions seemed obvious. The key question in the move-

ment was whether a doctor could or would go on strike. Since the idea of these organizations came from the interns and residents who united to stage "job actions" a few years before, the answer might well be affirmative.

The traditional voice of medicine in the U.S. has been the American Medical Association (AMA). In his inaugural speech, the organization's 1971–72 president, Wesley Hall of Nevada, asked for a constitutional convention to reform the organization. While resisting the proposal, the AMA House of Delegates agreed to hold hearings on it over the next year. Because some doctors thought the AMA too conservative, while others condemned it as liberal for proposing its own national health insurance plan, any attempts at change would prove doubly difficult.

Yet another potential spokesman in medical affairs was the newly formed Institute of Medicine of the National Academy of Sciences (NAS). Since the U.S. Civil War, the academy had been a respected adviser to the government in matters of science. Very few physicians were elected to membership, and the medical issues considered by the NAS expert groups were comparatively rare. In 1970, a separate wing of the academy was formed by a mass admission of several score nationally famous medical leaders. At this point, the Institute of Medicine was confining itself to considerations of broad social and ethical issues, such as death and dying. But if the history of the parent academy was a guide, the new body's voice would soon be heard in specific matters of national policy. (See *Death and Dying*, below.)

Of course, medical ethics is a serious concern, and in recent months the public had increased insight of the doctor's day-to-day ethical concerns. The Institute of Society, Ethics, and the Life Sciences, a nonaffiliated private group with members at dozens of medical schools, seminaries, and even in Congress, became the focus for a number of public controversies. The institute's spokesmen condemned a Texas physician who investigated the side effects of oral contraceptives by giving placebos to a group of uneducated, Mexican-American women. Several became pregnant. On another occasion, the *Journal of the American Medical Association* was criticized for publishing Federal Bureau of Investigation wanted notices of criminals with medical problems. The institute argued that this was a clear violation of doctor-patient confidentiality. The AMA Judicial Council declared that it was not.

Even the basic process of educating physicians became a storm center. The National Fund for Medical Education, headed by John S. Millis, proposed that the nation create no more medical

Courtesy, Dr. James G. White, MEDICAL WORLD NEWS



An electron micrograph of a blood platelet, the particle that aggregates to arrest bleeding, shows the open canal system winding through the organelle's interior. Platelet dysfunction was implicated in numerous diseases in which blood clotting or bleeding is a factor.

schools. Instead, Millis' report recommended increasing enrollments in existing schools while reducing the training required from four to just two years. This could be done by diversifying and specializing the students' training at an earlier stage on the way to the M.D. degree. Despite these revolutionary proposals, spokesmen for organized medicine praised the study as "the most comprehensive" since the 1909 report by Abraham Flexner, which had set the course for U.S. medical schools to date.

Research and funding. Any drastic change in medical education would require an equally impressive change in the pattern of federal funding. Currently, little support was given actual educational programs. The bulk of federal tax moneys going to medical schools was for research and patient care. For the coming months, the "stars" of medical research would include cancer, heart disease, and sickle-cell anemia. Investigators in all three fields received large increases in congressional appropriations for the coming year. Cancer received the first and largest increase (*see* Feature Article: CANCER UNDER ATTACK). Heart disease followed, as both leading killers received nothing less than "Manhattan Project" pledges of federal backing.

Sickle-cell anemia, by contrast, was a significantly less frequent threat to life. It received its name because certain drugs and environmental conditions cause the red blood cells of its victims to collapse into a sickle shape. It occurs predom-

inantly among blacks, and even then, among non-African blacks (an estimated 40 million West Africans carry the trait) the genetically acquired trait occurs far less frequently than such other diseases as diabetes or hypertension. Nonetheless, at least two million blacks in the U.S. carried the trait, and more than 45,000 were estimated to suffer crises of medical significance each year. Those with the trait had to be particularly careful about flying or exerting themselves at relatively high altitudes.

The national sickle-cell program authorized by Congress was to provide $105 million over three years, beginning in 1973. Emphasis would be on treatment, screening, and counseling. Despite the availability of cheap, rapid screening tests, many victims do not discover that they have the disease until the first crisis occurs. Until recently, sickle-cell anemia was a neglected recipient of research funds, averaging less than $1 million annually.

Mobilized medicine. Major efforts would be devoted during the next two or three years to detecting breast cancer by means of mobile X-ray units and intensified public education campaigns. The drive was launched by the American Cancer Society, which noted that the incidence of breast cancer had not declined in 35 years. Communities would be asked to push for such projects as the "Cancermobile," sponsored by the Brooklyn chapter of ACS and the Holy Family Hospital. This mobilized detection center utilized refined radiologic techniques, such as mammography and thermography, to pick out breast tumors in their earliest stage.

Ironically, the public health drive that first proved the value of mobile detection units was fading from the American scene. Vans carrying chest X-ray units for tuberculosis detection had done their job, according to the National Tuberculosis and Respiratory Disease Association. TB was now too infrequent to justify continued use of the red-and-white vans, a familiar sight in shopping centers, church parking lots, and other community centers since after World War II.

But the U.S. is basically a culture on wheels, and its concerns in health care were hardly excepted. Major public and professional campaigns were sprouting coast-to-coast to improve systems of prehospital emergency care. In the past, clinicians had derided most ambulance services as "taxis for sick people." But now the technology and the funds were becoming available to give patients better care on their way to the hospital. Three federal programs and uncatalogued scores of community groups in Kansas City, Mo., Akron, O., and Grand Rapids, Mich., were improving emergency systems with the assistance of such national groups as the AMA, American College of Physicians, American Heart Association, and ACT (Advanced Coronary Treatment) Foundation.

Much of the technology and training for better ambulance-to-hospital care was provided by medical interest in mobile coronary care units. Highly sophisticated units in such cities as Seattle, Wash., Miami, Fla., and Columbus, O., featured highly trained paramedical personnel who could give treatments on the spot with the advice of a doctor who communicated with them via radio and telemetry. In the spring of 1972 a University of Virginia mobile coronary care van was credited with bringing critical therapy to a famous heart attack victim—former U.S. President Lyndon B. Johnson. (See *Paramedical Personnel*, below.)

In their efforts to keep healthy and discover more about illness, Americans were spending $75 billion each year—7.4% of the nation's gross national product. Predictably, the expenditure seemed to have little relationship to the effect desired. While the dollars for health had increased steadily, the average citizen remained just as sick. Since 1959, the National Center for Health Statistics reported, average days of disability remained at 14–16 days per year. That included 5–6 days annually at home, sick in bed.

—Byron T. Scott

Alcoholism

Throughout history, man has used and abused the mood-altering drug ethanol to celebrate his triumphs and to soothe his frustrations. It has long been known that many people, in all walks of life and from many cultures, consume more alcoholic beverages than is good for their health and well-being and for the well-being of those around them. Only recently, however, have scientific and humane measures replaced moralism and punishment as methods of dealing with the problem drinker.

The past five years have witnessed a deepened awareness and understanding of the problems of alcohol abuse and alcoholism. Instead of being relegated to the category of willful misconduct or bad behavior, alcoholism has been recognized as a medical problem, a complex disorder with physical, social, behavioral, and psychiatric aspects. The chronic excessive drinker has come to be regarded with compassion rather than condemnation, as the helpless victim of an illness rather than the deliberate perpetrator of a criminal or moral offense.

Alcohol affects each person differently, and there are almost as many definitions of alcohol abuse and alcoholism as there are brands of whiskey, wine, and beer. In our society, most drinkers keep

their consumption of alcohol within socially acceptable and harmless bounds—limited to amounts they can readily handle. Drinking becomes a problem when the use of alcohol causes physical, psychological, or social difficulties to the drinker or to society. Alcohol is being abused when it leads to recurrent episodes of intoxication or heavy drinking that impair health, or when it is consistently used as a mechanism for coping with personal problems, to a point where it seriously interferes with an individual's effectiveness on the job, at home, in the community, or behind the wheel of a car.

A new force in the war on alcoholism. During the year a dramatic organizational change took place in the effort to combat alcohol abuse and alcoholism in the United States. Massive federal intervention in this previously neglected area officially began in December 1970, when the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (Public Law 91-616) was passed unanimously by both houses of Congress and signed into law by Pres. Richard Nixon. One of the most important pieces of legislation ever enacted in the field of alcoholism, Public Law 91-616 established the National Institute of Alcohol Abuse and Alcoholism (NIAAA) to serve as the federal government's principal agency for alcohol programs and activities.

Working closely with state and local governments, private voluntary agencies (such as the National Council on Alcoholism and Alcoholics Anonymous), and agencies involved in traffic safety (such as the Department of Transportation, the National Safety Council, and insurance companies), the NIAAA embarked on a broad range of research and service programs to meet the total needs of alcoholics and their families on the community level. NIAAA's project grants totaled $300 million over a three-year period, six times as much as had been available in the three years before its inception.

NIAAA had two main overall goals: to assist in making the best alcoholism treatment and rehabilitation services available at the community level, and the longer-range but even more important goal of developing effective methods of preventing alcoholism and problem drinking. To achieve these objectives, NIAAA aimed to foster, develop, conduct, and support broad programs of research, training, development and coordination of community services, and public education.

Research and training. Since alcoholism is the product of a complex interaction of biological, psychological, and social factors, an improved understanding of its causes, natural history, and treatment can only be achieved through a wide range of research. With increased funds made available by NIAAA grants, many highly competent researchers from a variety of disciplines became involved for the first time in research studies on alcohol problems. These studies were being conducted at universities and medical centers located in geographic areas with a high incidence of alcoholism.

One cause of death among alcoholics is cirrhosis of the liver, and investigation into alcohol-related liver disease was given high priority. Attention was also focused on other serious complications of alcoholism, including pancreatitis, gastritis, and withdrawal reactions. Another important research goal was to find ways of speeding the clearance of alcohol from the system. One study showed that alcohol can be removed rapidly from the bloodstream through hemodialysis (blood purification through an artificial kidney). While not currently practical for prolonged treatment, this technique had significant implications for the management of life-threatening intoxications.

In order to match specific treatment methods to particular patients, studies were conducted to differentiate between subtypes of alcoholic persons. One study identified "essential" and "reactive" types of alcoholic persons, while another categorized four subtypes based on the relationship between social factors and the individual. As subtypes of alcoholic individuals were identi-



"I'll be glad to listen to your troubles—yes. But, first, have you severed your connections with other bartenders to whom you've been relating them in the past?"

fied and specific treatments devised for each group, a higher success rate could be expected.

New treatments would remain ineffective, however, as long as relatively few physicians and other health personnel were sufficiently trained and experienced to deal with the complex problems of alcohol abuse and alcoholism. To meet this need, programs were initiated during the year for the inclusion of training in alcohol problems in the curricula of schools of medicine, social work, nursing, public health, psychiatry, and psychology. Other programs in progress included those aimed at development of specialists to assume leadership roles in training, research, education, and administration; training for private practitioners and hospital staff; and the preparation of counselors to function in both clinical and coordinating roles.

Special programs. NIAAA's formula grant program, the first of its kind to deal with this problem, enabled states to develop comprehensive plans covering all segments of alcohol abuse and alcoholism. Such programs made it possible to involve a wide variety of groups, including private citizens, voluntary agencies, medical professionals, health care and social welfare agencies, and court and enforcement personnel.

NIAAA community assistance programs provided aid in the development of comprehensive community services to meet the needs of alcoholics and their families, to coordinate these services, and assure their continuity. Prior to the creation of these programs, such comprehensive services were largely nonexistent. Most communities did have a core of medical and social services, however, and the comprehensive structures were being built around these existing services. A growing number of community alcoholic treatment centers were being established. Staff was being recruited not only from the ranks of professional health and social workers but from among recovered alcoholics as well.

Marshall Sovick



A Milwaukee, Wis., bartender listens to a customer's problems after completing an experimental course in elementary counseling skills sponsored by the local mental health association.

NIAAA was also collaborating with other federal agencies, state and local governments, and private organizations in the development of programs targeted at special population groups. One of the most important was a joint effort with the National Highway Traffic Safety Administration of the Department of Transportation aimed at reducing the number of deaths and injuries caused by drunken drivers. This program included a broad public information and education campaign on the dangers of mixing drinking and driving. Special demonstration projects enabled communities to show the appropriateness and effectiveness of providing a public health service for problem drinkers, rather than running them through the revolving door of arrest, fine, loss of driver's license, and jail.

The public inebriate—the chronic drunkenness offender or Skid Row derelict—represents only about 5% of the alcoholic population but accounts for 40% of all arrests for nontraffic offenses. During the year the NIAAA, in cooperation with mental health centers, law enforcement agencies, and other organizations, sought to find more effective and practical alternatives to the present costly and inefficient system of handling these offenders. Several states initiated legislation to remove public intoxication from the criminal statutes and define it as a health problem. Further positive developments in this direction were expected in the near future.

Another collaborative effort was under way on behalf of employed alcoholics, who were estimated to comprise about 5% of the U.S. work force. Based on the experience of industries that had established programs to help these individuals, more than half of alcoholic employees can be rehabilitated. During 1971 the NIAAA, as required by Public Law 91-616, assisted the Civil Service Commission in developing guidelines for the implementation of alcoholism programs in all federal agencies and was fostering similar programs in state and local governments and in industry.

To help meet the needs of the American Indian population, which is troubled by severe problems associated with alcohol abuse, NIAAA inaugurated a collaborative program with the Indian Health Service, the Bureau of Indian Affairs, and other

concerned agencies. Twelve treatment and rehabilitation service projects designed and developed by Indians for their people were established during the year.

Prevention and education. An illness is never eradicated by treating only the casualties. To be effective, any public health endeavor must also be aimed at prevention. Accordingly, high priority has been placed on public education as a method of reducing and preventing alcohol problems.

The public information and education campaign, conducted through television, radio, the press, and special publications, has several objectives: to develop public recognition of alcoholism as a treatable disease; to encourage the health-care system to regard alcoholism as a medical-social-behavioral problem and to treat the alcoholic patient with the same attention and consideration as any other patient; to inform the public of the properties of alcohol, its effects on the body and on behavior, and its potential for harm; and to produce a new environment concerning the use and misuses of alcoholic beverages, with an eventual reduction in the rate of drunkenness, problem drinking, and alcoholism. No person is asked to abstain from drinking. Rather, the use or nonuse of alcoholic beverages is regarded as a personal decision to be made by each individual.

A worldwide problem. Outside the United States alcohol abuse and alcoholism were also being recognized as medical rather than legal problems. After two decades of attempting to enforce anti-liquor laws, the Indian government was being forced to recognize that a disease cannot be banned, and that the attempt to do so has resulted in a considerable loss of revenue while encouraging bootlegging, smuggling, and illicit distillation. Surveys in Great Britain and Western Europe revealed a substantial increase in the consumption of alcoholic beverages, particularly among the young. Yugoslavia, Poland, Hungary, and other countries of Eastern Europe were mounting intensive efforts to counteract the growing alcohol abuse problem.

On the international level, the first World Congress on the Prevention of Alcoholism was held in Kabul, Afg., in August 1972. It was followed by another international conference on the increasing problem of alcohol abuse held in Amsterdam, Neth., in September.

Future developments. The past year was largely one of planning and organization. The implementation and broadening of the programs described above would be the work of the months and years ahead. Like most legislation, Public Law 91-616 provided a framework for action. Filling in that framework would make a significant contribution to the needs of alcoholic people and to the goal of preventing and controlling alcoholism.

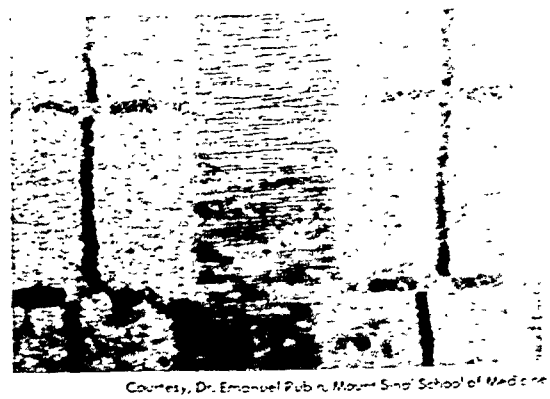
In addition to the benefits to be derived from Public Law 91-616, a uniform law on public intoxication, developed by the Commissioners on Uniform State Laws, was awaiting enactment by the states. The thrust of the law would be to move public intoxication out of the criminal area and into the health care service area where it belongs.

NIAAA's new National Clearinghouse on Alcoholic Information was expected to be in operation shortly. This was to be the mechanism for developing and distributing information on all aspects of the use and misuse of alcohol. In addition, the clearinghouse would distribute proceedings of research workshops and symposia, annotated bibliographies of treatment and rehabilitation literature, guides to federal assistance programs in the area of alcoholism, directories of alcoholic treatment programs, and fact sheets on alcoholism.

—Morris E. Chafetz

Muscle tissue (left) taken from a subject who consumed 225 gm of ethanol daily for four weeks reveals extensive damage, including swollen interfibrillar spaces clogged with glycogen and lipid droplets. A second specimen (right) taken six months later shows the muscle has returned to normal.





Courtesy, Dr. Emanuel Rubin, Mount Sinai School of Medicine

Alcoholism today

The first annual report on alcohol and health, prepared by the National Institute on Alcohol Abuse and Alcoholism, was the most comprehensive report ever published on the subject. It gave ample proof that alcohol is the most abused drug in the United States today. Among the principal findings of the report:

Nine million Americans are alcohol abusers and alcoholics. This constitutes about 5% of the adult population and almost 10% of the nation's work force.

Alcohol plays a major role in half the highway fatalities in the U.S., costing thousands of lives each year.

Alcohol abuse and alcoholism drain the economy of an estimated $15 billion annually.

Public intoxication alone accounts for one-third of all reported arrests.

Among American Indians, alcoholism is at an epidemic level; the rate is at least 10%, or twice as high as the national average.

Alcoholism is not a crime but an illness that requires rehabilitation through a broad range of health and social services tailored to the individual case.

Present programs dealing with alcohol abuse and alcoholism are accorded a low priority and are unrelated to most of the health and social resources within communities. What community services are available are frequently fragmented and fail to take into account changing life-styles or the unique characteristics of various population groups.

Establishment of modern public-health-oriented facilities to deal with intoxicated persons will free law enforcement agencies from being overburdened with a great many ill people.

The criminal law is not an appropriate device for preventing or controlling the health problems brought on by alcoholism. To deal with alcoholic persons as criminals because they appear in public when intoxicated is unproductive and wasteful of human resources.

Death and dying

In recent months a rash of articles in major newspapers and national magazines dealt with aspects of death and dying that had rarely been written about before. Should a patient dying of widespread cancer be kept going by artificial means only to die several times over and in great discomfort? Should a retarded infant with intestinal obstruction have his life saved surgically only to spend it in a state institution, unproductive and at public expense? Such questions were surfacing more and more frequently and attracting wide public attention. At the opening of the John F. Kennedy Center for the Performing Arts in Washington, D.C., in October 1971, a capacity audience of professional and lay people listened to panels debating these and related ethical issues for two days at the International Symposium on Human Rights, Retardation, and Research.

Several centers for the study of ethical problems in medicine had been established recently in the U.S., notably the Institute of Society, Ethics, and the Life Sciences at Hastings-on-Hudson, N.Y., and the Kennedy Center for Bio-ethics at Georgetown University, Washington, D.C. Programs under government or foundation support were

The growing percentage of people over the age of 65 presents a set of unique problems for today's physician. Social attitudes toward the elderly and the lack of training in geriatrics and gerontology often hinder decisions regarding the proper care of the aged.



Joe Baker, MEDICAL WORLD NEWS

exploring these and related problems at Cornell, the University of Virginia, Stanford, Yale, Harvard, Case Western Reserve, the Hershey Medical Center of Pennsylvania State University, and the University of Washington, among others.

Medical advances. Until the past few decades the powers provided by medical science to prevent death were relatively feeble. That is, people lived and died largely independently of major intervention. When the time came, the heart stopped, as did breathing, and that was death. But now the human organism can be kept going despite cessation of normal brain, heart, respiratory, or kidney function, and other procedures for replacing lung and liver function by artificial means were in the experimental phase. Several hundred bodies were being maintained at the temperature of liquid nitrogen against the day when medical science will have discovered enough new information to revive them and patch them up.

Thanks to these rapidly developing technologies, dying is no longer a simple matter. Sharp controversy exists as to the use of these powerful tools. What are the proper procedures for deciding who shall be kept alive and who shall be allowed to die? When *is* a person dead? Certainly not when his heart stops; it can often be started again and kept going by an electrical pacer. Is he dead when his brain has irreversibly ceased to function, even though his vital organs otherwise continue with or without assistance? This was spoken of as "brain death," and many felt that it was a more reasonable criterion of death than failure of circulation and respiration, arguing that a human body without a brain, and hence no mind or sensibilities, is no longer a human being. But then the question arises: Must the entire brain cease permanently to function or is the loss of higher cerebral function, that part responsible for conscious thought and feelings, sufficient? Is an individual whose lower brain centers continue to keep the body going, but whose mind is irretrievably gone, no longer a human being? Is he essentially dead? Or should he be allowed to die and if so how? By whose decision?

These were some of the difficult questions being debated. They were raised most urgently by the ever increasing numbers of families who watched the death of a relative by the long-drawn-out and tortuous route made possible by modern medicine—in a respirator, on antibiotics, fed intravenously, with the family excluded from the intensive care unit in which it all took place.

Whatever the criteria for death, it was clear that the doctor could no longer consider it his duty solely to prolong life and fight death to the bitter end as he once could. Part of his charge was the difficult business of considering the quality of life as well as its duration and of accepting the responsibility for helping patients to die with as much dignity and peace as possible at the right time. Public sentiment seemed to be swinging this way, as judged by the recent press and the recent growth of interest in euthanasia.

Euthanasia and the living will. Euthanasia, derived from the Greek, meaning "a good death," was once an accepted part of many societies. For example, Eskimos who simply could not survive otherwise let disabled old people die as painlessly as possible when the rations got short. Modern Western societies, on the other hand, generally were strongly oriented toward the protection of individual life at all costs, especially favoring the weak and helpless. Nevertheless, the withholding of extraordinary measures to prolong life was widely condoned in private, and most physicians agreed that when the family consented and the patient was clearly demonstrated to be beyond salvage, resuscitative measures were not required at the end.

Passive, or negative, euthanasia was the next step; that is, the withholding of ordinary life-preserving measures in the hope of shortening painful or useless life indirectly. This also was practiced by many physicians when, in their judgment, it was the proper and humane course of action. Of a group of professors of medicine recently surveyed, 87% favored negative euthanasia.

Active, or positive, euthanasia, that is, the taking of definite measures to terminate or shorten life, is not generally condoned in Western society at present. Sir George Pickering, in his address at the opening of the new medical school in Nottingham, Eng., expressed the prevailing opinion about euthanasia among British physicians when he said, "I reject euthanasia—killing people is not what doctors should, or could, do." At the same time, he strongly endorsed letting old people die with dignity and not trying to prolong the lives of "old men and women stuffed with other people's viscera but with their own senile brains." Various groups, such as some members of the Euthanasia Society, argued that there was little difference ethically between active and passive euthanasia, once it was decided that it would be best for a patient not to go on living. In the survey just mentioned, almost half of the students of medicine and nursing questioned favored positive euthanasia, but this was true of only 15% of the professors of medicine. This perhaps indicated a trend in favor among the young, which society as a whole might well embrace in the future.

The Euthanasia Educational Fund, whose membership had grown from 600 persons in 1969 to

Joe Baker, MEDICAL WORLD NEWS



Though young physicians can learn much from treating the elderly, often the lack of time and patience impels them to concentrate their efforts on younger patients, who respond quickly and provide a greater and more immediate sense of achievement.

over 5,000 in 1972, had received more than 65,000 requests for living wills, documents designed to help physicians and families make decisions about life-prolonging measures in terminal illnesses where the patient may be unable to communicate his wishes. A person executing a living will indicates in part that "I do not fear death as much as I fear the indignity of deterioration, dependency, and hopeless pain." The signer asks that when any of these conditions are present he be allowed to die "in dignity." It was generally conceded that these documents did not bind the physician or the family legally. They did, however, help the consciences of both when the terminal patient was comatose or non compos mentis.

The legal and medical professions were still quite uncertain as to their respective roles in making the necessary decisions. How much should be left to the doctor, the doctor and the family, a committee of doctors, a committee with lay members, or the courts? Arguments were advanced for all of these, but in general the physician still took the major responsibility, in consultation with the family when possible.

Special problems arose in relation to organ transplantation. This new and very powerful technology depended on the recovery of viable organs from a donor as soon as possible after death. The kidneys of a person who is dead by any of the usual criteria remain viable for a limited time and can be transferred to a patient needing a transplant, but the shorter the time interval the better the chances for success. Obviously, a physician caring for both the donor and the recipient would be in a position of potential conflict over the interests of his two patients. It was, therefore, generally agreed that a different physician or group should be responsible for the donor's care and make decisions quite independent of the needs and wishes of the recipient and his physicians. Also, these decisions were generally made by more than one physician.

Legal aspects. Recognizing the need for changes in statutes relating to death, in 1971 the state of Kansas enacted the first law in the U.S. that attempted to redefine death and to take into account problems of organ transplantation. It read in part: "A person will be considered medically and legally dead if, in the opinion of a physician, based on ordinary standards of medical practice, there is the absence of spontaneous brain function; and . . . [that if] during reasonable attempts to either maintain or restore spontaneous circulatory or respiratory function in the absence of aforesaid brain function, it appears that further attempts at resuscitation or supportive maintenance will not succeed, death will have occurred at the time when these conditions first coincide. Death is to be pronounced before artificial means of supporting respiratory and circulatory function are terminated and before any vital organ is removed for purpose of transplantation."

This statute had a mixed reception in both medical and legal circles. Some greeted it as an important advance while others deplored it as both

unnecessary and dangerous. In these times of rapidly changing technology, no consensus had developed in the medical world as to the criteria of death or its precise time. In an article in *Science* Robert Morison argued persuasively that death is a process and not an event; in which case, any attempt to fix an exact moment of death is necessarily arbitrary. In the same issue, Leon Kass vigorously defended the classical view that death must be defined and timed precisely as an event.

The courts in several cases upheld the right of an individual to refuse life-prolonging treatment. Thus, the right to be allowed to die had been established under some circumstances, especially, but not exclusively, where religious convictions were involved. On the other hand, other courts had held the reverse, and life saving measures were ordered despite opposition by a patient's family. As of 1972 there had not been enough cases in the courts to establish legal precedents.

Thanatology: the care of the dying. In addition to the medical and legal aspects of the care of the dying patient, there are psychological factors of great importance. These were well known to the old-fashioned family doctor who had little but comfort to offer his terminal patient. He usually presided over death in the home, among the patient's family, in circumstances favorable to human contact and psychological support. This pattern of dying now tended to give way, especially in the U.S., to a more common one of death in the hospital. There, in addition to the indignities associated with overenthusiastic prolongation of life, the patient may find himself lonely and virtually abandoned as the end draws near. The team of busy physicians and nurses who visited regularly and were solicitous and attentive early in the terminal illness find it more difficult to face the patient. Too rarely are they willing or able to answer the questions he really wants to pose and to help him understand and accept his impending demise with equanimity and with a hand to hold.

Medical educators were, fortunately, becoming more and more concerned about reintroducing the human touch into modern, scientific medicine. The Society for Medicine and Human Values, with support from the National Endowment for the Humanities, held a national meeting at Williamsburg, Va., in April 1972 where the role of the humanities in medical education was the central theme. In June 1972 another national conference was convened in Tarrytown, N.Y., by the Hastings center, under the directorship of Daniel Callahan, to evaluate the teaching of medical ethics in the nation's medical schools. This center was also serving as a clearinghouse for information on ethical issues in the life sciences and was publishing periodically its own ongoing research into the ethical, social, and legal problems of death and dying. Finally, Robert H. Williams of the University of Washington was engaged in editing discussions on death and dying by a number of distinguished authors.

—Thomas H. Hunter

Dentistry

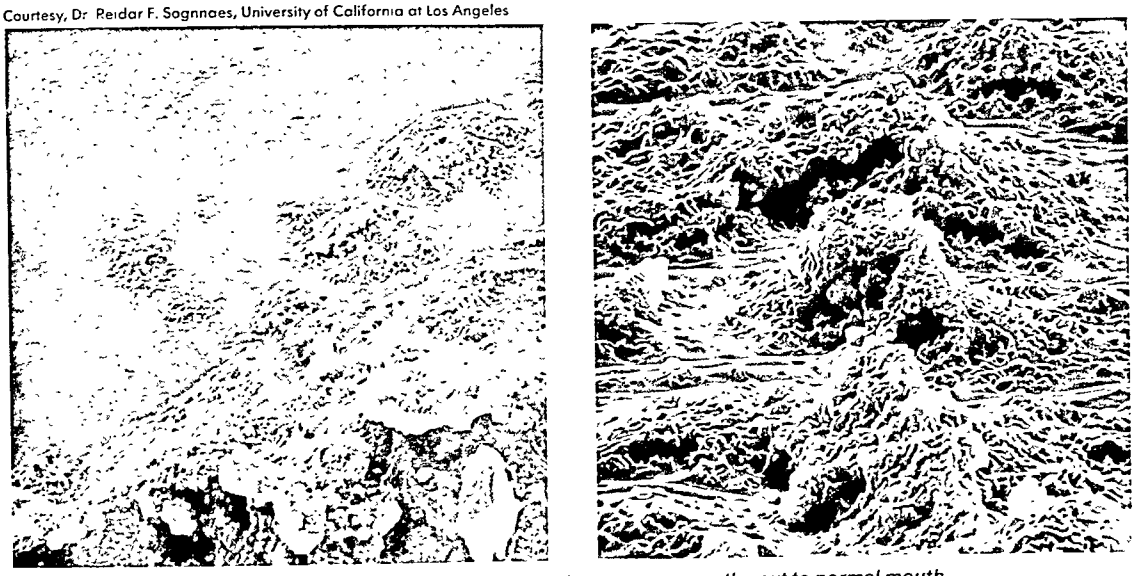
For decades the dental profession has advocated that teeth can last a lifetime through proper care. In early 1972 this idea was markedly advanced as dentistry began to move on many fronts toward stepping up the prevention of oral disease. The American Dental Association pointed out that the "profession now has the scientific knowledge to recognize and control dental disease and the technical ability to correct its harmful effects." A special ADA coordinating committee on preventive dentistry had the task of studying ways of implementing a large-scale prevention program that would include utilization of all research achievements and massive public dental education programs.

Control of dental plaque. Dental scientists long recognized dental plaque as a major culprit in the development of tooth decay and periodontal disease. The gummy masses of microorganisms develop constantly in the mouth; toothbrushing alone will not remove them. Effective plaque control, according to studies at the National Institute of Dental Research (NIDR), Bethesda, Md., can only be achieved through a variety of steps including proper eating habits, use of dental floss or tape to remove plaque and food debris from spaces between the teeth, use of water sprays and jets, use of solutions to identify areas where plaque is most likely to persist, and most of all, regular dental examinations.

Tooth decay research. Scientists at NIDR and at other research centers were studying the development of more effective and practical techniques for destroying existing plaque and blocking its further formation, possibly through the use of enzymes and chemicals. A number of antibacterial agents were discovered to be highly effective but had not been sufficiently tested for human use.

More progress was reported with studies on adhesive sealants that are painted on the occlusal (biting) surfaces of teeth to seal off areas particularly susceptible to decay. The sealants could not be applied to the sides of the teeth and therefore would not protect against smooth-surface or gumline cavities. The ADA announced provisional recognition of one sealant material as an agent

Courtesy, Dr. Reidar F. Sognnaes, University of California at Los Angeles



Precise silicone impressions of living tissue reveal islands of cancerous growth next to normal mouth tissue (left) and a malignant growth under an ill-fitting denture (right) when magnified under a scanning electron microscope. The technique can be used to replicate any easily accessible tissue.

capable of "restoring or sealing off anatomically deficient regions of the tooth," but cautioned that this recognition in no way pertained to any possible decay-preventing characteristics of the product.

Emotional stress and gum disease. Unusual emotional and physical stress may be the cause of a type of periodontal disease in teenagers and young adults known as pericoronitis (an inflammation of the gum tissues surrounding the crowns of partially erupted teeth). In a study conducted at the University of Kentucky dental school, more than 70% of 136 patients suffering from the disorder were under severe emotional or physical pressures. Unerupted third molars or wisdom teeth were most commonly affected. Fatigue, financial worries, and, in women, menstruation were mentioned among major causative factors.

Patients suffering from advanced periodontal disease frequently incur bone loss in the jaw. To correct this, a U.S. Army dentist, Robert G. Schallhorn, developed a unique surgical technique in which he implanted bone grafts from the patient's hip in the defective areas of the jaw.

Oral cancer prevention. Smoking was linked to the development of oral cancer and, according to University of California at San Francisco dental scientist Sol Silverman, Jr., even if an oral cancer patient quit smoking he might still develop a second oral malignancy. Such patients, however, might have a better chance of preventing a second malignancy than those continuing to smoke.

At the University of California at Los Angeles, Reidar F. Sognnaes developed an elastic silicone process for making living tissue impressions precise enough to be magnified thousands of times under the powerful scanning electron microscope (SEM), thus helping to detect early oral cancer. The technique provided nondestructive and painless micro-replication of all easily accessible hard and soft tissues, such as those in the mouth. Malignant cancer growths bulging up next to normal tissue were clearly visible in micro-replicas examined under the SEM. Small silicone discs carrying the fluid impression mixture are placed on the surface being examined. In a few minutes the mixture hardens and the replica can then be examined directly or be converted to a positive replica made of a harder resin material. The replica is also coated with a thin film of evaporated gold or other material to make the surface conductive to the beam of the SEM.

—Lou Joseph

Paramedical personnel

In 1900 the doctor's chief help in caring for the sick came from the patient's family, and most medical services were rendered in the home. At that time there was approximately one nonphysician health worker for every doctor in the United States.

In 1972 almost all medical services were performed in offices, clinics, and hospitals, and there were an estimated 12 nonphysician workers for every doctor, a ratio that continues to rise annu-

ally. Of these workers, about half were in nursing and its related professions; about 7% worked as secretaries, receptionists, and in similar positions; slightly more than 6% were in dentistry and its related fields; and slightly less than 6% were various types of environmental control workers. Pharmacists and their helpers, clinical laboratory technicians, physical therapists, various basic scientists, dieticians, and administrators formed the remainder of this large segment of the U.S. work force.

How and for what reason have these professions evolved? Some resulted from the subdivision of already existing professions. Two examples are X-ray technology and laboratory technology. At one time a doctor did his own X rays (radiographs) and his own laboratory work. In the course of time, it became apparent that these tasks could be taught to nonphysician helpers, and that this delegation of work was more efficient. At first, doctors trained their own helpers, but soon schools were created for the purpose.

Other professions emerged in response to new needs. Physical therapy arose out of a post-World War I need for professional persons to care for disabled veterans. Radiation safety, a relatively new field, grew from a need for persons to set up testing and surveillance programs to ensure the safety of patients and workers in hospital radiographic units. These skills were never possessed by more than a very few doctors, and were therefore the basis for truly new professions.

Impetus for this continuing creation of more and more medical professions came from the increasing specialization and institutionalization of medical care. Because of the rapid increase in knowledge and the parallel development of new technical capabilities, new skills became necessary. An example is kidney transplantation. This demands a team to operate the artificial kidney machine while the patient awaits a transplant; an immunologist to determine the best match of donor kidney to recipient patient; and, finally, a team that receives the donor kidney, preserves it, and prepares it for the procedure. All this is in addition to the surgeon who actually performs the transplant, along with his own team of helpers.

The generalist helper. While these developments have created a demand for more "specialty" workers in the hospital setting, many segments of the population have not been receiving adequate care for less sophisticated but far more common medical problems, and some members of society have practically no access to medical care. As the magnitude of this problem became apparent to the public and to medical, nursing, and other health professionals, there was a corresponding interest in the creation of still other categories of health workers to deliver needed services to these underserved groups.

Paramedical students learn laboratory procedures (left) and practice artificial respiration (right) during the course of a six-month training program at the University of New Mexico. The goal of the program is to improve the quality of health care in rural counties, many of which have no doctors.



Margie McCurry, University of New Mexico

Joe Baker, MEDICAL WORLD NEWS



Operating room nurses at Monmouth Medical Center in Long Branch, N.J., have become better informed about the total patient-care program through a series of regular conferences with physicians and post-operative patients. Many nurses had expressed a feeling of isolation from their patients because of the technological orientation of surgical procedures and the lack of post-operative contact.

The year 1971 was characterized by the emergence of physician's assistants, nurse practitioners, and other "generalist" assistants as accepted members of the health care team. Although these groups had been on the scene for five or six years, there had been considerable debate regarding their capabilities and, in some cases, serious controversy. During 1971 several developments all but assured the permanence of these new professions. There was a sharp increase in the number of operational training programs. A number of states passed laws recognizing these assistants and providing a legal framework for their activities. The American Medical Association (AMA) adopted a set of minimal educational standards for approved training programs for "assistants to the primary care physician" (as opposed to assistants to various medical specialists). The federal government also recognized the potential importance of such programs, and the creation of new programs was designated in the president's health care message as an area for special emphasis.

These new professionals came from various backgrounds. Physician's assistants usually had previous experience as military corpsmen, but an increasing number were entering the profession from nonmilitary backgrounds. Most were trained in two-year programs in which about half of the curriculum was classroom work, the other half practical work under physician direction. The nurse practitioner was usually a registered nurse who had had six months to a year of added training. The "Medex" was the product of a training program that accepted trainees with previous military or civilian experience and then provided 3 months of intensive instruction followed by 12 months of on-the-job training in a doctor's office.

Relatively few representatives of these new professional groups had been integrated into actual work settings in 1971. According to an AMA survey in October 1971, 96 physician's assistants had graduated (74 from the Duke University program) and Medex programs had graduated 56 persons (22 from the University of Alabama, 19 from the University of North Dakota, and 15 from the University of Washington.)

Licensing and certification. These developments highlighted some major problems associated with licensure, certification, and accreditation. The higher levels of medical and related professions are generally licensed by individual states; each state has passed laws defining the role of each profession, setting educational and ethical standards for entry into the profession, and establishing an examination to test skills and knowledge. Such laws exist for doctors, dentists, and nurses, and occasionally for other professionals as well. These laws are designed to protect the public by ensuring a minimum level of competence before entry into practice.

Other health professionals are not licensed, but are certified by a given training program as having

Michael Mauney, LIFE Magazine © Time Inc.



A nurse-midwife, an R.N. with specialized training to help ease the nationwide doctor shortage, by Kentucky's Frontier Nursing Service presents a newborn baby to its mother shortly after delivery.

completed a prescribed course of study. Some programs of this type are accredited by various professional bodies as being in conformity with established minimum standards. The AMA, for example, has set up criteria for a number of such programs and accredits those that meet or exceed these criteria. Most certification and accreditation programs, like licensure programs, are established with quality control as the primary objective. However, it is also recognized that such mechanisms can become the means whereby a profession protects its own interests by preventing competition.

In August 1971 the U.S. secretary of health, education, and welfare, Elliot L. Richardson, announced the recommendations of a special committee appointed to study the problem. The states were urged to observe a two-year moratorium on enactment of legislation creating new categories of health-care personnel. The states were also urged to expand existing health practice (licensure) acts, granting broader delegational authority to already licensed professionals. The two-year period was to be utilized to develop equivalency and proficiency examinations for use on a national basis. Inclusion of public (consumer) representatives on health licensing boards was also recommended.

Community health aides. Another significant development over the past few years has been the use of community health aides, particularly in low-income, medically deprived areas. These are generally residents of the area to be served, and usually have had no prior formal health training. Often they were employed after efforts to recruit more formally trained personnel had failed, and frequently their employment was opposed or received with misgivings by conventional health-care personnel.

In almost all areas where they have been employed, these workers have more than met expectations. An often encountered comment is that they were able to communicate with residents of the areas where they work when regular professionals could not. Generally, they have been trained in short courses of several weeks' duration, followed by on-the-job supplementation of training. Their jobs vary considerably. Some are trained to educate area residents regarding immunizations and regular health care. Others assist in family planning and in drug abuse programs. Still others assist in direct medical services. In all cases, the empathy, understanding of problems, and ability to communicate have proved highly useful and unique assets, far outweighing the lack of formal instruction.

Further developments. Federal support for various paramedical programs received a great boost in 1971 in the form of the Comprehensive Health Manpower Training Act. This act provides added support for training institutions, through special improvement grants and through incentive grants for programs producing physician's assistants and nurse practitioners.

There have also been a number of studies aimed at measuring the improvement in services associated with use of physician's assistants and nurse practitioners. Reports suggest that the use of a physician's assistant augments the volume of medical services produced by 50 to 70%. Analyses of the pediatric nurse practitioner indicate that such a person can effectively handle 80% of the cases once seen by the pediatrician.

Pharmacy faced a number of issues during the year, most of which remained unresolved. The primary issue was should the pharmacist remain as a dispenser of drugs, or should he redefine his role, assuming a larger responsibility in health care? Most observers agreed that the present educational base of the pharmacist should enable him to assume a broader set of functions than merely operating a retail drugstore. One possibility was that he could function within the hospital as an expert on drugs—in charge of dispensing drugs, consulting with doctors on the choice of drugs, and instructing patients regarding them. Another was that he could serve as a primary contact with the patient in areas with a shortage of doctors. In many cases, the latter function would require changes in state laws. It was noteworthy that those who favored changing the role of the pharmacist usually favored the training of a pharmacist's assistant to dispense drugs under his supervision.

Within the nursing profession, a considerable amount of energy was being expended on discussion of the proper stance of nursing vis-à-vis the physician's assistant. Many nurses felt that widespread assumption of such a role by nurses would negate the gains that had been fought for during the past 20 or 30 years in obtaining recognition of nursing as an independent profession. Others believed that a professional colleagueship with the doctor in the care of patients is a satisfying role, in no way threatening to the professional stature of the nurse. The more youthful members of the profession seemed much more inclined toward the latter view.

—E. Harvey Estes

Psychiatry

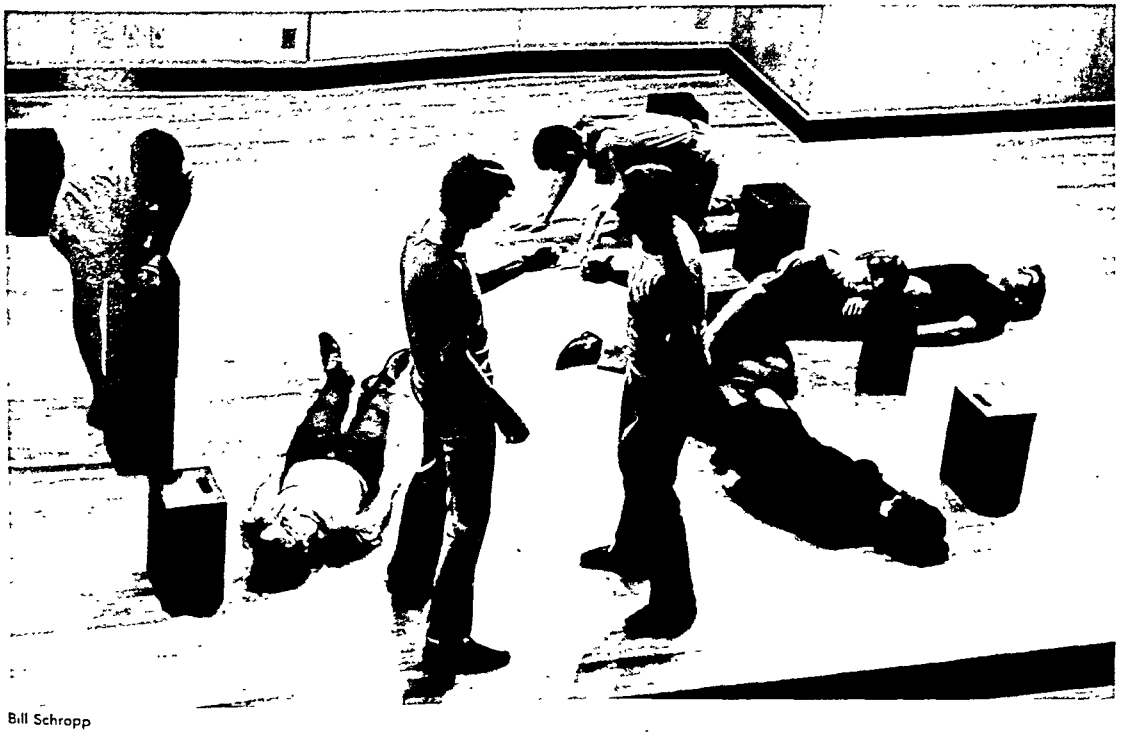
During the past year, researchers in the field of psychiatry made a number of significant discoveries. Work was done on the genesis and treatment of such diverse illnesses as schizophrenia, temporal lobe epilepsy, and alcoholism, as well as manic-depressive psychosis.

Depression. Lithium carbonate, a drug that had been reported to be effective in the management of manic-depressive psychosis in 1943, was finally cleared by the U.S. Food and Drug Administration for use with manic patients. Numerous papers published during the year attested to the therapeutic usefulness of this compound in the alleviation of mania or hypomania. In addition, recent reports from England and Scandinavia indicated that it may be effective in the treatment of bipolar depression.

Studies by the Scandinavian researcher K. Leonhard indicated that there are two types of depressive illness. One, referred to as unipolar, occurs in patients without any history of a manic attack. The other type, which Leonhard labels bipolar, occurs in patients who have had mania in the past. R. Fieve at Columbia University showed that lithium carbonate is effective in alleviating the symptoms of depression in patients with bipolar illness. Further, lithium carbonate seems to be associated with a decrease in the frequency of recurrent attacks. Lithium does not appear to be effective in the treatment of unipolar depression, however.

This finding supports the concept that patients with bipolar illness may suffer from some form of biochemical abnormality that is corrected by the

Actors stage "The Concept," a psychodrama on drug abuse, for the personnel of a New York company. Large corporations throughout the U.S. are discovering many drug users among their employees and are sponsoring several types of programs to combat the problem.



Bill Schropp

administration of lithium carbonate. Further evidence is provided by genetic studies. Several researchers have noted that a large number of bipolar patients have bipolar parents. George Winokur at the University of Iowa showed that, in two families under study, family members who were color-blind were also bipolar patients, indicating a genetic linkage between color blindness and bipolar depression.

Schizophrenia. Whether environment or genetic makeup is related to the development of schizophrenia has long been the subject of debate. D. Rosenthal at the National Institute of Mental Health (NIMH), in reviewing case records of the offspring of schizophrenics who were put up for adoption at birth, noted that even though these patients had been adopted by nonschizophrenics, roughly one third of them developed schizophrenia in later life. However, a small number of adoptees from nonschizophrenic families who were raised by schizophrenics also developed schizophrenia. Rosenthal concluded that both genetic and environmental factors are important in the development of the disease.

A methadone "disket," widely used in heroin addiction therapy, begins to dissolve in water. Properly prescribed and taken, methadone curtails an addict's craving for heroin and stabilizes his condition so that rehabilitative measures have a chance to succeed.



Leonard Komsler, MEDICAL WORLD NEWS

Chemotherapy continued to be the primary treatment for schizophrenia. Chlorpromazine was joined by haloperidol as an effective antipsychotic agent. Studies by Larry Stein of Wyeth Laboratories, Radnor, Pa., indicated that the administration of chlorpromazine during the first few months of schizophrenia may prevent the formation of an irreversible brain lesion. Stein hypothesized that schizophrenia in man can be explained on the basis of the destruction of the pleasure center in the septal region of the brain by the formation in the brain of a toxin, 6-hydroxydopamine, which has been shown to destroy selective areas of the brains of rats. Stein identified a metabolite of 6-hydroxydopamine exuded in the sweat of schizophrenics. Since administration of chlorpromazine to rats during the first six months of 6-hydroxydopamine injections prevented the destruction of brain centers, Stein believed that chlorpromazine used sufficiently early in the treatment of the schizophrenic patient could arrest irreversible destruction of the brain's pleasure center. His work had yet to be confirmed, however.

Other researchers believed that the delusions of schizophrenia are produced by a hallucinogen manufactured by the human brain. Under the direction of Julius Axelrod, researchers at NIMH discovered that the human brain converts tryptamine to n-methyl-tryptamine and di-methyl-tryptamine. The latter compound is a hallucinogen, raising the possibility that the delusions of a schizophrenic may be explained on the basis of genetic predisposition to form di-methyl-tryptamine. It is also possible that schizophrenic patients form the compound when undergoing stressful situations. Research was in progress to determine whether schizophrenic patients do in fact synthesize di-methyl-tryptamine in their brains.

Violent and aggressive behavior. Many patients who experience episodes of violence and aggressive behavior as a result of a disease known as temporal lobe epilepsy can be treated with tranquilizers, psychic energizers, and antiseizure drugs. In the past, if these compounds were unable to control violent outbursts, such patients were subjected to the surgical removal of part of their temporal lobe. This required quite a large incision, the sacrifice of a large amount of brain cortex that was not diseased, and the removal of a large amount of skull bone.

V. H. Mark and F. R. Ervin of Harvard University perfected a surgical technique in which tiny elec-

Culver Pictures



An etching by William Hogarth, published in 1735, depicts Londoners amusedly watching the cruel treatment of mental patients in Bedlam. As recently as January 1972, cruelty to patients in a British mental hospital was the subject of an official inquiry. A plan released in 1972 by Britain's Department of Health and Social Security proposed closing all the nation's mental hospitals and replacing them with small psychiatric units in local hospitals and outpatient care facilities.

trodes are implanted in the brain and used to destroy those few brain cells that act abnormally and that in the past have been associated with the symptoms of seizure and violence. The therapeutic results in patients suffering from unilateral or bilateral temporal lobe epilepsy have been excellent. It must be remembered, however, that this procedure is applicable only to those violent patients whose behavior stems from temporal lobe epilepsy. Mark and Ervin estimated that this disorder occurs in one out of ten people who exhibit excessively violent behavior.

Community and social psychiatry. The state of California closed three large state hospitals during the year. This was done in response to the decreasing patient population in these facilities, as well as to the increased availability of community mental health centers. Since chlorpromazine became available for the treatment of mental illness in 1955, the patient population in large state mental hospitals has decreased steadily. At that time there were more than 550,000 patients in state and county mental hospitals; as of 1972 the number had fallen to less than 400,000, despite the increase in the population as a whole. The number of admissions to state mental institutions rose during this period, but the patients were hospitalized for a much shorter time.

Animal models of psychosis. One of the factors that has prevented an early understanding of the causes of mental illness has been the lack of an animal model of any psychiatric disturbance. Whereas the infectious diseases, cancer, and a number of metabolic diseases affect animals as they do man, the mental illnesses that afflict man have appeared to lack counterparts in animals.

Working with rhesus monkeys, Harry Harlow and William McKinney at the University of Wisconsin developed an animal model of autistic behavior, involving severe withdrawal and inability to relate. Animals were separated from their mothers early in life and reared in isolation in large metal chambers. Their behavior following confinement in this chamber for two months or longer appeared autistic—the animals had little interest in food or sex, they were afraid of monkeys their own age, and did not enter into the play activities that their normal siblings enjoyed. Whether or not this behavioral state is related to schizophrenia or to any other human psychosis was still in question. Two forms of therapeutic intervention were successful in reversing this autistic behavior. Observations by the group in Wisconsin revealed that if one of the autistic monkeys was placed in a cage with another, younger monkey, this younger and more socially adept "therapist" monkey served to increase the socialization of the autistic animal. Over the course of several weeks the "therapist" monkey was able to engage the autistic animal in play with other animals, and after several months of group interaction with the "therapist" monkey the autistic animal seemed to be highly socialized with respect to the other animals in the group cage. The Wisconsin researchers also noted that the administration of chlorpromazine reversed some of the symptoms of the maternally deprived

animals. Thus, both environmental and drug treatments appeared to be effective.

Future developments. Rubidium carbonate showed some promise as an antidepressant in pilot studies under Fieve's direction at Columbia University. It has been thought by many researchers that depressed patients may suffer from a functional deficiency of norepinephrine in the brain. Rubidium carbonate increases the rate of release and uptake of norepinephrine in the brains of rats and monkeys, and it has been hypothesized that the compound may be effective in increasing the functional availability of norepinephrine in the brains of depressed patients.

With the federal government placing great emphasis on the treatment of alcoholism and drug abuse, it was not unlikely that major discoveries would occur in this area in the near future. The finding by E. P. Davis in Houston, Tex., that alcohol may lead to the formation of a substance similar to morphine stimulated research to discover whether this morphine derivative is responsible for the addicting effects of alcohol. Several investigators were attempting to isolate this morphine derivative in the spinal fluid of alcoholics.

To date, methadone has proved to be the most effective compound in the treatment of heroin addiction, but its effects are short-lived, requiring frequent dosage. A possible replacement was α-acetyl-methadol, a methadone derivative, which was shown to be longer lasting in its antinarcotic effect than methadone. It is also more potent, and therefore can be given in a smaller dose. Another drug treatment was being developed by Sydney Spector at the Roche Institute of Molecular Biology, Nutley, N.J. He produced antibodies to morphine and heroin in animals, and it was possible that the administration of these antibodies to man would eliminate the narcotic effects of heroin.

Studies on the use of nondominant brain hemispheres were expected to reveal some interesting therapeutic results. This work, carried out under the direction of E. Callaway at the University of California in San Francisco, focused on the training of stroke victims to use their nondominant hemisphere. The training involved a feedback technique using electroencephalographic (EEG) tracings taken from scalp electrodes, which were displayed to the patient in a feedback loop. The EEG reading enabled the patient to know when he was using his dominant or nondominant hemisphere in a specific process. The possibility of tapping the potential of the nondominant side of the brain, which normal man has never used, is tremendously exciting and may offer hope for thousands of stroke and cancer victims.

—H. Keith H. Brodie

Venereal disease

In 1972, venereal diseases continued at pandemic levels in the United States, as an estimated 80,000 new cases of infectious syphilis and 2.2 million new cases of gonorrhea joined the carrier pool. Reported congenital syphilis continued its rise from 300 cases in 1970 to 397 in 1971.

The incidence of venereal diseases in the U.S. varies widely by region and age distribution. Not surprisingly, the greatest incidence occurs in areas of high population density and among the largest age groups within a population. Thus, as the mean age of population decreases, the incidence of venereal disease among young people increases.

Regional variation is more complex: the national rate of infection for gonorrhea is 285 per 100,000 population. Yet in fiscal 1970 (July 1, 1970, through June 30, 1971) gonorrhea occurred at the rate of 2,486.7 per 100,000 in Atlanta, Ga.; 1,262.2 in Chicago, Ill.; and 2,121.4 in San Francisco, Calif. The average rate of gonorrhea infection for the 61 major cities of the U.S. was 640.2 per 100,000. For the same year, syphilis rates ranged comparably from 10.4 cases per 100,000 population nationally to 93.4 cases per 100,000 in Newark, N.J.

Whence VD? Venereal disease is an old problem. Gonorrhea has been with us at least 5,500 years, and although the history of syphilis is not as clear, it does extend beyond the memory of modern Western man. The spread of venereal disease is encouraged by its high infectious rate and by its status as a shameful and secret illness. Equally infectious diseases such as smallpox have been conquered, but venereal disease eludes eradication, due in part to a fundamental contradiction between sexual mores and actual practice.

Historically, the chief prophylactic, or preventive, measure offered the general public against venereal disease has been abstinence from sex until the beginning of a monogamous marriage. In fact, however, if one generation had ever practiced virginity until monogamous marriage occurred, no venereal diseases would exist. The fact that gonorrhea and syphilis together outnumber all other communicable diseases attests to the ineffectiveness of such an approach and to the serious need for more realistic preventive measures as well as treatment.

VD in the twentieth century. During World War I, venereal disease ranked second only to influenza among infectious diseases. Venereal disease kept men out of the service and, once in service, out of combat. Thus, the military began a massive venereal disease control program which ended at the conclusion of the war. Not until the build-up for World War II was another major program begun.

and with the discovery of the effect of penicillin on venereal diseases, early in the 1940s, their eradication seemed in sight.

Unfortunately, that very possibility led to changes in the treatment of venereal disease which virtually assured its survival. With the advent of penicillin, venereal disease treatment was taken out of the hands of the U.S. Public Health Service and shifted into those of the private physician. The American Social Health Association estimated that in 1972 private physicians treated 75% of all venereal disease cases yet reported less than 15% of them, despite mandatory state reporting laws. Because venereal diseases are highly infectious, this failure to report cases and follow up on infectious contacts leaves the diseases free to spread.

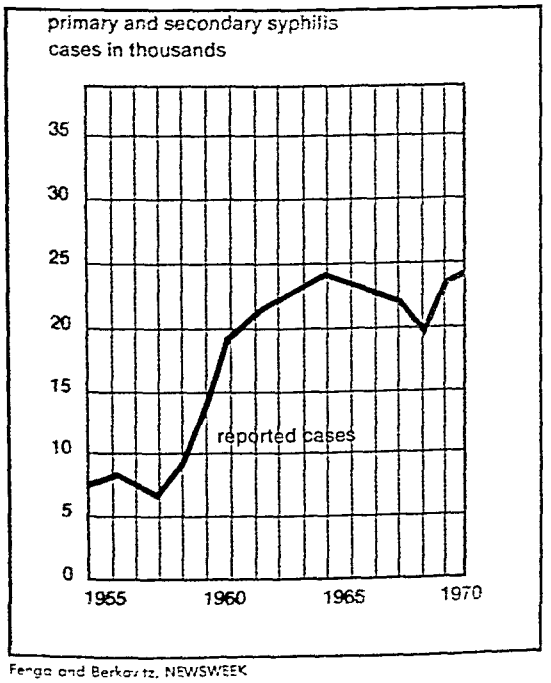
Failure to report also accounted for an apparent decline in venereal disease infection, and consequent reduction of venereal disease control programs. Following World War II, tax dollars allocated for venereal disease control were cut from 11 cents per capita to 3 cents per capita, closing down federal, state, and local case-finding programs. By the late 1950s, alarming new rates of syphilis infection had appeared, and in 1961 a federal task force was created to recommend steps to eradicate the disease. 1971 witnessed the formation of a second task force, this time to investigate the epidemic of gonorrhea.

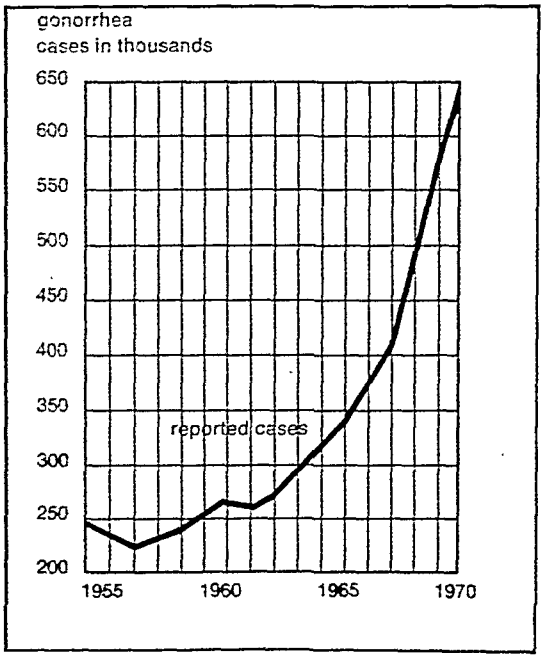
Why the rise? A secondary effect of the discovery of penicillin as an effective treatment for venereal disease was public apathy. With a fully effective curative treatment at hand, one could assume that the danger of infection had passed. Many assumed just that, and paid less heed to available preventive measures.

Among the chief preventive measures generally available was the condom. Military experience in World Wars I and II indicated that use of the condom could substantially reduce, if not eliminate, the danger of infection by genital contact. An Army study demonstrated that gonorrhea infection rates could be reduced from the 625 per 1,000 current in the Army at that time to 35 per 1,000.

A second factor in venereal disease control, principally control of gonorrhea, was the use of female contraceptive devices. Although not intended as venereal disease prophylactics, the diaphragm and various contraceptive foams and jellies effectively prevented infection of the cervix by the gonococcus. Use of the birth control pill, which had become widespread by the early 1960s, displaced these devices and opened the way for increased gonorrhea infection.

The pill had one final effect which passed unnoticed for some time. Oral contraceptives cause the normally acid vaginal flora to become alkaline, and increase moisture in the vaginal tract. Gonococci thrive in conditions of moisture and alkalinity, escalating the chances of infection on a single exposure from 40% in the female not taking the pill to 100% for the woman who is.





Fergo and Berkowitz, NEWSWEEK

VD today. Today, as in the past, venereal disease control depends on five basic procedures: public education; development of effective prophylactics; case finding; treatment; and follow-up. In a sense, these measures are self-evident. They are standard for the conquest of any communicable disease, and have been apparent for many years. With venereal disease, however, shrouded as it is in centuries of unjust prejudice, shame, and myth, conquest depends on the cooperation not only of the public but of the medical profession, drug manufacturers, and government agencies active in funding and carrying out effective programs. Venereal disease education illustrates the interrelationship of these groups.

To be effective, venereal disease education must deal with access to the health care delivery system. It is not enough to inform the public about the symptoms and consequences of venereal diseases. We must also be certain that physicians, hospitals, and the public health services are prepared to handle the huge caseload that would result from effective education. At present this is not so. Many physicians are not adequately trained in detecting and treating venereal diseases; others suffer from the same taboos about venereal disease that afflict the general population. Public health services were admirably designed to tackle case finding, treatment, and public education. However, today, with the barest minimum of funding in relation to the problem, they are unable to provide the services required. Finally, the finest case finding and treatment services will not avail unless financial barriers to care are removed. Even free treatment will fail to solve the problem if unrealistic scheduling or remote locations add indirect costs such as transportation and time off work.

A poster prepared for the United Givers Fund expresses the growth of venereal disease among teen-agers.



Courtesy, UGF, Washington, D.C.

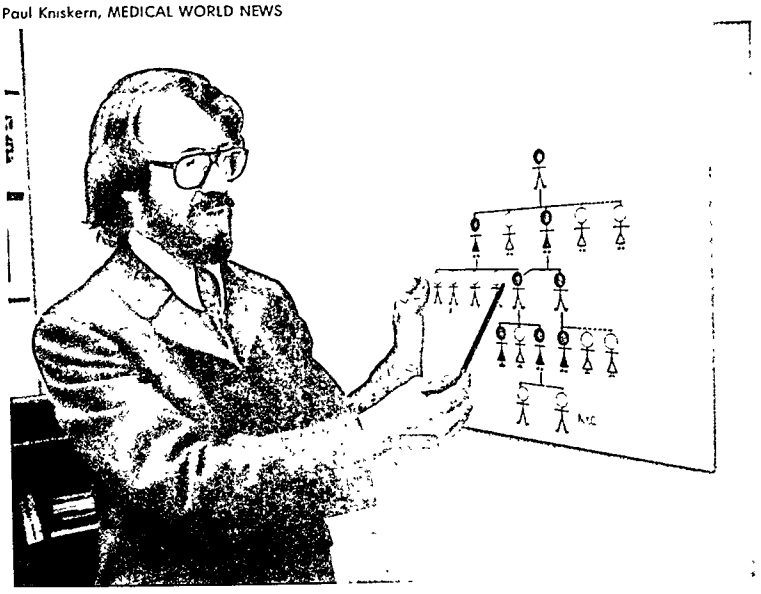
National Commission on VD. In March 1972, the National Commission on Venereal Disease issued its report, detailing the rise of venereal disease infections to their highest point since the introduction of antibiotic drugs 20–30 years earlier. Warning that venereal disease was epidemic and gonorrhea "out of control," the commission offered 40 recommendations aimed at controlling the spread of these diseases. The commission added that even if its recommendations were fully implemented the number of cases could be expected to continue to rise in 1973.

The campaign recommended by the commission would include a voluntary venereal disease education program for school children starting in the seventh grade; enforcement of existing mandatory tests for syphilis and gonorrhea; stricter reporting; and more money for case finding, follow-up, and treatment. Enforcement of mandatory tests alone would result in the screening of 40 million people in fiscal year 1973. The commission recommended a federal investment of almost $300 million over the next five fiscal years, including $46.1 million for the coming year. However, in 1972 the federal budget called for spending only two-thirds of that amount. Commission officials pointed out that while an estimated $43 million is being spent this year on venereal disease control by all groups combined, the total cost of the effects of syphilis and gonorrhea would be $364 million for the same period.

Beyond the commission. Broader steps against venereal disease will entail reevaluation of many attitudes toward venereal disease itself and the nature of health care, and a restructuring of the systems that deliver all forms of treatment today. Stricter observation of those firms engaged in testing and manufacturing prophylactics and curative drugs may be required. And recommendations for increased government and medical school funding for venereal disease control programs will require close scrutiny to prevent the creation of a new class of "VD professionals" and assure the delivery of services to the public.

Realistic prevention programs must operate at several levels to identify the massive pool of those carriers who show no symptoms of disease, treat them and their contacts, and reach new cases. The first level of prevention should be case finding, currently impeded by failure to report cases. Mandatory testing should be expanded to screen more potential cases; for example, marriage require-

Paul Kniskern, MEDICAL WORLD NEWS



Alan Hinman, New York's chief of epidemiology, examines a chart diagramming the sexual contacts of a gonorrhea carrier. New federal grants to state health departments totaling $16 million were to be used for diagnostic laboratories and screening programs to seek out and eradicate the disease in asymptomatic carriers.

ments could add a gonorrhea test to the syphilis screening already in force. Tests for both syphilis and gonorrhea should be required as part of prenatal care. The U.S. Public Health Service began a pilot screening program for gonorrhea among women having a routine vaginal examination. Other times when a patient routinely passes through the hands of a physician could be developed as opportunities for screening.

All partners of an infected person must be identified, tested, and treated. This second level of prevention, treatment of all exposed persons regardless of test results, must be enforced because of the relative inefficiency of tests and the great increase of gonorrhea that does not present obvious symptoms.

The third level of realistic prevention is the development and use of effective prophylactics, devices that will prevent infection upon exposure. In this area, vaccines are the traditional remedy. But research on vaccines is hampered by the nature of the diseases and the lack to date of a reliable experimental animal model. The potential prophylactic role of contraceptives other than the pill has been largely ignored, despite a report issued by Pfizer Laboratories that indicated that eight such devices have been proven in laboratory studies to prevent gonorrhea, syphilis, and other vaginal tract infections as effectively as they prevent conception.

Realistic prevention depends finally on each of these steps, and upon the equitable distribution of all the services they entail. If treatment, including access to prophylactic drugs, is limited only to those who can afford to pay the direct and indirect cost of service, venereal diseases will continue to spread epidemically.

—Jerry Lama

See also Feature Articles: TEST-TUBE BABIES; CANCER UNDER ATTACK; THE NOTORIOUS TRIO: MERCURY, LEAD, AND CADMIUM; NUTRITION AND THE AMERICAN DIET; Year in Review: VETERINARY MEDICINE.

Microbiology

Advances were made in several areas involving microscopic organisms during 1971–72. As is always the case, these results had implications in other biological and medical sciences.

Subcellular studies. Ecologists had long had the problem of how best to measure community activity in a given natural environment. For example, it was difficult to determine whether forms of microbial life observed in a natural environment were metabolically active, dormant, or even dying. Recent studies of the cell's fundamental energy-producing mechanism, however, led to the development of a technique that may be used as an objective criterion of community activity.

Adenosine triphosphate (ATP) is the principal compound involved in a cell's energy-yielding and energy-requiring reactions. Energy is released from ATP by hydrolysis (decomposition by the action of water), and ATP is converted to adenosine diphosphate (ADP) and adenosine monophosphate (AMP). Thus, these three nucleotides couple all of the metabolic reactions of living cells. The amount of metabolically available energy that is

Courtesy, Litton Bionetics, Inc.



Degeneration characterized by abnormal structures within the nuclei and by cavities near them was found in lung cells infected with Mason-Pfizer monkey virus. The virus is characteristic of tumor-causing RNA viruses, but its effects on cells had never before been observed.

momentarily stored in this system is related to the mole fractions, or concentrations, of ATP, ADP, and AMP in the system. This value was being termed the "energy charge." The value of the energy charge during growth of bacterial and mammalian cells is about 0.8. Maintenance of life, but not growth, seems possible at energy charge values between 0.8 and 0.5. Energy charge values below 0.5 appear to be incompatible with maintenance of life, and such cells appear to be in a dying state.

The bacterial cell membrane regulates the transport of nutrients into the cell and wastes out of the cell, contains enzyme systems involved in energy production and in respiration, and serves as the site of synthesis of many cellular components. All biological membranes are composed almost entirely of two classes of compounds, proteins and lipids (fatty subtances). The proteins have enzymatic or transport activities and provide the membrane with its distinctive functional properties. The actual molecular organization of membranes, however, remained poorly understood.

A recent concept visualized a fluid mosaic model for biological membranes. In this model, globular protein molecules are considered to be partially embedded in a matrix of lipid, with the protein molecules being mobile in the plane of the membrane. This fluidity might be important in the transport of substances across the membrane and in other biological functions peculiar to the membrane. Recent experiments provided strong supporting evidence for the fluid mosaic nature of the bacterial cell membrane. Bacteria were induced to synthesize the protein that transports the milk sugar lactose into the bacterial cell. It was found that this transport protein was inserted in all regions of the cell membrane rather than at fixed regions. These experiments also showed that the lactose transport protein molecules were inserted equally well into both previously and newly synthesized portions of the membrane.

In the area of genetics, scientists presented indirect evidence that they had succeeded in introducing an active bacterial gene into human cells. The human cells were derived from a patient with galactosemia, a disease caused by the absence of the gene that directs the synthesis of the enzyme enabling the person to metabolize the sugar galactose. A bacterial virus picked up the specific gene from bacterial cells that could metabolize galactose. When the human cells were exposed to the virus, an active enzyme was produced that enabled the human cells to metabolize galactose. Whether this gene could be replicated by the human cells and passed on to the daughter cells was not determined. It was thought by some scientists that human genetic diseases may be cured some day by such "genetic engineering."

Disease-causing microbes. Infection of newborn infants by the bacterium *Staphylococcus aureus* (staph) acquired in hospitals continued to be a serious problem. Although staph is a common human parasite, especially deadly and often drug-resistant forms are found in hospitals. To guard against staph infections, the germicide hexachlorophene long had been used in soaps and medicinal cleansers. Hexachlorophene was also used in certain adult cosmetics. The U.S. Food and Drug Administration (FDA) banned hexachlorophene from cosmetics early in 1972 and advised hospitals not to bathe babies in substances containing it. This action was based on the experimental finding that brain damage occurred in animals that had absorbed high quantities of hexachlorophene through the skin, although no such injuries had been reported for humans.

Following the FDA ban, a sequence of events occurred that illustrated how the beneficial and the potentially harmful effects of a drug must be weighed in order to determine proper use. A rising incidence of outbreaks of staph infections among

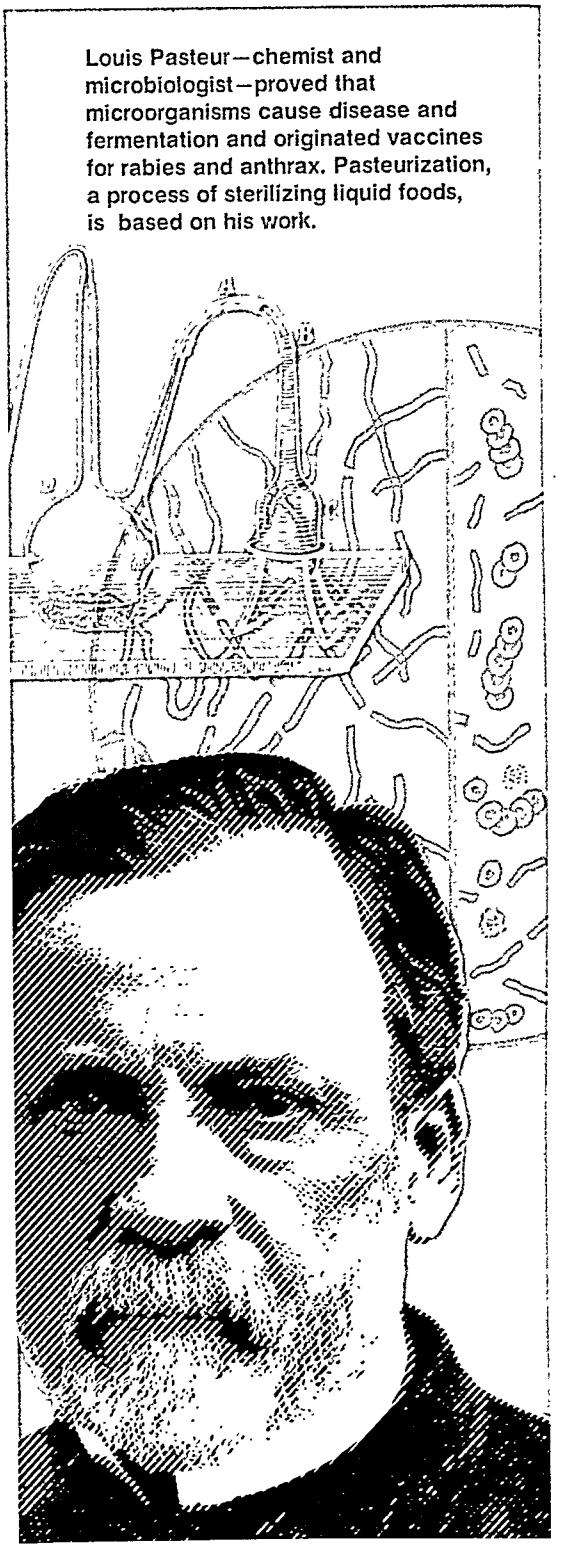
newborn infants was noted and was attributed to the discontinuance of the use of hexachlorophene. Hospitals may have overreacted to the directive by not using hexachlorophene-containing cleansers at all, even on the hands of nursery personnel, a use that was not banned. The FDA changed its ruling to state that babies may be bathed in hexachlorophene-containing solutions on a temporary basis should there be signs of an impending staph outbreak.

Rabies is a virus considered to be invariably fatal in man. Recently, however, a six-year-old boy was reported to have recovered from the disease, contracted from the bite of an infected bat. The child began the 14-day course of the rabies vaccine four days after his exposure to rabies, but symptoms of the disease began to appear two days after completion of the series. Scientists from the National Communicable Disease Center, Atlanta, Ga., took charge of the case and began a program of symptomatic treatment. There are no drugs known to be effective against the rables virus (or any other virus), and treatment of the symptoms was the only alternative. The treatment included continuous monitoring of heart and lung functions; prevention of an oxygen deficiency by cutting an opening into the windpipe; and mechanical assistance for the lungs. Further experience with specific treatment measures on rabies-infected laboratory animals and prolonged survivals achieved with other recent human patients resulted in hope that the possibility of recovering from the disease might be increased appreciably.

In contrast to the case of many cancers in animals, no cancer-causing viruses had as yet been isolated from human cancer patients—even though virus-like particles were observed in a variety of human cancer tissues. In late 1971 and early 1972, there were reports of at least three viruses thought to have been isolated from human cancer tissue. One, however, was shown instead to be an animal virus and research was still in progress on the others.

The C-type virus was considered by many scientists to be able to cause cancer. Viruses of this type were thought to be able to exist in unexpressed and unobservable forms in many cells as a part of their genetic makeup. Recently, two chemicals, both of which were structural analogues of a component of the genetic material deoxyribonucleic acid (DNA), were shown to be able to activate C-type virus particles in animal cell lines. These chemicals might be useful as "tools" with which to demonstrate the existence of unexpressed C-type viruses in human cell lines.

New evidence was obtained that Hodgkins' disease, a lymphatic cancer, may be caused by two



Louis Pasteur—chemist and microbiologist—proved that microorganisms cause disease and fermentation and originated vaccines for rabies and anthrax. Pasteurization, a process of sterilizing liquid foods, is based on his work.

viruses working together, one containing ribonucleic acid (RNA) and the other containing DNA. The latter was thought to be related to the herpes family of viruses. There was also speculation that Hodgkins' disease is contagious, most likely because of transmission of the DNA-containing virus.

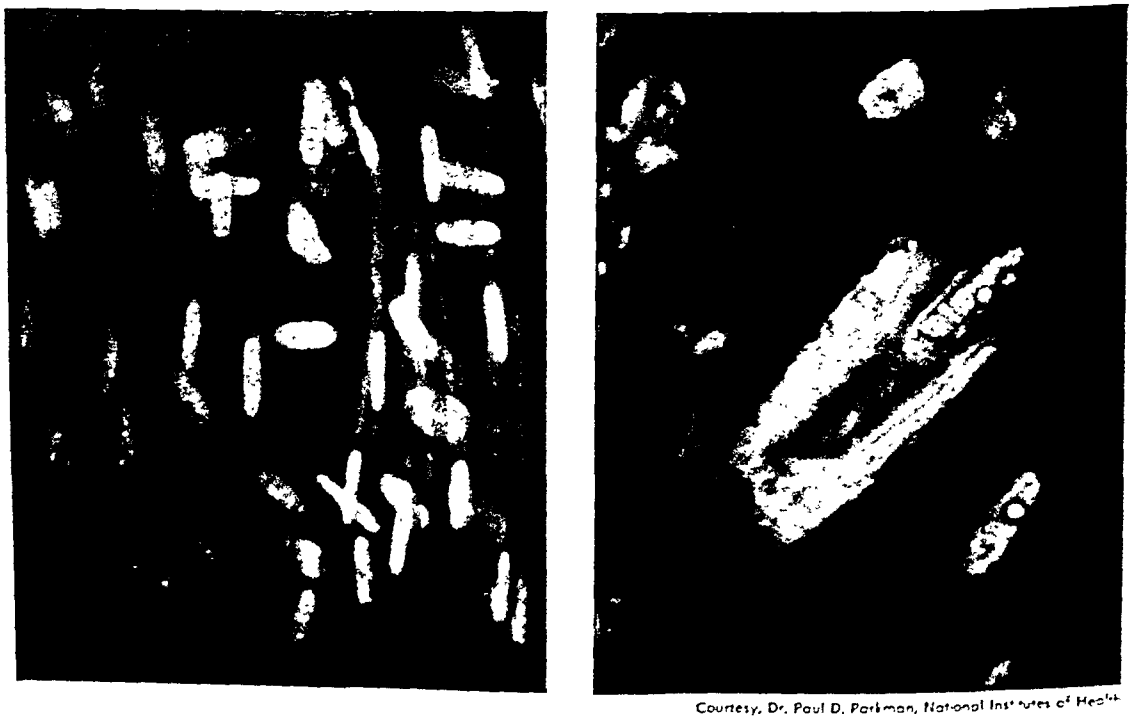
Although it was discovered in 1874, the bacterium that causes leprosy had never been cultivated in a test tube. Leprosy infects only humans and has not even been transmitted to higher primates. The bacterium prefers the cooler regions of the body for optimal growth, and it had been found to grow very slowly in the foot pads of mice. There was evidence that the armadillo might be a good experimental animal host for leprosy. It has a low skin and body temperature, which the leprosy bacterium requires, and has a long enough life to give scientists time to study the slowly progressive nature of the disease.

Smallpox, an entirely human viral disease, appeared to be almost extinct, so much so that the U.S. Public Health Service no longer advocated routine vaccination against it and most states had ceased to require vaccination of school-age children. Eradication of smallpox was brought about by a worldwide vaccination program. It was thought that the virus no longer existed in those societies in which extensive vaccination programs had been enforced and in which there have been no recently reported cases. (The last reported case in the U.S. occurred in 1949.) There were, however, annual reports of instances of severe complications resulting from the vaccination itself; a few instances even resulted in death. The disease was still residual in a few countries, most notably Ethiopia, India, and Pakistan, and continued surveillance for it would be required, with routine vaccination recommended for persons who might be exposed to it.

A 1971 epidemic in the U.S. of horse sleeping sickness (Venezuelan equine encephalomyelitis, or VEE) was confined to southern Texas by the cooperative action of various state and federal agencies. By a stroke of good fortune a vaccine against VEE had been developed by microbiologists at the U.S. Army Medical Research Institute of Infectious Diseases at Fort Detrick, Md., several years prior to the epidemic. The U.S. Department of Defense provided the vaccine, which was distributed to veterinarians who administered it at federal expense to over two million horses in 19 states and the District of Columbia.

VEE is frequently fatal to horses but is seldom fatal to man, who is also susceptible to it. The vac-

A new herpes virus, the type responsible for recurring blisters in humans, was found during research on another virus suspected of causing cancer in rhesus monkeys. Disruption of white cells by the virus is evident in the contrast between a normal cell culture (left) and one infected by the new virus (right).

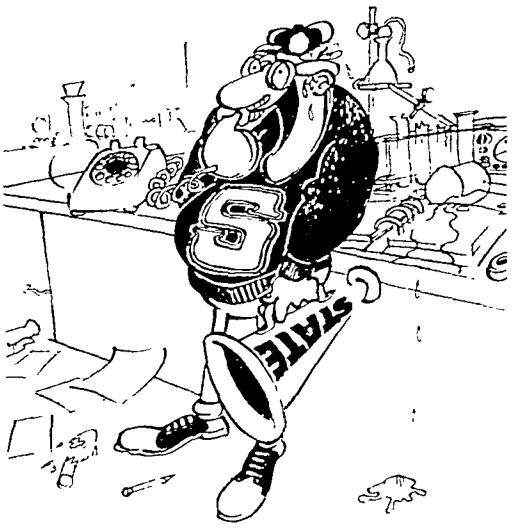


Courtesy, Dr. Paul D. Parkman, National Institutes of Health

cine was still considered to be experimental, and it was unlicensed in the U.S. for human use. VEE was first detected in Venezuela in 1935 and spread to southeastern Mexico in 1970. In early 1971 the virus "jumped" into the Tampico area of central Mexico. VEE is usually transmitted through the bites of infected mosquitoes, but it can also be transmitted by other biting insects, or it can even be airborne. Most recently, the VEE virus was also found in an infected vampire bat in Mexico. Vampire bats subsist on a blood diet and frequently feed on horses. They also cohabit with other species of bats, including those that migrate in massive numbers to the southwestern U.S. from Mexico. Thus, there was ample opportunity for the transfer of the VEE virus to areas far from an epidemic area. For these reasons, VEE continued to be a significant public health problem, and a joint U.S.-Mexican effort was under way to vaccinate all horses in northern Mexico to provide a barrier against the northward spread of the disease.

—Robert G. Eagon

Redfern, INDUSTRIAL RESEARCH



"I've just discovered a new and less expensive method of exciting molecules."

Molecular biology

Developments in molecular biology in recent months displayed more clearly than ever the dissolution of distinct areas of study for its subdisciplines. Basic research was more often than not producing information that had immediate, often practical applications in other sciences, especially in medicine.

Biochemistry

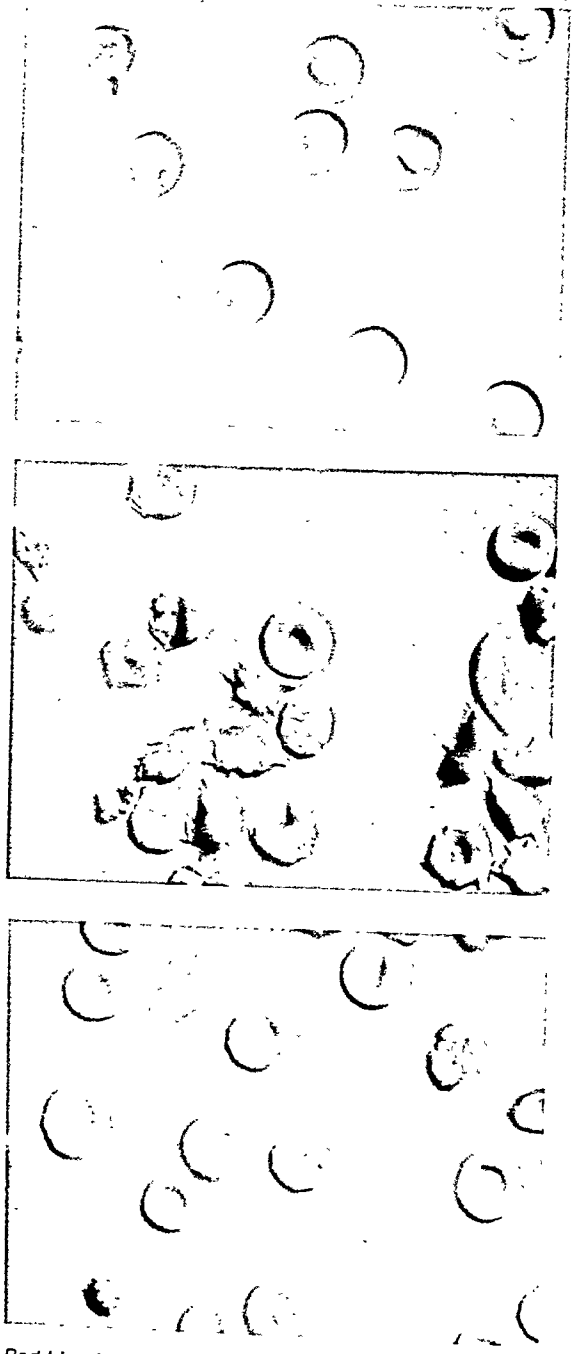
Many developments in biochemistry in the past year provided insight into relationships between the structure and the function of the chemical constituents of living things. Significant advances in our knowledge of carbohydrates, lipids, nucleic acids, and enzymes were reported, but proteins received particular attention. The most noteworthy advances in protein chemistry concerned hemoglobin, the oxygen-carrying protein of red blood cells (erythrocytes); the immunoglobulins, which act to neutralize foreign chemical substances; and the protein hormone insulin.

Modifying hemoglobins. Through the efforts of many investigators over the past 20–25 years, it was established that hemoglobin from most vertebrates is composed of two pairs of different polypeptide chains, and that each chain contains a molecule of heme, the iron-containing group to which oxygen molecules are bound during their transport throughout the body. Thus, the protein portion of hemoglobin, called globin, may be designated $\alpha_2\beta_2$, in which α and β indicate the two different chains. Each of the chains is folded in a unique, three-dimensional shape, and the four chains are combined together in a precise manner to form the functional molecule.

In man over 100 different variants of hemoglobin are known, most of which occur only in one of the amino acids in either of the two chains. The most widespread variant is hemoglobin S, the major species of hemoglobin in persons with sickle-cell anemia. This molecule contains normal α-chains, which are identical to those found in the vast majority of persons, and abnormal β-chains in which the amino acid valine is found instead of glutamic acid at what is described as the sixth position from the amino-terminus. When oxygen is removed (deoxygenation), hemoglobin S is less soluble than normal hemoglobin and cells composed of it are deformed. The deformed cells have a shorter lifetime than normal and masses of them can block blood flow in capillary networks, causing severe anemia and periodic episodes of pain and fever (a crisis). Although sickle-cell anemia is a genetic disease and an obvious candidate for management in the future by genetic engineering, other, more immediate approaches to its management must be sought.

Recent studies by Anthony Cerami and Charles Manning at Rockefeller University in New York City provided a most promising approach. Other workers had reported that the sickling process was inhibited if high blood levels of urea, the compound that is the chief end product of protein

Courtesy, Dr. Anthony Cerami, Rockefeller University



Red blood cells (erythrocytes) from a patient suffering from sickle-cell anemia show the beneficial effects of treatment with the compound cyanate. Cells carrying oxygen (top) show the normal erythrocyte configuration. Deoxygenated cells (middle) assume the deformed sickle shape. Cells that have reacted with cyanate (bottom) retain their normal shape when oxygen is removed

metabolism, could be maintained in patients with the anemia. The concentrations of urea required, however, were many times greater than normal and adverse side effects occurred.

Cerami and Manning were aware that many of the effects of urea on proteins can result from cyanate, a compound that may be derived from urea and is often present in urea solutions. They treated erythrocytes from patients with sickle-cell anemia under very mild conditions with rather low concentrations of cyanate and found that a large majority of the cells retained their normal shape when deoxygenated. In addition, the effects of cyanate were irreversible; treated cells did not sickle even after removal of cyanate and when re-oxygenated and deoxygenated again.

Cerami and Manning also found that no more than two molecules of cyanate were incorporated per molecule of hemoglobin S, and that both cyanate molecules had reacted with the two α-amino groups of the valyl residue at the amino-terminus of the two α-chains. The modified hemoglobin S also had a near normal solubility, which appeared to account for its lack of sickling. It was of considerable interest that amino groups in other proteins involved were not reactive with cyanate.

These impressive results prompted further studies with experimental animals to determine whether cyanate could be used therapeutically. Blood levels of cyanate sufficient to modify hemoglobin could easily be obtained by injection or feeding under conditions that produced no adverse side effects. In addition, only the hemoglobin had reacted extensively with cyanate. The modified hemoglobin retained its ability to transport oxygen and help maintain the normal pH (acidity) of blood. Early results of further studies, still in progress, indicated that erythrocytes in human subjects partially modified with cyanate were not destroyed at the rapid rate found in sickle-cell anemia, and that there might be a general improvement in the disease.

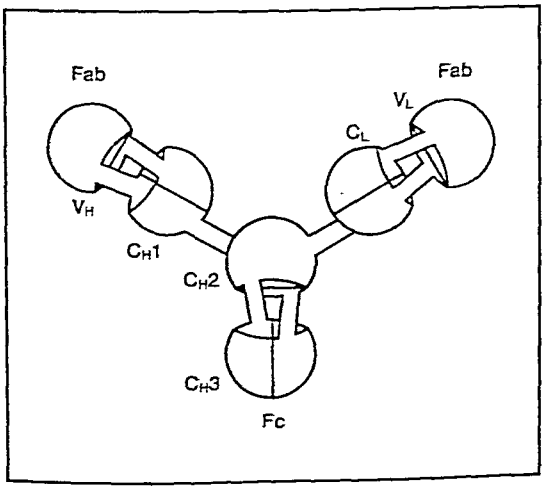
Immunoglobulin structure. Studies over the past decade provided much insight into the structure of the polypeptide chains of the major classes of immunoglobulins and of the G class in particular. Immunoglobulin Gs have a molecular weight of about 150,000 and are comprised of two heavy (H) chains with molecular weights of about 50,000 and two light (L) chains of about half this weight. The four chains are combined to form a molecule thought to be in the shape of the letter Y. The two arms of the Y, called Fab fragments, are each comprised of a light chain and about half of a heavy chain. The leg of the Y, called the Fc fragment, contains the remaining portions of the heavy

chains. The heavy chain can be divided into four quarters of about equal length that are designated the V_H, C_H1, C_H2, and C_H3 domains, and the light chains can be divided into equal halves designated as the V_L and C_L domains (V = variable region; C = constant region). The amino acid sequences of each of the six domains are very similar. Four domains are present in each Fab fragment, two composed of variable regions (V_H and V_L) and two of the constant regions (C_H1 and C_L). The remaining domains are in the Fc fragment and are formed from two C_H2 regions and two C_H3 regions.

It is believed that the variable domains in Immunoglobulin G form the antigen binding site, the part of the molecule that combines in a complementary fashion with a specific foreign substance, and that the amino acid sequences forming this site vary from one specific immunoglobulin to another, depending upon the nature of the antigen. The constant domains mediate other important effector functions of immunoglobulins. Although this model of immunoglobulin structure was consistent with available information, the detailed structure of the antigen binding site, as well as the structural relationships among the domains, would be ascertained only with a more exact knowledge of the spatial arrangements of their atoms.

A crystallographic analysis at low resolution of the Fab fragment from a human immunoglobulin was reported in 1972 by R. J. Poljak, L. M. Amzel, and H. P. Avey at Johns Hopkins University, Baltimore, Md., in collaboration with A. Nisonoff at the University of Illinois. Greater resolution was needed to distinguish the exact location of groups and atoms and to see details of the antigen binding site, but the investigators were able to conclude that the Fab fragment contained two globular structures thought to correspond to the variable and constant domains. This was interpreted as good evidence that the similarity in amino acid sequence between regions is reflected in conformational similarities in domains.

A model of immunoglobulin suggests that it consists of two heavy (H) polypeptide chains and two light (L) chains combined into a Y shape. Each arm (Fab) has two variable (V) and two constant (C) regions, each with an L and part of an H chain. The leg (Fc) contains the rest of the H chains in four C regions.



Otto Epp of the University of Graz, Austria, working at the Max Planck Institute in Münich, W.Ger., with W. Palm, H. Fehlhammer, A. Rühlmann, W. Steigeman, P. Schwager, and R. Huber, used X-ray diffraction methods to examine crystals of a Bence-Jones protein, one produced in persons with bone marrow tumors and corresponding to a single type of immunoglobulin light chain. They also found that the molecule is composed of two globular parts, with characteristics most probably corresponding to the V_L and C_L domains.

Another group at the National Institutes of Health in Bethesda, Md. (V. R. Sarma, E. W. Silverton, D. R. Davies, and W. D. Terry) reported crystallographic studies on an intact Immunoglobulin G molecule that provided convincing arguments that the Y-shaped structure for it was indeed correct. Globular regions corresponding to the Fab and Fc fragments were discerned and appeared to be joined by nonglobular stretches of polypeptide chain. Analysis at higher resolution was needed to see more structural detail, including the antigen binding site, but it was encouraging that these analyses confirmed to a substantial degree the model of immunoglobulin structure deduced by other means.

Insulin binding. Although insulin had been used for 50 years in controlling diabetes and was the first protein whose complete amino acid sequence was established, its mechanism of action remained poorly understood, primarily because insulin's effects are produced indirectly. It was generally agreed that insulin binds target cells to cause selective amplification of preexisting cellular processes. Recent studies on the nature of the insulin-binding substances in target cells began to shed light on the molecular basis for these events.

Particularly noteworthy were studies by Pedro Cuatrecasas at Johns Hopkins University, who had shown earlier that the metabolic effects of insulin were obtained when it was bound to cells under conditions that did not allow it to penetrate the cell. It was further found that the specific insulin-binding structures were associated with isolated liver membranes. Cuatrecasas now reported that it was possible to solubilize the insulin-binding structures by extraction of either liver or fat cell

membranes with detergents. The solubilized preparation specifically and reversibly binds insulin, whereas derivatives of insulin appeared to bind in direct proportion to their biological activity and other polypeptide hormones did not bind. Evidence was also provided that the isolated molecule is a protein with a molecular weight of about 300,000. Although this protein must be closely associated with lipids (fatty substances) in the cell membranes, it did not appear to be a lipoprotein. The dissociation constant for the insulin-receptor protein complex was of the same order of magnitude as antigen-antibody binding and highly suggestive of considerable binding specificity.

G. Vann Bennett and Cuatrecasas also found that the number of insulin receptors in fat cells from rats made diabetic by chemical means was not decreased and that the diminished responsiveness could not be explained by structural alterations in the receptors. How the event of insulin binding to receptors is transmitted to other molecules in the cell and translated into altered, specific chemical processes could only be answered by additional studies.

Insulin and nerve growth factor. An interesting and somewhat surprising relationship between insulin and nerve growth factor was reported. NGF is a protein with a molecular weight of about 26,500 that contains two identical polypeptide chains. It was known to enhance the growth of sympathetic ganglia and appeared to be essential for maintaining the sympathetic nervous system. W. A. Frazier, R. H. Angeletti, and R. A. Bradshaw at Washington University in St. Louis, Mo., had established previously the complete amino acid sequence of the 118 residues in the single polypeptide chain of NGF, including three intrachain disulfide bonds. Although at first the sequence did not seem to resemble other proteins, the observation that NGF had many biological effects in common with insulin, prompted a closer comparison of its sequence and those of insulin and its precursor, proinsulin.

Some degree of structural similarity was found, although not as much as is found in other sets of structurally related proteins. The fact that NGF contained 33 more residues than proinsulin did not minimize the resemblance since the additional residues were similar in some respects to the amino-terminal portion of proinsulin. Most significantly, one of the three disulfide bonds in the two molecules was in a closely corresponding position.

On the basis of these apparent structural relationships between NGF and insulin and their analogous physiological effects on their target cells, it was suggested that the two hormones are evolutionarily related. The gene controlling the sequence of NGF may have been derived from an ancestral gene for proinsulin.

The relationships between proinsulin and NGF suggested goals for future studies on the mechanism of action of NGF. For example, it will be interesting to find whether NGF forms a complex on target cells analogous to that of insulin and its receptor protein.

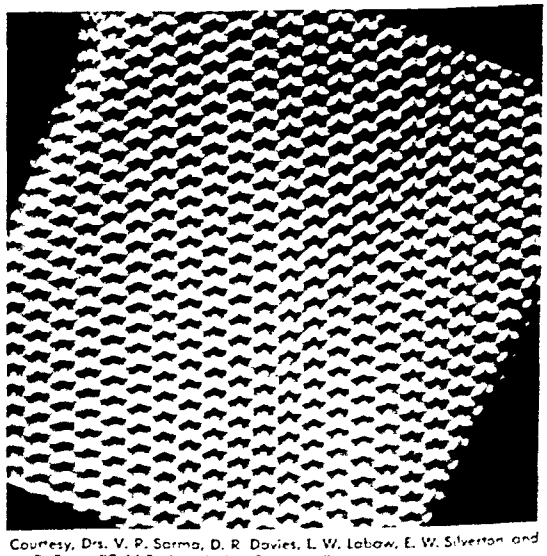
—Robert L. Hill

Biophysics

X-ray diffraction and refinements of its technique continued to be the mainstay of the biophysicist's application of the principles and tools of the physical sciences to the elucidation of the structure and function of biological systems. Materials that were periodic, or that could be crystallized into periodic structures, including enzymes, muscle proteins, metallo-proteins, and viruses, were studied by this technique. Other techniques were being adapted for use on other biological materials. Nuclear magnetic resonance, for example, was used quite widely for the determination of protein configuration and the mapping of active sites.

New techniques. Infrared spectroscopy appeared to hold considerable promise for the study of the orientations of nucleic acids, the compounds found primarily in cell nuclei, usually in combination with proteins. Nucleic acids consist of four bases, or side groups, attached to a backbone of

Crystals of human immunoglobulin subjected to electron microscopy revealed that the molecule has three very distinct globular regions. This overall shape was consistent with what had been predicted in many other chemical, enzymatic, and microscopic studies.

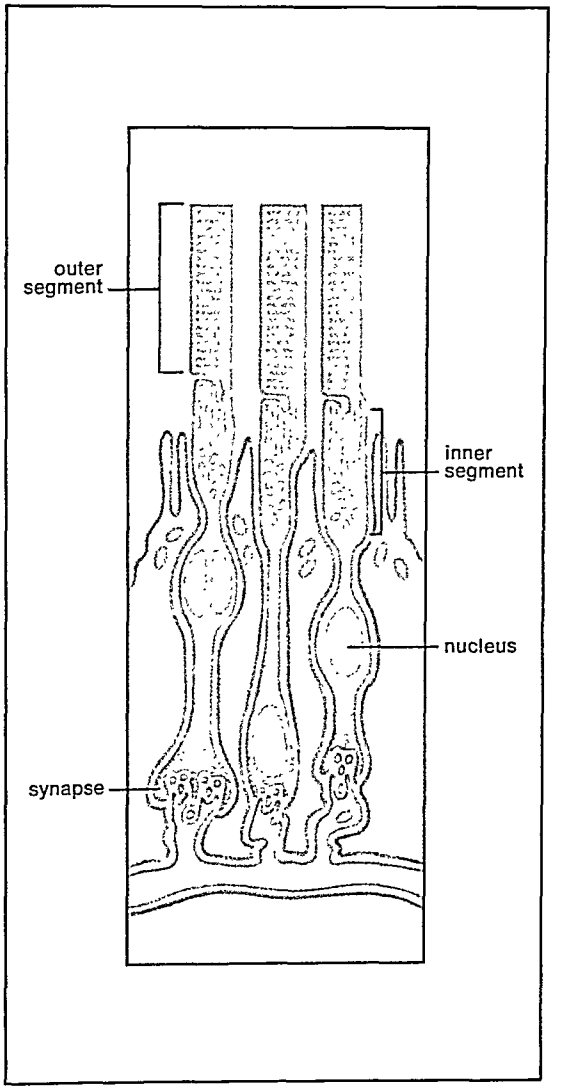


Courtesy, Drs. V. P. Sarma, D. R. Davies, L. W. Lebow, E. W. Silverton and W. D. Terry, "Cold Spring Harbor Symposia"

alternating sugar and phosphate molecules. Recent studies looked at the transitions of deoxyribonucleic acid (DNA) from the B to the A form. Polarized infrared light was used to measure and compare the differences in absorption of light caused by vibrations of the backbone. From the recorded differences it was possible to estimate angles of the sugar-phosphate groups that were in good agreement with X-ray diffraction studies. Because proteins do not absorb strongly in the infrared region used, this technique should prove ideal for studying nucleic acid structure, and for determining the effects of agents that modify it.

During the year several promising methods were developed for use in biophysical studies. In one of these, the photoelectric effect, a phenomenon long the province of the physicist and more recently of the chemist, was added to the tools of the biophysicist. The photoelectric effect occurs when high-frequency radiation impinging on certain substances causes bound electrons to be given off with a velocity proportional to the frequency of the radiation. Chemists use photoelectron spectroscopy for chemical analysis: a sample is irradiated with ultraviolet radiation and emits photoelectrons (or with X rays and emits Auger electrons) whose energy spectra are analyzed in a high-resolution spectrometer to determine directly the electronic energy levels of the elements present in the sample. This technique can be used to analyze unknown samples for their elements; it is also useful for the study of surface phenomena since in a solid sample the electrons that form the spectrum come from a thin layer near the surface, usually less than 50 Å in depth (one angstrom, Å = 10^{-8} cm). By replacing the spectrometer with a phosphor screen and a camera and thus forming a photoelectron microscope, it became possible to map the structure of biological surfaces and membranes.

Visual excitation studies. Recent experiments offered intriguing clues about the mechanism by which incident light causes visual excitation of the rods, the achromatic photoreceptor cells in the retina of the eye. In vertebrates, the photosensitive pigment in the rods is the protein rhodopsin. Rhodopsin is located in the membrane of the rod outer segment and accounts for about 80% of its total protein. It consists of the lipoprotein opsin and a group of atoms that gives rise to color, the visual chromophore 11-cis retinal (which is derived from vitamin A). As a result of alterations that can occur in its atomic bonds, retinal can exist in the form of either cis or trans isomers; to combine with opsin it must be in its 11-cis form. Phospholipids in the membrane of the rod outer segments are thought to stabilize this association. Exposure



Rod cells in the retina of the eye have outer segments of thin disks with the pigment rhodopsin attached. The effects of light's action on rhodopsin spread to the inner segment housing the cell's energy supply and then past the nucleus to the synapse, a point of near contact with a nerve cell leading to the brain.

to light photoisomerizes the retinal and initiates a series of changes in the configuration of opsin as its deep red color is replaced by light yellow (bleaching process), which apparently results in the release of retinal. If during this process retinal is reisomerized to cis form, rhodopsin is regenerated.

Recent studies of frog retina indicated that rhodopsin undergoes free rotational diffusion motion in the visual receptor membrane. Having

established the rotational relaxation time of 20 μs (one microsecond, $\mu s = 10^{-6}$ seconds) and assuming rhodopsin to be a sphere of about 25 Å radius, researchers determined the effective viscosity (ability to flow) of the membrane medium to be that of a typical light oil, such as olive oil. On the basis of these properties, it was suggested that rhodopsin may function as a diffusional carrier in the membrane transport processes that lead to excitation of the visual receptor.

Other recent experiments suggested that rhodopsin may have a more indirect role in the excitation process. Adenylate cyclase (cyclase), the enzyme that catalyzes the primary energy-producing activity of cells, the conversion of adenosine triphosphate (ATP) to cyclic adenosine 3',5'-monophosphate (cAMP), was found to be present in the rod outer segments at a specific activity higher than that reported for any other tissue. Furthermore, illumination decreased cyclase activity in direct proportion to the bleaching of rhodopsin, which suggested some sort of direct coupling between the bleaching process and the enzyme. Other investigators reported finding a light-stimulated phosphorylation (conversion into a phosphate) of rhodopsin by ATP that will occur even if ATP is added after the flash of light. Since this reaction would not proceed after the membrane was disrupted, a membrane-bound kinase (enzyme catalyst) appeared to be involved.

It was not clear whether there was any relationship between the inactivation of cyclase by the bleaching of opsin and the photo-induced phosphorylation of rhodopsin, but there was evidence to suggest that the actual excitation of the visual receptor may be mediated by cAMP. Electrophysiological studies using the eye of the horseshoe crab *Limulus* showed that the addition of cAMP mimics the effects of light on the photoreceptor cell. Aminophylline and theophylline, two inhibitors of phosphodiesterase (the enzyme that hydrolyzes cAMP to 5' AMP), also produce identical effects, presumably by increasing the intracellular concentration of cAMP by inhibiting its breakdown by phosphodiesterase.

It was also reported that the addition of small amounts of extracellular calcium decreases the sodium permeability of visual receptors, again mimicking the effect of light. Since cAMP was known to affect the transport of calcium in heart muscle and intestinal mucosa, it was possible that it also regulates the calcium transport in rod outer segments. Calcium, in turn, may regulate the changes in the permeability of the photoreceptor membrane to sodium and, thus, excitation of the visual receptor.

Research on membranes. Cell membranes were the subject of intensive research because of the numerous biochemical processes that occur on or in them. Their dynamic nature was well illustrated in the studies of rhodopsin. The complexity and diversity of their structure was being pursued with a variety of techniques in many laboratories.

From these studies the cell membrane emerged as a structure about 80 Å thick with a bimolecular phospholipid core (two molecules of fatty complexes), large portions of which are covered with proteins, glycoprotein, glycolipids, cholesterol, and other molecules. In some cases these protein molecules span the membrane from inner to outer surface. The ratio of lipid to protein appears to vary with the physiologic function of the membrane, from about 75% lipid for the relatively inactive myelin sheath around nerves to about 75% protein for active bacterial and mitochondrial membranes. Further studies suggested that the conformation of membrane proteins may be related to function. Mitochondrial membranes show a high proportion with spiral shapes, whereas myelin membranes have more of their protein flattened. Recent evidence also suggested that the bimolecular core of the plasma membrane of mammalian erythrocytes is asymmetrical, having two types of phospholipid on the outer half of the bilayer and two different ones on the inner half.

Another very active area of membrane research studied the differences between the surfaces of normal cells and cancer cells (or mammalian cells after viral transformation). After transformation, new antigens (foreign substances) appear; in most cases these are identical to antigens produced by fetal tissue (*see* Feature Article: CANCER UNDER ATTACK). Recent studies indicate that polyoma-transformed cells synthesize more glycoprotein, which is loosely bound to the cell surface. There may also be changes in the sites of transport across the membrane. Finally, the transformed cells lose their sensitivity to contact inhibition, which normally restrains growth.

During the year it was found that transformed cells treated with the cAMP analogue dibutyryl cAMP regain many of the characteristics of normal cells, including sensitivity to contact inhibition. Levels of cAMP were found to be lower in polyoma-transformed cells than in normal cells and this decrease was shown to precede the establishment of the transformed state, suggesting that cAMP is the cause rather than the effect of the properties of the transformed cells. Cyclic AMP, in fact, might control cell growth and morphology in mammalian systems.

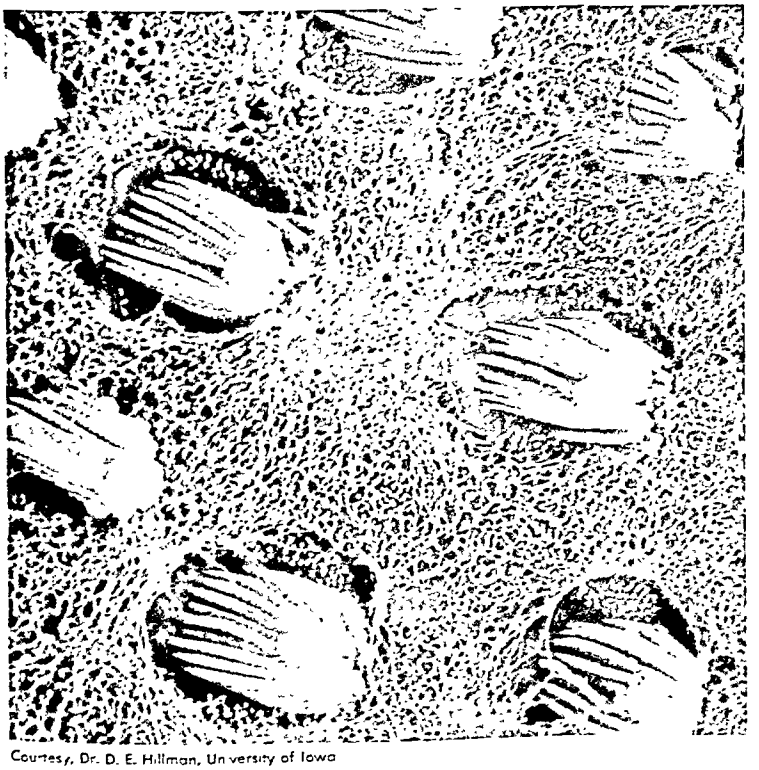
Radiation biology. It was well known that DNA is implicated as the target of the primary biological lesion induced by ionizing or ultraviolet radiations.

For this reason repair of DNA continued to be the main preoccupation of workers in radiation biology. Three enzymatic mechanisms for the repair of DNA were known to occur in the much-studied bacterium *Escherichia coli (E. coli).* The first mechanism, photoreactivation, acts specifically to split pyrimidine dimers formed in DNA exposed to ultraviolet light into their respective monomers when the cells are subsequently exposed to visible light. The second system excises radiation-induced damage from one strand of DNA and resynthesizes the missing segment by using the opposite, complementary strand of DNA as the template. Since this mode of repair does not require light it is called a dark repair process. The third mechanism is under the control of the genes involved in genetic recombination and is called recombinational, or Rec, repair. It appears to repair single-strand breaks in the sugar-phosphate backbone that are induced primarily by such ionizing radiation as X rays, and by certain chemicals, but that may also be present after DNA replication in ultraviolet-irradiated cells. Rejoining of single-strand breaks by this method requires that the cells be incubated under growth conditions, generally for 10–30 minutes at 37° C.

Evidence for two other repair mechanisms was reported recently. Both of these modes were faster than Rec repair for mending X-ray induced, single-strand breaks in DNA. Ultrafast repair, which occurs in less than one minute at 0° C, rejoins breaks produced under anoxic conditions (severe oxygen deficiency), with the result that there are only about one third as many breaks remaining in the cells irradiated in the absence of oxygen as in cells irradiated in the presence of oxygen. Thus, oxygen acts not by increasing the number of breaks produced but by changing them so that they are no longer reparable by the ultrafast repair process. The second mode of repair recently reported appeared to involve the enzyme DNA polymerase I. Repair of about 80% of the remaining breaks, whether induced by X rays delivered aerobically or anoxically, is completed by this method, Pol repair, in 2–5 minutes at room temperature.

It was thought that these two fast systems repair relatively simple breaks by a simple rejoining of the DNA backbone (ultrafast) or replacing a few bases (Pol repair). Rec repair presumably rejoins more complex breaks using some of the steps involved in genetic recombination.

Certain drugs, namely quinacrine, N-ethyl maleimide, and hydroxyurea, were found to inhibit this ultrafast repair of anoxically produced breaks in *E. coli.* In addition, quinacrine inhibited Rec repair. These results had interesting implica-



Courtesy, Dr. D. E. Hillman, University of Iowa

A scanning electron micrograph shows how sensory hairs (cilia) on receptor cells in the saccule of a frog's ear may function to transfer sound waves into messages to the auditory nerve. The cilia can be seen bound to the bulb atop one specialized cilium, which rests on a portion of the receptor membrane lacking the rigid base under the other cilia. Movement of the masses distends the membrane at the base of this cilium; the distension is thought to bring about changes that stimulate nerve activity.

tions for the treatment of solid cancers, which, because of low oxygen tension in the tumor mass, are generally more resistant to irradiation treatment than surrounding healthy tissue. It would, therefore, be desirable to make these tumors at least as sensitive as the more fully oxygenated surrounding tissue by the use of such drugs.

Future trends. After several years of decline and stagnation, the U.S. budget for science appeared to be on the increase. The emphasis, however, would be on applied research, with the National Science Foundation proposing to eliminate its science development grants and further reduce funds for graduate traineeships and institutional grants for science. Basic research funds would increase slightly, but the largest increases would be for mission-oriented research and development. Funds for research on cancer, and probably on diseases of the heart and lungs, would be increased sharply. Thus, human cells and their viruses would be the new *E. coli* as molecular pathology replaced molecular biology.

—Jeremy Baptist

Genetics

Molecular genetics remained the focus of intensive exploration, with ever more sophisticated techniques, and ever more specific questions being asked about cell mechanisms. The year was marked by no excitements to compare with the discovery the year before of reverse transcriptase, an enzyme responsible for the production of deoxyribonucleic acid (DNA) from a model provided by ribonucleic acid (RNA), a thoroughly unexpected operation for RNA. There was, however, growing appreciation that every seemingly simple mechanism of DNA is involved in increasingly more complex networks of relationships within the cell.

This overall complexity, rather than any profound difference in basic operation, may well have accounted for the puzzling recalcitrance of some underlying problems in the molecular biology of eukaryotic cells (those with distinct nuclei). These problems included the physical structure of the chromosome and the mechanisms of regulation of gene activity—problems that are rather well understood now for the simpler viral and bacterial systems. In responding to these challenges of higher organisms, molecular geneticists began crossing traditional boundaries that once compartmentalized biological research.

Reverse transcriptase studies. The main thrust of studies with the enzyme reverse transcriptase was the tracing of viruses newly implicated in cancer in primates and perhaps in man. Research groups led by Sol Spiegelman at Columbia University, David Baltimore at the Massachusetts Institute of Technology (MIT), and J. Ross at the U.S. National Institutes of Health (NIH), Bethesda, Md., also used this enzyme with a sample of messenger RNA (m-RNA) as a template. The m-RNA, isolated from immature red blood cells of rabbits and other mammals, was prepared in a way believed to encode for the globin protein portion of hemoglobin. In a cell-free protein-synthesizing system—containing ribosomes, amino acids linked to transfer RNA (t-RNA) molecules, iron-containing hemin molecules, and the appropriate enzymes—this m-RNA did indeed effect the synthesis of mammalian hemoglobin. The DNA that was synthesized under the influence of the reverse transcriptase may, therefore, be equivalent to the gene for the globin, an identity that remained to be confirmed.

Apart from speculations about its use for the genetic "engineering" of tissue cells, the ability to produce quantities of a specific gene would be technically invaluable. It would be an ideal method of assaying specific m-RNAs in cells at different stages of development or in different states. It would also facilitate the analysis of the nucleotide sequence of RNA through stepwise synthesis of the corresponding DNA by the action of transcriptase. In its natural occurrence, the DNA for a specific gene accounts for less than one millionth of the DNA content in a mammalian cell, which evokes despair about attempts to isolate it directly. However, m-RNAs, which reflect the activity of specific genes, are produced differentially in various tissues, and often amplified manyfold. We can, therefore, be more optimistic about extracting specific RNAs, and then using reverse-transcriptase to produce the DNA corresponding to a specific gene.

Further studies with m-RNAs will be facilitated by the finding, by J. B. Gurdon and his colleagues at the University of Oxford, that living frog eggs can "translate" injected samples of RNA into their corresponding proteins. The eggs are a relatively simple biological system technically and retain their activity for 24 hours or longer, during which each m-RNA molecule can be translated many times. The system can recognize and encode into DNA as little as one billionth of a gram of RNA added to it.

Reverse transcriptase is inactive on pure, single-stranded RNA templates; a short segment of complementary RNA is required as a primer to which DNA can attach and assemble itself. This primer segment functions like the poly-A (adenine)-rich ends found naturally in many RNAs. In the reverse transcriptase experiments just described, the prim-

er was a synthetic poly-T (thymine), which binds to the complementary As on the RNA and helps initiate DNA synthesis.

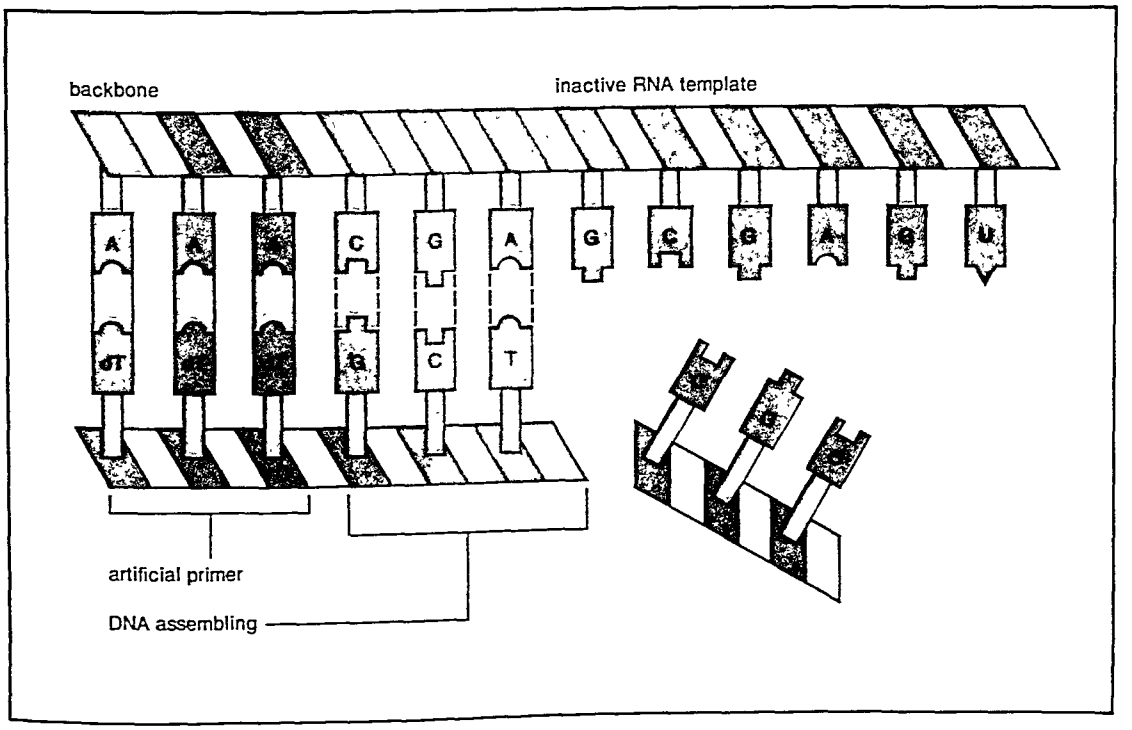
Similar requirements had been established in 1967 by A. Kornberg's group at Stanford University for the replication of viral DNA. In later studies it was found that the RNA polymerase enzyme probably initiates replication in bacterial cells infected with the bacteriophage (virus) M13. RNA polymerase was now commonly thought of as the agent of translation, the production of m-RNA copies of DNA genes. Short segments of such copies may also be indispensable for the initiation of replication of DNA, which once begun is sustained by DNA polymerase.

Ligase and the swivelling enzyme. Ligases, enzymes that repair nicks in one strand of a duplex of DNA, were now a routine part of the repertoire of molecular genetics. V. Sgaramella, H. H. van de Sande, and H. G. Khorana (working at the University of Wisconsin) reported that ligase associated with the bacterial virus T4, besides showing the nick-sealing activity of other ligases, can join free ends of two separate DNA duplexes. The application of this tool to biologically active genes derived from various types of cells was under active study in several laboratories.

Many DNA molecules are found in closed circles, and much thought has been given to the way a double helix might be wrapped into simple circles without excessive twists. When DNA circles were proven to be pure DNA lacking any protein linkers, wrapping was thought to be due to a combined action of nicking enzymes and sealing enzymes. J. C. Wang at the University of California at Berkeley and J. J. Champou and R. Dulbecco at the Salk Institute, San Diego, Calif., have now described a protein (swivelling enzyme) that appears to untwist supercoiled DNA molecules. The reaction appeared to occur at one turn at a time, rather than the simultaneous relief afforded by a nicking enzyme. The molecular mechanism of the swivelling enzyme would be difficult to determine unless intermediate stages could be captured.

Solving DNA puzzles. The molecular requirements for DNA recombination were illuminated by studies on a protein coded by T4 and called simply the product of gene 34 of that virus. Because an enormous number of gene-34-protein molecules are produced during viral growth, some struc-

In the test tube the enzyme reverse transcriptase requires a primer to initiate DNA production from an RNA model, or template. The primer is poly-T (dT), a synthetic of the nucleic acid thymine. When this piece of artificial RNA bonds with its complementary nucleic acid, adenine (A), on the template, the RNA becomes active. DNA then begins assembling with the aid of the enzyme.



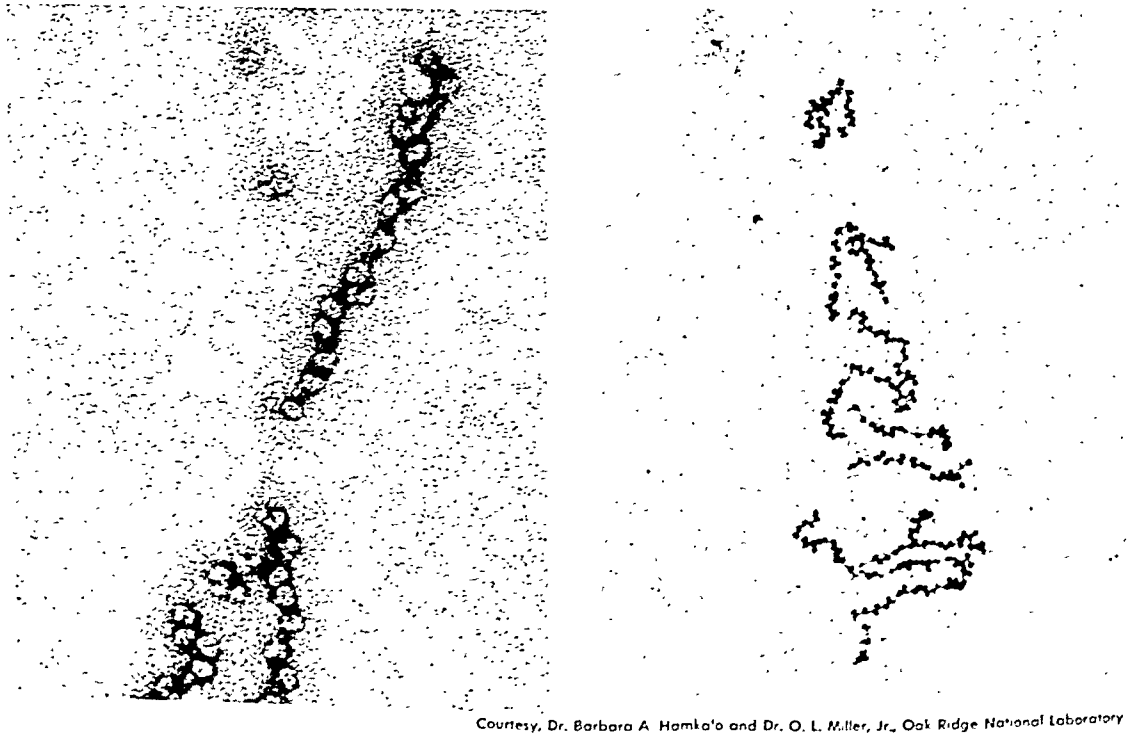
tural rather than catalytic role for the protein had been suspected. Bruce M. Alberts and Linda Frey at Princeton University isolated the protein and showed that it binds to single-stranded DNA in such a way as to minimize self-associations and to encourage the unwinding of duplexes, in effect stretching out sequences to enable their exposure to complementary ones. The addition of gene-34-protein, therefore, facilitates the resynthesis of DNA that has been melted with the strands separated. The protein may be a prime mover in the mechanism of genetic recombination. More recently Y. Hotta and H. Stern at the University of California at San Diego found that this protein, designated by them "meiotic protein," is almost always found in cells in meiosis (reduction division).

Of growing interest was the work by L. S. Lerman at Vanderbilt University, Nashville, Tenn., on another puzzle of DNA—how the extended fibers of the double helix of a phage particle in an infected cell can be condensed and packaged into the tiny space of the phage head. Similar problems of DNA compression in the sperm head and in chromosomes in higher forms had been explained (correctly?) by invoking complexes with basic proteins that neutralize the multiple negative charges of the DNA phosphates and allow tight compaction. Lerman found a remarkable collapse of the extended structure of DNA solutions—but no chemical binding—in the presence of neutral water-soluble polymers. The phage head contains the compact DNA until the phage infects a new host and the DNA springs back into expanded form.

Cell fusion techniques. Parallel to the deepening of biochemical probes into basic genetic functions was the explosive development of somatic cell genetics. The underlying theme was the progressive domestication of tissue cells in culture. This consisted primarily of the accumulation of cell lines and techniques to display precise features of chromosome content or of enzymatic function—in all events revealing the potentialities and the regulation of the genetic information in the cell. The most striking advance was the fusion of cells, in many cases facilitated by the use of an enzyme associated with inactivated virus particles.

After cells from different species have been fused, clones of hybrid cells can be found that may contain a sum of the parents' chromosomes, many of which are unfortunately unstable in such com-

Transcription, the copying of a DNA sequence into messenger RNA, and translation of that information into protein can be seen occurring simultaneously in the bacterium Escherichia coli. *Special electron microscope techniques developed at Oak Ridge (Tenn.) National Laboratory captured RNA linked by spherical ribosomes attached to strands of DNA magnified 306,000 times (left) and 72,000 times (right).*



Courtesy, Dr. Barbara A. Hamkalo and Dr. O. L. Miller, Jr., Oak Ridge National Laboratory

binations. In the fusion of a mouse cell and a human cell, the human chromosomes are particularly unstable. Such instability is a mixed curse: it interferes with the observation of controlled variations from the norm, but it also produces a rich variety of cell types, with different sets of chromosomes whose effects can then be measured.

The pathologist Henry Harris at Oxford, who introduced virus-mediated fusion for genetic analysis, pursued it with particular vigor to study the genetic basis of malignancy. The results vary considerably depending on the particular cell lines under study; however, overall malignancy is attenuated, or even extinguished, when cancer cells are augmented with normal chromosomes. These observations were the first steps to a formal genetic analysis of the chromosomal basis of malignancy. They would advance much further as techniques were developed for identifying specific chromosomes and for the construction of cells with a normal complement of chromosomes of known origin.

Cell fusion techniques also offered a unique opportunity to study the possible genetic role of particles in the cytoplasm of cells. The occurrence of DNA in mitochondria and other particles suggested that these may be more than mere passive reflectors of the information in chromosomal DNA. In several experiments it appeared that the human chromosomal contribution was overridden by the mouse contribution, arguing for negative control as a common cellular mechanism. Negative control was also inferred from studies on biochemical attributes, including regulatory functions. The conclusions of all such studies indicated: (1) that unexpressed functions in a cell derive from negative control (that is, the active inhibition of certain genes, an inhibition that also regenerates new chromosomes); (2) that these functions can be revived upon extraction of the controlling factors; and (3) that the controlling factors are stably associated with certain chromosomes.

The nature of the stable activation of the controlling chromosome was the central challenge to developmental genetics. One hypothesis had some support from studies of X-chromosomes: stable changes of a chromosome are often deletions of some part of the chromosome. The activation of a controlling chromosome would then result from removing a small regulating unit from it, unleashing the negative control over other specific gene functions. In other cases, such deletions are already known to unleash positive functions.

While these studies were still at an exploratory stage, cell fusion was a well-established method for mapping genetic mutations on various human chromosomes, greatly accelerating work that formerly required the painstaking collection of pedigrees often insufficient or inappropriate to allow firm conclusions. In the course of gene mapping F. H. Ruddle's group at Yale noted the first evidence of a translocation (breakage and new union) between a mouse and a human chromosome, which may reflect the actions of a two-strand-repairing ligase, as noted earlier.

Testicular feminization. During the year testicular feminization (Tfm), a fascinating rare genetic disease, was critically reviewed. It is a disturbance whereby an XY embryo, normally male, is switched into a female pattern of development, but is sterile. A similar condition in the mouse is firmly linked to the X chromosome. S. Ohno (City of Hope National Medical Center, Duarte, Calif.) and his colleagues offered an explanation of the defect: the body cells of the Tfm type appear to be unable to respond to testosterone for lack of a primary protein receptor for it. The Tfm "female" thus differs from normal females as well as from males, both of whose tissues do respond to male hormones.

—Joshua Lederberg

Obituaries

The following persons, all of whom died between July 1, 1971, and June 30, 1972, were noted for distinguished accomplishments in one or more scientific endeavors. Biographies of those whose names are preceded by an asterisk (*) appear in *Encyclopaedia Britannica.*

***Adams, Roger** (1889—July 6, 1971). U.S. organic chemist and recipient of the National Medal of Science, Adams was head of the University of Illinois department of chemistry for 28 years. He received an A.B. degree (1909), an A.M. (1910), and a Ph.D. (1912) from Harvard University, and then studied at the Kaiser Wilhelm Institute in Berlin before returning to Harvard as an instructor. In 1916 he went to the University of Illinois as an assistant professor, served as head of the department of chemistry and chemical engineering (1926–54), and became research professor emeritus in 1957. Adams and his students explored the many methods of organic synthesis, determined the structures of synthetic and natural products, and discovered a platinum oxide catalyst for further research in organic chemistry and biochemistry. He investigated (1947) the structure of marijuana, isolating and identifying cannabidiol, and then synthesized a drug that was 70 times stronger.

Among the many honors bestowed upon Adams were the Davy Medal of the Royal Society (London, 1945), the Priestley Medal of the American Chem-

ical Society (1946), and the Perkin Medal of the Society of Chemical Industry (1954). He was awarded the 1964 National Medal of Science for his many years as the recognized leader in organic chemistry.

Armand, Louis (Jan. 17, 1905—Aug. 30, 1971). A French engineer and nuclear energy executive, Armand was responsible for the reconstruction of the French railway system after its almost complete destruction during World War II. He had joined the Compagnie des chemins de fer de Paris à Lyon et à la Mediterranée (the PLM) in 1934, and with the Nazi invasion of France in 1940 became a member of the railroad underground intelligence network, and subsequently was captured by the Gestapo. Released in 1944, Armand returned to the railroad and five years later was named director of the nationalized rail system, the Societé Nationale des Chemins de Fer (S.N.C.F.). He was assigned to rebuilding the lines and converting them from steam to electric power.

In 1958 Armand resigned his directorship to serve a two-year term as president of Euratom (the European Atomic Energy Community). He was the author of works on geology and mining, on transportation, and on the construction and unification of Europe. Some of his better known writings include: *Plaidor pour l'avenir* ("Plea for the Future"), published in 1961, and with Michel Drancourt *Le Pari européen* ("The Wager for Europe") published in 1968.

Babakin, Georgi N. (1916—Aug. 3, 1971). Soviet space expert, believed to have been involved in the design and production of Soviet automatic space probes, Babakin was credited with having an important role in U.S.S.R. space technology and in the study of the moon and of the planet Venus. He undoubtedly contributed heavily to the construction of the unmanned Lunokhod 1 moon rover and of the Venera 7 space probe.

Babakin began his career in 1930 as a radio technician and by 1949 was actively involved in Soviet aircraft and space technology. Although unlisted, he was presumed to be a corresponding member of the Soviet Academy of Science.

Bernal, John Desmond (May 10, 1901—Aug. 30, 1971). British physicist and natural philosopher, Bernal was also a crystallographer and helped establish the foundations of molecular biology. He served as professor of physics at Birkbeck College, University of London, from 1937 until 1963, when he became that institution's first professor of crystallography, a position he held until ill health forced his retirement in 1968.

During his undergraduate days at Cambridge University Bernal wrote a paper that brought him a research post to study crystal chemistry at the Royal Institution. He returned to Cambridge in 1927 and began a series of investigations into a wide range of scientific subjects, including the taking of the first X-ray photographs (in 1933) of a single protein crystal (pepsin). His works include *The Social Function of Science* (1939), *Freedom of Necessity* (1949), *Science in History* (1954), *World Without War* (1958), and *Origin of Life* (1967). Bernal was a fellow of the Royal Society and a recipient of the 1953 Lenin Peace Prize.

Blegen, Carl W. (Jan. 27, 1887—Aug. 24, 1971). U.S. archaeologist, Blegen was professor of classical archaeology at the University of Cincinnati from 1927 until 1957, when he became emeritus professor; he also served as head of the classics department from 1950 until 1957. Blegen led many expeditions in search of the site of the ancient city of Troy, and in 1939 discovered the palace of Nestor, King of Pylos. At that site a number of tablet fragments in Linear B (Mycenaean) Script were found.

Blegen was a fellow of the British Academy, a member of the Archaeological Institute of America, and a winner of the gold medal from the Society of Antiquaries of London. He was the author of several books, including six volumes on Troy and the palace of Nestor.

***Bragg, Sir (William) Lawrence** (March 31, 1890—July 1, 1971). British physicist Sir Lawrence Bragg was joint recipient (with his father Sir William) of the 1915 Nobel Prize for Physics, awarded for their discovery of the method of determining the structure of crystals by the use of X rays. Sir Lawrence was Fullerian professor of chemistry at the Royal Institution from 1953 until 1966, and its director from 1954 until 1966. He became a fellow of Trinity College, Cambridge, in 1914, after having produced an original work on the structure of crystals; from 1919 until 1937 he served as Langworthy professor of physics at Victoria University of Manchester, and then as director of the National Physics Laboratory (1938), and Cavendish professor of experimental physics at Cambridge University from 1938 until 1953.

Bragg did fundamental work on the structures of metals and minerals and developed new techniques for the study of X-ray diffraction. From 1954 he concentrated his efforts on the study of the structure of proteins. He became a fellow of the Royal Society in 1921. He was the author of *The Crystalline State* (1934), *Electricity* (1936), and *Atomic Structure of Minerals* (1937). With his father he wrote *X-Rays and Crystal Structure* (1915).

Buu Hoi, Prince (1917—Jan. 28, 1972). A Vietnamese physicist, Buu Hoi was head of the National Research Center of the French Radium

Wide World



Edward C. Kendall



Lillian Moller Gilbreth

Institute (the Curie Foundation), and a pioneer in radiological cancer research. In 1957 he discovered 3-4-9-10 dibenzpyrene, a chemical substance in cigarette smoke that caused cancer when injected into mice.

Fesenkov, Vasiliy G. (1889—March 12, 1972). A Soviet astronomer, Fesenkov was an early investigator of zodiacal light, a nebulous glow observed in the west after twilight and in the east before dawn. Fesenkov was chairman of the Soviet Committee on Meteorites and, from 1935, a full member of the Soviet Academy of Sciences, also serving as editor of the academy's astronomical journal.

Gilbreth, Lillian Moller (May 24, 1878—Jan. 2, 1972). U.S. industrial engineer who pioneered in time-motion studies, Gilbreth was the inspiration for the popular book *Cheaper by the Dozen.* The book, written by her two oldest children Frank Gilbreth, Jr., and Ernestine Gilbreth Carey and published in 1948, recounted the parents' methods of applying their knowledge of industrial management to the running of the household and family of 12 children.

Gilbreth received her B.A. degree from the University of California in 1900, her M.A. in 1902, and her Ph.D. from Brown University in 1915. In 1924, upon the death of her husband, she took over his consultant firm and continued its successful management. As consultant to the Institute of Rehabilitation Medicine (at the New York University Medical Center) in the early 1950s, she set up a program to augment the capabilities of disabled homemakers, incorporating features to accommodate workers in wheelchairs or on crutches.

***Kendall, Edward Calvin** (March 8, 1886—May 4, 1972). U.S. chemist and Nobel Prize winner, Kendall was visiting professor of chemistry at Princeton University from 1951. Prior to his appointment at Princeton he headed the Mayo Clinic biochemistry section for 37 years, and served as a professor in the graduate school of the University of Minnesota from 1921 until 1951.

While at the Mayo Clinic, Kendall succeeded in isolating the hormone of the thyroid gland (thyroxin), used to correct glandular deficiencies and permit normal growth in human beings. In 1930 he began his extensive studies on the chemical nature, physiological activity, and synthesis of adrenal cortex hormones. By the end of the 1930s he had isolated six of the gland's hormones and named them Compounds A, B, C, D, E, and F—E later became known as cortisone. Further investigations led to the identification of the chemical structure and composition of the compounds, and subsequently to a partial synthesis. Not until 1948, however, was the synthesis of E produced in enough quantity for human experimentation.

For this work on the adrenal cortex compounds and the resulting large-scale production of cortisone and hydrocortisone, Kendall (with P. S. Hench and Tadeusz Reichstein) received the 1950 Nobel Prize for Physiology or Medicine. Other awards bestowed upon Kendall included the Lask-

Wide World



Maria Goeppert Mayer

er Award of the American Public Health Association and the Kober Medal of the Association of American Physicians.

Lynch, William A. (June 21, 1892—Feb. 14, 1972). U.S. physicist and expert on earthquakes, Lynch was emeritus professor of physics at Fordham University. He taught at New York University a number of years before going to Fordham in 1937. As assistant director of the seismological laboratory at Fordham, Lynch came to be recognized as an authority on deep-focus earthquakes and the analysis of earthquake waves.

MacLeod, Colin Munro (Jan. 28, 1909—Feb. 13, 1972). A U.S. microbiologist, MacLeod was a research professor on the faculty of New York University's School of Medicine when, in 1953, he was appointed deputy director of the White House Office of Science and Technology. After leaving Washington in 1956 he returned to New York University and remained there until 1970, when he assumed the presidency of the Oklahoma Medical Research Foundation. MacLeod pioneered in immunology, working in the field of bacterial genetics concerned with phage viruses. His research aided in the discovery of treatment for all forms of pneumonia.

***Mayer, Maria Goeppert** (June 28, 1906—Feb. 20, 1972). German-born U.S. theoretical physicist and Nobel Prize winner, Mayer was a professor of physics at the University of California at San Diego from 1960. Previously she had held teaching positions at Johns Hopkins University (1930–39) and Columbia University (1939–45). During 1945–59 she was a professor at the University of Chicago and at the Enrico Fermi Institute of Nuclear Studies (under Enrico Fermi), at the same time serving as senior physicist at the Argonne National Laboratories, near Chicago.

Early investigations into theories of nuclear structure came into sharp focus for Mayer in 1948 as she discussed her work with Fermi. Her thinking led to the explanation that a measured spin of a nuclear particle could correspond to one of two different orbits, making possible a description of the nucleus in terms of orbits of single particles. Mayer then worked out a "shell model" of the way in which nuclei absorb neutrons in high-energy physics. This work paralleled that of J. Hans D. Jensen, who at that time was working at the University of Heidelberg. The two scientists met in 1950 and collaborated on a book advancing their theories. Their investigations brought Mayer and Jensen the 1963 Nobel Prize for Physics (which they also shared with Eugene P. Wigner).

Sampsonov, Nikolai Nikolayevich (1906—1971). A Soviet scientist, Sampsonov's promising career was stifled because of his outspoken criticism of the Stalinist bureaucracy. In the 1930s he worked for the Directorate of the Northern Sea Routes and was in charge of prospecting for valuable arctic mineral deposits. During World War II he was engaged in scientific work, also seeing action on the Leningrad front.

In 1956 Sampsonov published *Thinking Aloud*, an attack on Stalin and a call for the return to Leninist democracy. For this he was arrested and confined in a special psychiatric hospital where he remained for eight years, refusing to plead insanity. After repeated threats to his health and family Sampsonov finally capitulated and was discharged with a pension. In 1950 he and S. A. Poddubny were awarded the Stalin Prize for designing a new type of gravimeter.

Sarnoff, David (Feb. 27, 1891—Dec. 12, 1971). U.S. executive and the "father of American television," Sarnoff was president of the Radio Corporation of America (RCA) from 1930 until 1947 when he became chairman of the board, a position he held until retiring in 1970.

General Sarnoff (he was a communications officer during World War II) launched TV into American homes when he made a personal appearance before the television cameras at the New York World's Fair in 1939.

***Tiselius, Arne Wilhelm Kaurin** (Aug. 10, 1902—Oct. 29, 1971). A Swedish chemist and recipient of a Nobel Prize, Tiselius joined the faculty of the University of Uppsala in 1925. He was assigned as an assistant to T. Svedberg of the Institute of Physi-

cal Chemistry and in 1930 became a lecturer in chemistry. After several years of study at Princeton University, and work at the Rockefeller Institute in New York City he returned to Uppsala in 1938 as a professor in biochemistry.

Tiselius was awarded the Nobel Prize for Chemistry in 1948 for his discoveries concerning the complex nature of the serum proteins. This work on electrophoresis and adsorption analysis included the development of a system for moving large molecules (such as proteins) through a solution by means of electricity. The two instruments he devised, the "Tiselius apparatus," have been utilized by scientists everywhere to separate proteins into their many complex chemical compounds.

***von Bekesy, Georg** (June 3, 1899—June 14, 1972). Hungarian-born U.S. physicist and Nobel Prize winner, von Bekesy was professor of sensory sciences at the University of Hawaii from 1966. He received a Ph.D. in physics from the University of Budapest in 1923 and became an engineer with the Hungarian telephone system, where he began his research work into the mechanism of hearing. In 1947, after several years at the Royal Caroline Institute in Stockholm, von Bekesy went to the U.S. and joined the faculty at Harvard University. His continuing experiments led to the discovery that the human ear distinguishes the pitch of sounds in the cochlea, the part of the inner ear shaped like a snail shell, and that the cochlea works as a sort of microphone to convert the mechanical energy of sound into electrical impulses received by the brain. For this major research concerning the ear and for his pointing the way for advances in the diagnosis and correction of damaged hearing, von Bekesy was awarded the 1961 Nobel Prize for Physiology or Medicine.

Photography

The year 1971–72 was one of outstanding progress in photography. In particular, research on the theory of sensitivity, emulsions, sensitizers, and color formers resulted in a tremendous improvement in color films, together with simplification of the processing. Research on black-and-white films also progressed, resulting in the production of recording films of greatly enhanced speed, with low grain and high definition, and direct positive films using a single stage of development.

While amateur photography continued its steady growth of over 5% a year, the largest amount of photographic material was still consumed in the nonamateur fields. Remarkable growth was shown in medical and industrial photography, microfilming, audiovisual uses, and the application of photography to the fields of graphic arts and reprography.

Silver and nonsilver processes. Most photographic processes rely on silver; in the U.S. the photographic industry is second only to the U.S. mint in silver consumption. In recent years the price of the metal has undergone extreme fluctuations, ranging from a high of $2.57 an ounce in 1968 to a low of $1.30 in October 1971. As of 1972 it showed a slow upward trend, leading to increased interest in silver-recovery systems. A number of such systems were proposed for photofinishers, radiographers, motion-picture and microfilm processors, and other large producers of waste silver. A further impetus to research in this field stemmed from the general interest in recycling of wastes in order to minimize environmental pollution.

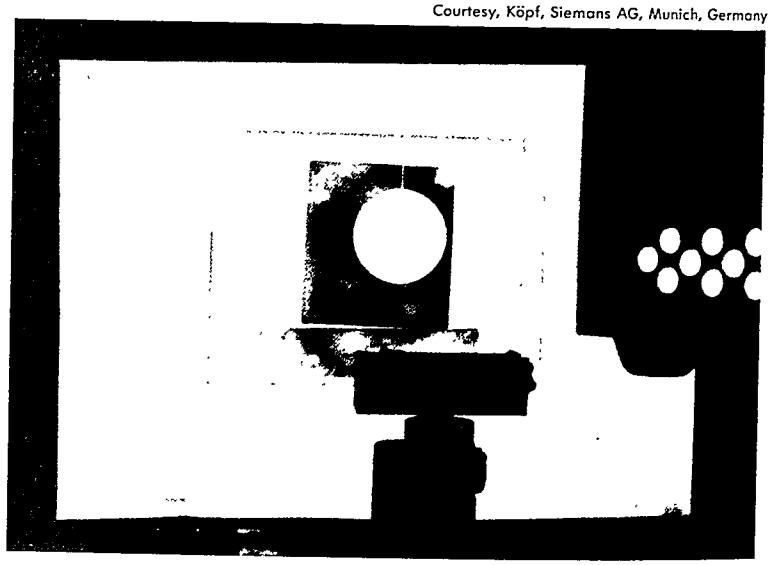
Prompted in part by the high price of silver, considerable investment was being put into research on nonsilver photographic processes. As of 1972, no satisfactory substitute for silver in conventional photographic uses had been found, although nonsilver processes had been adopted for special uses, such as electophotographic systems for document copying, diazo and vesicular systems for microfilm duplicate prints, and photopolymer systems for printing plates and so-called photofabrication.

Practical photography. Nine years after the introduction of its highly successful Instamatic cameras, Eastman Kodak Co., in March 1972, introduced the Pocket Instamatics, a series of five $1 \times 2 \times 5$ in. cameras capable of being carried in a pocket or purse. The drop-in cartridges are loaded with Kodak Ektachrome-X and Kodachrome-X films, a Verichrome pan, and a specially developed Kodacolor II film for color negatives. Color prints are $3\frac{1}{2} \times 4\frac{1}{2}$ in., larger than the 3X prints made from normal Kodacolor negatives and of comparable quality. The slides are 30 mm square in plastic mounts. Kodak announced that it would license other manufacturers for production of the new series.

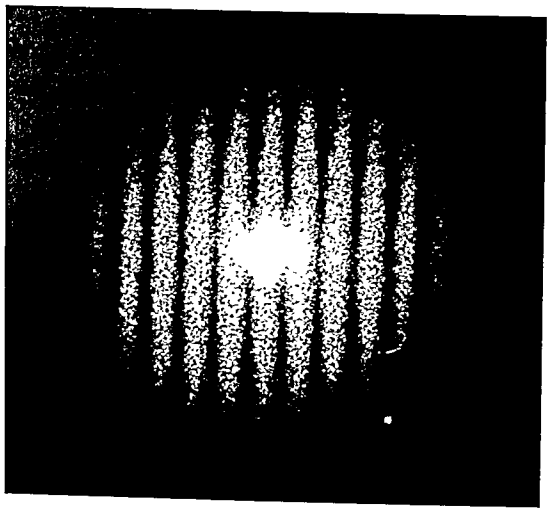
In September 1971 Kodak started to sell its new XL movie cameras and Ektachrome 160 Super 8 film in cassettes, permitting motion-picture photography indoors with existing light (XL). This was made possible by basic changes in camera design, including a specially designed high-aperture lens and an opened-up shutter. With the new film, the system gives 24 times the light-recording power of previous systems, and movies can literally be taken by candlelight.

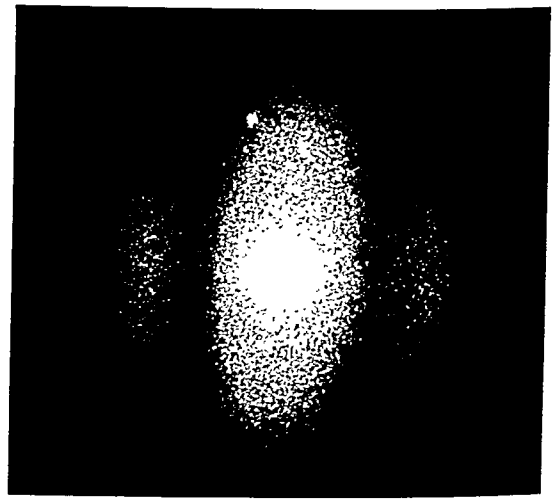
Considerable work was being devoted to video cassette systems, in which a video cassette player

Courtesy, Köpf, Siemans AG, Munich, Germany



Device for making speckle interferograms, photographs that accurately measure the tiniest displacements of moving objects, is at the right. Coherent light of a laser is used because it causes speckling when reflected by a dull surface and the amplitude of a displacement can be determined by examining the pattern of the speckles. The patterns below indicate a large (left) and a small (right) displacement.





is attached to a conventional television set to give a display on the TV tube. Rapid progress in the field had been hampered by such factors as cost, lack of standardization, copyright and union problems, and programming uncertainties. In 1971, however, Kodak demonstrated a feasibility model of a system using conventional Super 8 film cartridges in a special player attached to the antenna of a TV set, and Fuji announced the CVR (Cine Video Recording) system for its straight-8 movie film.

A number of new Polaroid Land Cameras were introduced in 1971, including a 400 series of folding pack cameras featuring a "Focused Flash" system in which louvers open or shut in front of the flashcube according to the distance of focusing; a camera for making color close-ups; and a camera for taking square pictures. A new Polaroid pocket camera was demonstrated to stockholders at the company's annual meeting in the spring of 1972. It was claimed that the new systems made it unnecessary to stabilize the prints by coating them.

In 1969 Kodak and Polaroid had announced a new agreement whereby Kodak would continue to make color negative film for Polaroid and could make color film packs for Polaroid cameras. In 1971 Kodak announced intensification of research on its own in-camera color system, including new color chemistry and coating techniques and new portable cameras. Meanwhile, Polaroid, which in the past has contracted out much of its manufacturing to other firms, was developing its own chemical-, film-, and apparatus-manufacturing plants.

Use of color photography continued to expand; about 80% of all still pictures were in color and some 70% of these were color prints, while practically all amateur movies were in color. Further, the number of hobbyists making their own color prints was growing. Important advances in color photography, besides the Kodacolor II negative film for the Pocket Instamatic cameras and Ektachrome 160 for the XL movies, included special high-quality color film for photomicrography; high-definition film for high-altitude aerial reconnaissance; Ektachrome duplicating film; and three-solution processing for Ektaprint paper for printing from color negatives and new Ektachrome processing machines, both for photofinishers.

The Kodak Ektaprint three-solution chemical system and processing machines inaugurated a trend toward simplification of color processing, partly by combining bleaching and fixing stages in one solution. Associated with this system was a process that regenerates the bleach-fix (blix) for further repeated use and recovers practically all the silver.

For the professional color finisher, the Vericolor system, using a special color processor and new chemistry, permitted processed and dry color negatives to be produced in 11 minutes, compared with the one-hour wet time previously needed. For color printers, there were attachments that scanned incoming negatives with photosensors and set the printing exposures automatically.

Current trends. Active research was taking place in the field of color xerography, and it was expected that a practical system would be available within four years. New instant-picture cameras were anticipated, not only from Polaroid but also from Kodak and probably others. The advanced amateur would probably do more personal darkroom work, especially in color. The 8-mm video cassette systems could well provide an important stimulus to the expected boom in cable TV.

In education, the entire audiovisual field was expected to undergo rapid growth, not only through Super 8 films but also in slide-sound presentation and a variety of other display techniques. In the fields of medical, dental, and industrial radiography, in microforms, especially micropublishing, and in the graphic arts, the systems approach—film, chemistry, processor, and auxiliary equipment regarded as a system—was finding rapid acceptance.

In printing, the trend to phototypesetting continued. There was increased use of scanners to give color-corrected color separations and of photographic methods for producing lithographic printing plates.

—Walter Clark

Physics

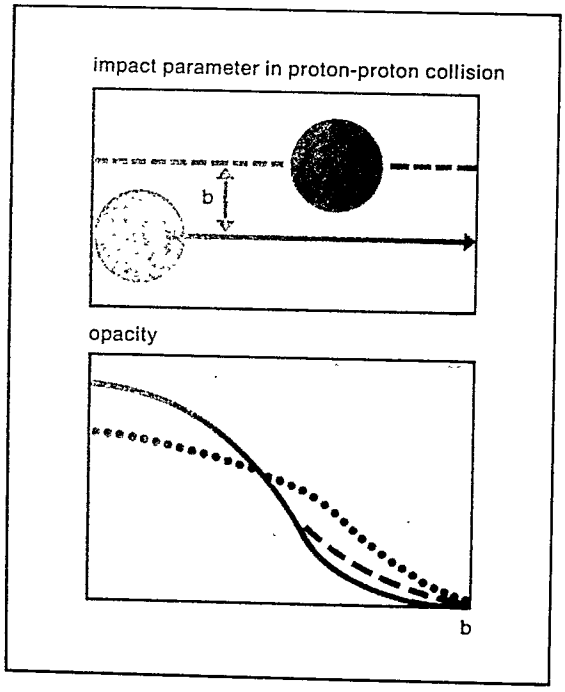
The discovery of the heaviest element occurring in nature, an isotope of plutonium, was among the outstanding developments of the past year in physics. In high-energy physics new facilities at the U.S. National Accelerator Laboratory and the European Nuclear Research Laboratory were being used to probe the world of subatomic particles.

High-energy physics

Intersecting storage rings. A number of important experiments were carried out at the new intersecting storage rings (ISR) of the European Organization for Nuclear Research laboratory at Geneva. The ISR consists of two beams of protons, each with a maximum energy of 26.5 GeV (billion electron volts), circulating in opposite directions. These beams intersect at points about the storage rings. The energy of the head-on collision of such protons is 53 GeV, which is equivalent to the collision between a 1,500 GeV proton and a stationary proton. The ISR thus provides energy 7.5 times higher than the 200 GeV achieved at the National Accelerator Laboratory, Batavia, Ill. (However, large classes of experiments are not accessible to the ISR, since collisions when the two proton beams pass through each other are rare. Even counting all its protons, the ISR beam is an excellent vacuum.)

Two ISR experiments are of special interest. Elastic proton-proton scattering shows an angular distribution which scales to that at lower energy. (A collision is elastic when no energy of motion is lost to other forms, such as the creation of particles.) That is, one looks at this distribution with respect to "momentum transfer" to judge whether there has been a change in apparent particle size compared to that of the protons at low energy. The proton's apparent average diameter was observed not to change with energy. It had been speculated that particle production, through conversion of energy into mass, would lead to an ever-increasing apparent diameter with increasing energy for strongly interacting particles. A classic geometric view of fixed particle size, seems, instead, to be indicated by the experiment.

The second experiment also suggested a simple geometrical view. In this experiment just one particle was observed of the many that generally result from a high-energy collision. If the "Lorentz contraction" of special relativity is taken into account for the initial protons, and special relativity is also taken properly into account for the observed particle, a prediction can be made for the rate of particle production. This prediction was con-



Distribution of strength of interaction, or opacity, of a proton can be determined during interaction with another proton of high energy. Experiments revealed that the proton's opacity distribution does not expand with increased energy (dotted curve) but is independent (solid curve), though a slight effect (dashed line) might be present.

firmed in a striking manner by the experiment: the probability for producing a particle of a particular velocity, when expressed in a certain scaling form, was predicted to be independent of the total energy. This was confirmed for a number of energies (quoted for a proton on a stationary proton target) of 12 GeV up to 1,500 GeV.

A number of other new and important results are expected from experiments with the ISR. These include the numbers of particles produced in collisions at various energies and a very extensive "map" of likelihood for producing each of a variety of particles at various velocities.

Amplitude analysis. The general technique for discovering properties of nuclear particles is to observe incident and outgoing particles associated with collisions. The general types of information arising from experiments on elastic scattering of particles are the existence of "states" and the properties, such as range, of forces or of distributions of matter. (A state is a spatially localized system that remains compact for some time.)

The tool used to extract detailed information about states and range of forces from collision data is "amplitude analysis." Observables (perceptible events), according to the quantum theory, are always products of two amplitudes, for example A^2 or AB. Amplitude analysis involves extracting the amplitude (A or B), which can be difficult. For example, if $A^2 = 4$, the amplitude is ambiguous: $A = \pm 2$. But as improved information has become available, it has gradually become possible to remove these ambiguities for certain cases of scattering.

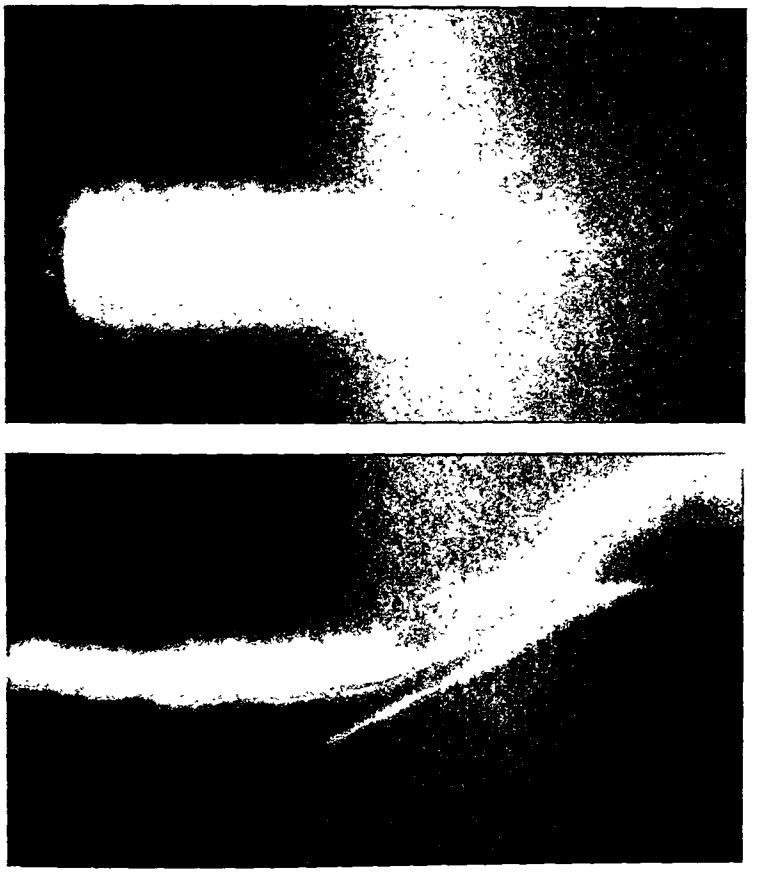
An exciting development in this subject occurred during the year: the determination of the amplitude for pi-meson nucleon scattering at a high energy (6 GeV) over a range of small angles. This amplitude analysis was not intended to reveal any "states." (States are not expected to be observed at this energy because they may be too broad and overlapping or, perhaps, because there are no more states at this energy.) However, in the case of the two-nucleon problem studied in the 1950s, although no states were found, amplitude analysis had made possible the detailed determination of the two-nucleon potential—the force that holds atomic nuclei together. The high-energy amplitude analysis of the pi-meson nucleon system might have equally powerful implications for the behavior of strongly interacting particles at high energy.

One possibility, about which the present analysis is not yet definitive (complete experiments at other energies are needed), is that the apparent particle size is independent of energy, as also suggested by the ISR experiments discussed above. But a small amount of matter at a large distance from a particle's center may influence collisions at very high energy; thus, although average apparent particle size at high energy does not appear to grow rapidly with increased energy, it is possible that there is a small effect of this kind.

Deep inelastic scattering of electrons by neutrons. What is the neutron like internally? Does it differ substantially from the proton? "Deep" inelastic scattering of electrons at the Stanford (Calif.) Linear Accelerator Center—collisions in which the electrons are observed to lose a great deal of their energy of motion to particle production—confirmed that the proton should be thought of as a composite system. That is, the proton is made up of several, or many, parts. The neutron should be similar.

New experiments on the neutron showed that it is not identical to the proton, but the question is whether the difference can be understood in terms of electric charge. As a simple exercise consider a "quark" model for a proton and a neutron such that the proton is made up of three particles, called quarks, with charges $+\frac{2}{3}$, $+\frac{2}{3}$, and $-\frac{1}{3}$ to total one

Courtesy, Physics International Co.



Very intense beam of electrons moving at about the speed of light is disrupted (top, flare at left) shortly after leaving a vacuum and entering a gas. Electrons collide with the neutral gas atoms and ionize them. The positive ions almost totally neutralize the negative charges of the electron beam, and the magnetic field at the edge of the beam bends the electrons sharply around. Below, a tilted metal plate placed in the path of an intense electron beam causes the beam to appear to "bounce" off without actually striking it. The only illumination in both photographs was that produced by the recombination of ionized gas molecules in the path of the beam.

unit of positive charge, and the neutron is made up of three quarks with charges $+\frac{2}{3}$, $-\frac{1}{3}$, and $-\frac{1}{3}$, so that it is neutral. The probability of deep inelastic electron scattering would be expected to be proportional to the sum of the squares of the quark charges: $\frac{4}{9} + \frac{4}{9} + \frac{1}{9} = 1$ for the proton and $\frac{4}{9} + \frac{1}{9} + \frac{1}{9} = \frac{2}{3}$ for the neutron. Experiments to demonstrate this were exceedingly challenging both to perform and to analyze. The latest results indicated a rate of scattering for the neutron that is lower than the $\frac{2}{3}$ predicted by this model.

National Accelerator Laboratory. Important milestones were passed in the construction of the accelerator at the National Accelerator Laboratory during the year. Protons were accelerated to full energy in the "booster ring," and protons were injected and accelerated to nominal full energy (200 GeV) in the "main ring." Despite these achievements, there were serious difficulties, especially with magnets in the main ring. Much work remained to be done before acceleration at full current, or intensity, would be possible. The accelerator, however, was expected to operate effectively at a reduced intensity, thereby making possible a series of interesting experiments. *See* A Gateway to the Future: THE WORLD'S LARGEST NUCLEAR PROBER.

One of the early experiments was scheduled to be a Soviet-U.S. collaboration on elastic proton-proton scattering using a jet of hydrogen gas inside the vacuum chamber of the main ring as the target. This technique had been used successfully at the Serpukhov accelerator near Moscow. Another early experiment was expected to make use of the hydrogen bubble chamber successfully moved from the Argonne (Ill.) National Laboratory. With the bubble chamber, studies were to be made of the number of particles produced in collisions, and of correlations among such properties of the produced particles as velocity.

Neutron stars. High-energy physics seldom makes a direct, as contrasted with a philosophical, contribution to other subjects. A recent example of a direct contribution is to the theory of "pulsars," pulsating neutron stars. To understand the state of the condensed nuclear matter in such a neutron star one must understand thoroughly the states of nuclear matter at high energy. Recent speculations

on these states, their density, and their "elementary" as opposed to composite, character, were being used by research physicists and astronomers as a basis for constructing theoretical models of the interior of neutron stars.

The key question in the investigation concerned the role of the Pauli exclusion principle. The exclusion principle states that two or more particles of a certain type cannot occupy the same space. If one visualizes a large number of such particles being gradually pressed together, which mutual gravitational attraction would cause to happen in a star, the consequence of the exclusion principle would be a rapid rise in pressure in order to prevent particles from occupying the same space. The exclusion principle does allow a completely different particle to occupy the same space, however. In a neutron star the question concerns the series of excited states of the neutron (particles like the neutron but more massive). If these excited states are fundamentally different particles from the neutron itself, the exclusion principle does not apply and the neutron star would be relatively easily compressed. But if these particles are simple composite systems they would then probably be similar to the neutron, as discussed above in connection with deep inelastic scattering, and a neutron star would, therefore, be relatively incompressible.

—Marc Ross

Nuclear physics

Some impression of the nuclear domain—how far man has progressed in his exploration of it and how much remains totally unknown—is provided by the accompanying figure. This is a map obtained by plotting the number of protons (Z) in each variety of nucleus (nuclear species) against its number of neutrons (N). In each atom the number of positively charged protons in the nucleus is balanced by an equal number of orbital electrons, with equal negative charge, so that the atom as a whole is electrically neutral. The number of protons determines which chemical element is involved; different numbers of neutrons associated with a given number of protons result in the different isotopes of this element.

The valley of stability. For N or Z of less than 20, the most stable nuclei have $N = Z$; with increasing Z, however, the electrostatic repulsion between the protons acts to make the nuclei less stable, and so the most stable, increasingly, are those with more neutrons than protons. If the nuclear domain is considered to have three dimensions, reminiscent of a relief map, the instability of a particular isotope can be represented by its elevation above some selected "sea-level"; therefore, on such a relief map the most stable species lie at the bottom of a deep valley, the valley of stability, which runs diagonally across the map. In the figure the stable species are shown as the black squares; in all of nature there are only approximately 300 of these.

Until late 1971, physicists and chemists always stated, without question, that uranium—the element with $Z = 92$—was the heaviest in nature. This is no longer true. Darleane Hoffman of the Los Alamos (N.M.) Scientific Laboratory and her collaborators succeeded in 1972 in showing that an isotope of plutonium ($Z = 94$) occurs in nature as an extremely rare component of a rare earth mineral, bastnasite, from the Mountain Pass Mine in southern California. This came as a complete surpirse and provided important information that supported those who believe that such heavy nuclear species were formed in a supernova explosion of a giant star somewhere near our galaxy about 5,000,000,000 years ago.

Since the early 1940s nuclear scientists have made and studied approximately 1,300 artificially radioactive isotopes; these fall within the inner solid outline surrounding the stable species in the figure. These 1,300 along with the 300 stable species represented all that physicists knew about the nuclear domain in 1972. Extrapolating from these to describe the characteristics of all possible nuclei is something like attempting to describe the geography of the United States from a detailed study of the floor of the Grand Canyon. Physicists have really only begun to study the very lowest levels of the walls of the valley of stability. Enormous regions remain unexplored.

The continent of stability. *Can* nuclear scientists say anything about the unknown regions? One thing they have learned is that adding more and more protons to a nucleus eventually will produce a nuclear species that will disintegrate instantly because of the electrostatic forces of repulsion. If more and more neutrons are added to a nucleus, a limit is eventually reached where the additional neutrons can no longer be bound and they will "drip" out of the nucleus. These two limits can be calculated rather well from current knowledge of nuclear forces, and they establish the upper and lower boundaries of the continent of stability in the figure. In the case of very heavy, proton-rich isotopes, a spontaneous fission process competes with the emission of protons or of alpha particles (two protons and two neutrons very tightly bound to give a helium nucleus, a frequent nuclear decay product).

The continent of stability is a broad and unexplored one. Spanning it are the isotopes of calcium

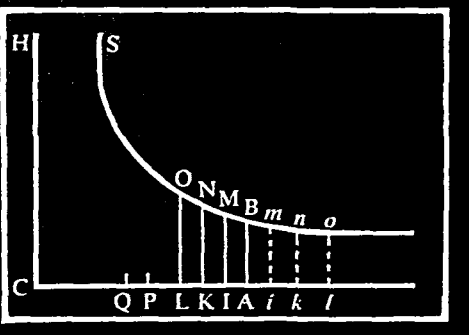
from calcium-31 to calcium-70; each isotope contains 20 protons, but the numbers of neutrons range from 11 to 50. Similarly, uranium extends from uranium-195 to uranium-302 with 92 protons in each isotope and neutron numbers ranging from 103 to 210. Of these 39 calcium and 107 uranium isotopes, which are predicted as stable against instantaneous disintegration, by 1972 only 24 and 14, respectively, had been discovered.

Fortunately, probes for exploring these new nuclear regions were expected to be at hand soon. G. N. Flerov and his associates at the Joint Nuclear Research Institute laboratories at Dubna in the Soviet Union calculated that if a uranium target could be bombarded with a 2,000 MeV (million electron volt) beam of uranium ions, the collision would produce at least 6,000 different nuclear species as compared to the 1,600 now known.

Quite apart from the great scientific interest in exploring this new territory, the discoveries might lead to valuable new applications. For example, many more varieties of radioisotopes would be produced. These radioactive nuclei have already had a revolutionary impact on medicine. In almost every application, however, the radioisotope has been selected for its chemical or biological characteristics—it had to follow and tag a certain chemical species or process, or concentrate in a certain organ, as, for example, iodine in the treatment of human thyroid disorders. Having made this selection, however, the user was then very limited in the radioisotopes of the selected element available to him. At best, he selected the one that came closest to giving the desired results while having minimal unwanted side effects. All too frequently, if the radioisotope had the desired radiation it had the wrong lifetime or dangerous associated radiation. With many more radioisotopes to choose from, physicians could hope to approximate much more closely the ideal isotope characteristics for a given application. The new isotope iodine-131, as an isolated example, was shown to be vastly preferable to the iodine-133 previously used in human thyroid therapy in terms of both its lifetime and its unwanted radiations.

The islands of stability. The extent of the continent of stability in the upper right portion of the figure remained unknown except that it shades gradually into the surrounding oceans of instability. Possible outer islands of stability in these oceans were predicted where $Z = 114$ and 126 (and possibly also $Z = 164$) and where, simultaneously, $N = 184$. There are no obvious natural processes whereby the elements in these islands would have been made during the history of the universe so that, even if stable, it is not surprising that they have never been found. Collisions of mas-

Sir Isaac Newton
—physicist and mathematician—
is one of the greatest figures in the history of science.
He discovered gravitation, the composition of white light, and the nature of colors, and helped develop differential calculus.





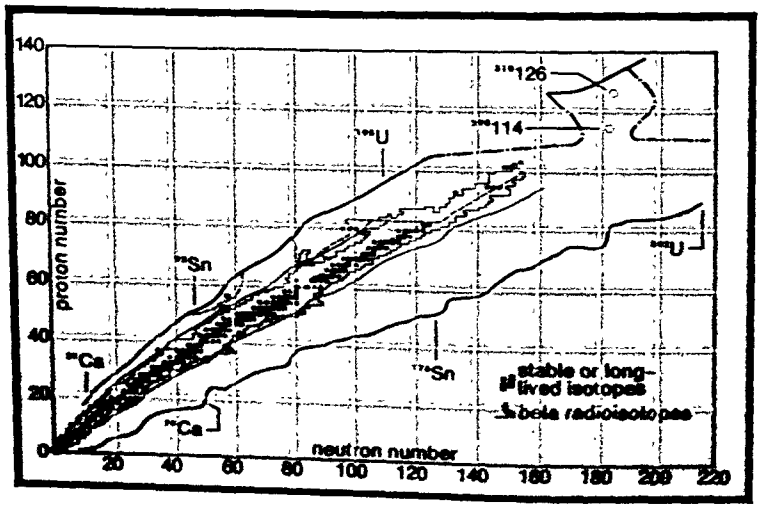
sive chunks of nuclear matter, similar to the uranium on uranium example described above, provide a mechanism for the production of these very heavy nuclei, and programs under way at Berkeley, Calif., Dubna, Paris, and at Darmstadt, W. Ger., were directed toward their possible production.

Part of the interest in these potentially stable heavy nuclei stems from the fact that the same calculations that predict the possible long-term stability of these new species also predict that when they fission they might release 10 neutrons as compared to the 3 to 4 in the case of the more familiar fissile materials. This has potentially important consequences in reducing the critical mass required to support a nuclear chain reaction, thereby producing electric power from nuclear energy more easily.

Excitations above ground level. Thus far only the actual surface of the continent of stability has been discussed. It is traced out by the location of the most stable, or ground, state of each nuclear species in question. Each of these species, however, has many configurations lying at higher excitations (greater levels of energy) above the ground state; in terms of the figure, these would be in the "atmosphere" above the continent. Until recently, nuclear science concentrated on the structure very close to the ground levels. This reflected both experimental and apparatus limitations that made other studies difficult and also a reluctance to tackle those higher, more tightly packed, states until a better understanding of the lower, and presumably simpler, ones was at hand.

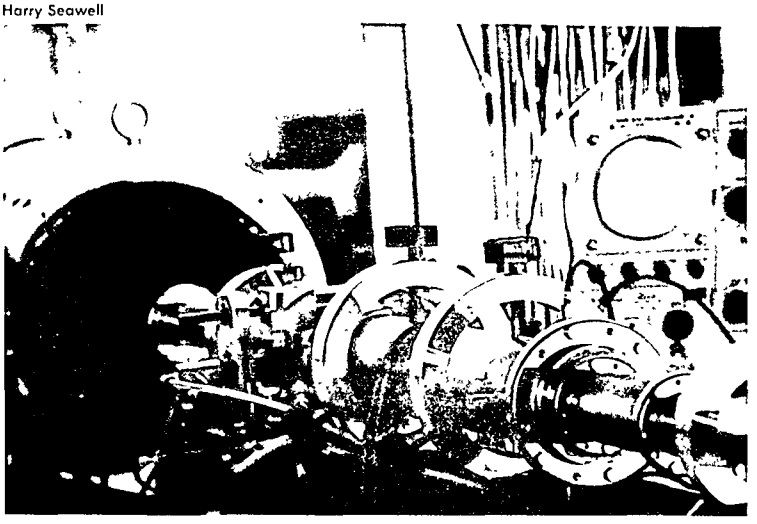
In recent years, however, major progress has been made in moving up from the ground state to more excited levels. In many nuclear regions—around lead ($Z = 82$) for example—it was found that the nuclear structure is much simpler than had been expected, with individual neutrons and protons moving largely independently in well-defined orbits much like those of the more familiar electrons in atoms. Pioneering work on this region was done by Nelson Stein and his collaborators at Yale University. Groups at Copenhagen and at Los Alamos found evidence for pairs of neutrons and protons moving together as single entities and making up whole new classes of states. More recently, Rolf Siemssen and his collaborators at the Argonne National Laboratory in Illinois, Henriette Mathieu-Faraggi and her collaborators at Saclay, in France, and Roy Middleton and a group at the University of Pennsylvania, found evidence for yet another class of structures where four particles—two neutrons and two protons—moved together in so-called quartet configurations. Proceeding in this way researchers were able to disentangle what seemed to be a wildly complex situation into overlapping families of relatively simple nuclear structures. This new work surveyed the "atmosphere" of the nuclear domain up to an elevation of approximately 10 MeV and covered hundreds, if not thousands, of different energy states in many different nuclei.

But what is the situation in the "stratosphere" of the nuclear domain? The question of what happens to a nucleus as energy is continually pumped into it has long been an open one. In the simplest models, such as those that were remarkably successful in the hands of Niels Bohr and John Wheeler in explaining the phenomenon of fission, the nucleus was likened to a liquid drop. When such a droplet has energy added to it—is heated—its components (molecules) move ever more rapidly



The "valley of stability" for atomic nuclei can be drawn by plotting the number of protons in each nuclear species against the corresponding number of neutrons. The heavy black lines and dots in the center of the valley represent the most stable species. The solid boundary lines show the limits of stability, beyond which the strong nuclear forces would cause instantaneous decay of a species. The region of heavy man-made elements is defined by the broken line at the upper right; the circles indicate two potential man-made elements, 114 and 126, that would be islands of stability.

Harry Seawell



A 2.5 million-v ion accelerator developed by IBM applies the techniques of nuclear physics to analyze materials and make new electronic devices. Beams of ions, giving off glows characteristic of their composition, are directed at high velocities to be embedded in silicon crystals and thereby create new devices.

under thermal agitation until some, on a statistical basis, achieve enough energy to escape from the drop altogether. They have been evaporated. Similar phenomena have long been observed in nuclear science where neutrons having a familiar evaporation spectrum of energies are frequently observed. If this were all that happened, the nuclear stratosphere would be dull indeed. But recently Adriano Gobbi and his co-workers at Yale obtained evidence for energy states near 40 MeV in silicon-28; these states have a striking molecular structure in which two well-defined carbon nuclei are bound together by the exchange of an alpha particle. Also, preliminary results on the capture of negative K mesons in material such as nickel, obtained by collaborating groups from Carnegie-Mellon University, Pittsburgh, Pa., and the Argonne National Laboratory, provided evidence for the presence of large nuclear subunits (for example, carbon-12 or beryllium-8) orbiting at a large radius from the center of mass of the parent nucleus. At such large radii they can be effectively unhooked from the parent nucleus by the energy release from the decay of the captured K mesons.

Heavy ion nuclear science. In a new frontier area of the nuclear sciences, beams of heavy ions (normally any nuclear species heavier than helium, $Z = 2$) are used to initiate nuclear reactions. They have the advantages of permitting the study of reactions when large clusters of neutrons and protons are transferred between projectile and target, of giving access to very-high-spin situations, and of selectively focusing on the surface regions of nuclei rather than upon their interiors.

In the areas of high spin, heavy ions allow the study of states having spins at least 10 times higher than ever before seen. Andrew Sunyar and his collaborators at Brookhaven National Laboratory, Upton, N.Y., found in preliminary heavy ion studies that in dysprosium-156, as the nucleus is spun faster and faster, an abrupt and striking change occurs in the moment of inertia (the sum of the products of each mass particle of a body multiplied by the square of its respective distance from the axis of rotation). The reason for this was unknown, but the phenomenon provided a stringent test for the current understanding of the microscopic bases of nuclear structure.

—D. Allan Bromley

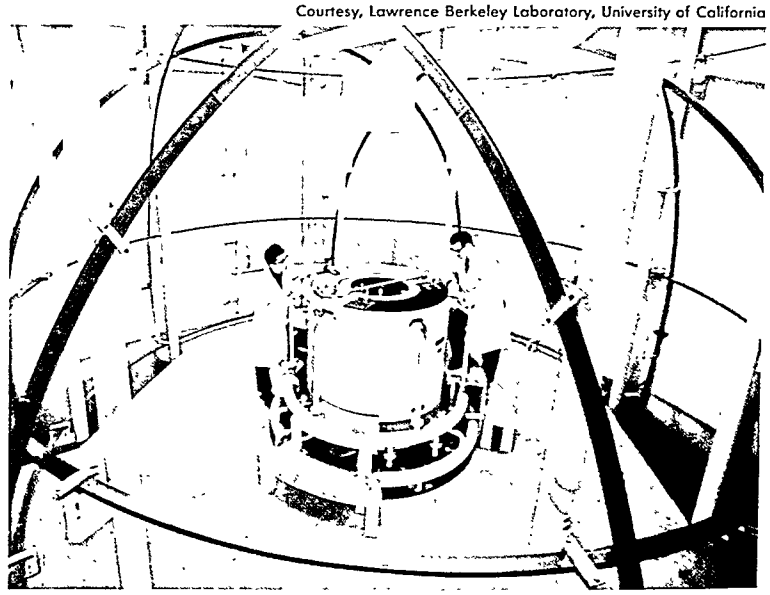
Science, General

In general, the basis for federal support of the U.S. scientific endeavor has been the belief that, out of its vast array, useful information will surely emerge. Although few specific basic research efforts will produce economically beneficial results, it is necessary to support the overall research program because its value will be greater than the total investment. Although no one could fully document the relationship, it has been a commonly held assumption that the substantial technological superiority of the United States derives from its leadership in almost every field of science. During the year, however, doubts began to emerge.

A business survey published in February 1972 by the Morgan Guaranty Trust Co. of New York reported:

> While the U.S. still enjoys a sizable trade surplus in transactions involving technology-intensive manufactured products—such as chemicals, electronic equipment, machinery, and transport equipment—a threat to that surplus unmistakably exists. This is emphasized by the fact that imports of such products grew more than twice as fast in the 1960s as exports. One of the most visible manifestations of this, of course, has been the

Courtesy, Lawrence Berkeley Laboratory, University of California



A photoelectron spectrometer at the Lawrence Berkeley Laboratory of the University of California will be used for chemical analysis of atmospheric particulates as part of an interdisciplinary environmental research program coordinated by the laboratory. By mid-1972, 14 projects had been funded by various governmental agencies.

spectacular progress Japanese industries have made in cracking U.S. markets for electronic products such as calculators and television sets. But such other technology-intensive industries as machinery producers also have found themselves increasingly hard pressed to maintain a competitive stance in domestic and foreign markets.

New directions for R and D

In the White House the realization was growing that the vaunted U.S. superiority in technology was being challenged—not only by Japan but also by West Germany and other European nations. Furthermore, technological proficiency did not seem to be of great help in solving such severe societal problems as the deterioration of the cities, crime, and the crisis in transportation. The result was a rather fundamental shift in attitudes toward the allocation of federal resources for the support of science and technology.

A decade earlier the scientific community was being asked to identify those fields of science that would most benefit from increased support. Now the question seemed to be: How should the national research and development program be directed in order to solve societal problems and restore the U.S. technological advantage in international trade? In addition, if the research and development effort could provide a boost to the domestic economy, that would be of great interest to an administration concerned about rising prices in a period of rising unemployment.

Searching for projects. Few appointments to Washington officialdom aroused as much interest and speculation among professional science-policy watchers as that of William M. Magruder to serve as special consultant to Pres. Richard Nixon, effective Sept. 8, 1971. The initial announcement was made in rather low key by an assistant press officer at a routine White House press briefing. Reporters were told simply that the former director of the supersonic transport program in the Department of Transportation would be working with the White House "in the areas of research and development which hopefully will lead to potential new technology which could help the United States in our domestic and foreign export policy."

Magruder saw his mission as the identification of promising technologies that would have the potential of solving one or more of the nation's pressing problems. In an effort to unearth these new technological opportunities, as he called them, he invited government agencies, private organizations, and industries to send in their pet ideas. Letters went out by the thousands. The following is a typical example outlining the principal concerns of the White House:

Dear Dr.——:

On behalf of the President's Domestic Council, I am writing to solicit the views of your organization, or even the individual views with respect to potential new technology opportunities in the civilian sector and how the Federal Government might stimulate these potential opportunities. Generally, these programs might include efforts (Federal, private, or both) in areas such as desalinization of water, advanced energy systems, low pollution automobiles, solid waste recycling, new teaching methods, new health care methods, new housing construction, oceanographic exploration, means for incurring industrial productivity, transportation systems, new law enforcement methods, and so on. The objective is to stimulate innovation in the civilian sector of the economy

directed at basic national problems and/or economic opportunities.

The study should apply at least these basic criteria to each technology project or program before any increased funding is recommended;

1. Importance: Project or program must relate (a) to a significant and urgent national problem (b) to a significant opportunity for economic growth, increased exports, or technological leadership.

2. Pay Off: The cost/benefit ratio must be favorable. What are the social and economic benefits—including impact on balance of trade productivity and employment? What will be the distribution of benefits among different industries and areas of the country?

3. Budget Impact: What are estimated long-term costs over next six years of full systems costs?

4. Non-Federal Support: What is the feasibility and likely maximum extent of cost sharing by industry? Can the project be achieved through steps short of direct Federal funding: regulation or deregulation, standard setting?

5. Potential Problems: Are there potential institutional or economic barriers to acceptance and implementation of the technology and how are they to be overcome? Are there any undesirable side effects from the technology and how are they to be dealt with?

6. Organization and Management: Assuming several programs or projects meet the above criteria, what kind of organization (existing agencies, new agency, or quasi-public corporation) should be created (if any) or redirected to carry out these programs?

A second area wherein I seek your counsel relates to potential stimulus that could be offered to industry in order to create innovation, higher productivity, etc. by revision of tax laws, grants, prizes, etc.

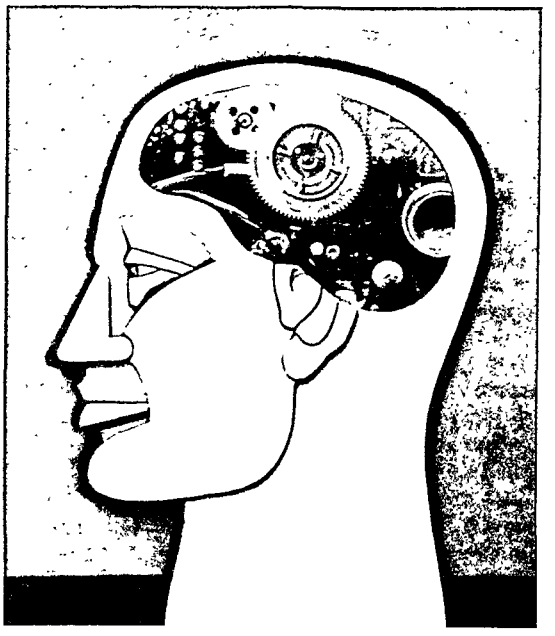
A third area about which I would appreciate your ideas concerns potential changes in anti-trust and patent law practices to encourage innovation, higher productivity, improved export business and greater overall employment . . .

Sincerely,

William M. Magruder
Special Consultant
to the President

As the months wore on and proposals for the new technological initiatives began to pour into the Executive Office Building, visitors returned from the screening sessions with a sense of awe at the size of the input. Piles of paper were said to reach to the ceiling. Projects were coming in by the hundreds, and some of them were accompanied by stacks of supporting documents three feet high. Unfortunately, there appeared to be few good ideas per pound of paper. Proposals from government agencies looked like warmed-over versions of ideas that had been turned down several times by the Office of Management and Budget or by lower echelons of review. Proposals from industry looked as if the sponsors had good reason for not investing their own money.

Courtesy, F. E. Compton Company



Can man and his culture survive only if he is conditioned to want what best serves group interests? Harvard psychologist B. F. Skinner (Beyond Freedom and Dignity) *thinks so, but his critics contend that self-determination is vital and behavioral manipulation violates man's essential humanity.*

Even though Magruder had attempted not to raise expectations too high, the absence of any significant reference to his mission in the president's message on science and technology on March 16, 1972, evoked bitter expressions of disappointment from much of the science press. *Science* magazine called the technology plan "vapid" and described the message as "little more than reshufflings of existing rhetoric and known policies" in "sad contrast to the optimistic hints that emanated from the Administration last summer and fall."

Nevertheless, many of those close to the exercise refused to write it off as a failure. They argued that its primary accomplishments had been, on one hand, to convince top government officials that there was a solid connection between R and D and the quality of American life, and, on the other, to educate them in the intricacies of dealing with such issues. Said one budget official: "The political officers in the Office of Management and Budget began for the first time to understand the complexity of the R and D process—its complicated relationship to such things as balance of trade, productivity, and jobs." Magruder pronounced his own valedictory: "I'm satisfied that we served the top decision makers in at least bringing the con-

flicts and hard questions out into the open. . . . Beyond that . . . the operation gave the Administration a whole credenza of projects whose time will come sooner or later."

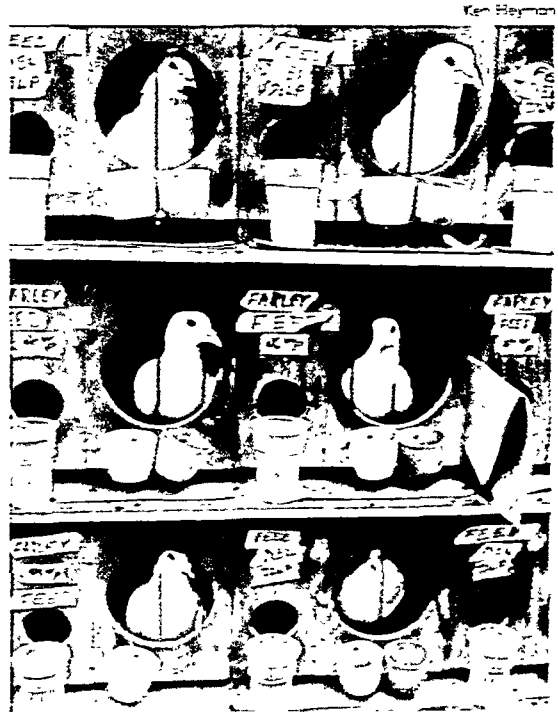
A budgetary step upward. One reflection of the administration's growing awareness of the value of a healthy R and D effort appeared in its proposed budget for the 1973 fiscal year. Once again there was a small but significant increase in the overall figures, as contrasted with the abrupt leveling off that had characterized the Johnson administration. The total figure rose 9%, from $16.4 billion to $17.8 billion. The increase was almost precisely divided between the military and civilian sectors.

Responses to the stimuli that had given rise to the Magruder program were also evident in the budget. The high-technology agencies were directed to engage in activities with broader social benefits. Thus the Atomic Energy Commission (AEC) received increased funding to work on electric automobile batteries and cryogenic transmission lines, and the National Aeronautics and Space Administration (NASA) was asked to work with the Department of Transportation on a variety of vehicle-development projects.

Most evident, however, was the effect on the budget of the National Science Foundation (NSF). Although the budgeted figure of $653 million represented only a 5% increase over the previous year, the release of previously impounded NSF funds brought the total available amount to $674.7 million, a far more significant increase of 12%. In a period of belt-tightening, few other agencies gained as much.

Of special interest were three new programs, again related to the new emphasis. One $36 million item, the Experimental R & D Incentives Program, was to be conducted jointly with the National Bureau of Standards. Its goal was to encourage increased investment by the civilian sector and to improve the application of R and D results. Another $2.5 million was requested for a National R & D Assessment Program, to study how science and technology contribute to such national objectives as improvement of the quality of life, economic growth, productivity, and employment. A third program, Institutional Grants for Research Management Improvement, would set aside $4 million to encourage academic scientists and administrators to study and experiment with new arrangements for the management of research.

Once again, the overall NSF budget provided evidence that the administration preferred to spend its funds on targeted research rather than on producing scientists per se. There were almost no funds for the continuing support of science education, and support for graduate students was



Pigeons in B. F. Skinner's laboratory have been central to his experiments in controlled behavior. By setting up "contingencies of reinforcement" under which desired behavior is rewarded with food at critical moments, Skinner has disciplined the pigeons to walk figure eights, dance, and play Ping-Pong.

reduced from $20 million to $14 million. At the same time, funds allocated to the two-year-old NSF program in Research Applied to National Needs increased 43% to $80 million, mostly under the headings of Advanced Technology Applications and Environmental Systems and Resources. Major emphasis was placed on energy R and D, particularly solar energy. The largest single addition, however, was in basic research: $3.7 million for initial funding of a huge new radio astronomy facility, with a Y-shaped interferometer with 13-mi arms for the placement of movable antennae.

An increase of $736 million in R and D funds, larger than the total NSF budget, was granted to the Department of Defense. The 9.5% increase was justified by the need to catch up on projects deferred because of the Vietnam war and the apprehension that the Soviet Union was outspending the U.S. in this area. NASA's budget remained essentially level at $3.2 billion. A proposed grand tour of the outer planets, dropped as not cost-effective, was to be replaced by individual flights to Jupiter and perhaps Saturn. Additional funds were allocated to two remaining Apollo flights, three Skylab launches, and developmental work

on the space shuttle (*see* Year in Review: ASTRONAUTICS AND SPACE EXPLORATION).

The AEC budget showed a slight increase, with R and D emphasis on the development of clean energy sources, such as the liquid metal fast breeder reactor and controlled thermonuclear fusion. Total federal funding allocated to the environment, scattered throughout a number of agencies, rose only slightly—from $1.1 billion to $1.2 billion—despite public interest in the problem. Health-related research was programmed to increase from $1.8 billion to $2 billion, mostly in the National Institutes of Health; cancer research received a substantial increase of $93 million, to $430 million. The Food and Drug Administration was also strengthened, with a jump from $38 million to $56 million in research funds.

Technology assessment

The year 1972 brought a little closer to reality an attractive governmental concept that had produced more words and fewer concrete results than any similar idea in recent years. This was technology assessment, a term possibly coined and certainly made popular by former Representative Emilio Q. Daddario of Connecticut. (See *1971 Britannica Yearbook of Science and the Future*, Feature Article: PRIORITIES FOR THE FUTURE: GUIDELINES FOR TECHNOLOGY ASSESSMENT, pages 292–311.) For more than five years Daddario had insisted that Congress, whose acts of appropriation make possible the development of such powerful new technologies as atomic energy and supersonic flight, had a corresponding responsibility to discern the future effects of these new technologies on national life.

Despite the obvious difficulties involved, Congress and much of the rest of the national leadership had come to accept the need for some kind of capability to predict the consequences of technological change. A number of programs to prepare and evaluate methodologies for making such predictions sprang up on university campuses, notably at Harvard, Columbia, and Cornell. Of these three, only Cornell remained, along with smaller programs elsewhere. Congress, however, had had the issue brought home to it with increasing intensity. Much of the deliberation about funding the development of the supersonic transport hinged on environmental consequences. The National Environmental Protection Act calls upon government agencies to predict the environmental consequences of their activities. Rep. Mike McCormack (Dem., Wash.) noted that in the 89th Congress 9 bills were introduced to create new committees with a special interest in science, technology, and the environment; in the 90th Congress the number rose to 27, and in the 91st, to 132.

The OTA proposals. The principal bills in the 92nd Congress concerned the establishment of an Office of Technology Assessment (OTA). As originally written in the House, the proposal would have provided for a policy-making Technology Assessment Board, consisting of one senator and one



Ken Heyman

B. F. Skinner demonstrates the laboratory apparatus that he has designed to carry out experiments in controlling animal behavior. The wires are connected to the animals' cages and to the trigger mechanisms that provide rewards to reinforce the desired behavior.

representative from each major party, four private citizens appointed by the president, plus the comptroller general, the director of the Congressional Research Service, and a director of the OTA, who would be appointed by the board. The principal assignment of the office would be to contract out studies that would provide Congress with early warnings concerning potential consequences of new technologies and with analyses of alternative measures. Its initial operating budget was to be in the neighborhood of $5 million, and it would have a staff of a dozen or so.

When the OTA bill came before the House, there was little argument over the need for such advice, but there was an unexpected reluctance to go outside Congress to find it. Although the framers of the original bill conceived of the board as a device whereby scholars and civic leaders could peer into the crystal ball alongside Congress, House members doggedly refused to admit that they could profit from such assistance. Nor did they want the staff director of the office to enjoy the privilege of assigning studies. Congress has been elected to draw up legislation, they argued, and it alone was capable of deciding what kinds of information it needed to carry out its function.

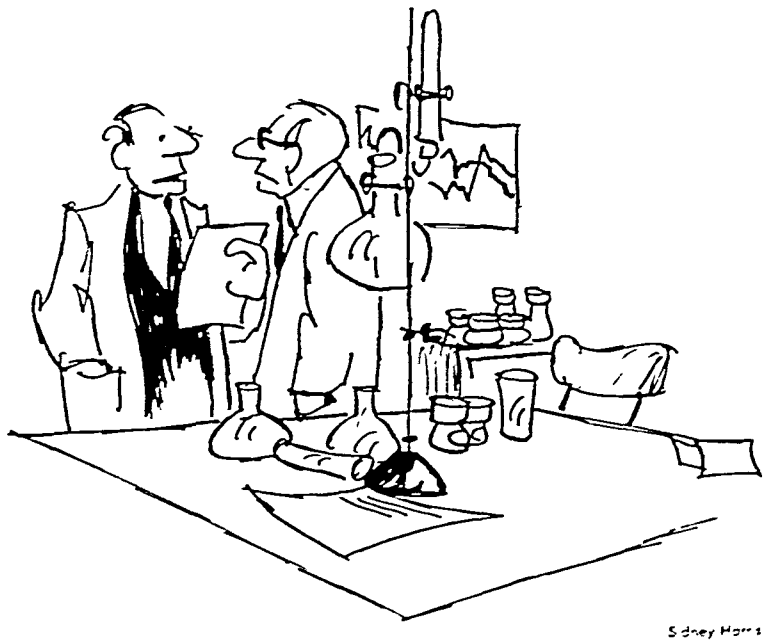
Since no other body had yet conducted a successful technology assessment study of the magnitude needed by Congress, it could not be argued that Congress would do a worse job. The bill sailed through the House in its amended form. It was expected to pass the Senate easily, and probably in a version very like that approved by the House.

The Safeguard controversy. An example of the controversy that can arise when an outside group attempts to assess a technology being promoted by a federal agency occurred during the winter of 1971–72. The groundwork for the furore was laid in a series of Senate hearings in the spring of 1969 dealing with the merits of the Safeguard antiballistic missile system. In those hearings and in various publications, a group of scientists had argued that the supporting evidence for authorizing the Safeguard system was faulty, and that the system itself was neither sufficiently necessary nor reliable enough to justify the funding that would be required.

Much of the argument for and against the Safeguard system fits under the general rubric of operations research or systems analysis. Thus it was that in November 1969 one of the proponents of the Safeguard system, Albert Wohlstetter of the University of Chicago, wrote to the council of the Operations Research Society of America (ORSA), asking it to

> . . . appoint a panel to consider some aspects of professional conduct during the ABM debate this last spring and summer. . . . The conduct of the controversy on the ABM provides many outstanding examples of the violations of professional norms . . . Some basic issues in the public debate concerned matters of analysis. Other issues concerned matters of fact. . . . Many of these questions both of fact and analysis can be answered quite precisely by a competent panel of operations research men. I believe the profession owes this to the public and the Congress.

The ORSA council satisfied itself that Wohlstet-



"How's this for recycling? We get some heavily polluted air, put it in an aerosol can, and use it as an insecticide."

Sidney Harris

ter, a member in good standing, had raised an important issue. It agreed to conduct an examination and to accept, by and large, Wohlstetter's formulation of the issues. A committee of inquiry was set up and, in an effort to avoid the appearance of a kangaroo court, the president of ORSA invited George Rathjens of the Massachusetts Institute of Technology (MIT), a chief Safeguard opponent and Wohlstetter target, to designate a competent systems analyst to serve on it. In a joint reply, Rathjens and two other Safeguard opponents, Jerome Wiesner, then provost of MIT and formerly science adviser to Pres. John F. Kennedy, and Steven Weinberg, also of MIT, argued that the inquiry as formulated did not address itself to the principal issues and was, in fact, loaded against them. They also pointed out that, since they were not members of ORSA, that body had no right to evaluate their professional conduct.

Nevertheless, ORSA proceeded with the study and in September 1971 reported its findings. "No significant defects" were found in Wohlstetter's study of Safeguard, and much of it stood "as a model for the professional and constructive conduct of a debate over important technical issues," but those opposing Safeguard were frequently guilty of faulty methodology. Although some shortcomings were found in the testimony of the proponents, the report said, "they nowhere equalled the cumulative mass of inadequacies compiled by the opposition."

The report then addressed itself to the larger and more difficult question of the ambiguous role of scientific advocate:

> There was present, throughout the debate, a complete intermixture and confusion of the roles of the analyst and the advocate. To the extent that advocating analysts attempted to provide convincing arguments supporting the validity of the conclusions and recommendations they favored, the calm orderly presentation of the analysis on which these conclusions were based suffered.

Issuance of the report was followed by a controversy between the original antagonists that often became acrimonious. The fiery exchanges that appeared in the letters columns of major national newspapers and in the *Congressional Record* failed to settle the fundamental questions concerning the usefulness of the Safeguard system, but they did serve to underline in bold strokes that, in the absence of sufficient data, scientific confrontations can be as inconclusive as those in any other field of human endeavor—and as fierce.

In the arena of public debate

Despite the painful experiences of a number of scientists who had thrust themselves into controversy in public forums, and despite the determined efforts of many scientific societies to avoid politicization, the pressures on scientists to become involved in political issues continued to grow. Many of these pressures were exerted by younger scientists, who shared with some of their generation a growing conviction that the scientific establishment had become, through indifference, an instrument to consolidate the control of an already powerful elite group. But in April 1972, George B. Kistiakowsky, vice-president of the National Academy of Sciences and formerly science adviser to Pres. Dwight Eisenhower, appeared before a meeting of the American Chemical Society and argued for involvement.

Looking to a future of increased population pressures and depleted natural resources, of mounting demands for a cleaner environment, and of rising expectations in the less developed nations, he declared:

> We cannot deal with these problems and meet these obligations without either a large decrease in our standard of living or the development of new technologies for public use and benefit, based on scientific knowledge that is still to come. That is self-evident. The real challenge is to design attacks on specific problems as they arise and bring the resources of the scientific community to bear on them. To meet these challenges, I now urge far greater social and political involvement than heretofore. In the past the practitioners of science have tended to let others in the society decide how to apply their findings. The results, as I in company with many others have emphasized, have not been uniformly good. Together with those especially knowledgeable in the problems of society, we must now try to separate the good and bad potentialities and then lend our weight to the good side.

Meeting the challenge. There appeared to be many volunteers to take up the cudgels. The Federation of American Scientists, a Washington-based national organization openly dedicated to lobbying activities, primarily in the field of arms control and disarmament, established a new program called TACTIC (Technical Advisory Committees to Influence Congress). Its announced goal was to create, at the grass roots, a "nationwide network of scientists and engineers" who would press for favorable national policies—"first of all, by providing constituent pressure on their Congressmen, and secondly by alerting the public, thereby generating political pressure for a change." By February 1972 its organizers claimed that 850 participants had signed up in 300 out of the country's 435 congressional districts; their goal was to establish an active working group in each of them.

As the federation set out to pursue its original purposes more vigorously, a number of other scientific groups were following courses of action that had not been envisioned by their founders. Members of the American Physical Society attend-

Stuart Ackerman



Stanford professor William Shockley confronts a group of demonstrators dressed as Ku Klux Klansmen who disrupted his electrical engineering class. Shockley became a controversial figure in academic circles because of his theories on the relationship between race and intelligence. He requested permission to teach a course based on his thesis that blacks suffer an innate intelligence disability as compared to whites, but was refused after a faculty committee found him unqualified and not sufficiently objective.

ing its annual meeting in April 1972 found themselves voting on a constitutional amendment to "shun all those activities which are judged to contribute harmfully to the welfare of mankind" and listening to a symposium on the significance to the physical sciences of the conspiracy trial of the "Harrisburg 7" antiwar protestors. The American Chemical Society, considered by many to be the most conservative group of its kind, confronted a choice of presidential candidates that included not only the two routinely selected by a nominating committee but also an aggressively outspoken retired industrial chemist named Alan C. Nixon. Nominated by a discontented group within the membership, Nixon quickly distinguished himself by appointing a campaign manager, stumping for improved working conditions for chemists, and boldly advocating that employed members of ACS be assessed to fund a political arm to lobby in the tradition of the American Medical Association. Nixon further distinguished himself from the other candidates by winning, hands down. He was scheduled to take office Jan. 1, 1973.

Even more flux developed within the engineering societies, whose members were hard hit by cutbacks in specific areas of research, notably space and electronics. Although surveys conducted by the NSF produced far less alarming statistics among the group responding to a questionnaire, a reporter for the *Wall Street Journal* estimated in February 1972 that 35,000 engineers were jobless and as many as 65,000 more were not able to work full time in their profession. Whatever the actual numbers, the technical societies were taking extraordinary steps. Even before Alan Nixon took office, the ACS set up an independent, nonprofit corporation to establish a national pension system that would permit members to take benefits with them when they changed jobs. The American Society of Civil Engineers sought to persuade employers to accept minimum standards for working conditions as well as salary guidelines. With an obvious reference to a burst of organizing activity by major AFL-CIO unions, the executive director of the ASCE said, "We hope employers will voluntarily adopt these guidelines. We're not turning into a union, but we're taking a more realistic role—and maybe we can bring economic improvements through responsible leadership."

The argument over growth. Controversy within the scientific community was not limited to institutional problems. Continuing along lines that had been taking shape for several years, scientists began to choose sides on a number of broad policy issues in which science and technology played key roles. Two of the most provocative issue-raisers were an MIT engineer named Jay Forrester and a young colleague named Dennis L. Meadows.

Forrester set the stage for controversy by fitting a pet theory to the announced concern of a floating international body of industrialists, statesmen, and academics calling itself the Club of Rome. The club, organized by an Italian industrialist named Aurelio Peccei, had proclaimed its anxiety over what it termed the "predicament of mankind"—an inexorable slide toward global catastrophe through uncontrolled population growth and industrial pollution. Forrester's theory, which he had espoused in his book *World Dynamics*, was that a global model of the dynamic interactions between world population, industrialization, depletion of natural resources, agricultural productivity, and pollution could be created through the use of an intricate and complicated computer program.

Meadows and a group of young associates took it from there, cranking a variety of numbers and relationships into a computer and reading the depressing tapes that spewed out. To those who questioned the accuracy of the data that went into the machine, Meadows responded that it did not appear to make much difference whether population growth or agricultural productivity or pollution increased according to this projected curve or that one; sooner or later the interrelationship produced a catastrophic dive in the population curve. The only arrangement that forestalled such sudden population decreases within 60–100 years was a tightly managed equilibrium, in which not only population growth but also industrialization and agricultural productivity were flattened out or forced into a negative growth curve.

Meadows' wife, Donella, worked the results of the study into a short book of simple and dramatic statements, *The Limits to Growth.* A Washington firm specializing in attractive social policy issues joined the Club of Rome in promoting it. The result was the most sensational display of publicity ever granted to what purported to be a scientific statement. It was not the publicity, however, but the science in the statement that led to widespread challenges by other scientists. Economists were especially aroused; they charged that the methodology employed by Meadows and his associates was faulty, especially in that no allowances were made for policy adjustments by social and political institutions as the effects of the predicted developments began to be felt. Meadows retorted that his group was simply trying to develop a useful methodology, designed to lessen the possibility that the effects of disastrous policy (or nonpolicy) might be felt too late.

At issue. Only slightly less attention was devoted to the theories of the internationally renowned behavioral scientist B. F. Skinner. In his *Beyond Freedom and Dignity,* he argued that human beings are hardly the free spirits of which the poets sing. Instead, they are manipulated throughout their lives by a series of operant conditionings generated in their environment, over which they have little or no control. His fundamental proposal was that since we are all the objects of external manipulation, we should try to order society so that the manipulation is done by individuals equipped to ensure that the greatest benefits ensue.

Skinner was attacked with far greater ferocity than Meadows—primarily because he offended the humanists, who tend to be considerably more articulate than social scientists. As in so many instances in which controversies arise between groups who speak essentially different languages, the argument was rarely joined properly. Skinner was attacked because he dared to suggest that behavioral scientists were uniquely equipped to manipulate human conduct and produce an orderly and placid society. He replied that we are now



Stuart Ackerman

Officials inspect the damage caused by the explosion of two bombs in the klystron gallery of the Stanford Linear Accelerator Center on Dec. 7, 1971. The blasts damaged $45,000 worth of electronic equipment. Most of the damage was repaired within a week, and tests of the accelerator proceeded on schedule.

already being manipulated by individuals—knowingly or unknowingly—who cannot always be expected to have the best interests of society at heart. Why not consciously define and strengthen that capability and turn it over to those groups now thought to constitute our ethical and moral leadership—the clergy, the humanists and scholars, and the worldly philosophers?

The arguments raging around the Skinnerian view of life were not notably reduced when the retiring president of the American Psychological Association, in a valedictory address to the annual meeting, suggested that world political leaders be tested for dangerous tendencies in conflict situations and appropriately medicated by psychopharmacologists. (*See* Year in Review: BEHAVIORAL SCIENCES, *Psychology.*)

Two areas of scientific research were so ridden with controversy that some scientists found themselves in the unusual position of suggesting that, in certain fields, too much knowledge is a dangerous thing. One was the artificial development of human beings; the other was the nagging question of whether there are heritable differences in intelligence linked to racial characteristics.

The first dispute arose from the work of Patrick Steptoe and Robert G. Edwards in England. These two researchers had succeeded in carrying the human development process from fertilization of a human ovum through several stages of cell fission to a 32-celled embryo, all within the glass walls of a laboratory test tube. Despite the shock that reverberated through the press when this achievement was announced, Steptoe insisted that he intended to push forward with his research. As the next step, he was seeking willing mothers in whose womb a laboratory-raised embryo would be placed to complete the birth process.

Steptoe faced up to the outcry by pointing out the benefits that might derive from his research, particularly to women who might be able to bear their own children but whose internal environment was hostile to fertilization. But to the more forbidding question—what would be done if the experiment produced living monsters?—the scientific team could only respond by asserting that their proposal involved no more risk than the natural act. (*See* Feature Article: TEST-TUBE BABIES.)

A larger question was posed by Leon Kass, executive secretary of the National Academy of Sciences Committee on Life Sciences and Social Policy. Addressing not only the question of in vitro conception but also such related questions as cloning (producing an embryo from an individual somatic cell of a single parent) and the production of living chimeras (organisms carrying genetic material of two different species), Kass asked whether such avenues of research should be explored at all, given man's present state of wisdom:

> To have developed to the point of introduction such massive powers, with so little deliberation over the desirability of their use, can hardly be regarded as evidence of wisdom. And to deny that questions of desirability, of better and worse, can be the subject of rational deliberation, to deny that rationality might dictate that there are some things that we can do which we must never do—in short, to deny the need for wisdom—can only be regarded as the height of folly.

Contention over the relationship between heredity and intelligence raised even higher waves in academia. Indeed, when physicist William Shockley, Nobel prizewinner, proposed that research be undertaken to determine whether an alleged 15-point deficit in IQ among American blacks was due primarily to heredity or environment, the dispute approached violence. Shockley, whose scientific credentials rested chiefly on his contributions to the development of the transistor, was at the center of the storm. He returned again and again to the assertion that blacks, as an identifiable genetic group, suffered from an inherited deficiency in intelligence as measured by the available standard tests. Others, notably Arthur Jensen of Berkeley and Richard Herrnstein of Harvard, also wrote in this difficult area, but it was Shockley who appeared to move further along the path toward the promulgation of social policies based on his assertions.

On numerous occasions he petitioned the National Academy of Sciences, of which he was a member in good standing, to undertake or foster the required research. Each time, the NAS flatly declined his invitation or pointed out that a majority of its members thought the task to be impossible. Then he appealed to his fellow faculty members at Stanford for approval to teach a special graduate course on "the dysgenic question: new research methodology on human behavior, genetics, and racial differences." In May 1972 the graduate dean at Stanford notified Shockley that the course could not be given. Shockley bowed to the edict, but refused to bend in his beliefs. He retorted publicly, "The flat human equality illusion that thwarts objectivity is, in my opinion, far more threatening to the future of the U.S. than was the flat earth illusion to the future of Italy in Galileo's day."

Even those who quarreled with the methodology of Jay Forrester and Dennis Meadows could agree that there were indeed some limits to growth. The suggestion that there were also limits to knowledge was a far more disturbing thought with which to end the year.

—Howard J. Lewis

Transportation

A relatively poor year for many transport carriers tended to slow down research and development efforts by private industry but did not have that effect on the U.S. Department of Transportation, which accelerated its efforts in this area. The department continued to concentrate mostly on the passenger field, especially urban mass transport and the development of futuristic high-speed passenger vehicles.

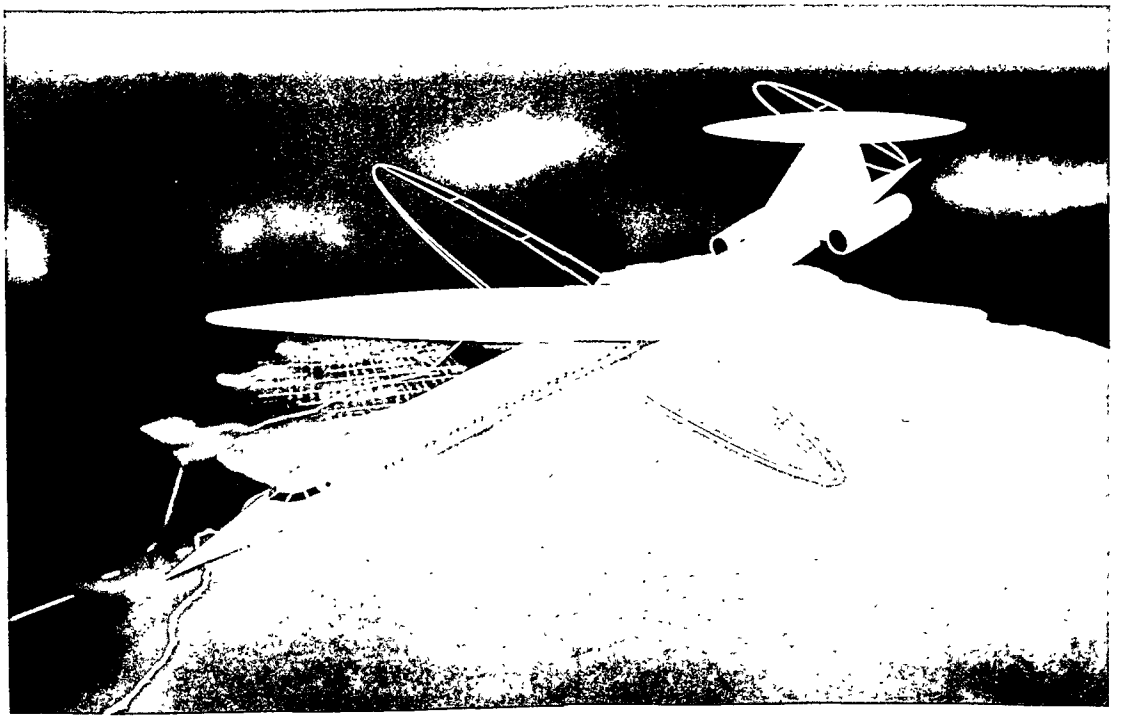
From a technological point of view, a major change in transportation was the strong emphasis being placed on the demands for greater safety and environmental protection. This affected virtually all modes of transport, and caused a growing proportion of research and development to be devoted to such things as antipollution and safety devices, and noise suppressors.

To illustrate the across-the-board nature of this challenge, airlines faced tougher engine noise and smoke standards, as did trucks. Automobiles had to meet new pollution and safety standards. Railroads were confronted with newly imposed federal track standards. Water carriers faced costly penalties for spillages. Even the largely unseen pipelines were facing growing opposition to construction for environmental and safety reasons.

Aviation. There were signs that the trend toward progressively larger jumbo jet transports might have reached its peak for the commercial market in the B-747, which experienced both mechanical and load factor problems. Also, the even larger C-5A, built for the U.S. Air Force, continued to have airframe problems, which helped accelerate the cost per aircraft from $28 million to about $56 million. No orders for the L-500 commercial version of the C-5A were reported. In mid-1972 Lufthansa German Airlines introduced the B-747F all-cargo version for service between New York and Frankfurt; Boeing Co., makers of the B-747, hoped that this would help them recapture some of the canceled orders for this version. Another sign that the B-747 might get a firmer hold in the cargo field was an order by World Airways, a U.S. supplemental air carrier, for three B-747Cs, a convertible version that could be switched quickly from passenger to cargo service.

The McDonnell-Douglas DC-10 wide-bodied, trijet began commercial service and, over-all, provided "generally trouble-free" service. Major breakthroughs for the 230-to-345 passenger jet

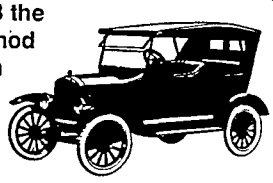
A radical new design for a supersonic transport incorporating an elliptical pivoting wing was proposed by Robert Jones of NASA's Ames Research Center. He claimed the plane would be relatively quiet, prevent pollution of the stratosphere, and produce no sonic boom under normal atmospheric conditions.



Courtesy, NASA



Henry Ford shaped modern industrial society by creating in 1913 the assembly-line method of mass production in his automobile factory.





included engines that were much quieter than previous ones and that emitted virtually no smoke. Having overcome their serious financial problems through U.S. and British government aid, Lockheed proceeded to build the L-1011 and Rolls-Royce the engines, for this wide-bodied, tri-jet. Flight tests of the plane appeared to substantiate claims by its manufacturers that it would be the "world's quietest jet airliner."

The long-delayed European (France-West Germany) A-300B, twin-engine Airbus finally got the boost needed by receiving its first firm order —from Air France for six aircraft. Deliveries of the 270-passenger, short-haul plane were scheduled to be made in 1974. Other members of the Atlas Consortium (Air France, Alitalia, Lufthansa, and Sabena), along with Iberia of Spain, an associate member, were considering ordering the A-300B after completing a nine-month evaluation of it.

There were no indications that the U.S. would resume its program to develop a commercial supersonic transport (SST). Meanwhile, costs of the Anglo-French Concorde SST continued to rise. The cost per aircraft was expected to be more than $31 million to holders of the initial 74 options to buy. Even at that price, the manufacturers did not expect to recover a major share of the nearly $2 billion committed to research and development on the aircraft. Concern was also expressed that rigorous noise and emission standards in the U.S. might sharply limit operations of the Concorde to and from U.S. airports.

Like the Concorde, the Soviet Union's Tu-144 SST continued to be test-flown. The U.S.S.R. predicted that it would enter regular air service in 1974, although the commercial version was to be designed to have a greater capacity than the three prototypes, from 150 to 180 passengers compared to the 120-passenger version being tested.

Supporters of vertical and short takeoff and landing aircraft (V/STOL) received two setbacks during the year. The U.S. Department of Transportation's Northeast Corridor study of passenger transportation needs through the 1980s concluded that V/STOL aircraft for high-volume, short-haul travel "are not considered practical for application during the 1970s," and that much more research on them would be required for their use in the 1980s. Major roadblocks, according to the study, were community opposition to the noise, air pollution, and the safety hazards that these craft might generate. Also, American Airlines, which conducted extensive operational tests of commercial-type STOL aircraft and which evaluated proposals for propeller-driven STOL aircraft from three U.S. and Canadian firms, terminated its program. The airline concluded that a propeller-driven, lift-

augmented STOL aircraft "probably won't work" for a trunk airline and would be "risky financially."

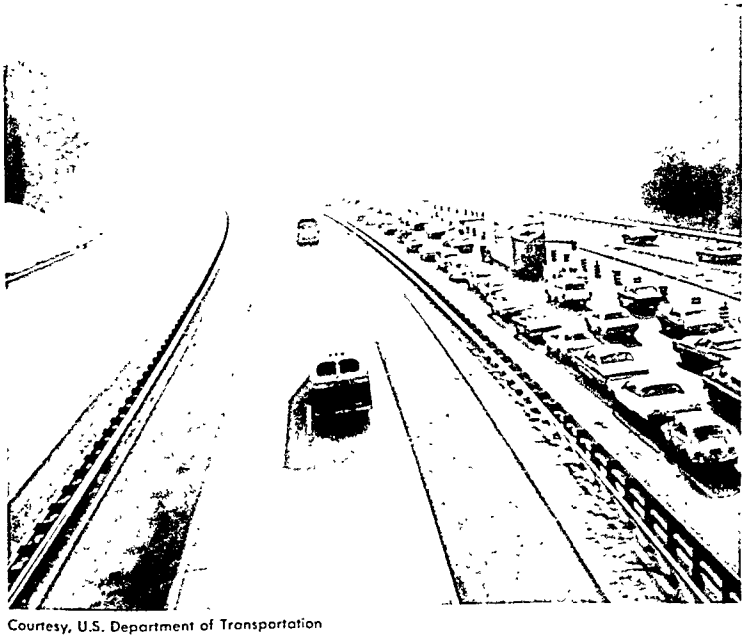
On the plus side for V/STOL aircraft was an agreement by three major West German firms to join in a 12-year development plan, with government backing, to have a competitive prototype vehicle ready by early 1982. Also, a joint Japanese government-industry group was planning to develop a 200-passenger STOL airbus, and the U.S. National Aeronautics and Space Administration announced plans to build two test STOL transports.

Highway transport. As the May 12, 1972, deadline for a decision by the U.S. Environmental Protection Agency on imposing rigid statutory emission standards for 1975 autos came closer, the number of opposing views and claims increased. All major automakers stated that they could not meet the deadline and needed another year for further research and tests. Two major studies, by special White House and Academy of Sciences panels, both concluded the extra year was needed. The White House panel criticized both proposed pollution and safety standards for 1975 autos, contending that the public benefits would not justify the higher additional costs, estimated at $873 for 1976 *v.* 1971 models—$350 for emission and $523 for safety devices. The other panel said that compliance with pollution standards, while possible, would be accompanied by the following: a need for more costly low-lead gas, more expensive maintenance, periodic reinstallations of antipollution devices, less engine power, and higher initial costs of about $200 per car.

General Motors began pilot production of 60 gas turbine engines for industrial and large truck and bus use, with installations made on many vehicles for over-the-road tests. Plans called for mass production of the 325-hp engines starting late in 1972, building up to a rate of 50 per month. General Motors estimated that the engines would cost about 20% more than a comparable diesel engine and consume more fuel (getting only 5 *v.* 7 mi/gal), but would otherwise be less costly to maintain and operate.

General Motors also reported "good progress" in its development work on the Wankel rotary engine, but said that reports that it might soon go into mass production were premature. While the Wankel is said to be quieter, smoother, and simpler than the piston engine, and weigh only about one-third as much, it uses as much as 25% more fuel and has an imperfect sealing system. While not much better than the piston engine in preventing air pollution, the Wankel is smaller and thus allows more room for the installation of antipollution devices.

Three of four experimental safety cars were turned over to the U.S. Department of Transportation for further evaluation and for 12 of the best model to be produced at a later date. They were designed to meet demanding goals, including survival in a 50-mph crash, but all proved to be much heavier than present cars; and the cost, if sold on the market, would probably be twice that of a current-model family car, according to a General Motors official.



Courtesy, U.S. Department of Transportation

Commuters to Washington, D.C., travel unimpeded by rush-hour traffic jams on special highway lanes reserved for buses only. This test and another in New York demonstrated time savings of up to 30 minutes per one-way trip. The U.S. Department of Transportation granted $36 million for a similar project in Los Angeles.

Regina, Sask. (population 137,759), called its six-month experimental "Dial-a-Bus" service a "remarkable success," and it announced plans to expand it from serving 18,000 residents to 60,000 by the end of 1972 and to the entire city by the end of 1974. In this system collection buses pick up callers within 15 minutes for trips to waiting rooms for regular bus service. Several smaller-scale tests were being financed by the U.S. Department of Transportation, including one in Camden County, N.J.

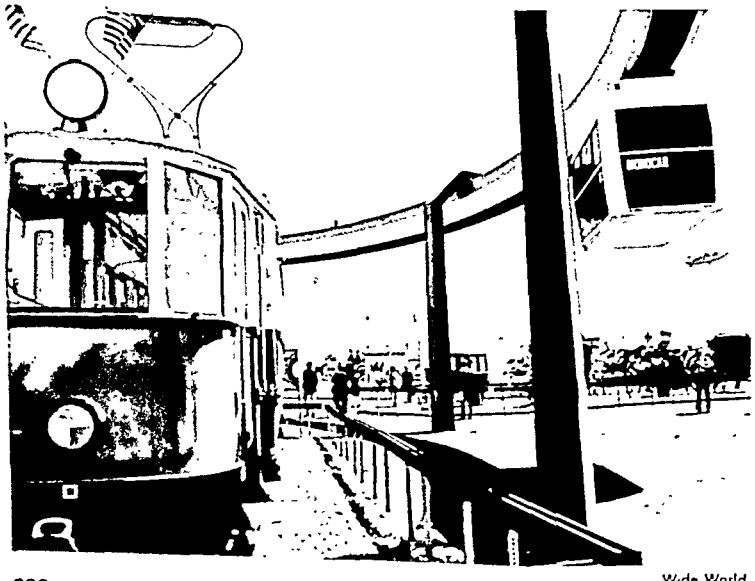
The U.S. Department of Transportation continued to promote the use of exclusive bus lanes and highways. It approved a $36 million grant toward a $52 million project to build an 11-mi busway in the Los Angeles area for use by buses only during rush hours over a two-year test period. Similar projects involving approaches to New York City and Washington, D.C., proved attractive to commuters, with 35,000 using the former and 20,000 the latter daily—at savings of up to 30 minutes per one-way trip. The Department of Transportation granted an additional $2.2 million for the Washington project for 30 more buses and fringe parking lots.

Pipelines. Another major U.S. oil pipeline was completed and being filled for commercial service in 1972. The 1,300-mi Explorer Pipeline moved refined petroleum from the Gulf of Mexico to Chicago via Dallas, Tex., Tulsa, Okla., and St. Louis, Mo.

Despite an unprecedented amount of research and planning to satisfy objections of environmentalists, the Alyeska Pipeline Service Co. was in 1972 still awaiting approval from the U.S. Department of the Interior to proceed with construction of the 789-mi, 48-in. crude-oil pipeline from the Alaskan North Slope south to Valdez, an ice-free port on the Gulf of Alaska. One major roadblock was removed when Congress passed legislation settling century-old land claims of natives of Alaska, thereby providing for rights-of-way for the pipeline. In addition, a comprehensive, nine-volume environmental impact report required by law was submitted, and it did not appear to contain any information that would call for rejection of the project. Even if approved by the secretary of interior, however, the project may well be delayed further because of court action by environmental groups. In the meantime, the estimated cost continues to rise, from an original $1.4 billion to more than $2.5 billion.

A new concept in the movement of solid materials through pipelines was announced during the year by Trans-Southern Pipeline Corp. The system, called TUBEXPRESS, was designed to move either packaged or bulk material through a large pipeline in wheeled capsules that are propelled by a moving column of air at essentially atmospheric pressure. Flow-through pumps move the air, and by-passes separate the vehicles from the air column at loading and unloading sites. Since the system does not require a vacuum, airtight seals are not needed.

The capsules are equipped with flat endplates at the front and rear that have a flexible surface nearly the diameter of the pipeline, thus permitting movement at nearly the velocity of the propelling column of air. The vehicles themselves roll on load-bearing wheels and have side-guide wheels to



Wide World

Prototype of a monocab, one of several possibilities for a future urban transportation system exhibited at Transpo 72, passes above an old trolley car, one of the older forms of transportation that were also on display.

stabilize their movement through the pipeline. Two-way traffic can be achieved by using a closed-loop system. Loading, unloading, removing, and inserting the vehicles in the air column can be automated to the extent warranted.

Initial plans called for the use of such a pipeline for the movement of mail and baggage over short hauls, and the U.S. Postal Service is now evaluating the system. Backers claim, however, that the concept has "virtually unlimited" potential as a new mode of transport. A prototype was built near Stockbridge, Ga., and was extensively tested.

Railways. To help speed up rail freight service throughout the U.S., railroads introduced more "run-through" trains that by-passed intermediate yards between two distantly separated points. Such service usually required cooperation by at least two roads, especially when the same locomotives were used. These trains carried a variety of commodities, as compared to unit-trains, which carry only one commodity.

The number of products moving in long-distance, shuttle-type, unit-train services continued to grow. One sizeable potential market was the movement of entire trainloads of modular homes, and initial runs were successfully made under a program in which the railroads and builders were cooperating with the U.S. Department of Housing and Urban Development and the General Services Administration. A study of expanded unit-train operations by the steel industry in the Great Lakes area claimed that savings of more than $585 million in capital outlays and $83 million a year in operating costs would be possible if such trains replaced the present rail-ore ship system.

General Motors Corp., which shipped about three million motor vehicles by train in 1971, reported that 10% of them were stolen, vandalized, or damaged. The company foresaw the use of specialized unit-trains as the solution to this problem and continued to work closely with the railroads toward that end. General Motors reported that its Vert-a-pak cars, which load 30 Chevrolet Vegas per enclosed car in a nose-down position, proved successful, with 183 now in use and 134 to be added in 1972. It also said early in 1972 that shipping Cadillacs by railroad in stacked containers had virtually eliminated damage claims, and that it was building 200 more containers and 50 railcars to handle more cars.

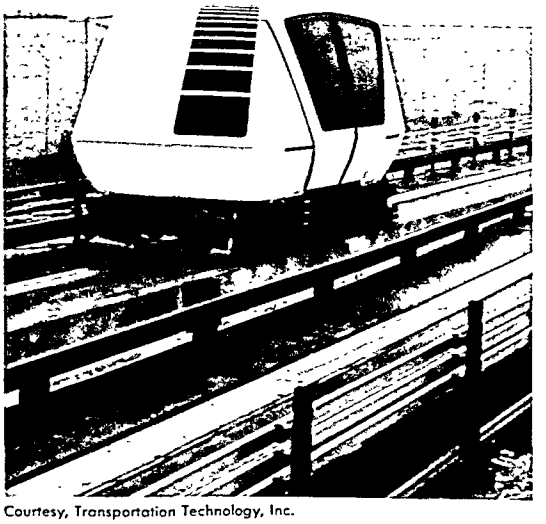
The piggyback unit-train, carrying mostly truck trailers but also containers, continued to grow, and by 1972 approximately 115 such trains moved between U.S. cities, mostly in the midwest and northeast. These nonstop trains covered from 400 to 500 mi in 10 to 12 hours, thus averaging about 10 times the mileage of regular-service freight cars.

Because of financial problems the railroads were not able to put into effect their program to computerize the control and utilization of freight cars. The labeling of freight cars was virtually completed, but the number of installed roadside scanners that "read" the labels as the trains moved by them remained small. Although a number of the 62 railroads that planned to use the computerized network had installed their own freight car control systems, the nationwide system was a long way off. Immediate plans called for installing scanners in the high-density Chicago terminal area, with the many railroads serving it sharing the costs. If successful, this may become the model for other rail terminal districts.

The potential of fully automated railroad operations was pointed out by an announced agreement to build such a train in Arizona to haul coal between mines and an electric generating plant. The electric-powered train was being designed to operate without any on-board crew and represented, according to an electrical industry spokesman, "a prototype of a modern electrification concept for high-volume railroads on the North American continent."

While hard-pressed to hold operating losses to a minimum, the U.S. Amtrak passenger-train service did report continued success for its high-speed, electric Metroliner Service between Wash-

A film of air supports this six-passenger Personal Rapid Transit (PRT) car as it traverses a test guideway in Denver. The vehicles, powered by linear induction motors that utilize the metal strips in the guideway, were demonstrated at Transpo 72.



Courtesy, Transportation Technology, Inc.

ington, D.C., and New York City. Amtrak reported that annual passenger volume along this route increased from 605,000 in 1969 to 1,635,000 in 1971.

About 40 countries, including the U.S., expressed interest in Britain's entry in the high-speed passenger-train field, the so-called Advanced Passenger Train (APT). The British government expects to put the APT in experimental commercial service in 1975, and, after removing all flaws, into the international market a year or two later. The lightweight trains were designed to operate at speeds up to 155 mph on existing rail routes with minor alteration to the track and signaling. High average speeds could be maintained around curves because of a "unique steering mechanism." Backers claimed that the basic high-speed capability of the APT was due to a new design that sharply reduced the characteristic side-to-side movement of railroad cars when operating at high speeds on tracks.

Urban mass transit. The rapidly increasing number of research grants from the U.S. Department of Transportation in the urban mass transit field were beginning to produce useful results. One example was the inauguration into rail transit service in Cleveland, O., of a new car that featured Westinghouse Air Brake Co.'s pulsewidth modulation propulsion. Made possible by a $1.3 million grant from the Department of Transportation, the unique propulsion system assured far faster, yet smoother, starts and stops for improved passenger comfort and safety. It also offered savings in power by returning energy to the electric power lines while braking and by the use of low-cost, more reliable alternating-current motors instead of the usual complex direct-current motors.

Another federal government grant of $7.4 million, to be matched by New York State and private industry funds, was made to develop and test in service eight combination gas-turbine/electric-powered rail commuter cars, which the Department of Transportation foresaw as the "trains of the future for suburban rail commuters." The dual-powered cars were designed to provide greater flexibility by being usable on both electrified and standard track, thus providing commuters with a one-seat, no-change ride between the city and suburbs.

Another milestone in rail rapid transit was passed when an eight-car train built by St. Louis Car for New York City passed a required test of operating 20 hours a day for 30 consecutive days without a breakdown. This cleared the way for delivery of the remaining cars in a 352-car order. They were designed to operate at speeds of 70 mph compared to 50 mph with existing equipment.

Boeing Co. and Bendix Corp. were selected to help build the "Personal Rapid Transit" system in Morgantown, W.Va. It was to consist of fully automated transit cars that would link West Virginia

New Chevrolet Vegas are shipped from the GM Assembly Division plant at Lordstown, O., by a unique method known as Vert-a-pac. Each Vert-a-pac railway car carries 30 Vegas nose down and is completely enclosed to protect the vehicles against damage during transit.



Courtesy, Chevrolet Motor Division, General Motors Corporation

University's two campuses, carrying passengers at speeds up to 30 mph. The rubber-tired, electric-propelled cars were to operate on a guideway, mostly elevated. Boeing was to design and construct prototypes of the cars, and Bendix would design and develop the automated control and communication system. The first section of the system was scheduled to start experimental operations by the end of 1972, with completion in 1974.

Water transport. While the trend toward construction of super oil tankers continued, even greater interest was being expressed in the need for specialized ships to haul liquefied natural gas (LNG), because of the rapidly declining supply of natural gas in industrialized nations including the U.S. A special Presidential Commission on American Shipbuilding estimated that up to 100 LNG tankers would be needed in the near future for U.S. requirements alone. While 14 such ships, mostly of smaller size, were in service, the new ones were to be huge, with one such ship being able to haul enough gas on a single trip to supply 11,900 homes for a year.

While LNG tankers may help assure an adequate supply of natural gas, they are considered to be the most complicated merchant ship to build and, except for luxury passenger ships, the most expensive. Their cargo tanks must be able to maintain liquefied natural gas at −260° F during long voyages and be strong enough to prevent breakages that would cause the liquid to heat and turn into gas, as its volume would thus expand by more than 600 times. A major supplier, El Paso Natural Gas Co., formally requested a federal government subsidy to help build six LNG tankers, at $72 million each, to haul gas from Algeria to the U.S. In 1972 it was building three similar ships in France.

The first European-built LASH ship started commercial service in February 1972. These specialized ships carry lighters and containers that are loaded and unloaded by on-board cranes. More than 20 were in service or being built. The three even larger SEABEE ships being built for Lykes Bros. Steamship Co. were expected to be in service by late 1972 or early 1973. They were designed to haul large barges that could be floated on and off a stern elevator for lifting and placing on any of three decks. They would have the most power (36,000 shaft horsepower) of any single-screw merchant ship and be the largest general cargo ship afloat.

Litton Industries, Inc., announced plans to build what it called "the largest push-type tug-barge cargo transporter in the world"; it would be 1,000 ft in length when being pushed by its 15,000-hp tug. This unique, self-loading/unloading vessel would be able to carry about 52,000 tons of a variety of dry bulk cargoes, including iron ore, limestone, and coal. Using a novel, on-board rotary elevator —which would be 67½ ft in diameter and look much like a water wheel—that would be linked to special conveyors, the barge could unload at a rate of 10,000 tons per hour. To be operated in the Great Lakes, the tug-barge was expected to be completed and undergoing sea trials and systems tests by the end of 1972.

Air-cushion and linear-induction motor vehicles. The U.S. Department of Transportation continued to put a strong research emphasis on the tracked air-cushion vehicle (TACV) as the most probable mode of high-speed surface passenger transport in the future. The department's comprehensive Northeast Corridor Transportation Project concluded that TACV is a "prime alternative" for passenger transport needs in the 1980s, because "it offers the potential for very good reliability, comfort and safety; high capacity; and decreasing passenger-mile costs at high volume."

Three major U.S. aircraft manufacturers were engaged in separate projects for the government. Rohr Corp. and Vought Aeronautics Co., under contracts totaling $2,850,000, were producing designs and mock-ups of a 60-passenger TACV to be powered by an electric linear-induction motor at speeds up to 150 mph. They were to be delivered in 1972, with one selected for possible construction and testing as a prototype for high-speed travel from urban centers to outlying airports and to other cities at distances up to 50 miles. Grumman Aerospace Corp. received the third contract, for $3.5 million, to build a TACV capable of speeds up to 300 mph for longer-distance travel. It was to be tested extensively in 1972.

Other countries were also continuing the development of such vehicles. Bertin & Co., with backing from the French government, had two types of air-cushion "Aero-trains" in operation. A larger version carried 80 passengers at normal speeds of 155 to 160 mph on an 11.2-mi elevated guideway north of Orléans, France. Its lift propulsion and braking (using reverse pitch) were provided by gas turbines. The smaller version carried 40 passengers at speeds of 112 mph. It was being tested on a shorter track at Gometz-la-Ville, France.

Outlook for 1973. After two years of traffic and financial setbacks, the airlines were expected to experience a resurgence that would result in the renewal of orders for new jumbo jets such as the B-747, DC-10, and L-1011. Efforts will continue to develop a suitable air transport for high-volume, short-haul trips.

Turbine engine output for large trucks and buses was expected to change from experimental to production-line models, giving a boost to twin-

Courtesy, Los Alamos Scientific Laboratory



An electrically powered rock-melting drill undergoes preliminary tests at the Los Alamos Scientific Laboratory. Scientists predicted that eventually the drills, called subterrenes, would be used for large-scale projects such as highway and railroad tunnels.

trailer and intercity bus operations over long, minimum-stop routes. The use of exclusive and/or separate bus lanes for rush-hour commuter traffic will be expanded sharply.

Railroads, with help from the government, will begin to develop their now individualized freight car control systems into a national network. Roadside scanners at key interchange terminals will record car locations for computerized control.

A sharp spurt in orders for supertankers to haul both petroleum and liquid natural gas was expected, along with the development of more offshore terminals to enable the tankers to operate to points that do not have ports that can handle them. The huge SEABEE barge-carrying vessels will start commercial service, and additional variations of deepwater tug-barge vessels will be ordered for construction.

—Frank A. Smith

Veterinary medicine

Several diseases of livestock and poultry reached epizootic proportions in the U.S. and focused renewed attention upon various eradication efforts. The two most serious outbreaks were those of Venezuelan equine encephalomyelitis (VEE) and of exotic Newcastle disease in poultry and pet birds. That both of these diseases were imported reflected the growing potential for inadvertent introduction of organisms and the need for increased surveillance at ports of entry.

Venezuelan equine encephalomyelitis. The first outbreak of VEE in the U.S. began near Brownsville, Tex., in late June 1971 and by the end of July had affected more than 2,000 horses, about half of which died. A national emergency was declared, and immediate steps were taken to control the disease by quarantine, vaccination, and aerial spraying to eradicate the mosquito vector. By the time the last case was confirmed in November, about 3,400 horses had been affected and some 1,400 had died. The virus, which also causes a relatively mild disease in humans, was isolated in 88 persons in Texas; there were no deaths. More than eight million acres in Gulf Coast areas were sprayed with insecticide, and 2.8 million horses in 19 states and the District of Columbia were vaccinated, including 80% of those in high-risk areas.

VEE had been present in South and Central America since 1935, and when a major outbreak erupted in Guatemala in 1969, the U.S. Department of Agriculture (USDA) began a cooperative vaccination program. This was extended to Mexico during 1970–71, when up to 25,000 horses died and perhaps 12,000 persons were affected. The rapid containment of the U.S. outbreak was attributable in large measure to the early release of vaccine that had been stockpiled as a potential biological warfare countermeasure. Though VEE resembles the disease caused by the eastern (EEE) and western (WEE) strains of the encephalomyelitis ("sleeping sickness") virus, both long present in the U.S., the vaccines against these two strains conferred no protection against VEE. Some concern was expressed regarding the safety of the relatively untested VEE vaccine. The results of a USDA study released in March 1972, however, made it clear that the vaccine was safe, and government veterinarians urged that all horses not vaccinated in 1971 be protected. Meanwhile, a commercial vaccine had been produced in ample quantities.

Poultry diseases. Newcastle disease of poultry and pet birds had been present in the U.S. and most of the more developed nations for several decades but had been kept under control by vaccination and sanitation. In 1970 an exotic strain

of the virus, apparently from the Orient, was found in ornamental birds imported to the U.S., and later in commercial poultry flocks in Texas and New Mexico. Hardest hit was southern California, where, since December 1971, the disease had affected flocks containing some 1.5 million birds. By March 1972 more than 350,000 chickens had died in San Bernardino County alone, and it was estimated that some two million birds would have to be destroyed before vaccination would bring the disease under effective control. In March a state of disaster was declared in this area.

Earlier, a "henocide" program had been urged to bolster egg prices, which were too low to make egg farming profitable, but the disease and the eradication measures being employed against it were expected to make such a program unnecessary. Import regulations affecting some 280,000 pet birds brought into the U.S. annually were extended to require blood tests overseas and again on entry.

Marek's disease, a form of leukosis (leukemia) in chickens and turkeys, had threatened to disrupt if not destroy the poultry industry in the U.S. and Europe until an effective vaccine had become available in 1971. Although the vaccine would not eradicate the disease, tests on two million broilers indicated that each dollar spent on vaccine (no more than two cents per bird) returned $2–$5 in profits, even when losses among unvaccinated birds were only 5%. If all laying hens in the U.S. were vaccinated, 8.1 million fewer chickens could produce the same number of eggs, saving 500,000 tons of feed annually and releasing 100,000 ac of corn land for other uses.

Toxoplasmosis in cats. During the year several women's magazines carried well-intended but ill-advised articles indicating that cats presented a major hazard to pregnant women because they transmitted toxoplasmosis. This disease is caused by a protozoan parasite and produces symptoms like those of infectious mononucleosis. If a woman becomes infected during pregnancy, the infant may be born with serious birth defects. But the hazard should be viewed in perspective. About 25% of the U.S. population has toxoplasmosis antibodies and, hence, presumed immunity to further infection. In addition, while toxoplasma eggs can be found in cat feces and can transmit the disease to other animals, there was no instance of infection in man traceable to either source. The American Veterinary Medical Association and the U.S. Public Health Service, without incriminating the cat as a major causal factor in toxoplasmosis, recommended that pregnant women not increase the risk of the disease by acquiring a new cat, nor allow household cats to catch birds or other animals that might transmit the infection. They should also avoid handling cat litter or digging in gardens frequented by cats.

Drug problems. In a continuing study of the safety and effectiveness of veterinary medications, the U.S. Food and Drug Administration (as it had with numerous drugs for human use) withdrew its approval of many compounds marketed years before claims for efficacy were closely scrutinized. The FDA, in cooperation with the USDA, was also enforcing more stringent regulations concerning the tolerable residues in meat of the chemical hormonal analogue diethylstilbestrol, fed or implanted in cattle to promote fattening. In late 1971 a random survey of 2,500 liver samples from slaughtered beef cattle turned up 10 with more than the allowable residues, the tolerance being zero, though the test was not sensitive to less than two parts per billion.

Stilbestrol had produced cancers in laboratory mice at six parts per billion, thus warranting rigorous supervision of its use in meat animals. Although no instance was reported of residues in meat causing cancer in man, the period of withdrawal from the drug prior to slaughter was extended from 48 hours to 7 days.

Veterinarians were reporting a few cases of "pot syndrome" in dogs and cats. Both animals appeared to be highly susceptible to marijuana, either by ingestion or by inhaling its smoke.

Animal disease eradication. The 10-year hog cholera eradication program begun in 1962 had made rapid strides since the use of vaccine was outlawed in 1969. Forty-one states had been declared cholera-free by late April 1972. In February 1972 the U.S. Department of Agriculture committed itself to a drive to eradicate brucellosis from livestock by the end of 1975, five years ahead of the original schedule. The disease causes abortion in cattle and affects other domestic animals; it can be transmitted to man, causing undulant fever. Twenty-four states were certified as brucellosis-free, but the three making the least progress (Texas, Nebraska, and Mississippi) had about 20% of all U.S. cattle.

Complacency and curtailment of test-and-slaughter programs had permitted swine and poultry to become important reservoirs of the tuberculosis bacterium. In 1970 lesions were found in 1.09% of all swine slaughtered in federally inspected plants, and the avian form was believed to be nearly as prevalent in small farm flocks. Both forms were potentially hazardous to man, but producers did not consider TB an economic problem and eradication would require cooperation with human health agencies.

—J. F. Smithcors

Zoology

Zoology as a discipline predates Aristotle and has attracted many of the world's greatest minds. In the 1970s the zoologist continued to work along traditional but exciting lines, discovering, describing, and classifying organisms and structures and thereby broadening the base for future research. This kind of work might have seemed unnecessary alongside such contemporary problems as drug abuse, pollution, population growth, and health care until one noticed how much the information gained from organisms could be applied appropriately for the benefit of man.

General zoology. The favorable economics of dwarfism, long exploited by plant geneticists in high-yield wheat and rice, was being applied in zoology. Selective breeding of fowl, utilizing a sex-linked dwarfing gene, produced a laying hen of the Leghorn type and a hen that produces broiler chickens; each was only two-thirds normal size. Three of these hens could fit in a standard cage for two, and each could be expected to produce 200 standard-size eggs, compared with 240 for normal birds, for an investment of the same 160 lb of feed per cage. This was a production gain of more than 20% at no increase in feed cost. Broiler chickens offered the same kind of feed economy. Researchers at Hy-Line Poultry Farms, Des Moines, Ia., were examining the possibility of exploiting a similar dwarfing gene in beef cattle, while, at the California Institute of Technology, an injection of minimine—a toxic polypeptide isolated from the bee venom—into fruit fly larvae was found to result in one-quarter-size adults that were normal in every way except that their individual cells were miniature. The new breed of fly lived a normal lifespan and produced regular-size offspring.

The alfalfa leaf-cutting bee, a wild bee, was a highly effective pollinator in Idaho, where after introduction it would often double alfalfa seed yield. But efforts to introduce the bee in California were less than successful mainly because the bee had difficulty in reproducing there. Robbin Thorp of the University of California at Davis said that in California the bee appeared to be the victim of a toxin, a steroid material called saponin, that occurs naturally in California alfalfa varieties. Thorp theorized that the bees, in preparing nests, bite out small circles of alfalfa leaf. Nectar deposited in the circular nest dissolves the saponin, and when the larvae feed on the poisoned food they die. To introduce the bee successfully in California would probably require the selection of nontoxic varieties of alfalfa.

Eldon Reeves and S. V. Amonkar of the University of California at Riverside found two species of algae in California that specifically kill mosquito larvae. The algae, *Cladophora glomerata* and *Chara elegans*, release toxic substances that attack the lining of the larva's alimentary canal and that are especially effective against *Aedes aegypti*, a disease carrier, as well as four other species of mosquito. The insects and fish that live in mosquito habitats remained healthy in the presence of these active compounds at levels that suppressed mosquito development.

Like mayflies, stone flies (order Plecoptera) pass through an aquatic nymphal stage commonly found in streams and rivers. Twenty new Australian species were added to the family list by I. D. McLellan, who, in a revision published in the *Australian Journal of Zoology*, described the new types, which include the new genus and species *Neboissoperla alpina* discovered in a small stream on Mt. Wellington, Victoria.

Because so many aphids were serious pests and because their life cycle was notoriously complicated, it was important to be able to identify the different stages of a particular species. This was often easier said than done. In the case of the woolly aphids, the Adelgidae, specific identification was very difficult or even impossible and in Europe only a dozen or so species of these serious pests of conifer trees had been recorded. Considerable help toward the identification of the winged forms (alatae) of adelgids was given in a new booklet by D. I. Carter of the British Forestry Commission. Three of the species described, *Adelges viridana*, *Pineus pineoides*, and *P. orientalis*, were recorded for the first time in Britain.

Ocelli are simple eyes found in adult insects. They are incapable of perceiving form but are receptive to changes in light intensity. Adult sphinx moths, *Manducta sexta*, lack external ocelli. Microscopic studies revealed tissue inside *M. sexta* that show structural similarities to ocelli of other insects. New electrophysiological studies of this tissue revealed a response to light stimuli similar to that recorded for external ocelli. These studies also showed that illumination of the ocellus inhibits the continuous discharge that occurs in the ocellar nerve during darkness. Further, behavioral studies showed that the ocelli are important in the regulation of the daily rhythm of insects.

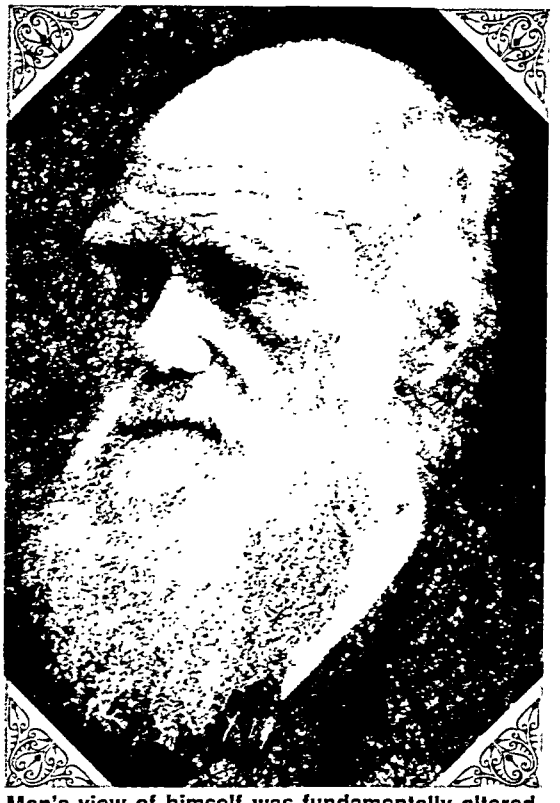
It was learned that insects are strongly attracted to a submillimeter radiation source. A theoretical study on the moth antennae, together with the frequency dependence of their response to electromagnetic radiation, strongly suggested that the antennae may be the receptor through which insects are stimulated to respond. The response is very pronounced and has strong potential for traps to control the population of pest insects.

In the central nervous system, the spinal cord and the lower brain were generally viewed as being little more than the passive recipient and the integrator of multiple sensory inputs more or less on a reflex basis. Recent investigations made the reflex hypothesis untenable. Nerve networks located in the central nervous system of both vertebrate and invertebrate animals appeared capable of numerous and varied functions that were essentially independent of sensory controls. Recent work showed that central-nervous-system networks, independent of the senses, could function in a wide variety of ways and give rise to kinds of behavior difficult to explain on the hypothesis that the nervous system is largely a reflex mechanism.

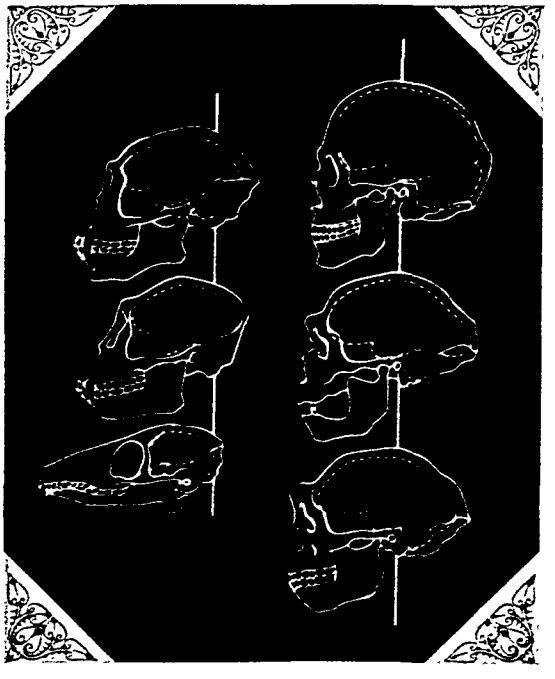
Iridescence caused by regular multilayer structures stacked in a medium of different refractive index was observed in a variety of animal tissues. Corneal iridescence had not received much attention in the scientific literature. It was found that fishes with iridescent corneas often, but not always, possess filters for yellow light at some point in the optical pathway. It was too early to speculate on the role of the yellow optical filters and the iridescent cornea on selective spectral absorption of light from different directions, but all fishes so far known to possess this iridescence lived and fed near the bottom of the sea.

The distribution of marine life in the sea was still difficult to determine with present methods of study. A technique that offered particular promise for defining the locales in which sea creatures dwell was deep-ocean photography. On a recent voyage of the USNS "Lynch," researchers obtained 340 exposures of the Caribbean Sea floor at 17 stations. Among the pictures obtained was the deepest photographic observation yet of a cephalopod (a class of mollusks that includes octopus and squid). The specimen, about 45 cm long, was identified as belonging to the Cirroteuthidae family, that of the octopus. It was about one meter off the sea floor, at a depth of 5,145 m.

The Pogonophora—marine, tubicolous, wormlike animals that live buried in soft sediments often in the abyssal regions of the oceans—were overlooked by biologists until 1955 when the phylum was established by the Soviet scientist A. V. Ivanov. One marine zoologist who made the group her special study was Eve C. Southward of the Marine Biological Laboratory, Plymouth, Eng. In a new report she added three more species —*Diplobrachia floridiensis*, *Suboglinoides caribbeanus*, and *Siboglinum bayeri*—to a growing list of species recovered by teams from sampling stations along the continental margin of North America. A total of 24 species from depths ranging



Man's view of himself was fundamentally altered by Charles Darwin. His *Origin of Species* established the theory of evolution by natural selection.



from 40 m to more than 5,000 m had been recovered as of mid-1972 by these teams.

Discussions of the evolution of vertebrate hearing systems tended, for lack of physiological data, to concentrate on changes in middle ear structure. Conspicuous differences are seen among reptiles, birds, and mammals in the shape of the basilar membrane of the inner ear. Use of a new method of frequency analysis indicated that "advanced" reptilian membranes analyze frequencies in a way similar to those of birds and mammals.

The distinctive markings and colors of birds are more than just decoration. They serve as camouflage, mimicry, social signals, and temperature regulators. Certain markings, according to Robert W. Ficken and Paul E. Matthiae of the University of Wisconsin at Milwaukee and Robert Horwich of the Chicago Zoological Society, may have yet another, very specialized, function. Eye lines, marks leading from the eye toward the tip of the bill of some predatory species, may serve as aiming sights in tracking and capturing swiftly moving prey. The researchers found a high correlation between the presence of eye lines in North American songbirds and their tendency to feed on swiftly moving prey.

The basis for the remarkable navigational ability of homing pigeons remained unknown. C. Walcott and M. C. Michener published the results of a major series of experiments designed to change the direction in which pigeons believe their home lofts to be by shifting their internal clocks from five minutes to six hours before releasing them. But no clock-shifted pigeon ever flew to or investigated a false home area. Slowing down the birds' internal clocks also had no effect on their ability to navigate to their home lofts.

Pigeons, like other animals, certainly use the sun as an azimuthal compass reference, but Walcott and Michener found no evidence that they can use it for true navigation. The "map" of the homing bird was, therefore, as great a mystery as ever, even more so in the light of recent evidence that pigeons do not depend on a view of any celestial body and can operate effectively even after many days' imprisonment away from the home loft.

For those who contended that inborn mechanisms other than genes control the timing of biological clocks, a blow was struck by two California Institute of Technology biologists. Hypothesizing that mutation of certain genes might lead to abnormal rhythms, Ronald Konopka and Seymour Benzer exposed *Drosophila* flies to a drug known to cause mutations. It did indeed upset the daily rhythmic cycles of emergence of the adult fly from the pupa and of locomotor activity. The changes in rhythms also carried over into subsequent fly generations. The work was not final proof that the key to the biological clock is internal, but it showed, said Konopka, that "genes play a key role in determining or in specifying rhythms."

Developmental zoology. Compared with the successful storage of spermatozoa and other tissue cells at sub-zero temperatures, attempts to preserve frozen mammalian eggs were disappointing. A new technique for obtaining a high proportion of viable embryos after subjecting them to sub-zero temperatures was described. These re-

Tiny insectlike tardigrade, seen here magnified more than 100 times, exhibits cryptobiosis (below), a dormant, deathlike state of almost complete dehydration. When the animal is moistened, it revives (right). By alternating these states, tardigrades greatly extend their life-spans.





Courtesy, Dr. John H. Crowe, University of California, Davis

sults demonstrated that mouse embryos could be frozen and thawed successfully if a suitable protective agent was added to the medium before freezing.

Having achieved external fertilization, the next step in this area of experimental embryology would be complete in vitro (in the test tube) growth of the embryo. Unfortunately, growth stops when the cells begin to form into specialized organs, in what is called the blastocyst stage, when the developing embryo normally implants itself in the wall of the uterus. Once this stage has been passed, growth in an artificial womb could take place. Therefore, reaching and passing this stage of development was a major research goal. Yu Chih Hsu of Johns Hopkins University, Baltimore, Md., announced that he developed mouse embryos beyond the implantation stage in culture dishes coated with rat tail collagen, a protein substance. Because, as Hsu put it, "all the embryos developed in vitro seem to be defective in one organ or the other with the present method," he concluded that "the supply of nutrients and gases may be inadequate for further embryonic development." Hsu believed that now was the proper time to begin work on an artificial placenta that could supply the necessary nutrients and gases to the embryo.

Independently, a handful of chemical engineers was turning from traditional industrial challenges to the creation of such biomedical devices. One of the more ambitious undertakings was to probe and simulate functions of the placenta in engineering terms. The work was detailed in September 1971 at a national meeting of the American Chemical Society in Washington, D.C. Chemical engineers Daniel Reneau and Eric Guilbeau of Louisiana Polytechnic Institute and their physician-physiologist co-worker, Melvin Knisely of the Medical College of South Carolina, developed a theoretical model of the placenta. They were planning to undertake animal experiments to test their simulation. The model, linked with a computer into which many variables could be fed, would help tell them what they should look for in their experiments. (*See* Feature Article: TEST-TUBE BABIES.)

For all its sophistication, modern biology was not able to explain why certain lower organisms can grow back certain injured or lost parts—the worm its lower body, or the lizard its tail. Nor had it been able to explain why higher animals do not have this capacity. R. Becker of the State University of New York Upstate Medical Center at Syracuse partially regenerated the forelimbs of several dozen rats amputated between what corresponds to the shoulder and the elbow in humans. Minuscule amounts of electric current applied to the severed sites stimulated the limbs to grow down to the elbows. Becker's was the most advanced success yet in regenerating a limb in an animal as high up the evolutionary ladder as the rat. For 15 years Becker has pursued the theory that mammals are not able to regenerate damaged limbs because they have lost the ability to generate enough electricity to stimulate the formation of a new limb bud.

Ecological studies. It was found that the large flightless grasshopper from Florida, *Romalea microptera,* probably takes the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D), metabolizes it, then uses it in a kind of chemical warfare to repulse predators. There were many documented instances of insects using chemicals produced by other species, but this was the first report involving a man-made pesticide, although such uses of man-made chemicals may not be all that exceptional.

A report that might surprise many was one that revealed mercury levels in several human tissues declined from the 34.5 parts per million recorded in 1913–19 to about 5.5 ppm currently. At a conference on pollution, J. Ui of the University of Tokyo spoke of the dangers to health that may arise from the release of mercury into the natural waters of densely populated areas. His opinion, endorsed by others, was that mercury pollution was likely only to be a local problem, because the amount of mercury reaching the sea from industrial sources was only a small fraction of that entering by normal geological processes. He considered that a much greater threat to man's health was posed by toxic chlorinated hydrocarbons, such as DDT, and polychlorinated biphenyls (PCBs), which enter the sea by way of the atmosphere and are, therefore, distributed globally. These compounds are concentrated by marine animals at many levels in the food chain. (*See* Feature Article: THE NOTORIOUS TRIO: MERCURY, LEAD, AND CADMIUM.)

DDT and other pesticides rendered some large bird species nearly extinct because they interfered with calcium metabolism and caused eggshell thinning. Such shells break before the embryos mature. L. Z. McFarland and R. L. Garrett of the University of California School of Veterinary Medicine at Davis used a scanning electron microscope to determine that the middle layer of the multilayered eggshell contributes the most toward structural strength, and that it was this layer that was most adversely affected by DDT.

One investigation of how, physiologically, pesticides kill insects was based on the observation that water conservation is critical for insects because of their large surface area relative to their volume and the generally arid environment in which they live. There were indications that the critical water balance is disrupted by poisoning

with certain insecticide chemicals, but the physiological basis for this action had not previously been defined. S. Maddrell and J. Casida of the University of Cambridge found that treatment of *Rhodnius* with DDT results in the massive excretion of a large volume of fluid into its rectum. Furthermore, the underlying mechanism involves the release of diuretic hormone, possibly from a bound form in the central nervous system, into the hemolymph (insect "blood"), where it contacts the Malpighian tubules (in the insect's "kidneys") and greatly increases their rate of secretion. The excretion induced by insecticide chemicals was always found to be initiated during the paralytic stage of poisoning. (*See* Feature Article: SPECIES IN PERIL.)

These findings were obviously of potential importance in the use and design of insecticide chemicals. The rapid loss of a large volume of fluid could kill the animal by dehydration. Furthermore, the Malpighian tubules secrete a fluid that is, in general, extremely rich in potassium, high in phosphate, and low in sodium and chloride. This changes the insect's ionic balance drastically, and probably enhances its disruptive action on the nervous system. Finally, these kinds of dehydration changes could be initiated by chemicals that are nonpersistent in the environment. All that needed to be discovered was whether the bug is killed first by paralysis, or by dehydration, or by both.

For those who might favor gentler methods of dealing with pests, J. S. Gill and C. T. Lewis of London's Imperial College of Science and Technology believed that applications of the nontoxic, distasteful chemical substances produced by some plants might deter insects from attacking crops and, thus, offer an alternative to toxic pesticides. A suspension of crushed seeds or leaves from the neem tree, a large East Indian tree with a bitter bark, deterred some insect species from feeding when applied to plant foliage. This compound can be absorbed by the roots of plants.

The ladybird beetle, *Stethorus punctum*, was being used by scientists at Pennsylvania State University and independent apple growers in a program of "integrated control" of mites harmful to apple trees. In this program the grower must arrange a careful balance between protecting the apple crop and the trees from injury by insects while at the same time not harming *Stethorus*, which preys upon the European red mite and the two-spotted spider. If these pests were destroyed by pesticides, the beetle would leave the orchard to search for mites elsewhere. The program had the advantages of eliminating some pesticides from the spray schedule and of reducing amounts of other sprays. This not only lowered the level of environmental pollution but also growers' costs. Another advantage was that *Stethorus* would eat mites that were resistant to the sprays.

The chemical 13-methylhentriacontane was identified in the feces and larvae of the corn-ear worm *Heliothis zea* (Boddie), a pest of considerable economic importance, as the major constituent that triggers the short-range host-seeking response of its parasite, *Microplitis croceipes* (Cresson). Bioassay of closely related compounds indicated that the structural requirements for activity are remarkably specific. This chemical, the first of its kind to be found, could also upgrade efforts to use parasites for insect control as well as lead to a better understanding of insect behavior mechanisms.

In a fascinating study, Sarah Corbet of the University of London reported that when caterpillars of the *Anagosta kuehniella* touch each other they deposit a secretion from their mandibular glands on the substratum. This secretion stimulates oviposition movements in its insect parasite *Venturia canescens* (Grav.) and a larger proportion of the host caterpillars are parasitized in a crowded population than in an uncrowded one. When a female of *V. canescens* oviposits in a larva of *A. kuehniella*, she taps her antennae against the host, unsheaths her ovipositor, and then makes jabbing movements, which, if they penetrate the host's cuticle, may result in the release of an egg. The experiments showed that the parasite responds quantitatively to its host's secretion. The finding of this substance, termed an epideictic pheromone, might have applications in the control of some other butterfly and moth pests, especially if their mandibular glands prove to have a similar function. Work was in progress on the chemical characterization of the components of the secretion, making use of the parasite's ovipositional response as a clever bioassay for its presence.

A very simple agent for controlling insect pests without harming other organisms (including man) was being investigated by three workers with the Agricultural Research Service of the U.S. Department of Agriculture. The agent was light. Larvae of many insects, such as the codling moth and corn borers, go into diapause, a state resembling hibernation, when the days become shorter in the fall. With spring, longer days, and more light, the larvae resume their life cycle and metamorphose into adults. Artificial light might be used to prolong the days so that the larvae would not go into diapause but would metamorphose in the fall and be wiped out by the winter weather. On a test plot where artificial light was supplied by 40-watt fluorescent lamps, more than 70% of the insects failed to go into diapause, continuing instead to

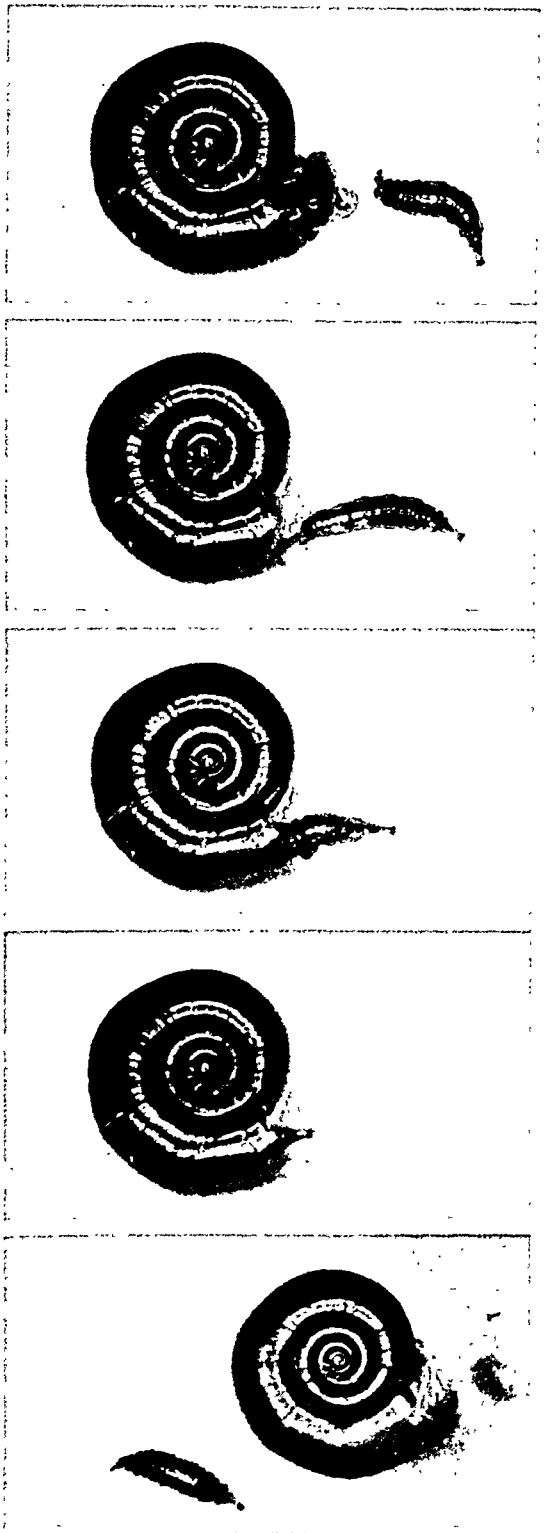
develop into adult moths in the fall. Apparently the major drawback of this procedure was the cost of optimum lighting conditions.

Evolution studies. The search into the details of the origin of life continued. There was speculation, for example, that the organelles, specialized cellular bodies, might once have been independent organisms. A new symbiosis theory held that the genetic material recently found in chloroplasts and mitochondria demonstrated that these two kinds of organelle were once free-living organisms. The theory proposed that the higher plants are the result of a symbiosis between animal-like hosts and photosynthetic blue-green-algalike guests whose partnership could not have evolved until relatively recent times, when mitosis had been perfected. Proof that the symbiosis theory is correct demanded experiment.

One of the major trends in evolution studies was a decline in subjective typological reasoning involving examination of single features only and a corresponding move toward the use of more objective, comprehensive, and, increasingly, statistical methods analyzing complexes of many traits. Because of the fragmentary condition of most fossil remains, the scope of the trait complex approach was very limited, but application of the statistical concepts of population genetics allowed the investigator to consider his sample, however small, as a part of a larger population, and to make the population, not the individual, the unit of study.

New techniques that detected patterns of fluorescence caused by the binding of the drug guinacrine to specific regions of chromosomes were being used in chromosome analyses of various mammals. It was found that fluorescence of the intensity found on the human Y chromosome was only present in the African great apes and man. Applying this information, the investigators suggested that the absence of intense fluorescence in the orangutan or gibbon makes it likely that these apes evolved from an ancestral stock before the origin of the lineage giving rise to the African great apes and man.

—John G. Lepp



Snails that transmit the debilitating disease schistosomiasis, or snail fever, can be controlled without pesticides. At top a marsh fly larva approaches a snail harboring the tiny flatworm larvae that cause the disease. The larva attacks the snail, pursues it into its shell, and feeds on it. Thus the snails can be destroyed without the harmful effects to the environment caused by pesticides.

Courtesy, Dr. Clifford O. Berg, Cornell University

A Pictorial Essay

Art and Technology

by Jack W. Burnham

Modern science has given rise to a wealth of technical gadgetry. Modern artists, in turn, are using this technology for their own purposes.

"Day Passage" by Rockne Krebs. Photo, Ed Cornachio.

Marcel Duchamp worked over a period of six years on sketches for this optical-precision machine, "Rotative Demi-sphere," 1925. It was finally made to his specification and used in a motion picture. When looked at for some time, the instrument's spirals seem to invert and become concave. While obviously a forerunner of optical art, "Rotative Demi-sphere" was reputedly made by Duchamp as a "mechanized" model for all the final stages of modern art.

In what seemed a meaningless act, the French artist Marcel Duchamp turned a bicycle wheel with its steering fork upside down and affixed it to the seat of a kitchen stool. That occurred in 1913. Since then the possibilities of mechanized art have intrigued many artists. Such avant-gardists as Laszlo Moholy-Nagy, Naum Gabo, and Alexander Calder pioneered in moving, or "kinetic," sculpture during the early decades of the century. But not until the 1960s did the impact of sophisticated technology make itself felt in the art world. Today we can begin to evaluate this period of intense experimentation, which has provided us with valuable insights into what makes the marriage of art and technology work.

Within the art world itself, the artist's use of sophisticated technology is a particularly sensitive issue. Many "humanist" art critics have repeatedly attacked such endeavors for producing trivia, wasting money, and making the artist dependent on large corporations whose goals are anything but aesthetically motivated. However, it is not in the use of new, exotic materials or power sources that "Teckart," as its critics label it, succeeds or fails, but in the threat that it poses to the traditional dichotomy between the fine and technical arts. It has often been said that people go to art museums to escape the sensory chaos of an over-mechanized environment. Yet when they find this very thing in the museum, they have reason to feel that art is no longer serving its function as a humanistic alternative. Some foresee a gradual fusion of artistic creation and the technology of industrial production.

Within this trend there lies a strange paradox. On the one hand, it could be proposed that art is in danger of becoming obsolete, of falling behind in the cultural onrush of applied scientific research. On the other hand, the more art begins to resemble some of our technologies, the less it satisfies our aesthetic instincts. Possibly this dilemma can be resolved if we look at some trends emerging from art and technology exhibitions in the last ten years.

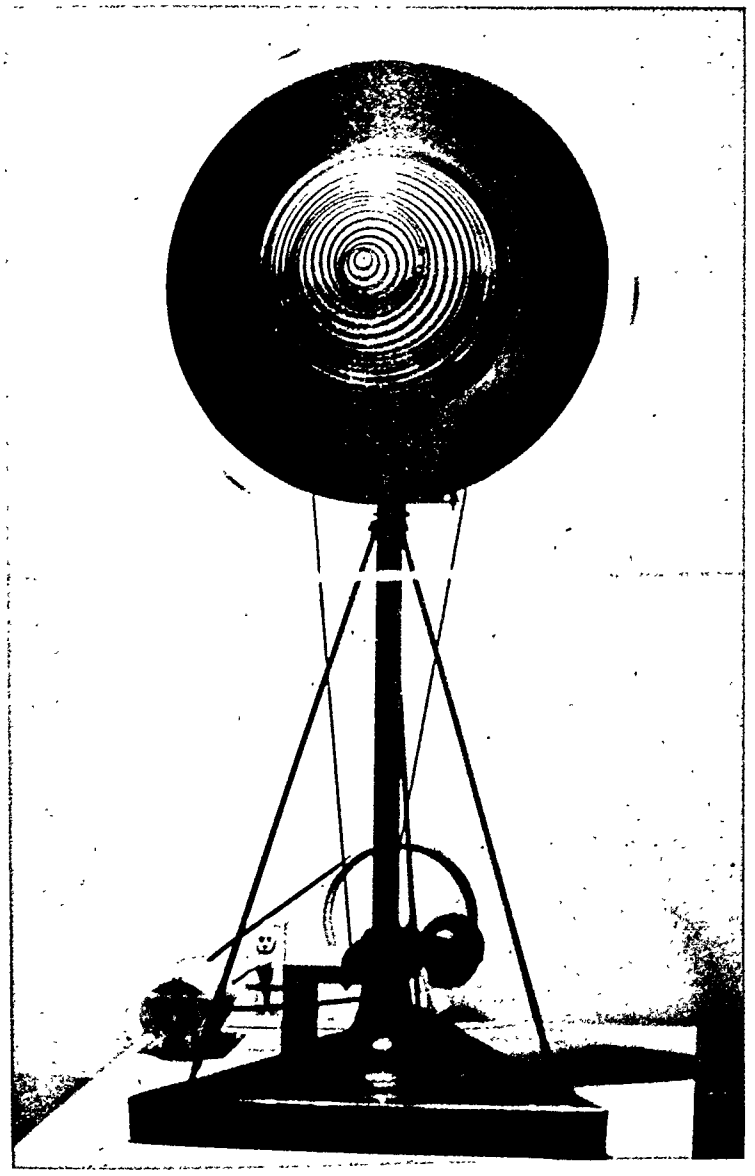
Artists and engineers

What might be called early contemporary efforts, such as the kinetic art exhibition at the Museum of Modern Art in Stockholm in the summer of 1961, emphasized the historical aspect of light and movement as art forms. At a practical level, this involved simple motor-driven devices and occasional mechanized light boxes. Following the Stockholm retrospective, a tendency developed toward an escalation of technical means, with an emphasis on collaborations between artists and research or engineering personnel. By the mid-1960s a dividing line had developed between "machine-art" as such and what could be labeled as "systems technology." This second includes artists' use of computer systems, laser technology, plasma physics, audio tape-controlled environments, color copy duplicating systems, programmed strobe light, and various artificially controlled ecological sites.

Such a division, which is perhaps more psychological than technical, was recognized in 1968 by the exhibition "The Machine as Seen at the

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Courtesy, Jack W. Burnham



End of the Mechanical Age" at New York City's Museum of Modern Art. The Swedish historian Pontus Hultén, who was mainly responsible for the earlier kinetic show in Stockholm, was its organizer. Hultén's selection dealt with the mythological aura that surrounded industrial design in the first half of the century. In no small way artists have been influenced as much by the shape of automobiles and airplanes as by the more practical considerations of technology.

During the fall of 1966 the first large-scale avant-garde festival of art and scientific research took place in New York City. "9 evenings: theatre and engineering" proved to be the training ground for all subsequent experiments in this direction. For the mostly hostile critics

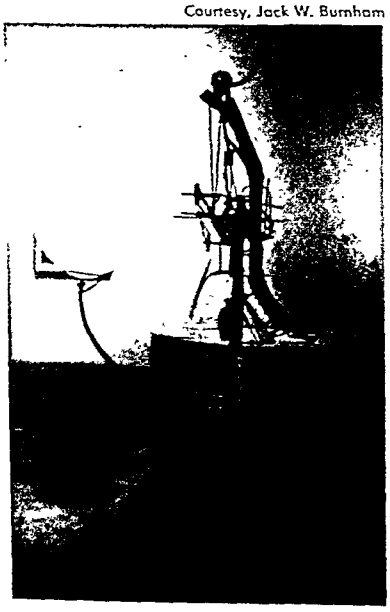
who attended, "9 evenings" appeared to be an unprepared series of Space Age happenings, beset by constant breakdowns and delays. Ironically, though, the year-long preparations for the "9 evenings" demanded a deep emotional involvement from many of the participants. It proved several things. Artists and engineers can work together toward common goals provided they share some degree of technical knowledge. Moreover, it demonstrated beyond doubt that the excitement of technology comes with using it rather than viewing it.

"9 evenings" was masterminded by Bell Laboratories scientist Billy Klüver, who subsequently founded Experiments in Art and Technology, Inc. Originally, Klüver's goal was to provide a parent corporation where artists worldwide could receive technical assistance from scientists and engineers interested in their projects. Soon EAT had several thousand names in its active file and the promised support of several important corporations and foundations. EAT's basic function was to facilitate technicalization of the arts, while also serving as an antidote to the dehumanizing aspects of social innovation.

EAT's most important statement came in the form of an open exhibition at the Brooklyn Museum and the Museum of Modern Art in New York during the winter of 1968–69. Its title, "Some More Beginnings," perhaps gives an indication of the caution that then prevailed. The earlier optimistic belief that technology was the wave of the future had given way to a realization that much technicalized art fails aesthetically and makes little sense financially to the artist, engineer, or gallery. Research costs for unique projects remain relatively high for the artist, as do maintenance expenses for the museum. A unique feature of "Some More Beginnings" was its attempt to give incentive to engineers. Considerable publicity, along with the main prizes, went to engineers rather than to artists. Well over a hundred entries of greatly varying quality were shown.

As the novelty gradually faded from technological art, EAT was confronted with several fundamental difficulties. Such art tends to attract more than its share of bad work. Artists of reputation do not need the sponsorship of EAT to gain help from corporations. Most decisively, few engineers are inclined toward extended collaboration with artists without the incentive of financial help. At present EAT is no longer a force in the art world, and its remaining energies seem to be focused on large-scale urban problems.

Courtesy, Jack W. Burnham



In "Meta-matic No. 17," 1959, one of a series of art-making machines by the Swiss-French sculptor Jean Tinguely, pens scratch random marks on a moving roll of paper, parodying the abstract expressionist style of the 1950s. Designed to break down, Tinguely's machines represent witty philosophical observations on machine-oriented societies.

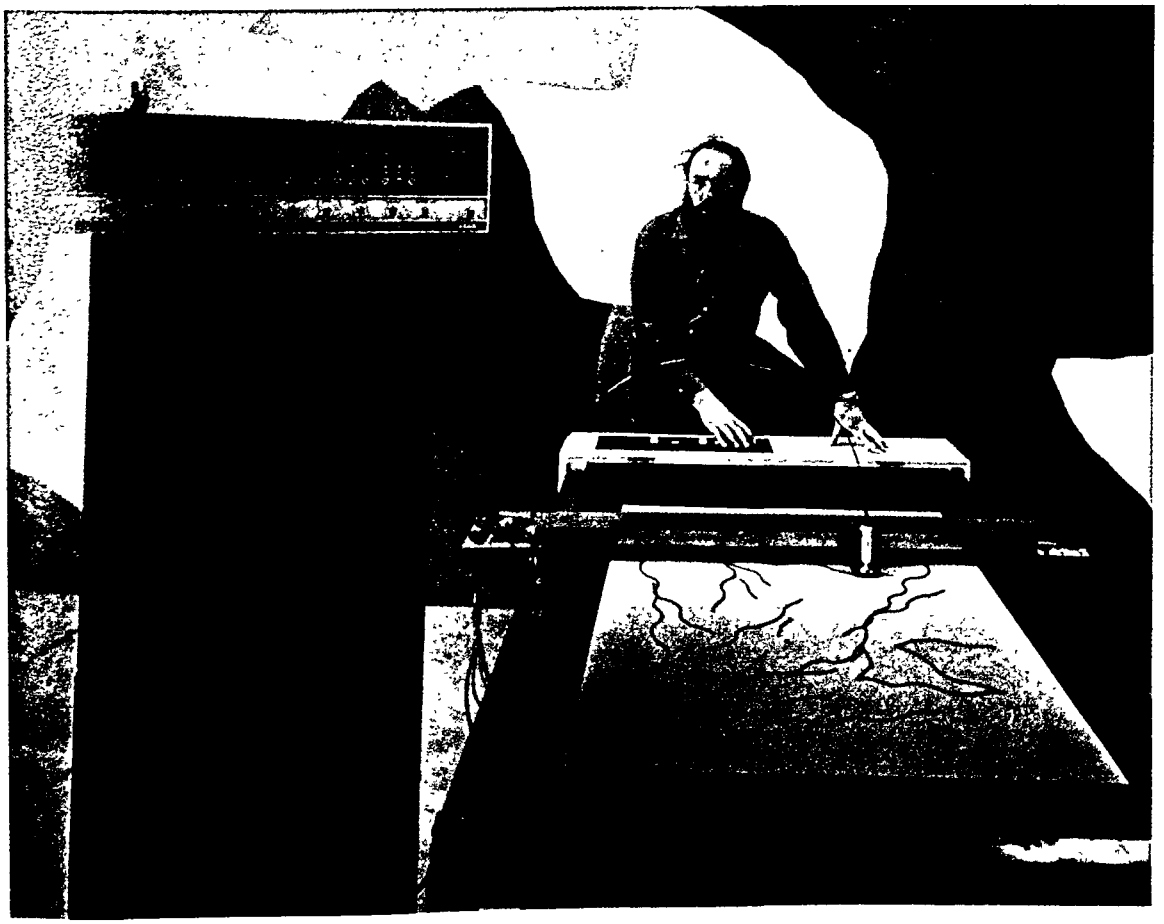
The programmed art experience

The first international exhibition of "post-machine" art took place at the Institute of Contemporary Arts in London during the summer of 1968. Jasia Reichardt's "Cybernetic Serendipity" attempted to document the creative use of computers and various cybernetic devices. Its book-catalog contains a good layman's account of the historical development of digital computers. "Cybernetic Serendipity" included some strictly scientific experiments, along with works by artists that utilized the principle of feedback in machines responding to both

internal and external stimuli. Other exhibits featured printouts (visual diagrams) from computers as used in music analysis, computer graphics and movies, computer-designed choreography, and computer poems and text analysis. Generally speaking, computer graphics and painting have found little favor in the art world. They usually seem to be pale imitations of earlier modernist styles. (There are a few exceptions to the "pretty picture" school of computer graphics. For instance, the English painter Harold Cohen is concerned with a "game theory" of strategies for creating paintings according to very primary assumptions. Cohen devises programs based on theories of graphic creativity.) Unfortunately, much of "Cybernetic Serendipity" was destroyed in transit when it was shipped to the Corcoran Gallery of Art in Washington, D.C.

The 1970 cybernetic exhibition at New York City's Jewish Museum proved to be a more interactional experience for the gallery goer. "Software" had the added complication of using several computers in the museum. It included a programmed catalog where viewers were encouraged to sit down at key-scope terminals and type out questions

Harold Cohen works with a Data General Nova 1200 computer and a flatbed graphic plotter. This plotter includes a freehand drawing simulator based on the artist's normal style of line drawing. A typical program has two parts. The first provides an "environment" consisting of a given set of digits randomly distributed within the cells of a grid. The program then selects a succession of digits, exhausting one number and then moving on to the next highest, the object being not to cross an existing line. Cohen is interested in problem-solving strategies inasmuch as they simulate a structure common to "art games."



Courtesy, John Waggaman

about nearby exhibits. "Software" also introduced algebraic and set-theory games played on special display scopes. More than just a display of electronic technology, "Software" focused on the creation of aesthetic realizations through communications media. Such a complete ephemeralization of the art object is connected with the idea of Conceptual Art, which emphasizes that sensory input need not be related to material art objects but only to an "art proposition" in some written or diagrammatic form. Closed-circuit television, audio tape players, environmental sensors, and photography are other forms of information technology organized to produce art experiences.

"Software" was not without its problems. Programs in the main computer, a DEC PDP-8, were short-circuited two days before the opening. The system was not sufficiently reprogrammed and debugged until just a week before the exhibition closed in New York. Because of differences of opinion over editing, five of the introductory film loops were destroyed on the second day of the exhibition and were not replaced for two weeks. Art critics were generally critical of "Software"; commercial trade journals saw it for what it was; some gallery goers construed it as a threat to the traditional art world. If nothing else, technological art seems to generate some very human reactions.

The Los Angeles County Museum of Art's "Art and Technology" program, as of 1972, was the most ambitious exhibition of its kind. Planned from 1967 by Curator Maurice Tuchman, "Art and Technology" appeared during the summer of 1971. Tuchman was fortunate to have the backing of nearly 40 corporations in the southern California area. In a selection process covering two years, the curator chose about 30 artists from a worldwide group numbering in the hundreds—although the final selection of artists was mainly from New York. Most significant from a planning perspective were "A & T's" exhaustive contractual relationships between artist, company, and museum; its relatively decent budgets for artists; and its attempts to produce a sustained and practical interchange between artists and the corporate-industrial sector. Quite aware of the strong antitechnological sentiments within the art world, Tuchman and his associates wisely chose a limited number of entries from some of the biggest names in the American art world: Roy Lichtenstein, Claes Oldenburg, Robert Rauschenberg, Tony Smith, and Andy Warhol.

There has been a steady escalation of means within technological art, and few significant projects are inexpensive. The proposed outlay for each "A & T" project was $15,000, but it seems certain that several works at least doubled that. Total costs mentioned for the exhibition ran upward to $1 million. For a profit-making investment such as a motion picture this would not seem unreasonable, but in the penurious museum world $50,000 to $100,000 is considered the range for a major show. Although "A & T" produced a fairly successful and entertaining exhibition, many art critics accused it of selling out, Disneyland fashion, to large corporations with interests in profits and war, and of perverting high art "aesthetics."

Courtesy, Newton Harrison



Each of the four water troughs in Newton Harrison's "Salt Water Ecosystem: Brine Shrimp Farm," 1971, has a different degree of salinity and thus a different color, since the amount of salt affects the growth properties of the algae in them. The troughs are seeded with brine shrimp, which grow to maturity in six or seven weeks. After they are harvested, the water evaporates and the salt is collected.

What was evident from the Los Angeles "A & T" effort was a certain inherent alienation from big technology on the part of the artists. Their projects either threatened viewers' sensory capacities or reflected the ironic vein of Chaplin's 1936 movie *Modern Times*. Much of the exhibition was implicitly antagonistic toward the effects of technology. Below the surface, few of the artists appeared to believe that U.S. corporate interests, controlling the overwhelming portion of the country's technology, have any real sense of social responsibility or direction.

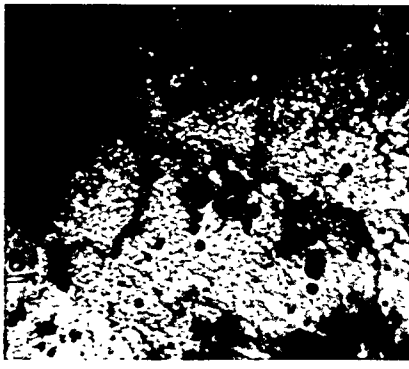
Is it "art"?

Coming back to the original question, can art and technology be reconciled? Do they have a common meeting ground where both perform according to everyone's expectations? Technological art that simply

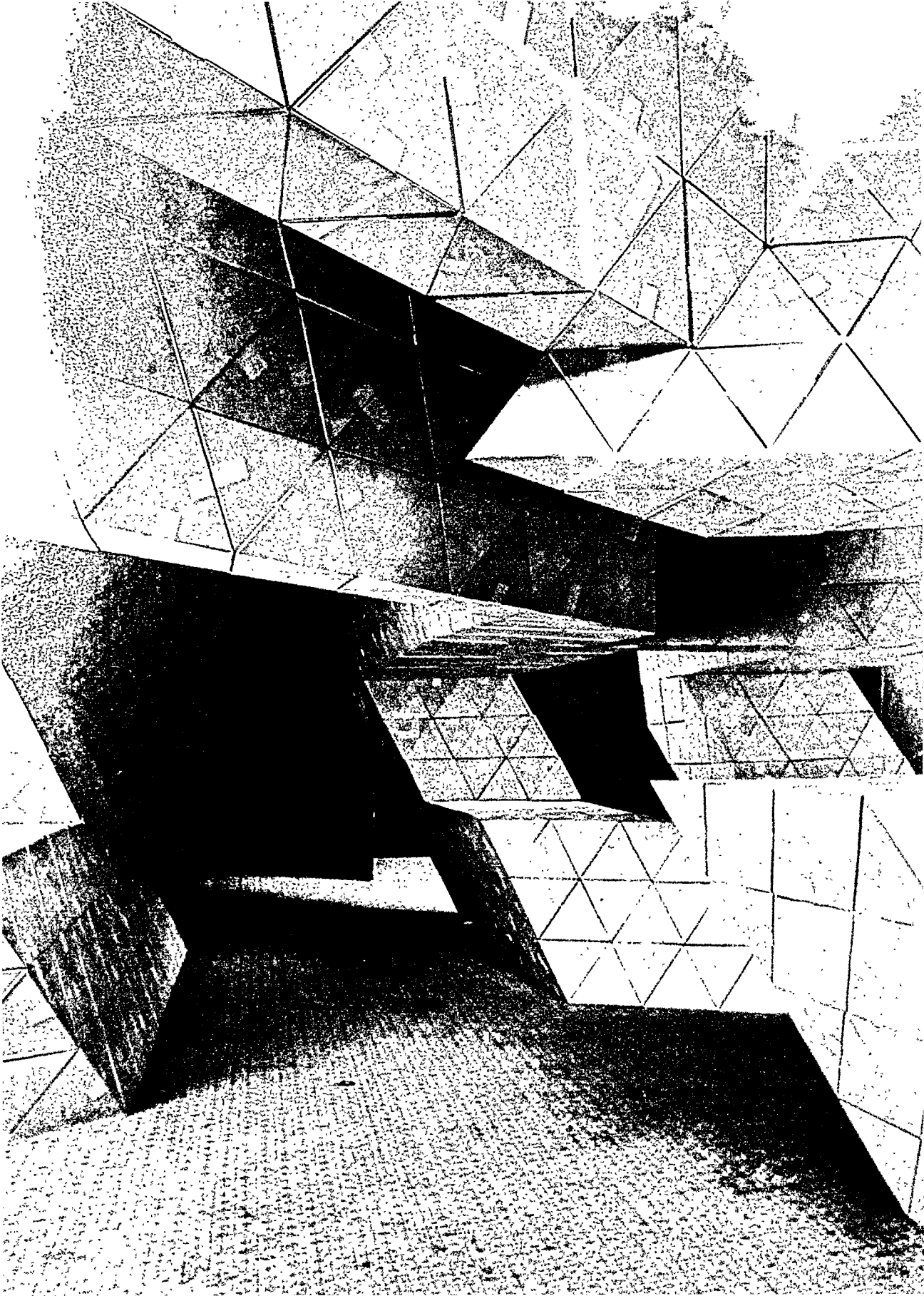


Courtesy, Alan Sonfist

Courtesy, Alan Sonfist



All Alan Sonfist's works deal with growth, decay, and interdependence. He sees "sculpture" in the ecological exchanges that occur every day and believes that man-nature stability will come only when we have become acutely sensitive to the natural changes around us. "Crystal Globe," 1968 (left), is a sealed hollow glass sphere containing natural mineral crystals. Through the effects of natural heat and light, some of the crystals vaporize into a purplish gas which rises to the top of the globe and crystallizes on its inside surface. "Micro-Organism Window," 1968 (above), appeared in the window of a New York City art gallery. The artist coated the glass with an agar-based substance, and within 48 hours growth patterns began to appear on it. In a sense, this is a way of dramatizing the toxic content of New York air.



duplicates the results of handcrafted art is in all respects a trivial contribution. Moreover, a great selling point of technological invention, time saving, has little meaning for the real artist. Making art embodies its own psychological reward. The dilemma of the alienated office and industrial worker is still a reality; consequently, it is not surprising that thousands of students enter art schools every year although the chances that they will find work in their chosen field are slim. Why does "art" feed the soul and "work," in a modern industrial society, deaden it?

At a fundamental level, technology serves the same purpose as art. It provides the link between physical need and social fulfillment. And while they are probably not inherently antagonistic, after a thousand years in which they have gradually separated, we have grown to think of production and research as "practical" while art remains merely entertaining and provocative. Many of the justifications for earlier art, *i.e.*, its spirituality, beauty, idealism, and emotional sentiment, no longer hold true for contemporary work. Where art objects were once carried through the streets of towns with adoration, the art gallery today functions as a tame sideshow for an easily jaded public. Perhaps the greatest victims of the Industrial Revolution, many artists are ridiculed as industrial "scavengers," more interested in the up-to-date trickery of modern technology than in its expressive appropriateness.

The artist finds himself in a strange double bind. On the one hand he knows that rewards in the art world usually go to innovators—just as they do in the world of business and production. Yet the craving for "new" effects has reached such a point of absurdity and diminishing returns that the artist is beginning to question the entire meaning of stylistic change. If art was once the essence of social stability and ritual, something has happened during its historical evolution to bring it to its present state of psychic and social ineffectuality.

One aspect seems to be that art fulfills certain inherent psychological needs, which, given man's symbol-making propensity, are biologically unique. Making a completed work of art denotes a kind of cycle. Machines incorporated into art, on the other hand, imply an infinitely linear event; that is, energy tamed to do man's will. Thus it is not surprising that little or no machine-driven kinetic art has found aesthetic acceptance. Machines may be used to *make* art so that the resultant object fits into a historic time slot. In such a way, the work of art is frozen in time. In contrast, many artists have become interested in the cycles of animal and vegetable growth, weather change, and ecological stabilization. Here the temporal dimension is repetitive. Perhaps for very profound reasons, such art appears to embody many of the technological and craft features developed by European Neolithic cultures between 6000 and 2000 B.C.

Rediscovering wholeness

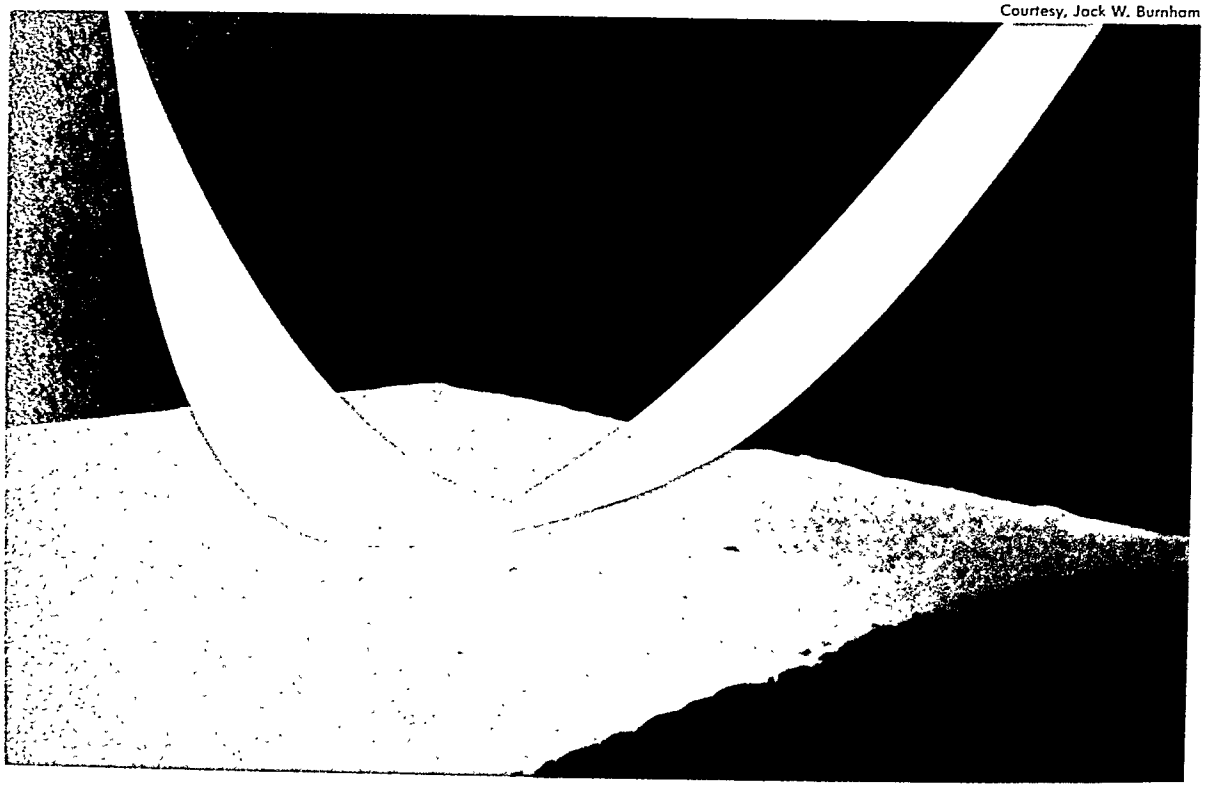
On one level this represents a rejection of the Industrial Revolution. Or, pessimistically, we could speculate that art is phasing itself out as

(Opposite page) courtesy, Los Angeles County Museum of Art; (below) courtesy, Jack W. Burnham



Using the research facilities of the Container Corp., Tony Smith designed his massive interior sculpture (opposite page) for the 1971 Los Angeles "Art and Technology" project. The cavelike structure uses thousands of assembled tetrahedral modules. Visually and spatially, it remains one of the most stunning experiences in modern sculpture, although Smith was never satisfied with the structural solution. The intense light source in "Heart Beats Dust" (above), a 1968 work by Jean Dupuy and Harris Hyman, is a 250-w quartz element with shutters and lenses. A very light red pigment, lithol rubine, palpitates on a stretched rubber membrane in time with a continuous loop tape recording of heartbeats played through a coaxial speaker mounted just below it.

Courtesy, Jack W. Burnham

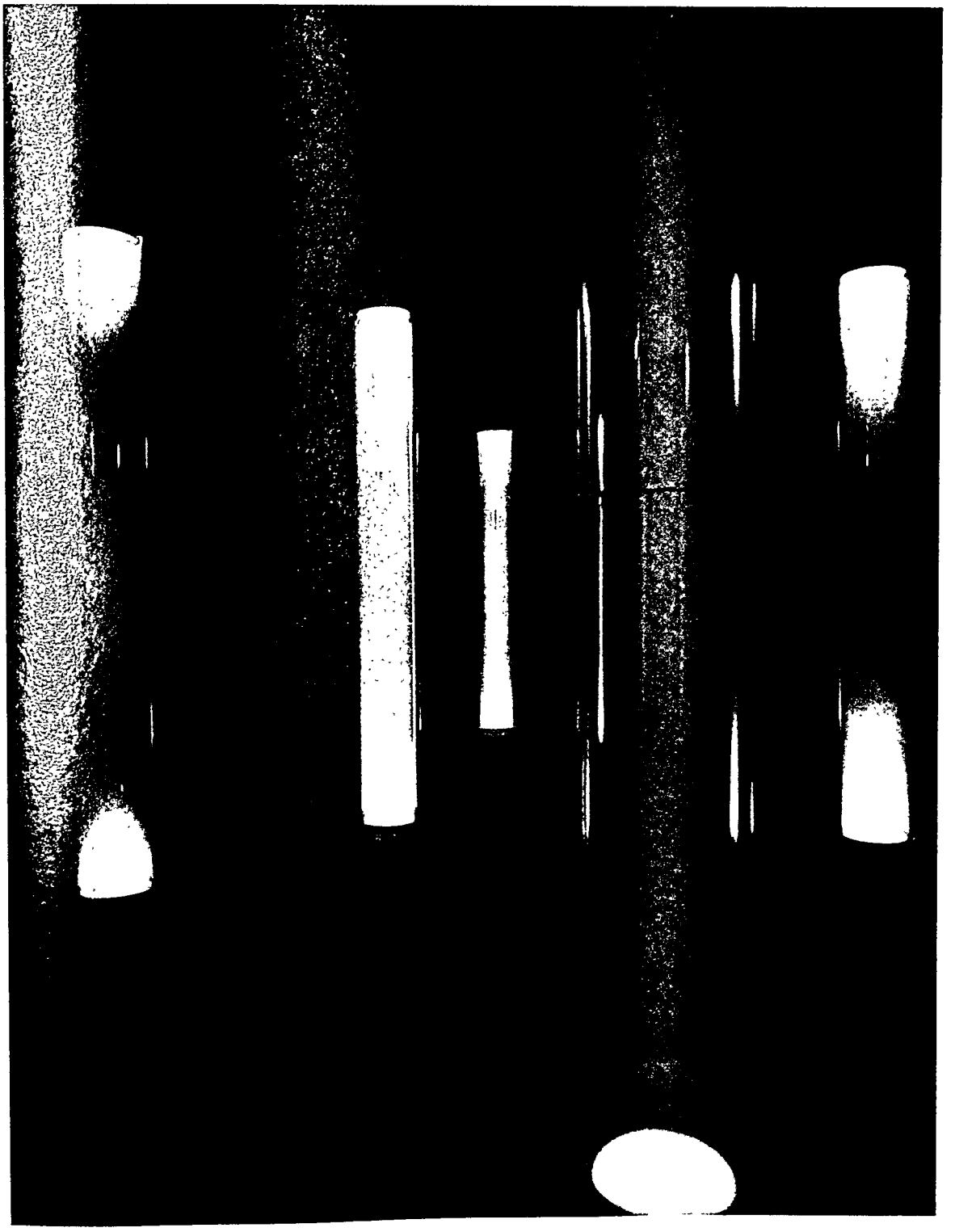


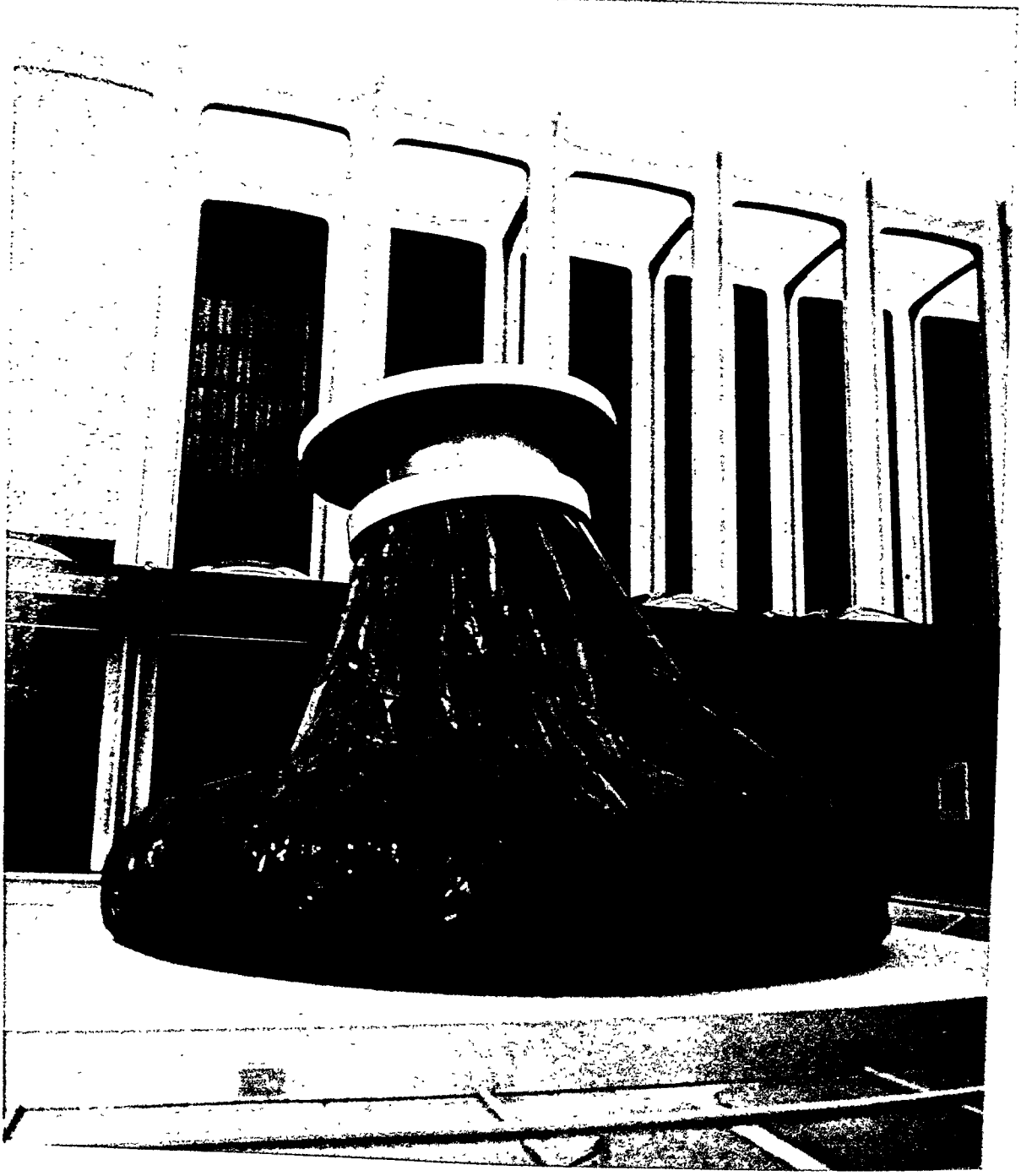
The light environment "Tripping" (above) was created by Jack Burnham for the Ravinia Art Festival, held near Chicago in 1969. Two 35-ft tapes, cemented back to back, are suspended the length of a room so that they nearly touch the floor and are illuminated by normal 115-v house current. A phosphorescent glow in materials distributed on the floor is generated by several ultraviolet lamps above the tapes. Another light environment (opposite page), designed by Newton Harrison for the Los Angeles "Art and Technology" project, uses five plastic cylinders, each filled with a different gas. An electric current passed through the cylinders ionizes the gases, causing each to glow with a different color. Changes of form in the light are induced by regulating the gas flow.

a meaningful activity, due to our ever increasing commitment to a rationalized and systems-oriented life-style. The truth probably lies with neither. The artist may be warning us that many of our technologies are dangerously unbalanced, that our waste disposal practices and use of resources represent massive social pathologies. What is more, unstable technologies have usually generated new methods whose instabilities lie farther in the future. While the concept of a steady-state world remains an impossible dream, many artists intimate that there is no other alternative. They seem to be saying that art properly made—that is, work accepted as "art"—embodies ancient patterns for balanced human behavior.

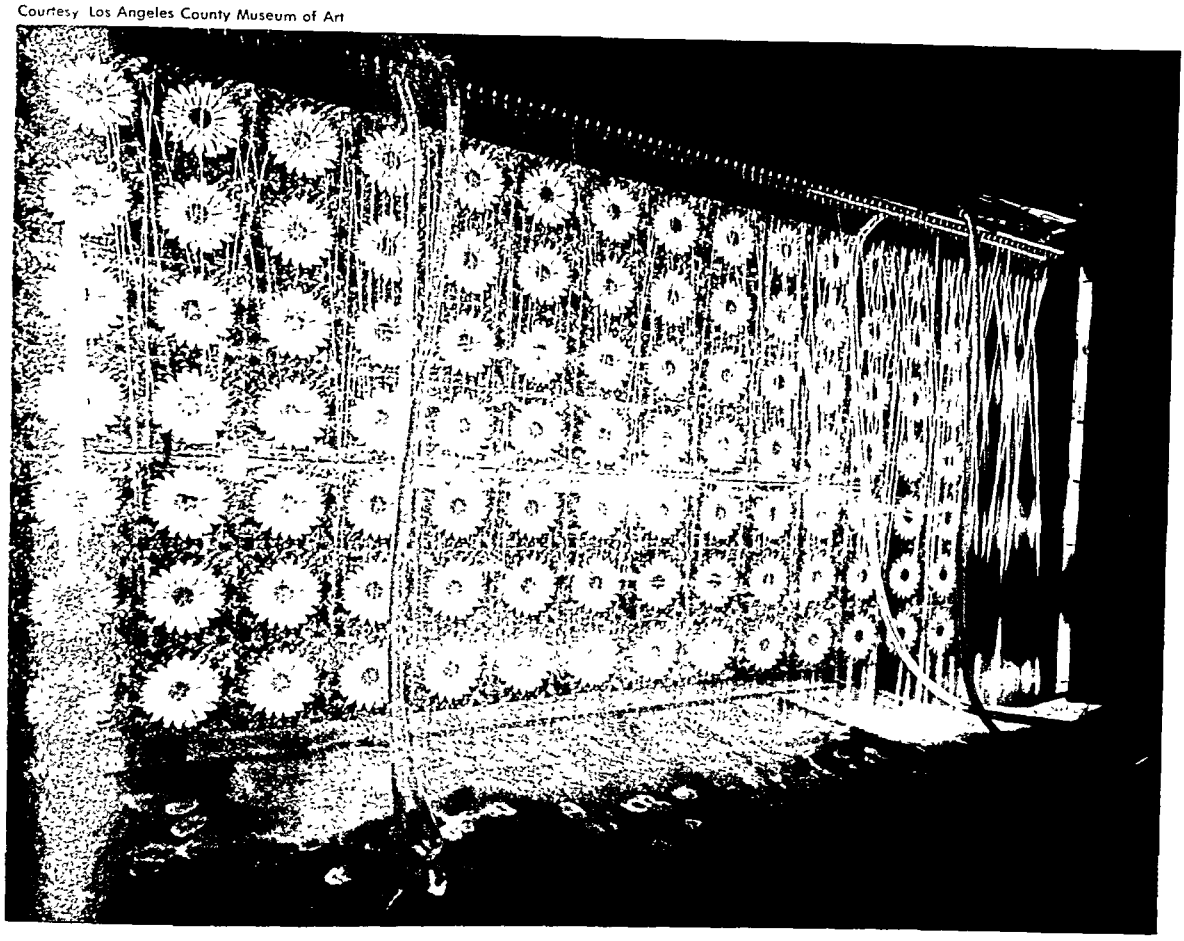
Some social scientists hold to the possibility that art and ritual are tied to each other through the same structure of relationships. Consequently, if much of the origin of physical sickness is psychosomatic, then the medical and, hence, aesthetic function of the shaman in primitive societies may be critical after all. In his book *Pigs for the Ancestors*, the anthropologist Roy Rappaport reports on a tribe of hill farmers in the Central Highlands of New Guinea. Taking all the aspects of their complex ecological system into consideration, Rappaport decides that their elaborate cycle of rituals functions as a feedback mechanism or a kind of spiritual thermostat controlling animal raising, farming areas, man-land ratios, protein consumption, war-making activities, human procreation, and other vital activities. Traditionally, Western culture has sought purely empirical answers to all of its immediate

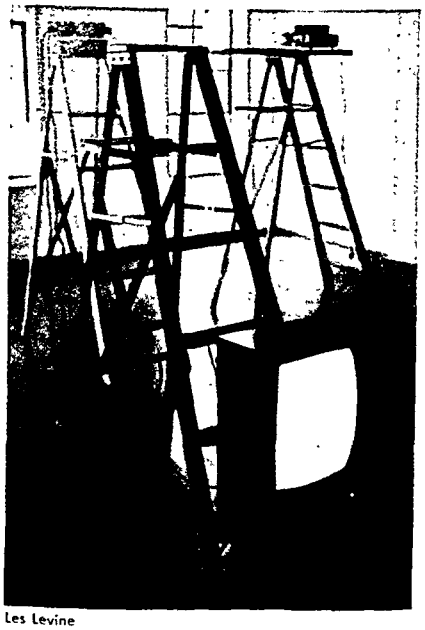
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Courtesy Los Angeles County Museum of Art



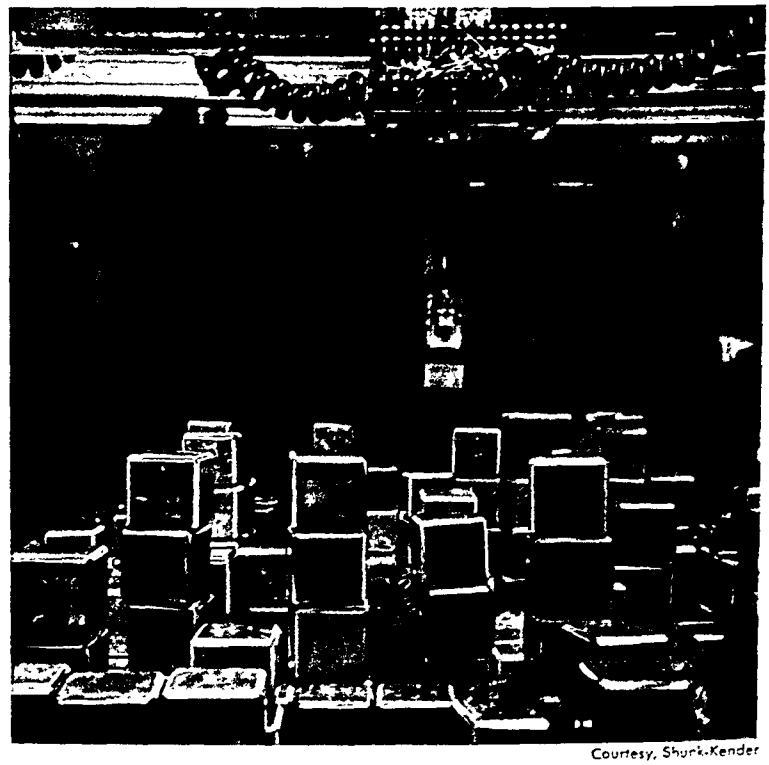


Les Levine

Claes Oldenburg's "Giant Icebag" (opposite page) rises from 7 to 16 ft by means of a hydraulic mechanism. In this 1968–71 work, Oldenburg, like Tinguely, is making the comment that there is something inherently absurd about both moving sculpture and icebags. Set against a backdrop of three-dimensional plasticized daisy panels, Andy Warhol's 1971 work "Rain Machine" (above) drops "rain" on plastic grass and recycles the water through clearly visible Teflon hoses. "Chain of Command," 1972, by Les Levine (left), involves three stepladders: one with a television monitor, one with a TV camera, and one with a slide projector that shows 80 slides, each with a different view of the three ladders.

problems. But as we erode our psychically organized activities such as the handcrafts, visual art, and ritual itself, we fall in danger of destroying the human will to act in unison. Given practical material solutions to pressing social problems, we must begin to ask ourselves if such solutions embody an artistic-ritual format, or do they further sever people from their sources of psychic motivation?

The 1970s appears to be a decade in which the artist is beginning to temper his desire to explore new technologies. A mood of discrimination is about. Just as the artist began to look like an ineffective manufacturer or a parody of the lonely research scientist—thereby denying his own unique contribution—we are beginning to rediscover his primal role as the soul's messenger and coordinator. Since the philosophy of aesthetics began in the 17th century, one thing has been



Courtesy, Shunk-Kender

"Seek," 1969–70, by the MIT Architecture Machine Group (above), deals with small blocks that act as an "environment" for a colony of gerbils. These little animals constantly bump into the blocks, thus disrupting the work of a computer programmed to build the blocks into towers. This produces a mismatch between the computer's memory and the gerbils' randomizing activities. Robert Rauschenberg's "Mud Muse," 1970–71 (opposite page), is a 9 by 12-ft glass-enclosed vat of driller's mud. In collaboration with Teledyne for the Los Angeles "Art and Technology" exhibition, Rauschenberg made recorded tapes of bubbling mud and used them to program a series of air jets, located beneath the tank, which sporadically produce bubbles and eruptions.

demanded from the artist: that intangible called "quality." Concerning past excellence we have developed adequate perspectives and theories of evaluation. But quality in present art eludes us more than ever. Consequently, we have begun to question the restriction of quality to the fine arts.

There is a deep longing for a wholeness within our technologies and their integration into our life rhythms. And we wonder why no systems analyst has ever been successful in achieving this. Perhaps it lies in the origins of culture itself. Some realize that quality most essentially belongs in our attitudes toward nature and our patterns of daily living. Therefore, a few artists are beginning to reexamine that most complex of all technologies: the human nervous system and its essential relation to the world.

Courtesy, Los Angeles County Museum of Art



The Notorious Trio: Mercury, Lead, and Cadmium

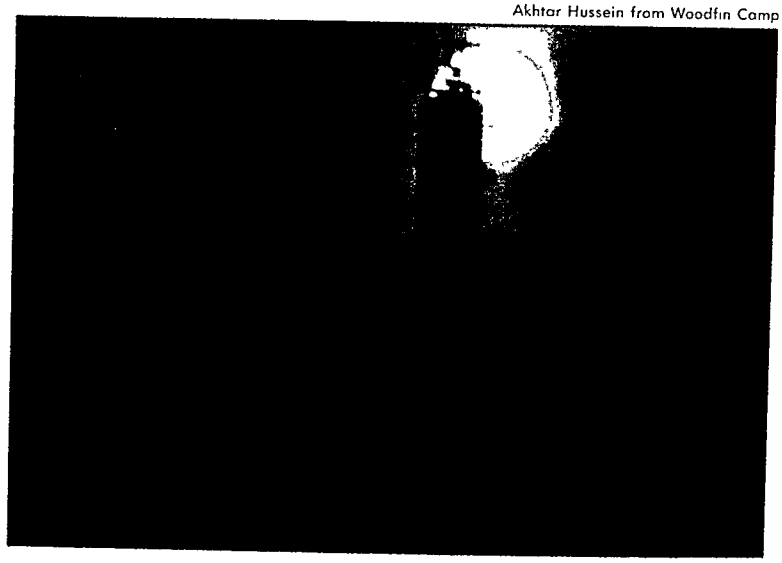
by John F. Henahan

Many refinements of modern industry are the result of man's increasingly sophisticated use of the earth's mineral wealth. The metals mercury, lead, and cadmium have been used with great success and in such quantities that each in its own way now threatens man's health and ultimate well-being.

At the time the earth was formed some 4,500,000,000 years ago, the metals mercury, lead, and cadmium were more or less safely locked in the minerals that contained them. About a hundred years ago, man discovered he could use these metals to make a better material life for himself, and he began to dig them from the earth. By converting the crude ores to refined metals or metal-containing compounds and by manufacturing new products from them, he gradually introduced millions of pounds of cadmium, lead, and mercury into an environment in which they did not occur naturally. Because all three metals are elements they contain atoms of only one kind and, hence, will not be broken down by chemical forces in the environment. With their concentrations pushed much beyond what had been their natural levels, the three metals began to disturb the balance of nature and by the 1970s their adverse biological properties were being recognized as threats to man's well-being.

Although each of the three metals has increased steadily in the environment in proportion to its value to industrial and technological expansion, each is now seen as a threat to life for different reasons. Lead has become ubiquitous in land, air, sea, plants, and animals in direct proportion to the proliferation of the automobile and the gasoline it uses as a fuel. The deadly effects of mercury, previously considered hazardous only to industrial and laboratory workers, have been magnified ominously with the discovery that by a natural phenomenon mercury is reacting with organisms in the bodies of water in which it is dumped to produce what may well be a common health hazard. Cadmium, which has so many applications that it is used at twice the level of mercury, is now suspected of being a major contributing factor to the increased incidence of high blood pressure and heart disease.

Akhtar Hussein from Woodfin Camp



The metals that may threaten man's well-being pollute in proportion to their usefulness. Fine particles discharged from forest product industries, such as the paper plant in Mississippi (above), rank second only to those of coal-fired power producers and are believed to include traces of the mercury found in pulp and its bleaching agents. Of all atmospheric emissions from industries, 45% are estimated to come from those processing cadmium-bearing ores, such as the copper being poured into molds at a Nevada mine (opposite page). Metallic runoff directly into water supplies has been curtailed, but little is known of the amounts of metals in particulate emissions and of their eventual dispersal in the environment.

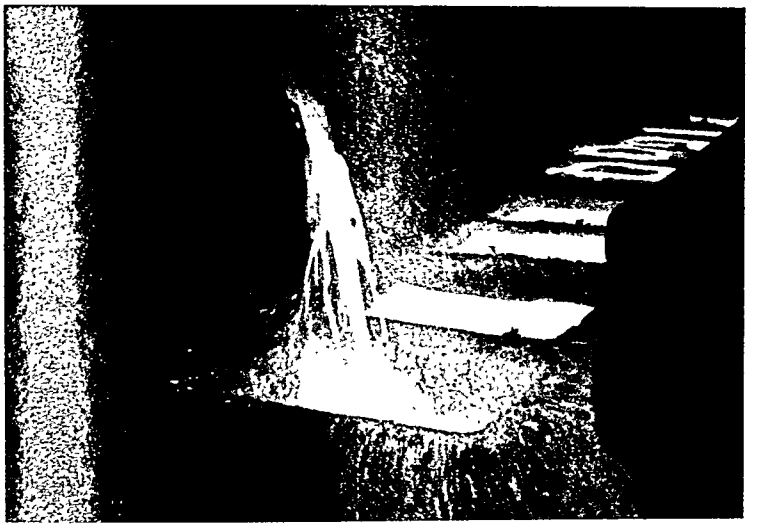
Mercury: messenger of death?

Only within the last ten years has man come to realize that the uncounted millions of pounds of mercury wastes previously believed to be safely resting at the bottom of the world's oceans, lakes, and rivers are slowly being converted into a toxic form called methyl mercury that has already had drastic effects on birds, fish, and other animals including man. Methyl mercury is formed by the combination of an inorganic mercury compound with a one-carbon organic molecule, an action that can be precipitated by the organisms in bodies of water. It is seen as a special threat to man because it has a long biological half-life (about 70 days in man) compared to the inorganic forms of mercury, which are usually excreted from the body in a few days. Methyl mercury's bad reputation is fortified by the fact that it easily passes through biological membranes, including the barrier that separates the brain from the rest of the body. The compound is particularly destructive to nerve cells, and early symptoms of methyl mercury poisoning include headache and fatigue. These are followed by sensitivity loss in toes and fingers, visual disorders, poor muscular coordination, speech and hearing difficulties, mental retardation, and death.

Mercury is not normally dangerous in its natural liquid metal form, although scattered deaths have occurred when industrial workers have inhaled its vaporized fumes. Inorganic mercury compounds, such as mercuric chloride, have been used to commit suicide, and workers in felt hat factories have been driven literally "mad as a hatter" by the mercuric nitrate used to improve the felting properties of wool. There have also been many deaths and illnesses recorded in the various industries that mine, manufacture, or use mercury. These cases, however, have never been seen as serious enough to pose an international threat to human health. Industries using the inorganic mercury compounds have felt no qualms about dumping wastes containing them into lakes and rivers, where they were presumed to settle safely.

JOHN F. HENAHAN, *a science writer for* Intellectual Digest, *is the author of* Men and Molecules.

Paolo Koch from Rapho-Guillumette



Within the 20th century, about 163 million pounds of mined mercury have been used; according to the U.S. Bureau of Mines, between 1959 and 1969 mercury consumption in the U.S. doubled to more than 6 million pounds annually. The greatest single use of mercury is as a component in the electrodes that prepare high-purity sodium hydroxide and chlorine gas from brine solutions to meet needs of the petroleum, glass, paper, and detergent industries. Mercury is also used in catalysts for the manufacture of the versatile plastic polyvinyl chloride (PVC) and is being used increasingly in specialized electrical applications, such as silent switches, arc rectifiers, high-intensity street lamps, and batteries for transistor radios. Mercury or its compounds is also used for making amalgams for dental fillings, for temperature and pressure control devices, in mildew-resistant paints, in agriculture as a seed sterilant, and in medicine as antibacterial agents (for example, mercurochrome).

Each of these applications is responsible to a greater or lesser extent for the increased presence of mercury in the environment. About one third of all mined mercury cannot be accounted for and is presumed to have been dispersed. Poor pollution control techniques used in smelters and ore-refining plants and in the chloralkali and PVC industries have been major contributing factors to mercury contamination; runoff from farms treated with mercury fungicides has been another; and simple carelessness in industry, dental office, laboratory, and home has also contributed. In addition, the burning of coal, oil, and lignite, which contain traces of mercury, spews a million or so pounds of the metal into the air every year, perhaps more than is released by any other means.

The methyl mercury crisis

The current concern over methyl mercury pollution can be traced to 1953 when residents of Minamata, a fishing village in Japan, reported

Courtesy, Dr. J. M. Wood, University of Illinois



Poisonous methyl mercury is formed by the chemical reaction of the less harmful inorganic form of mercury with an organic molecule. University of Illinois biochemists established that microorganisms commonly found in bodies of water can accomplish this synthesis. One such organism, Methanobacterium formicicum, *is shown above as it appears under a phase contrast microscope, which is used to reveal details not visible under a normal microscope.*

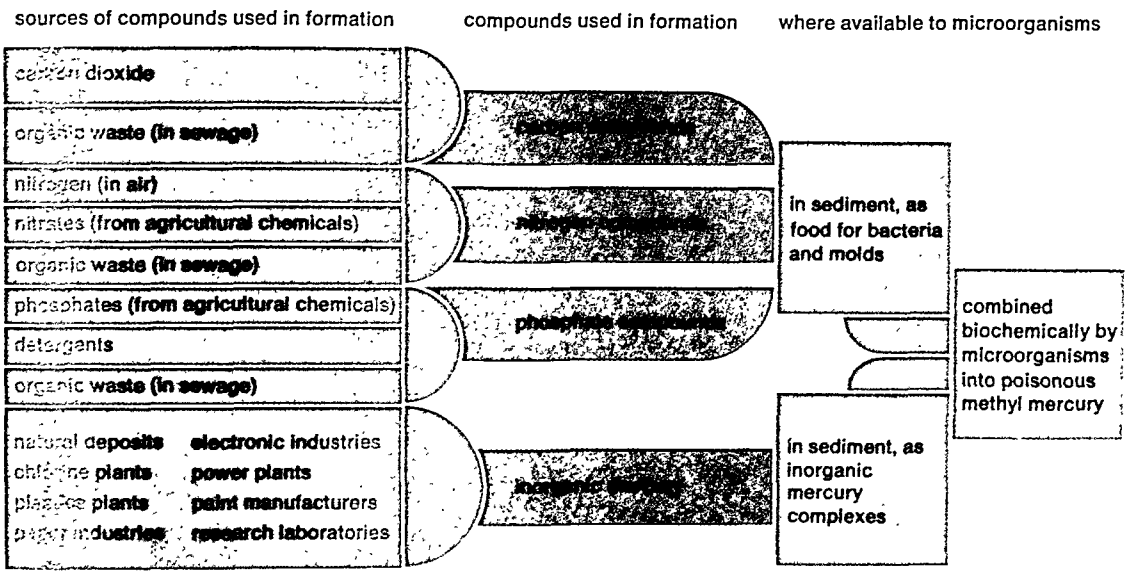
strange omens: cats ran screaming into the sea and crows fell from the sky. Soon after, Minamatans began to complain of aching muscles and distorted vision in which they appeared to be seeing through a long tube. Then a father and his young son went mad and died. In the next nine years, another 110 persons up and down the coast of Minamata Bay developed the same symptoms and 36 died. Some survivors were left blind and deaf, and many children were born with what came to be known as "Minamata disease." In 1965, the disease broke out in the Japanese city of Niigata; 50 residents became ill, 16 died, and many babies seemed to be affected by the disease.

In Minamata, physicians began to recognize that the symptoms of the strange disease were very much like methyl mercury poisoning. Their suspicion was strengthened when they learned that a PVC plant nearby was pouring large amounts of mercuric chloride into the bay and that all victims of the disease—including the cats and crows—ate fish from the bay as a major portion of their diet. (A PVC plant was also located in Niigata.) Originally, Japanese scientists speculated that the normally innocuous mercuric chloride had somehow been converted to toxic methyl mercury, perhaps by bacterial action in the water, but they learned later that the electrodes of the chemical plant contained appreciable amounts of methyl mercury.

Sediment near the Minamata plant was shown to contain two million parts per billion (ppb) mercury, while mercury in the bay water itself ranged from 1.6 ppb to 3.6 ppb, compared to natural background levels of from 0.3 ppb to 2.0 ppb. It was also learned that fish and shellfish eaten by the residents of Minamata and Niigata had somehow concentrated the mercury (predominantly in the form of methyl mercury) in their bodies at levels of 5–6 parts per million (ppm), about 100 times the 0.05 ppm the World Health Organization (WHO) considers the irreducible minimum of mercuric residue and 10 times the 0.5 ppm "interim guideline" suggested in 1970 by the U.S. Food and Drug Administration (FDA).

Methyl mercury poisoning cropped up in a different guise in Sweden in the early 1960s when conservationists observed population drops among many seed-eating birds, including pheasants and partridges, and among their predators. The decline was linked to an agricultural seed sterilant (methyl mercury dicyanodiamide), which had been in use in Sweden for more than 20 years. Apparently, the birds fed heavily on treated seeds and were poisoned. Sweden forbade the use of the compound in early 1966, and the bird population began to return to normal levels.

Three years later several members of a family in Alamogordo, N.M., came down with what appeared to be various stages of methyl mercury poisoning after they had eaten the meat of a hog that accidentally had been fed grain (millet seed) treated with the methyl mercury seed sterilant. Although the family was treated quickly with various metal-scavenging drugs, one child went blind and two others developed brain damage. The condition of a fourth child born after the mother had



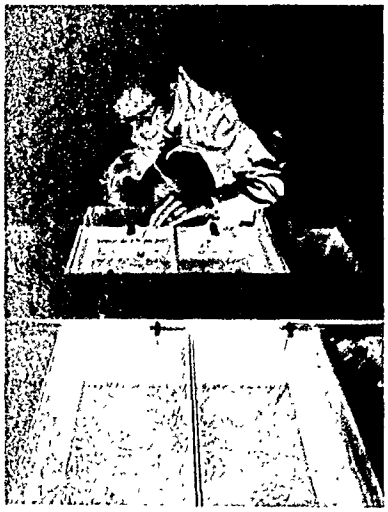
The potential for widespread methyl mercury contamination is enhanced by many kinds of industrial pollution. Carbon dioxide, organic wastes, nitrates, and phosphates provide food for the organisms that permit transformation of inorganic mercury runoff from industries into methyl mercury. Following alarming reports in 1970, U.S. and Canadian industries virtually eliminated the flow of new mercury into lakes and rivers. Nonetheless, enough remained in some sediment to permit methylation to continue for generations. Some control might be accomplished by limiting the entry of the carbon, nitrogen, and phosphate compounds into the water, which, in turn, would limit growth of the microorganisms.

eaten the contaminated pork remained uncertain. Shortly after the Alamogordo poisonings, the U.S. Department of Agriculture banned the use of methyl mercury fungicides but the manufacturer obtained a court injunction permitting the chemical to remain in use.

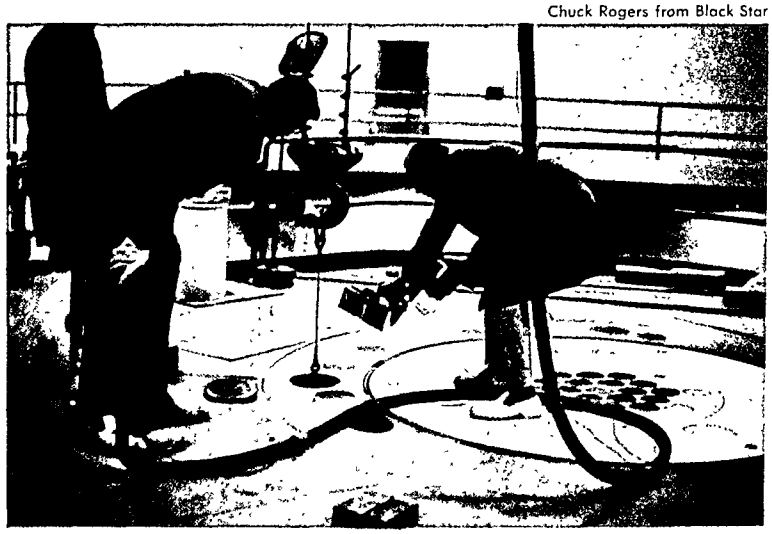
Despite the mercury-linked disasters in Japan, Sweden, and the U.S., response remained minimal until March 1970 when Norvald Fimreite, a chemist at the University of Western Ontario, found that commercial shipments of fish from Lake St. Clair (near Detroit) contained mercury close to the levels found in the fish involved in the Minamata and Niigata episodes. The Canadian government quickly closed its side of the lake to commercial fishing and warned residents against eating fish from the lake. Other chemists reported similarly high levels (about 7 ppm) in fish from many other lakes and rivers along the U.S.-Canadian border, including the Great Lakes, and, subsequently, from the waters of 33 of the 50 U.S. states. Many lakes and rivers were closed to fishing, and localities lost considerable revenues from tourism and license fees. In most cases chloralkali plants or pulp and paper processors were located on or near the polluted waters (the sodium hydroxide used in paper processing contains residual mercury). Prodded by quick action by then U.S. Secretary of the Interior Walter J. Hickel and several suits filed by the U.S. Justice Department, industries cut their mercury flow to a trickle.

The scope of the mercury pollution problem broadened throughout 1970 and 1971: Levels of mercury (primarily other than methyl mercury) in a range of Canadian foodstuffs, including bread, beef, and chicken, were almost invariably determined to be higher than the WHO minimum. The discovery that much tunafish and swordfish sold in the U.S. contained mercury (almost entirely methyl mercury) in excess of the

Jon Brenneis



Chuck Rogers from Black Star



Various scientific efforts attempt to assess the effects of high levels of metals in different environments. Above, salmon are raised in tanks with concentrations of heavy metals to establish whether contamination of the fresh water where salmon breed will affect their ability to survive their transition to the salt water where they will live most of their lives. At the right, researchers lower a sample of hair from Alaskan Aleuts into a nuclear reactor where it will be bombarded with neutrons so that traces of mercury in the hair can be measured. Hair is known to reflect the presence of poisonous metals in the body. The Aleuts were found to be ingesting very high levels of mercury with their food.

FDA safety level, resulted in the temporary withdrawal of some brands of canned tunafish and the virtual destruction of the U.S. swordfish industry. A New York physician found that a woman patient on a weight-reducing diet involving heavy intake of swordfish had symptoms typical of methyl mercury poisoning. Aleutian Eskimos were advised to discontinue their traditional practice of eating the livers of Alaskan fur seals and vitamin supplements made from seal liver were forced off the market because of their excessive mercury levels.

The most frightening aspect of mercury pollution, according to many scientists, is that there is an enormous reservoir of the metal on the bottoms of lakes and rivers waiting to be converted by microbial action into the deadly methyl mercury. The methyl mercury is absorbed by phytoplankton, which are eaten by small fish. As the small fish are devoured by larger fish, which are then eaten by man, methyl mercury contamination spreads throughout the food chain. John Wood, a University of Illinois biochemist who was among those who proved that the transformation of inorganic mercury to methyl mercury occurs, estimates that it will take about 5,000 years for microorganisms to eliminate all the 200,000 pounds of mercury now known to be in Lake St. Clair sediments.

A number of researchers have found that preserved fish—some as much as 2,000 years old—have as much mercury in them as today's "contaminated" fish. Some scientists interpret this finding to mean that the hazards of being poisoned because of the current mercury content of fish is overrated. Others maintain that this implies that there may be a vast natural reservoir of mercury, which, when coupled with man's mercury contribution, only means that more methyl mercury may be being formed than is currently believed.

Problems of mercury control

Many scientists are questioning the security offered by the FDA's 0.5 ppm guideline, preferring the much lower WHO minimum level. En-

vironmentalist Barry Commoner, for example, insists that the FDA guideline is far too narrow when compared with safety margins applied to other toxic materials. Wood argues that the current practice of measuring "total mercury" in foods is pointless because it does not distinguish between inorganic and methyl mercury. Even though Swedish scientists have established that most of the mercury in fish is methyl mercury, Wood maintains it is possible that the high levels of mercury in other foods may be inorganic and, therefore, much less hazardous. The mercury standards also appear to be questionable when eating habits are taken into account. Wood suggests that if Americans and Canadians ate fish as often as the Japanese in Minamata do, methyl mercury poisoning might be rampant in North America.

Safety thresholds for mercury are as vague as they are because it is not known just how much methyl mercury in the blood is required before poisoning occurs. Although death has occurred when mercury levels in blood reached 1.4 ppm, some populations have shown no symptoms of poisoning when mercury levels were as high as those of other populations showing overt symptoms. Neurological damage may occur at levels as low as 0.4–1.0 ppm of mercury, but little is known about what else happens at or below those levels. Treatment for mercury poisoning is even less well-defined. Physicians have used penicillin derivatives and agents for countering the effects of poison gas with uncertain success. In 1971, however, T. W. Clarkson of the University of Rochester, N.Y., reported that ion exchange resins similar to those used in water conditioners increased the rate of mercury excretion in laboratory animals.

Several methods, in addition to the better industrial controls, have been suggested to prevent the inorganic mercury–methyl mercury transformation. One obvious method would be to dredge the mercury from lake sediments. But, when that approach was tried in Minamata Bay, the sediments were stirred and inorganic mercury was spread over a wider area. The amount of methyl mercury actually increased. Covering the sediments with nonmercury-containing ores has also been tried on a moderate scale with some success. The best method, suggests Wood, might be to prevent the growth of the microbes needed for methyl mercury formation. This could be done by reducing the amount of phosphates and nitrogen compounds that normally promote microbial growth.

Erich Hartmann from Magnum



An emission spectrograph measures the presence of metals in water. Metal traces are isolated when water in the porcelain tray is vaporized by a spark from a graphite-arc device.

The lead problem

Man has been poisoning himself with lead for as long as he has known how to extract it from the earth. Romans are known to have died or gone insane from the lead oxide used to reduce the acidity of their wines. In the Massachusetts Bay Colony, settlers were poisoned when they drank rum distilled in lead vessels. In modern times, children are poisoned by nibbling the peeling paint of old buildings and adults can die from the poisoning effects of lead-bearing bullets rather than from the wounds they inflict. Other cases of lead poisoning appear wherever

Courtesy, Dr. Derek J. Cripps, University of Wisconsin



Industrial activity is responsible for the increased presence of lead in the body as well as in remote parts of the earth. Even exposure to quite low levels of lead produces changes in the synthesis of porphyrins, substances needed for the production of hemoglobin in red blood cells. In certain solutions, porphyrins show an intense red fluorescence, which is captured (above) in a highly specialized type of microphotograph. Far below the entrance to a tunnel driven into the permanent snowfields of Antarctica (opposite page), amounts of lead in ice and snow samples were found to have increased steadily with the passage of time. The largest increase occurred after the introduction of tetraethyl lead into gasoline in 1923.

lead or some of its more toxic compounds are manufactured, inhaled, ingested, or added to the air.

Lead poisoning is one of the most unpleasant ailments afflicting mankind. Yet, many of its symptoms are deceptively commonplace and often misdiagnosed as lesser problems, such as headache, diarrhea, or just plain irritability. As the lead reaches its as yet poorly defined toxic level in the body, the symptoms of poisoning become more characteristic and lead to wild delirium, coma, convulsions, blindness, mental retardation, brain damage, and death.

Every one million pounds of the earth's crust contains an average of 16 pounds of lead, usually in one of its three major mineral forms, lead sulfide, lead carbonate, or lead sulfate. Man has a great hunger for this lead. In the United States about 590,000 tons were mined in 1969, primarily in Missouri, Idaho, and Utah. Another 500,000 tons of lead scrap were recovered, usually from automobile storage batteries, and 250,000 tons were imported.

Lead ores are usually concentrated by a process called ore flotation and then sent to smelters and refineries to be converted into pig lead. In each part of the process, some lead is lost to the environment. It is spewed into the air through the giant stacks of the smelters or washed into rivers and streams adjacent to mining sites. Later it may be lost into the air, water, and soil in the course of any number of manufacturing processes that use or produce lead-containing materials.

Lead is also dispersed throughout the atmosphere in volcanic eruptions, in sea spray, and in the dust and smoke of occasional forest fires. Such natural sources of lead pollution existed long before man appeared, but it is now clear that the polluting effect of man's use of lead has far outstripped the natural background levels of lead in the world. C. C. Patterson of the California Institute of Technology measured lead levels in ice samples collected from Greenland, with the realization that the deeper the ice was the older it would be. In ice presumed to have

Courtesy, Dr Clair C. Patterson



been formed about 500 B.C. he found approximately eight grams of lead per ton of ice. Obviously, this lead could only have been introduced by natural processes. The lead levels in ice samples formed in 1950 were found to have increased to 90 grams per ton and to have risen again to 210 grams per ton by 1965. Such sudden increases are hardly the result of natural phenomena. In another study, Henry A. Schroeder and his colleagues at the Dartmouth Medical School, Hanover, N.H., measured the lead levels in the rings of an elm tree growing about 150 feet from a lightly travelled street. They found that the lead content per million parts of wood had increased from about 0.16 in rings dating from the mid-19th century to 3.90 in rings formed in 1960.

As with most of the environmental contaminants that now appear to plague man and threaten his future, lead pollutes more or less in direct proportion to the amount being used, even though different forms of lead pollute in different ways and to different extents. The two major sources of current lead pollution problems are related to the rise of the automobile and the internal combustion engine. In the U.S., most lead goes into the production of storage batteries in automobiles. Lead consumption for this purpose tripled from 1934 to nearly 600 million tons in 1970. Although, fortunately, most of this lead is recycled to make new batteries, battery lead makes up about 10% of the lead now being added to the environment.

The second major use for lead, and by all odds the greatest contributor of lead to the atmosphere, is in tetraethyl lead (TEL), an especially poisonous organic chemical used since 1923 as an antiknock additive to upgrade gasoline. Use of TEL increased phenomenally when it was found that it could enhance gasoline octane sufficiently to power modern high-compression engines. In 1970, 275,506 tons of lead, or anywhere from 2.5 to 4.0 grams of TEL per gallon of high-test gasoline, were added to gasolines in the United States; 50 years ago, essentially no lead was used for this purpose. Unlike battery lead, the lead in TEL

cannot be recycled, and is expelled into the atmosphere at the rate of 200,000 tons a year; the rest remains behind in the automobile's lubricating oil or exhaust system, where it prevents buildup of harmful iron oxide particles. In fact, lead from automobile exhausts accounts for 94.8% of the lead in the air we breathe, compared to 0.5% contributed by smelter stacks.

Toxicologists and pathologists are particularly concerned about the lead from automobile exhausts because it enters the air as extremely fine particles averaging 0.25 microns in diameter (one micron = 0.001 millimeter), which can be inhaled easily. When inhaled, about 45% of the lead from auto exhausts is absorbed into the lungs and then distributed throughout the rest of the body via the bloodstream; in contrast, the body retains only about 5–10% of the lead ingested with food.

Dangers of lead in the atmosphere

Very little is yet known about the effects of low-level exposure to lead, the kind of exposure persons breathing urban air may be experiencing daily, and the kind that poses a long-range threat to man, since lead is known to accumulate in the body, frequently in the bones, with advancing age. There is some evidence that low levels of lead inhibit the formation of an important blood enzyme, delta-aminolevulinic acid dehydrase (ALA-dehydrase), which aids in the synthesis of hemoglobin, the oxygen-carrying molecule in red blood cells. Without better evidence of this or other ill effects of low-level exposure, it remains difficult to establish reliable safety standards for lead in the human body.

There is little doubt, however, that the automobile is adding heavily to the danger of widespread low-level intoxication. In some large U.S. cities, such as Los Angeles and New York, lead concentration in the air is 20 times greater than it is in sparsely populated areas, and 2,000 times greater than it is in the uncluttered atmosphere above the mid-Pacific. In a report in 1971, the National Research Council of the National Academy of Sciences warned that traffic policemen at busy intersections, gasoline service station attendants, mid-city dwellers, and, especially, young children living in cities are potential victims of lead poisoning from the air. Recent surveys of children, and, in some cases, adults, in several large cities have found 40–60 micrograms of lead per gram of blood. This is about half the level known to cause clinical lead poisoning in adults in many well-documented cases. It is also well documented that children are more susceptible to lead intoxication than adults.

Getting the lead out

In 1970, gasoline and automobile manufacturers responded to the growing public clamor for controls on lead emissions. The gasoline manufacturers came out with low or no-lead grades of fuel, and the automobile makers redesigned the engines used in 1971 models so that they could handle the new gasolines. At the same time, federal, state, and municipal governments enacted legislation demanding de-

creases in lead levels to 1.7 grams per gallon or less by 1975. The automobile manufacturers were not reluctant to cooperate. They realized, among other factors, that if lead were still being used at 1970 levels in 1975 cars, the catalytic antismog devices they are compelled to develop by that date to meet federal standards will not operate properly.

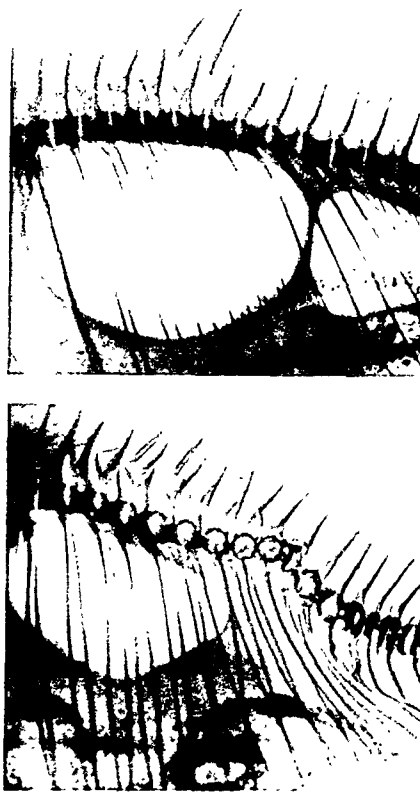
However, the good and bad aspects of the new low-lead or no-lead gasolines were still being debated in 1972. The new gasolines usually have a lower octane rating (about 91) than leaded gasoline (about 100) and they do not perform well in older cars, some of which will still be on the road in 1980. (Octane rating is an arbitrary measure of a gasoline's resistance to knocking and indirectly of its performance.) If the gasoline industry were to produce lead-free gasolines that would meet the needs of older cars, these highly refined gasolines would contain more hydrocarbons of the olefin and aromatic type, which could cause more eye-smarting smog than leaded gasolines do. The industry estimates that such a conversion would cost it $4 billion–$5 billion and add 4–5 cents to the consumer's per gallon gasoline costs. Manufacturers of TEL (Ethyl Corp. and E. I. du Pont de Nemours & Co.) assert that valves wear out quickly without TEL. Others point out that when lead is removed, mufflers, rings, cylinders, and exhaust control devices work better and longer and result in overall gasoline cost reductions of nearly two cents a gallon.

Although smelters, ore refineries, and other lead-using industries are also responsible for the increase in environmental lead, most of these industries are close-mouthed about how much lead they discharge, how they control it, and how much their abatement measures cost. Currently they use a variety of filters, precipitators, separators, and scrubbers, some of which are as much as 99% effective. Actual performance, however, depends to a great extent on how seriously the individual plant takes its lead control responsibilities. As for lead pollution of water supplies, a recent report prepared by the University of Illinois notes that standard water treatment processes in use in the United States can keep lead in the country's drinking water at a safe level (less than 50 micrograms per liter).

Cadmium: the most lethal metal?

Of the metals that may pose threats to human health, cadmium can be singled out as the most lethal, even though its ill effects have not been studied as painstakingly or completely as those of lead or mercury. Cadmium's deadliness comes from its known ability to build up in the body, especially in the kidneys, and its link, at least statistically, to hypertension (high blood pressure) and heart disease. In animals, even small dosages have produced brain damage, birth defects, damage to the reproductive organs, blood abnormalities, and many other physiological disturbances. In man, inhalation of cadmium dust is known to have caused lung damage resembling emphysema. The Japanese Ministry of Health and Welfare has reported that since 1962 cadmium from mine wastes have contaminated food and water supplies in parts

Courtesy, Dr J Kobayashi, Okayama University



Chronic cadmium poisoning was blamed for the contrast between the backbone of a normal young carp (top) and that of an abnormal one (bottom), as seen in X-ray photographs. The abnormal fish was raised in water containing a high concentration of cadmium. Its bones show the same damage noted among sufferers of Itai-Itai *disease in Japan: a loss of calcium leaves the bones transparent and severely softened, so that they collapse under slight pressure.*



Courtesy, Dr. J. Kobayashi, Okayama University

The incidence of Itai-Itai *disease was limited to inhabitants of low rice fields irrigated by a river carrying the waste waters of a mine producing zinc, lead, and cadmium. The farmers blamed the mine's wastes for damage to their rice crop (above) but did not connect the simultaneous appearance of disease among their families with their use of the river's water in their kitchens (opposite page). After 1955, when a dam began collecting the mine's wastes, crops returned to normal and the number of* Itai-Itai *cases dropped rapidly.*

of northern Japan and led to more than 220 cases of a severe degenerative bone disease, called *Itai-Itai*, or "It hurts! It hurts!" after the cries of patients suffering the severe pain that results. The disease has killed 50 people who were first exposed to cadmium discharges during or after World War II. The cause of the disease was not recognized until 1955 and, by that time, many sufferers had become hopeless cripples.

A study carried out for the National Air Pollution Control Administration (NAPCA) of the Environmental Protection Agency showed that about 13,328,000 pounds of cadmium were used in 1968 and that about 4,600,000 pounds of that were vented into the air. Consumption of cadmium and its discharge into the atmosphere can only have increased since 1968, since the industries that use it and its compounds have expanded. According to the NAPCA report most of the cadmium in the air is vented in the form of cadmium oxides and sulfides from smelters that refine cadmium-containing ores of lead, zinc, and copper. In 1968, about 2.1 million pounds of the cadmium delivered to the air came from ore processing and refining sources. Almost the same amount was produced as a result of the recycling of cadmium-plated iron and steel. Other sources of air-borne cadmium are scrapped automobile radiators, the incineration of plastic wastes, tire wear, combustion of motor oil, compounding of cadmium pigments and plastic stabilizers, preparation of cadmium alloys, and cadmium-containing fertilizers and pesticides. Cities closest to smelters and metallurgical industries usually bear the brunt of cadmium pollution of the air. Their water supplies are probably also polluted by cadmium, but no comprehensive measurements of this type have been made.

Toxicologists are concerned about cadmium as a hazard to man's health not just because of its well known effects on the kidneys and lungs but also because it appears to build up in the kidneys and other organs to concentrations equivalent to those known to shorten life and cause hypertension in rats. Dartmouth's Schroeder found more cause for alarm in the human situation when he measured higher levels of cadmium in the kidneys of patients who died from hypertension than in patients who died from cancer, hepatitis, or diabetes.

Because there is so little irrefutable evidence about the long-range effects of less than obviously toxic exposure to cadmium, health officials have been slow to set up standard levels for it in air, food, and water. A joint FDA/WHO commission has suggested but never established a maximum permissible level in food of 5 ppm (compared to 0.5 ppm for mercury), even though concerned scientists, notably Robert Nilsson of the Swedish Natural Science Research Council, insist that animal studies and the Japanese cadmium poisoning incidents make that level much too high. To date, the United States has established the maximum permissible amount of cadmium in drinking water as 0.01 ppm. Measurements of the metal's presence in rivers and reservoirs throughout the country carried out by the U.S. Geological Survey indicated that 33 out of 720 water samples tested were higher in cadmium than the prescribed level. The implications of these higher levels are

not clear, but some scientists give them an ominous interpretation since cadmium has proved to be such a frightening poison.



The metal crisis and the future

Discovery of the possible hazards evolving from the increasing amounts of mercury, lead, and cadmium in man's environment has triggered investigations of three other likely metallic hazards: nickel, zinc, and arsenic. Nickel, for example, has been found to have a proven ability to induce cancer. But, compared with what is known of the three notorious metals, very little has been established about any current or potential environmental impact of the others.

For mercury, if the most pessimistic predictions are correct, the potential for danger to mankind is growing every day. Even if the most effective methods for controlling further mercury discharges were put into practice overnight, millions of pounds of inorganic mercury would remain in lake and river sediments waiting to be converted to the lethal methyl form. An optimist might decide that the Minamata experience, the Swedish bird crisis, and the New Mexican disaster were only scattered incidents of carelessness and poor planning. If so, and if present levels of mercury contamination are not a long-range threat to the world's health, the optimist will have his day and so will mankind. The question is, how many are willing to gamble their futures on "ifs"?

The solution to the lead problem may be easier. Many authorities believe that if lead is removed from gasoline, the back of the lead pollution problem will be broken. Automobile owners may then have to settle for less powerful cars, but may gain longer lives in exchange.

Cadmium may be the most lethal member of the three notorious metals, but, for the most part, its environmental impact is unknown and befogged by inconclusive data. Perhaps the most that can be said about it at this time is that the enormous amounts of such a deadly metal that are now in the air will probably not improve anyone's health.

Confronted as the deadly trio they are already known to be, mercury, lead, and cadmium represent but one example of how man has altered his relationships with the earth and indirectly impaired his health and well-being. Once, each of the three metals occupied its niche in the balance of nature. Man removed them from the earth in great volume and distributed them unthinkingly into parts of the physical environment where they never really belonged. This may represent a small aspect of the current ecological crisis, but in the case of these three metals, it is certainly an ominous one.

FOR ADDITIONAL READING:

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Crime Fighters in the Laboratory

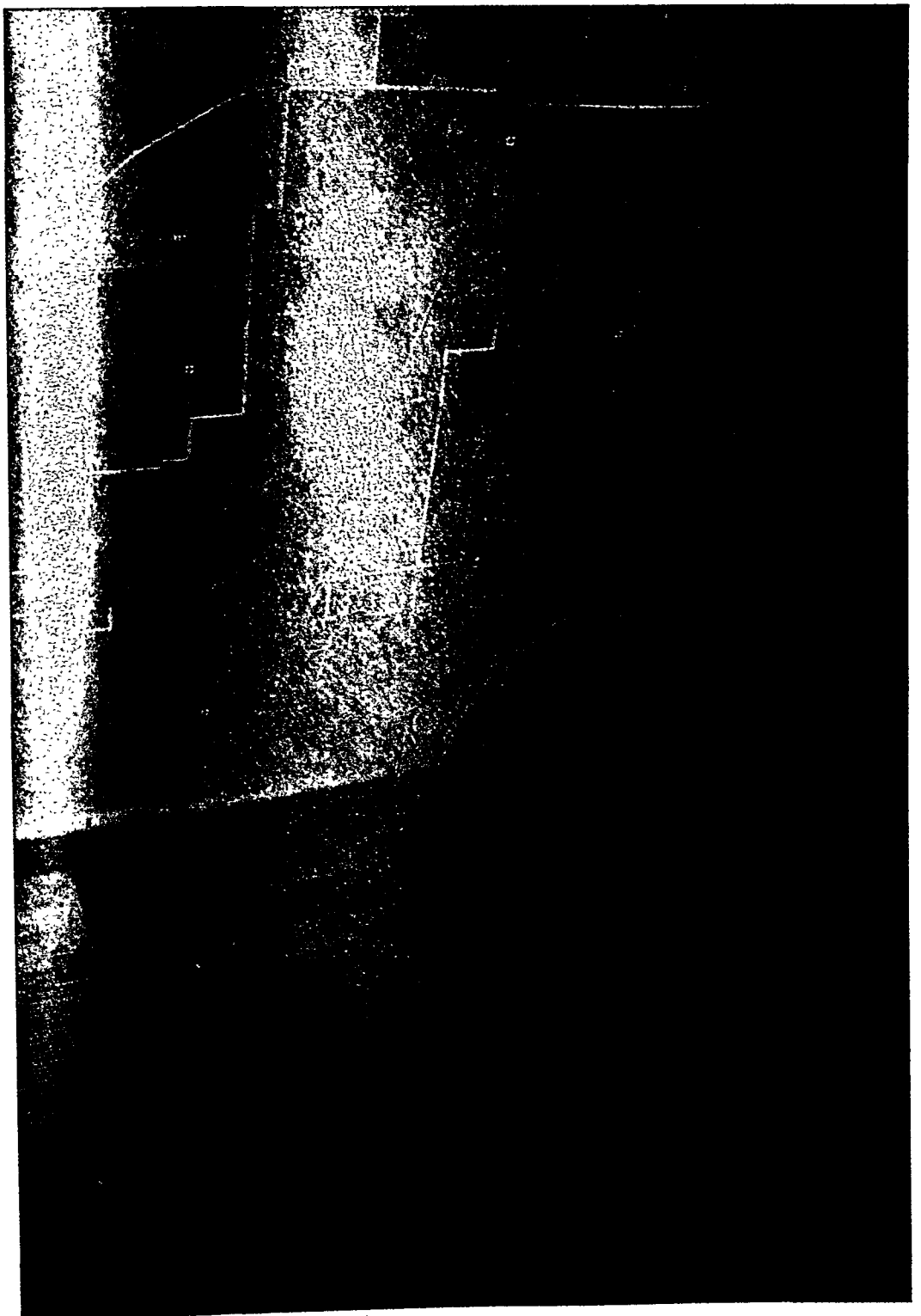
by Alexander Joseph

Backing up the modern detective is an armory of advanced scientific techniques undreamed of by Arthur Conan Doyle in his wildest flights of fancy.

> Detection is, or ought to be, an exact science, and should be treated in the same cold and unemotional manner.
>
> —Sherlock Holmes in *The Sign of Four*

The potential of science and technology in law enforcement was first recognized almost a century ago. Institutionally, it was introduced through the Assay Office of Scotland Yard. Dramatically, it was introduced through Sherlock Holmes in the narratives of Sir Arthur Conan Doyle. By the turn of the century, Holmes was triumphantly the image of the scientific detective—the cerebral man instead of the merely muscular one. In the real world, the Assay Office set the precedent for police departments throughout the world, which were to move from fingerprint identification—then a radically new procedure—and paraffin tests to emission spectrography, analytical gas chromatography, and X-ray diffraction. The "basic" police-lab sciences of chemistry, biology, and physics quickly became allied with the technologies of electronics, wide-spectrum photography, and light- and sound-wave mechanics.

In the last few years, the style, tone, and range of the science and technology of law enforcement have been given an enormous new thrust and a vast new urgency. These were generated in part by appropriations of the U.S. Congress, made in the 1960s to assist further and deeper research into the subject. They were complemented by the marketing mechanisms of U.S. private industry, which developed arcane devices in the 1960s—mostly for use in the Vietnam war—and was later impelled to seek alternative outlets for them.



Photos, Dan Morrill, courtesy, Chicago Police Department

Here, for example, are some of the devices and procedures that emerged from the Vietnam war to become part of the science and technology of law enforcement:

• Unmanned, remote-controlled aircraft equipped to pick up signals from ground sensors are being used by the U.S. Border Patrol to fly over isolated stretches of the Mexican-U.S. border. The system was initially designed for an anti-infiltration program in Indochina. The drone picks up signals from hundreds of sensors, adapted from devices used to detect the sounds and vibrations of troops and trucks moving along the Ho Chi Minh Trail. In this way, an enormous stretch of isolated border can be patrolled, without human personnel, in a very short time.

Moreover, the information thus gathered can be relayed instantly to a computer that will sift and collate it. In the past, it took days, weeks, or even months before human patrolmen scouting the same area could get their reports analyzed to see if there was a recognizable pattern of illicit traffic across the border. Now the same work can be done in microseconds. Border patrolmen can be dispatched to a scene while suspected offenders are still in the vicinity. There is one difficulty, however: the system detects movements, but it does not say who, or what, caused them. A wandering burro is as likely as a drug smuggler to send officers of the U.S. Border Patrol rushing to their jeeps.

• A "no-light" technology allows police officers to see suspects and other persons with great clarity at night, no matter how dim the light. The technology is based on a method of amplifying light levels as much as 40,000 times; even the light from a single star can be amplified satisfactorily for use in this system. Perfected to meet the need of the U.S. military for detecting night-fighting guerrillas in Vietnam, the "snooperscope" is now used by some big-city police departments against snipers and in other instances where night vision is required.

A more general adaptation of the technology involves the use of either still photography or closed-circuit television. The latter permits constant surveillance of many locations at night, even from long distances. Such a system is being used to scan the streets of Mount Vernon, N.Y. Its designers say that it is capable of discerning a man-sized object in extreme darkness from more than half a mile away. Thus, it holds promise of relieving the enduring problem of police patrols—that a crime may take place unseen at a location far from the area the squad car is patrolling.

• A "black box" device has been developed that gives radar an X-ray quality, permitting it to suggest who, or what, is behind walls. (Normally, the radar signal bounces back as soon as it encounters an obstruction.) The device, about the size of a cigar box and weighing less than 10 pounds, was originally conceived as a foliage-penetration surveillance system for use in Vietnam. In law enforcement, it can help to determine nighttime occupancy of supposedly "vacant" buildings —such as banks or warehouses—or the potential for ambush in a building that must be entered by police officers.

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To be sure, not all of the new law-enforcement technology is the product of the Vietnam war. For years an enormous stockpile of technological know-how has been building up that is just beginning to be applied to police work. It ranges from aerosol clouds that reflect light from searchlights and can be used to illuminate large areas at night to agents and devices, such as the chemical Mace and rubber bullets, that incapacitate but do not kill, to helicopters.

Some of the technologies have become established parts of the police armamentarium. Others are still controversial. Taken together they are revolutionizing police work.

Voiceprints: identification through the spoken word

According to the developers of the voiceprint system, no two persons have the same resonant cavities; thus, the voice pattern of each person is highly individual and can be used to identify the person in much the same way that fingerprints are used. Employing a machine called the sound spectrograph, researchers can graph the frequency, loudness, and other characteristics of the human voice. The graph—the voiceprint—is said to reveal the distinctive characteristics of each voice. The status of the voiceprint as legal evidence is still a matter of dispute, although it has been admitted as evidence in some cases. Its potential importance is indicated by those cases in which it has played a part.

One spring night in 1970, for example, police headquarters in St. Paul, Minn., received an anonymous phone call seeking help at a certain address for a woman who was about to give birth. A squad car was rushed to the address, but the policemen found only a darkened building. As they explored the area, a sniper suddenly opened fire and one of the policemen was shot and mortally wounded.

The only clue was the tape recording of the original call for help. The police kept that tape, developed its voiceprint, then began interviewing a number of women who lived in the neighborhood of the shooting. They recorded each response in an effort to get a voiceprint that matched the one from the phone call. Among the first 13 women interviewed, they found a suspect: an 18-year-old girl whose voiceprint exactly matched that on the tape recording. She was subsequently indicted and brought to trial for first-degree murder.

Another case in which a voiceprint proved crucial began as a civil suit. A businessman was sued for breach of contract, and the fundamental evidence against him consisted of an ordinary tape recording. The defendant asserted that he had never made any of the statements or promises that were recorded on the tape. This suggested that the man was lying or that the voice on the tape was an impersonation.

To determine the truth, the defendant was asked to speak into the microphone of a voiceprinter. He agreed readily. The voiceprinter showed his voice pattern was clearly different from that on the original tape, even though the words used in both cases were exactly the same. The result: the civil suit against the defendant was dismissed and a charge of fraud was entered against his accusers.

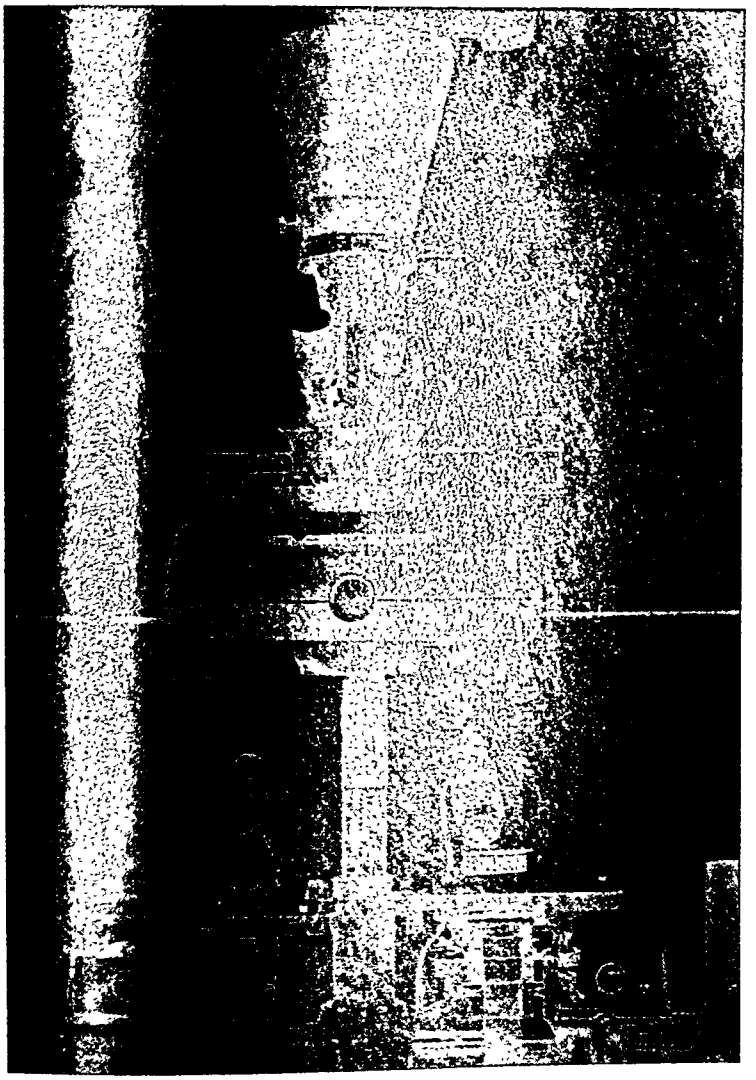
X rays leave the laboratory

Improving technology has made it possible to devise portable, low-voltage X-ray equipment that can be taken into the field. One such system, packed into a small box—about the size of an old-fashioned 4×5 inch press camera—and operated by a low-voltage battery, is virtually revolutionizing the technique of "lifting" latent fingerprints. These are prints taken from a surface that a person has touched. They are called latent because, unlike inked fingerprints taken directly from a person, they are not visible to the naked eye and must be "developed" by various scientific techniques. Historically, the methods used in developing latent prints involved the use of various powders or of chemicals such as iodine, silver nitrate, or Ninhydrin. The prints, when discovered, would be "lifted" off the surface, usually by applying a sticky tape to the chemically treated print. At the police laboratory, a photograph would be made of the tape and the film developed and delivered to a fingerprint division for identification.

This procedure had frustrating limits, however. Prints could not be developed satisfactorily after even a relatively short time had passed. Nor could they be lifted easily off all surfaces. Often the tape could not be applied to—or pulled off of—surfaces with a rough texture or a tendency to adhere or tear when the tape was lifted, such as clothing, paper, or skin. Thus, seven decades after fingerprint identification came into wide use, police departments still relied on prints left on smooth, hard surfaces: glass, polished wood, metal surfaces, and so forth. Not too long ago, New York City police-lab technicians were saying that they got usable fingerprints in only 10% of cases.

The X-ray system has helped overcome these difficulties. It was originally developed in a scientific laboratory in Glasgow, Scot., using full-size X-ray equipment, but recent modifications have brought it into play literally at the scene of the crime. It represents an enormous advance over the older systems. It can be used to pick up latent prints that are many months old. It can develop them from clothing, money, paper documents, "soft" curved surfaces, even the skin of dead bodies. (It was, in fact, used in this way by the Royal Canadian Mounted Police to help solve a quintuple murder in 1969.) And it can produce a usable image of a print within a minute or two of discovery.

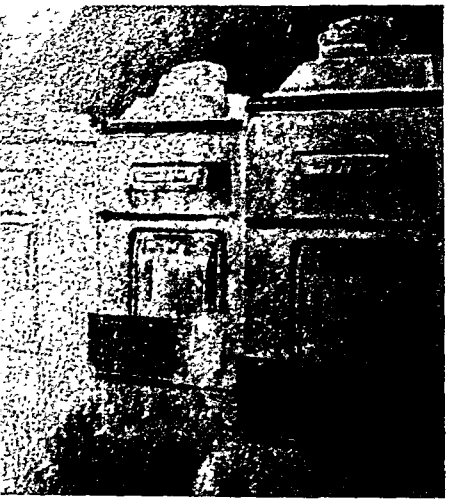
The X-ray system involves a "dusting" technique, as in the older system, but the "dust" is made from a dense metal that shows up clearly on X-ray film. The metal is ground down to an extremely fine powder that tends to arrange itself in the pattern of the print. A quick-developing film, similar to that used in home Polaroid cameras, is placed behind the surface that contains the print. The X-ray machine is brought up to the dusted print, the tube is focused on it, the machine is switched on briefly, and an image of the fingerprint is imprinted through the texture onto the Polaroid film mounted behind it. The film is then developed on the spot; in a minute or two the investigators have in their possession a clear image of a fingerprint and can start checking out the identity of the victim or potential suspect.



The microscope is a versatile instrument in the hands of the police lab technician. Through comparison of toolmarks, he can identify the tools used in the commission of such crimes as breaking and entering. Another use is in the detection of obliterated gun numbers through microscopic examination of the chemically treated surface.

Low-voltage equipment is used in this operation because high-voltage—and more powerful—X-ray units cannot be used casually in areas of high-density human traffic. Thus, magnetometers rather than X rays are used in screening baggage and passengers at airline terminals; otherwise, persons who took a plane more than once or twice a year might receive an overdose of radiation. Nevertheless, portable high-voltage systems are useful in some situations. They make it possible to examine, in isolated areas, those items that cannot possibly be brought to an X-ray laboratory.

For example, in the solitude of the night, U.S. customs agents brought a portable high-voltage X-ray tube to a deserted dockside building in New York City to examine a shipment of canned fish from Spain. Customs had been alerted that a company not normally engaged in canning or fishing was suddenly buying fish cans and—curiously—



Fingerprints obtained in the course of an investigation can be transmitted over telephone lines from a precinct station to the photofacsimile recorder (above) at Chicago police headquarters. The recorder produces a photographic copy that is then used to search the records. The computer (opposite page) in the police department's Data Systems Division can provide, almost instantaneously, information ranging from the license numbers of stolen cars to the arrest record of a suspect to overall crime statistics.

lead fishing sinkers. Quick diversification is not a characteristic of most European corporations, so when a shipment from this company arrived in New York, customs officers entered the dockside warehouse where it was stored and began to examine it.

First they weighed sample cans: the weight was exactly as indicated on the label. Then they brought in the X-ray unit and X-rayed a number of cans. Many of the cans did contain fish, but the X rays also showed that some of them contained lead sinkers. When those cans were opened, the customs officers found that they contained—in addition to the lead sinkers—a great deal of heroin. Heroin is lighter than fish, but the combination of heroin and lead sinkers gave the cans a total weight exactly equal to the listed weight of the fish. The discovery led to the seizure of a multimillion dollar cache of heroin and provided an insight into the methods of drug traffickers.

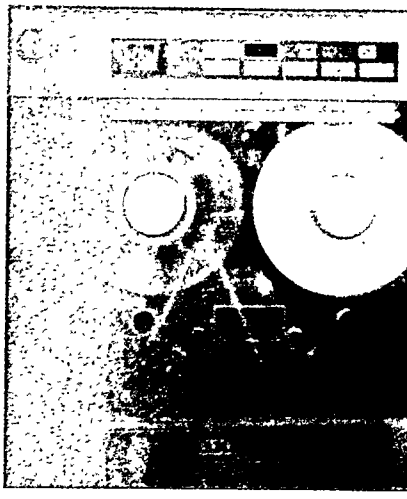
Still photography and videotapes

That photography is now being used effectively in solving bank robberies—and preventing them, by threatening certain identification—is due directly to advances in film technology. Until fairly recently, this use of photography was impractical because of the low light level in most banks. However, improvements in film speed and wide-aperture lens settings now permit clear photographs to be taken indoors. Indeed, the sharp increase in arrest and conviction rates of bank robbers identified through such photographs may have brought about a change in the robbers' methods of operation. The older bank robbers—who would go to prison for life if they were caught—do not appear on the film. Some law-enforcement officers believe they now act as teachers of apprentice thieves who take the risk and split the loot with the older men, especially since young criminals are turning up with exactly the same techniques long used by the older criminals.

Videotaping has also changed certain criminal methods of operation, particularly when it is combined with other advanced technologies, such as helicopters. For decades, thieves being hemmed in by police approaching at ground level would flee to safety over the roof tops. Now they can be spotted from helicopters and followed across the roofs. They can also be photographed, sometimes from great distances, and this videotaped record constitutes irrefutable proof that the accused man was at the scene of the crime.

One night a year or so ago, a thief who invaded a medical center in Kansas City, Kan., was the target of such technology. The report of a potential threat was radioed both to a patrol car and to a helicopter. The helicopter got there first, with a videotape system geared for night photography ready and running. The camera was on when the suspect appeared on the roof, fled across it, and descended to the ground via a fire escape on a nearby building. The helicopter followed the suspect, now in his car, while radioing reports of his position to the ground patrol. Meanwhile, the cameras recorded his every move, right up to the time of his interception and arrest. There was no alibi he could

offer that could contest the videotape record of his flight from the scene of the crime.



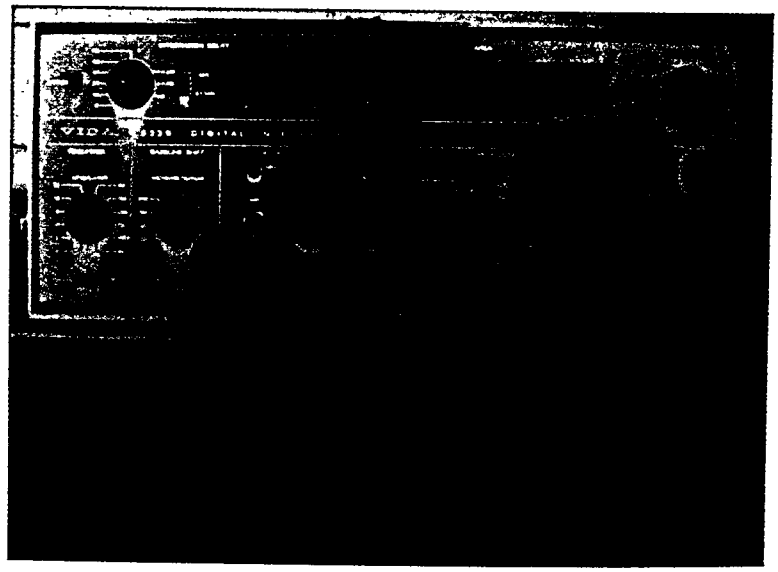
It is this element of proof that gives the general significance to videotaping, even in the most unglamorous areas of law enforcement. Thus the sheriff's police of Bernalillo County, New Mexico—where Albuquerque is located—mounted videotape cameras and recording units in two squad cars used principally in patrolling county roads and in the arrest of drunk drivers. When police officers see a car weaving down the road, they start to take a videotape recording of the car and its movements. When the car is curbed by the police and the driver steps out, his every move is also recorded. If he is falling-down drunk, if he is staggering, if he comes out swinging, the camera has it all on tape. It also has the driver's performance in the usual roadside tests for drunkenness—walking a straight line, picking up coins off the road, touching a finger to the nose.

The camera provides an authentic, irrefutable record of how the driver was behaving and performing at the time he was driving the car, not how he performed 20 or 40 or 60 minutes later when he was booked in the police station. Under the old system, which relied on a blood-alcohol test performed after the suspect was brought in for arrest and booking, the local prosecutor was getting convictions in 66% of drunk-driving cases. After the videotape system was introduced in July 1970, he got 100% convictions in the first 130 cases brought to court.

Enter the computer

The principal use of computers in law enforcement today is for information retrieval. More sophisticated uses of the computer have been slow in coming, but the speed and thoroughness of the information-retrieval program have been immensely gratifying. In fingerprint identification, for example, one reel of magnetic computer tape can hold 5,000,000 frames of fingerprints and a computer can scan those images at the rate of 2,000 a second. Thus, it is possible to make a fingerprint search of dimensions that would have been all but unthinkable before computers came into use.

When a townhouse on West 11th Street in Manhattan blew up in March 1970, for example, the numerical possibilities in fingerprint identification were astronomical. The investigators did not know how many people had been in the house at the time of the explosion. They did not know how many bodies there were; indeed, the blast had been so violent that they could not find enough remains from any one person to make an identification, much less a "body." They did find a number of finger fragments, but putting them together in the proper combination needed for identification, using pre-computer methods, might have been a job covering several lifetimes. High-speed computers were able to sift through all the possible combinations and produce three positive identifications in a matter of a day or so. At the same time, using an older technology—X-ray diffraction—police were able to analyze traces of dynamite found in the wreckage and compare



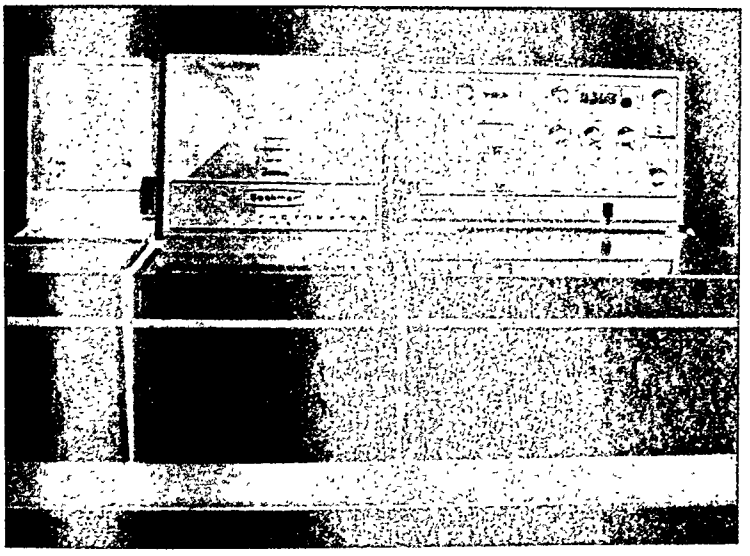
The gas chromatograph (right) is based on the principle that different complex molecules move at different speeds. Among its uses in police work are the analysis of trace amounts of materials that may constitute evidence, the separation and purification of such substances as narcotic mixtures and volatile solvents suspected of use in arson cases, and the exact determination of the amount of alcohol in the blood of an arrested person. The ultraviolet spectrophotometer (opposite page) has been used to identify certain types of drugs and to identify substances of suspicious origin in assault and homicide cases.

drivers, but the driver must have a radio, must have it on, and must be within range of the station for this service to be effective. Joscelyn suggests that it would be simple to relay information from the computer to every driver on the road simply by mounting electric signs along the highway. Because of its speed, the computer could flash a trouble signal immediately, while there was still time for the driver to take effective action. Furthermore, this would allow the police to use their energies in the most efficient way: in clearing up the accident, helping its victims, and guiding traffic back onto the main road beyond the accident site. Joscelyn estimates that such a system would cost $3,000 per mile of interstate highway—a negligible sum when compared with the million-dollar-per-mile cost of the superhighways themselves.

Science wins its badge

The significance of the Indiana experiment lies not merely in the potential of computer-surveyed traffic but in the willingness of a relatively small sheriff's police department to recognize that potential. This represents a notable change in attitude, for the acceptance of science and technology even by big-city police forces in America was slow in coming. At the time of the St. Valentine's Day massacre in 1929, the Chicago Police Department did not even attempt to identify the slugs found in the seven victims. But once the notion caught hold, the most exotic of scientific techniques became routine: the analytical gas chromatograph is used in many police departments for determining the amount of alcohol in the blood of a person accused of drunk driving; infrared and ultraviolet spectrophotometers are used to determine the presence of some narcotics.

More important, in cases that are not routine, the scientific approach can be conclusive. In New York City several years ago, for example, an



elderly woman was robbed and raped in her home. Her assailant had invaded the home while she was polishing silver, and in the struggle a smudge of the polish came off on his clothing. The police laboratory used X-ray diffraction to determine the crystalline structure of the polish the woman had been using. When a suspect was brought in, his clothing was analyzed by, among other things, X-ray diffraction, and a smudge on it turned out to have exactly the same crystalline structure as the silver polish. Confronted with this evidence, he confessed.

In another case, in a small mountain town in West Virginia in the mid-1960s, a woman we will call Vera Monahan was gradually poisoning her husband with arsenic. Arsenic poisoning is a slow process, however, and one day shortly before Christmas she lost patience and strangled him. Then she burned his remains for several days in a kerosene-fed coal-and-wood fire not far from their home. Eventually the man was missed, his disappearance was investigated, and Mrs. Monahan was arrested on suspicion, but the police lacked two things: a body, and proof that the murder was premeditated. They did suspect where the body had been burned, so they collected several hundred pounds of dirt and ashes from the site and shipped them to the FBI laboratories in Washington, D.C. There, scientists sifted through the debris and collected enough bone and tissue fragments—almost invisible to the naked eye—to fill a quart jar. With the aid of an anthropologist from the Smithsonian Institution, they were able to identify these remains as coming from a human male of the age and build of Monahan. That provided evidence of a body.

Next came the matter of premeditation. To prove this, the laboratory scientists subjected the remains to neutron activation, making the bone and tissue fragments radioactive so that they gave off gamma rays. The various elements present in any radioactive material can be identified precisely by measuring the gamma rays it emits. In this case, the mea-

surement showed an excessive amount of arsenic. The police were able to trace arsenic purchases in the region of the tiny town to Mrs. Monahan, and she was subsequently convicted of first-degree murder.

Angora fiber and blood alcohol

In a lonely spot in San Francisco one night in the 1960s, a man rose suddenly from the back seat of a parked car occupied by a young couple. He bound, gagged, and blindfolded the young man—a physical education instructor in a local high school—ordered the young woman into the back seat, and then proceeded to abuse her sexually for several hours. Later, neither the young man nor the victim could offer any description of the assailant, but certain aspects of the crime suggested that it had been carefully planned. The assailant carried with him a kit of ropes, chains, and sadistic devices that he was careful to clean up and carry away as he left. The character of the crime and the particular abuse he had heaped on the young woman suggested the working out of a profoundly macabre sadomasochistic drive. Lacking a distinctive description, the police searched through their files of sexual deviates for a man with this particular type of mentality. As it happened, they came up with the wrong man, but justice—and science—was working for him. Using an infrared spectrophotometer, experts in the police lab had found almost microscopic evidence of angora fiber on the victim's bra. At first the investigators hoped the angora had come from the clothing of the assailant, providing irrefutable proof of his presence at the scene of the crime and perhaps a clue to his character as well. Somewhat to their chagrin, it was found that the young woman had been wearing an angora sweater.

Specimens too minute to be identified with the naked eye may provide important clues to the solution of a crime. Shown as they appear under the microscope are (top to bottom) asbestos, mink, and wool and (opposite page, top to bottom) hemp, kapok, and dog hair.







Nevertheless, the discovery was to prove critical. Angora sheds easily, and during the assault it could easily have shed all over the assailant's clothing. But even before investigators could find and test the clothing of the suspect, the laboratory men made an astonishing discovery: under routine infrared spectroscopy, the clothing of another man, arrested for a nonviolent crime, proved to have traces of the same angora fiber as that on the victim's bra.

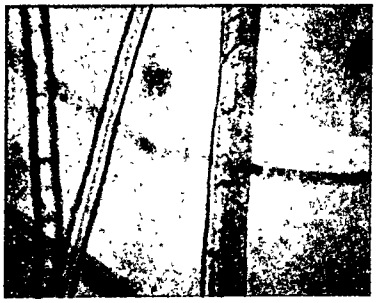
At first, the police could hardly believe the evidence, for the new suspect—who by some ironic coincidence had been lodged in the cell next to the original suspect—was not quite five feet tall. This fact alone would establish a powerful defense for him. On the face of it, it seemed unlikely that such a tiny man could subdue a healthy, muscular physical education instructor almost a foot taller than he, or that a woman could spend so much time in intimate contact with him without noticing his size. Yet the evidence provided by the laboratory, combined with the further evidence found in his home—including chains used in the assault—proved conclusive. The old suspect was released, and the new one was charged and ultimately convicted of the crime.

This was not the first case in which scientific evidence has been used to free the innocent as well as to convict the guilty. Take the case of a driver in New York City who was taken into custody after his car, weav-

ing back and forth on a crowded city street, sideswiped three cars and finally crashed into a stop sign. Two persons were known to have been in the car, but the passenger escaped before the police arrived. The driver was found slumped in the wreckage. The car reeked of alcohol, and an open bottle of liquor was dribbling the last of its contents into the smashed front seat. The driver was rushed to a hospital and, as a matter of routine, his blood was tested via the analytical gas chromatograph. It showed absolutely no alcohol in his bloodstream. The police wanted another test, but the hospital personnel intervened: their patient had suffered a stroke, which, of course, accounted for his erratic driving. Later, the police discovered that it was the passenger who had been drinking and who had left the open liquor bottle in the wreckage.

A somewhat similar case occurred in Baltimore, Md., where a man was arrested for drunk driving early one morning as he headed toward the Sparrows Point steel mills. When he was stopped by the police, he showed all the signs of drunkenness: slurred speech, very poor coordination, even a strange smell on his breath. But when he was taken to headquarters and given—with his permission—a test for blood-alcohol content, it proved to be negative. Unconvinced, the police made another test, but when it also turned out to be negative they began to investigate further and thus averted a possible tragedy.

The suspect was a diabetic who had been afraid to reveal his illness for fear he would lose his job in the steel mills. That morning he had taken his prescribed dose of insulin but—finding that he was late—he did not eat as he was supposed to do. While he was driving to work, an insulin reaction set in. The symptoms of approaching insulin shock —loss of motor control, nervousness, fear, a flushed face, sweating, and the vague smell of acetone on the breath—are similar to the signs of drunkenness. If the test for blood-alcohol content had not been easily available, he might have been thrown into a cell to "sleep it off," sunk deeply into insulin shock, and died.







Overcoming time and space

Some persons—bemused, perhaps, by fictional tales of scientific detection—believe that science and technology have made shoe-leather detective work dispensable. This is not the case: the hard, grinding work of gathering facts and details is more vital than ever. But science and technology have expanded the horizons of detection —and of justice—to an extent that even Sherlock Holmes could never have imagined. Consider what they have made possible.

• Overcoming remote evidence: In 1960, the automobile of a suspect in the kidnap-murder of a wealthy brewer, Adolph Coors III, was found rusting in a gutter near Atlantic City, N.J., some 1,800 miles from the scene of the crime in Colorado. Hardened mud scraped from beneath the fenders of the car was subjected to emission spectrography, in which a substance is vaporized and the light-spectrum of the gas it emits is analyzed. After comparison with 421 other soil samples, the mud from the car was found to match the soil from the area in which

Removed from the front lines of the confrontation with crime and the headlines that accompany violence, the crime laboratory is an increasingly vital part of any big-city police department.



Coors had been kidnapped and killed. This finding was instrumental in obtaining a conviction of the suspect.

• Overcoming time problems: In December 1967 the body of a rooming-house caretaker was found in Manchester, N.H. Bloody heelprints on the tile floor around the body were readily identified as those of a man we will call Tom Mahoney, but Mahoney claimed that the heelprints had been made after the murder. The police gathered up the tiles and shipped them to the FBI laboratory in Washington. There painstaking scientific analysis proved that one heelprint, partially obliterated by the victim's blood, had been placed on the tile before the blood fell on the floor. The testimony of the FBI experts on this matter led to conviction of the accused man and a sentence of life imprisonment.

• Overcoming the possibility of cover-ups: In what might be called the Case of the Decapitated Driver, New York City police found a convertible jammed against the left-hand curb of the Long Island Expressway in Queens. The driver was seated at the wheel, but his head was on the floor of the back seat. There were no signs of a struggle. However, the windshield and front frame of the convertible were broken and there were scrapes on it suggesting that it had been driven at high speed under something very low. There were no nearby structures that seemed to qualify, and it seemed unlikely that the car could have passed completely under a truck without the truck driver noticing. The only alternative left was that something had passed over the convertible, moving at high speed and in the opposite direction.

So, improbable as it seemed, the police began searching for an airborne car that had been going the opposite way. After canvassing dozens of auto-repair shops, they found a car that had been brought in for body work on the underside, and chips of paint from this car were sent to the police lab for comparison with microscopic chips of paint that had been found on the top of the convertible. To make the comparison, the experts in the police lab used spectroscopy. In such an

analysis, a technician burns a fragment of paint in an instrument that records the varying wavelengths given off by each element of the paint. By comparing one wavelength pattern with another, he can determine whether or not they are identical. If they are, the paint source is identical. Even repainting will not change the evidence: the FBI once traced a Cadillac that had been repainted seven times. In this case, the two sets of paint scrapings matched.

The owner of the second car had an astounding—but plausible—story. He was driving with a companion along the nearly empty expressway when he lost control of his car. It hit the narrow curb that served as a median strip, was catapulted into the air by the impact, "flew" through the air for several feet, and landed on its wheels in the opposite lane. With traffic coming at him head-on, the driver wasted no time in making for the nearest exit ramp. When he realized that his car had been damaged on the underside, he thought it had been caused by the landing and took the car to the repair shop without a second thought. His companion supported his story. He did not know he had hit another car and, indeed, most people would be so startled at finding their car suddenly airborne and so involved in trying to get back to earth safely that a "collision" below them could well go unnoticed.

The research goes on

More research in this and other matters now is under way. At John Jay College of Criminal Justice in New York City and at Scotland Yard, studies are going on that may lead to automated processes of drug identification—which represents a large proportion of the case load in certain big-city police laboratories. Research into fingerprint identification involves everything from laser technology to use of an electronic scanning system, akin to a cosmic ray scanner, in an effort to find ways of establishing identification by using only a portion of the information available in a fingerprint. One highly publicized area of research concerns the development of nonlethal weapons for quelling riots.

In law enforcement, as in other research activities, the solution to one problem opens fascinating new ways to attack other problems. Today there are more than 140 criminalistic laboratories in the United States —run by state and city police, the FBI, the U.S. Treasury, the Bureau of Customs, even the Food and Drug Administration. In those laboratories, as in private research facilities, research into everything from cathode-ray tubes to computers is expanding rapidly. It is as if the whole law-enforcement establishment had decided to respond to the ultimate imperative of Sherlock Holmes. "You know my methods," he said in *The Sign of Four*. "Apply them!"

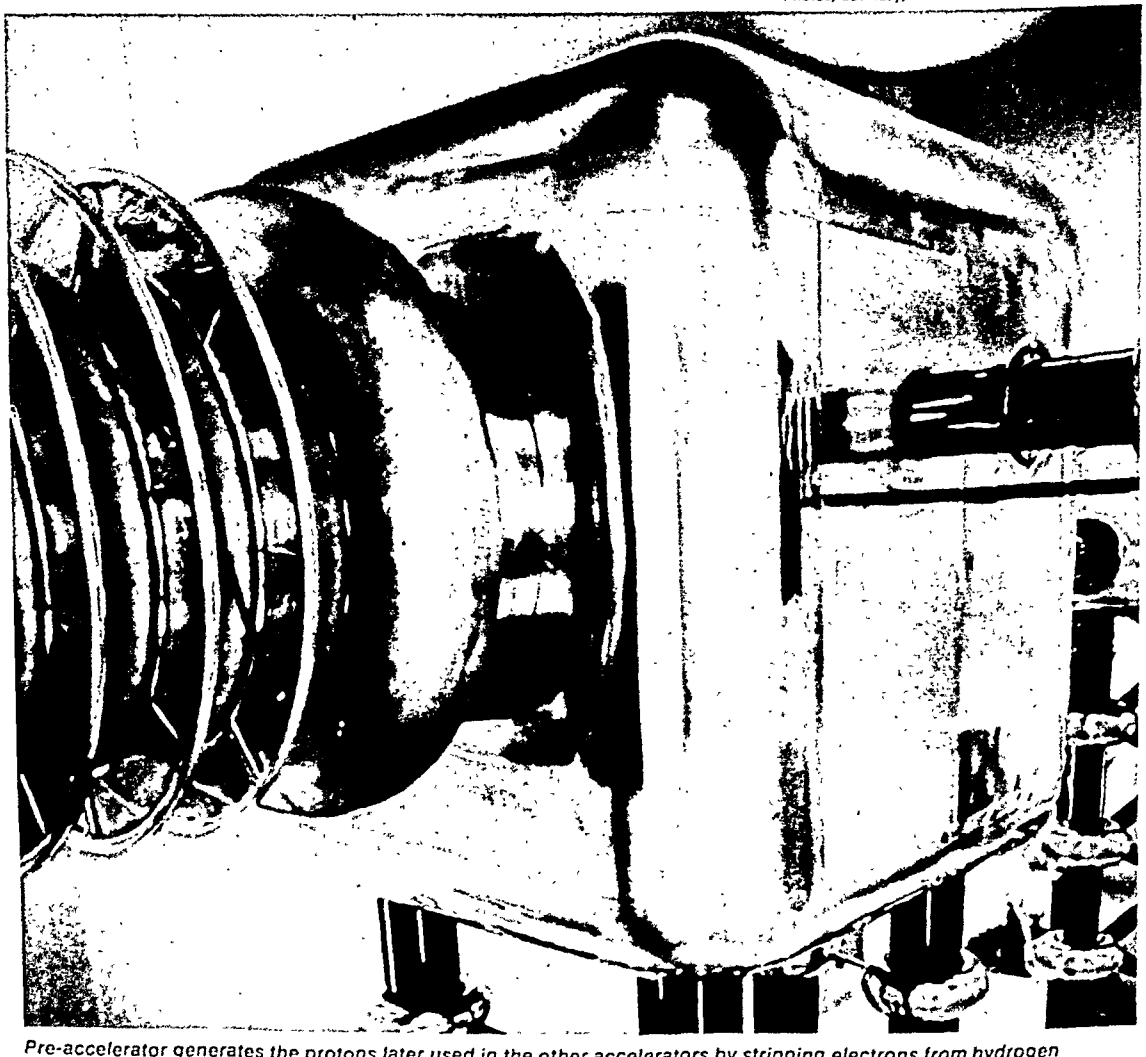
A Gateway to the Future

The World's Largest Nuclear Prober

by Howard J. Lewis

Finding the tiniest particle, the most fundamental constituent of all matter, is the goal of the scientists at the U.S. National Accelerator Laboratory, the world's most powerful particle accelerator.

Photos, courtesy, National Accelerator Laboratory



Pre-accelerator generates the protons later used in the other accelerators by stripping electrons from hydrogen atoms. Here the protons get their first energy boost, to 750,000 electron volts.

A billion electron volts is not a great deal of energy. Not when you consider that the equivalent of one billion billion billion electron volts is required to keep a 20-watt light bulb burning for an hour. On the other hand, if you can apply that much energy to particles of matter so small that ten thousand billion of them could crowd into a linear inch, you can give them quite a wallop. There's a problem in doing it, but it's a problem well worth solving if you wish to discover the most fundamental secret of nature—how matter is arranged and held together by a variety of powerful forces we are only dimly beginning to understand.

This problem—of imparting enough energy to atomic particles to break them apart—has occupied scientists since the early years of this century. And since the middle 1940s, when an explosion over the New Mexican desert demonstrated that man could extract the enormous energy locked in the nucleus of the atom, it has also interested governments.

Pioneering work

Let us start at the beginning. From the work of several French physicists, Henri Becquerel and Pierre and Marie Curie, it was discovered that radium, one of the heavier elements, emitted three different forms of radiation. Two of them could be deflected by magnetic fields, and from this it was determined that one of those two consisted of particles with a positive charge, the other negative. In 1909 a British physicist, Ernest Rutherford, and several colleagues discovered that if a stream of the positively charged particles was directed against an extremely thin sheet of gold foil, almost all of them went through the sheet; a number of these particles, however, were scattered from the sheet at sharp angles. Since it was well known that positively charged particles repel each other, it was clear from the undeflected passage of most of the particles that the atoms in the apparently solid sheet of gold metal were actually far from solid. It also was evident that the sharp deflection of some indicated that almost all the mass of the gold atom was concentrated in a tiny positively charged region, which was called the nucleus.

Later discoveries by others revealed that the basic structure of the atom consisted of a dense nucleus containing one or more positively charged particles called protons, around which orbited, at relatively enormous distances, negatively charged particles called electrons. The key to unlocking the secrets of atomic structure is the proton—specifically the proton of the hydrogen atom, which contains a single electron orbiting around a single proton. Stripped of its satellite, the hydrogen proton becomes an ideal missile with which to bombard the nuclei of more complex atoms. Its relatively large mass, at high speeds, provides for a great deal of energy; its electrical charge makes possible (1) its acceleration, by manipulating the potential of electrical fields through which it passes and (2) its direction, through the use of powerful magnets surrounding its path of flight.

First accelerators

The fascination that atomic structure holds for scientists can be measured—in part, at least—by the number of Nobel Prizes that have been awarded to scientists working in this field. Besides Becquerel, the Curies, and Lord Rutherford, John D. Cockcroft and Ernest T. S. Walton received one for the design of the first machine that was made specifically to increase the kinetic energy of protons by accelerating their velocity. Although the energy imparted by the Cockcroft-Walton accelerator was measured in the thousands rather than the billions of electron volts, it was adequate to perform an experiment that had been a long-standing

dream: the transformation of one element into another. Not lead into gold, as the ancient alchemists had sought, but lithium into helium. More importantly, Cockcroft and Walton demonstrated beyond any question that the accelerator was an instrument whose potential exceeded man's ability even to dream.

The Cockcroft-Walton accelerator was able to impart only one quick boost to the flight of protons. Another Nobel Prize awaited the man who first realized the possibility of bending the flight path of atomic particles into a complete circle, thus providing the opportunity to give an almost limitless series of kicks to speeding particles as they raced around the course. He was Ernest O. Lawrence, of the University of California, the first American to occupy a central role in the development of the accelerator. His machine was called the cyclotron. Its energy was measured in the millions of volts and one of the things that it did was to create a new element, called plutonium.

With such potentialities unfolding, the search began for ways to increase the energy of the accelerator. With the proton synchroton, the Brookhaven National Laboratory, Upton, N.Y., reached 2.3 billion electron volts (GeV) in 1952. Still later developments made it possible for Brookhaven to reach an energy level of 33 GeV. Several European countries combined to build a 28-GeV machine in Switzerland, and early in 1968 the Soviet Union placed in operation a machine operating at a peak level of 76 GeV.

If one thinks of an accelerator as a telescope in reverse, whose energy levels permit it to peer deeper and deeper into inner space, then the question arises: what energies are attainable? By the time the Soviet machine was built at Serpukhov, it was apparent that advances in accelerator theory and technology had reached a stage when man's ignorance was no longer the limiting factor. It was money. When U.S. scientists were asked by their government what kind of a machine should next be built, desire said 1,000 GeV, but a realization of the available funding said 200–300. Two other considerations led to this more conservative decision. Although it was true that available technology made 1,000 GeV possible, scientists also realized that probable advances in technology would make it possible by about 1980 to build such a machine at far less cost than was the case in 1972. Second, since it was apparent that even the largest nations could build only one such accelerator, there was much sentiment for the idea of looking to the day when all the major powers would agree to collaborate in the construction and operation of a single machine at that energy level or better.

HOWARD J. LEWIS, director of the Office of Information at the U.S. National Academy of Sciences—National Academy of Engineering—National Research Council, is also editorial consultant for the Britannica Yearbook of Science and the Future.

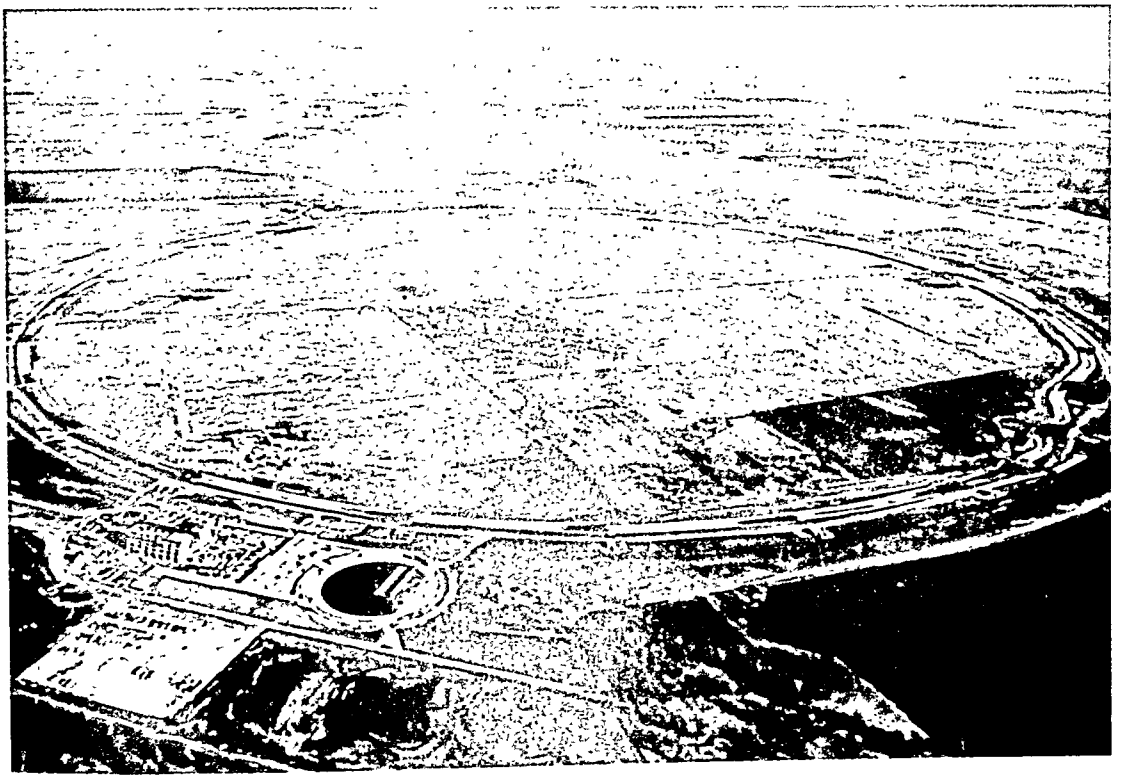
Building the national accelerator

For the builders of the U.S. National Accelerator Laboratory at Batavia, Ill., Feb. 29, 1972, was a day of great importance. On that date they wanted to bring their massive new machine to its design level of 200 GeV—before the Joint Committee on Atomic Energy of the U.S. Congress concluded its annual hearings on March 1. It was the powerful Joint Committee that authorized the U.S. Atomic Energy Commission to spend $250 million on this machine.

That the accelerator was so near completion by February 29 was in great part due to its director, Robert R. Wilson. When he was persuaded by the consortium of universities that had contracted to construct and operate the accelerator to leave Cornell University in early 1967 and direct the project, he was given a preliminary design study prepared by the Lawrence Radiation Laboratory at Berkeley, Calif., that called for a seven-year construction program.

Wilson promptly notified all concerned that he would not spend seven years building an accelerator. He announced that his target date was June 30, 1972. Later, he confided to his close associates that his real target date was June 30, 1971—an unheard-of four-year span between the reworking of the original plan and the beginning of operation at 200 GeV.

Wilson and his doughty crew almost made it, mainly by taking a series of audacious shortcuts that brought cries of "Irresponsible!" from some of the most respected accelerator physicists in the country. One shortcut involved the 240 quadrupole magnets that focus the proton beam. Because each must be located relative to its neighbors within an accuracy of 0.0005 inch (1/10th the width of a human hair), the original Berkeley design called for pilings to be sunk down to bedrock. Wilson, however, ordered borings to be taken around the four-mile circle the main accelerator ring was to occupy and decided that the glacial till, lying approximately 20 feet below the surface, had been sufficiently compressed during the ice age to bear up under its new and less demanding load. Nevertheless, after the 36,000 cubic yards of concrete that make up the tunnel for the main ring had been laid down, with its 2,750 tons of reinforcing steel, the ground under

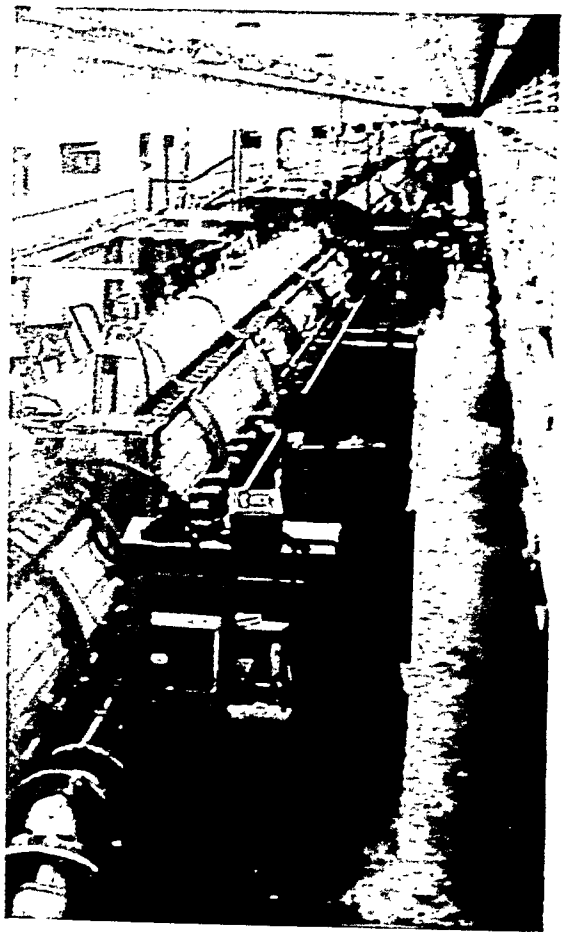


Aerial view of the National Accelerator Laboratory shows the main ring, four miles in circumference, and the smaller booster ring in the right foreground. After being boosted to 8 GeV in the small ring, proton beams are fed into the main ring, where they are raised to an energy level of 200 GeV.

the tunnel began to settle at what experts termed a "violent" rate of one-tenth of an inch a month. Again there were bitter outcries that the largest accelerator in the world was too precious an instrument for such shortcuts. By November 1971, however, the settling had smoothed down to a uniform three-hundredths of an inch per month and by mid-1972 posed no problem for the operation of the accelerator.

One other shortcut, however, did hurt. It denied Wilson his dream of a 1971 completion date and worked a considerable hardship on those experimental scientists who had taken academic leave and rushed to bring their instrumentational apparatus to completion by the earlier date. Because the operation of a proton beam inevitably induces radioactivity within the ring enclosure, safety precautions dictate that the ring be buried under 15 feet of earth. When the last concrete section of the Batavia ring was lowered into place, it was midwinter on the Illinois prairie and the 15 feet of dirt that was piled back onto the precast concrete semicylinders was at freezing temperature. The massive concrete envelope remained abnormally cold throughout the spring and when the humid air of midsummer entered the tunnel, condensation swiftly generated a London fog within. Thus it was that when the eager director ordered the first tests to determine whether his personal 1971 date was to be reached, his magnets blew. They had been tested for every environmental factor save one. They had not been tested under water. In order to save time and money, the epoxy resins used to insulate the magnets had been applied at normal atmospheric pressure. Hairline cracks had developed, undetectable by the tests used but sufficiently large to permit permeation by the vapor-laden atmosphere in the ring tunnel. Before energy approached design level, the entire operation had to be shut down to prevent catastrophic damage to the equipment. The staff tried everything, including setting up giant fans to flood the tunnel with superheated air. But eventually, some 350 of the total 1,014 focussing and bending magnets had to be withdrawn from the enclosure and undergo reimpregnation with epoxy in specially built vacuum chambers.

Thus it was that through a succession of daring



Interior of the linear accelerator tunnel shows several of the nine tanks in which protons, after being received from the pre-accelerator, are boosted to an energy level of 200 MeV.

forward leaps and an occasional misstep. Wilson found himself at the end of February 1972 hurrying back from the first of two days of hearings in Washington to reach his new self-imposed goal of design energy while the hearings were still in session. The accelerator had already surpassed all previous achievements by reaching 100 GeV more than two weeks earlier, on February 11. When Wilson arrived at Batavia on the evening of February 29, he was told that while the thousands of components were being tuned and adjusted to reach 200 GeV problems had arisen in the magnet ring. A 12-hour shutdown was necessary. Wilson called a full staff meeting the next morning, March 1. He told them of his testimony the previous day and expressed his disappointment that it had not been possible to announce the attainment of 200 GeV. He urged the staff to try to reach the goal before the Congressional committee concluded its hearings that day.

The magnet problems had apparently been cured during the early hours of the morning. While Wilson was exhorting the staff, Francis T. Cole was directing activities in the main control room, communicating constantly with James Griffin some six blocks away. Griffin had the task of turning on the radiofrequency stations that provide the incremental boosts in velocity to the particles as they race around the four-mile circle.

The *Village Crier* of the National Accelerator Laboratory tells the rest of the story:

> At 11:00 (March 1) a steady, stable beam was achieved. By 11:30 beam had passed transition energy (17.4 GeV). According to Ed Gray, synchrotron physicist on duty at the main control console, from then on things just got better and better. A slight jolt to the system—a 'quad bump'—gave the beam further intensity. At 12:30 P.M. the beam reached 167 GeV for the first time. More and more people clustered around the screen in the Control Room lobby, watching the narrow band that typifies the beam as it crept slowly to the right to match the triangular peak representing 200 billion electron volts of energy. By 1:00 the screen was completely hidden by a crowd of forty or more people. The ding-ding-ding of a bell signalled the coming of the 200 GeV pulse in the bi-modal ramp.
>
> At the R. F. (radiofrequency) building, Jim Griffin recalls, all controls were in ideal positions, but the noise of the gathering crowd in the Control Room drowned out the warning bell on the inter-com; his adjustments had to be cautious. Stan Tawzer, working with Griffin, watched the screen. At 1:03, Tawzer noted, 'That one went all the way out,' but they waited for the next pulse to be sure.
>
> In the Control Room on the next pulse, someone in the hushed crowd said, 'There it is!' and a rousing cheer filled the room, at 1:08 P.M.

Financial problems

What did Wilson build and what did he have to work with? First, he had more than a quarter-century of experience working with protons and accelerators. He had the institutional support of the Universities Research Association, the consortium of 52 universities in the United States and Canada that held the AEC contract to build and operate the accelerator. He had the preliminary design of the Lawrence Radiation Laboratory, made by those who were then generally regarded as the preeminent people in the field. He had a small team of particle physicists and engineers to adapt the Berkeley design and then build the accelerator and experimental buildings. And he had, as a gift from the state of Illinois, 6,800 acres of prairie about 30 miles from Chicago, containing several farm buildings and—more importantly, as it turned out—about 100 small homes, all identical, in the unincorporated village of Weston.

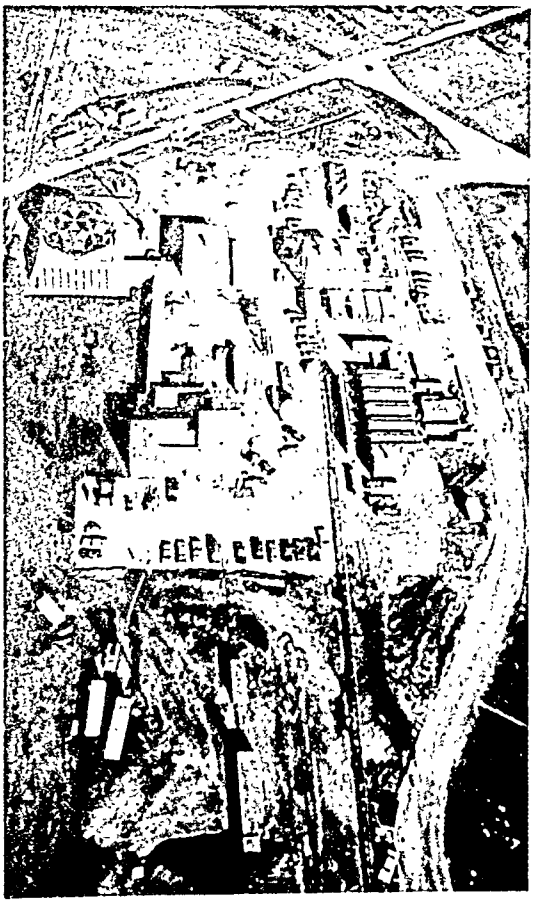
What Wilson did not have was money. Although the U.S. scientific community has come to depend

heavily on the federal government for the funding of research, the money is not always easy to obtain. First the budget bureau of the administration in power decides how much the individual executive agencies may ask of Congress for the conduct of their business. Then, normally, one committee in each branch of Congress decides which of the major tasks the agency wants to perform should in fact be authorized. Still other committees decide how much money, if any, should be appropriated to actually carry out the work in any given fiscal year.

Such an arrangement creates an odd variety of problems for the director of a federally funded facility that takes time to build. And it sets a high premium on improvisation. In the case of the National Accelerator Laboratory, for instance, the Bureau of the Budget allocated $50 million for the accelerator, with the promise of additional allocations for experimental equipment. The payroll began in the spring of 1967 and ground was broken in December 1968; final authorization of the full $250 million did not occur until July 11, 1969. The unpredictability of the financing created some of the more unusual physical characteristics of the installation. For example, Wilson had asked for funds to build a 17-story central laboratory building, into which he would move most of the facility's activities from expensive rented facilities in a nearby town. But when the money was not forthcoming and there was almost literally no place to move his now large operation, Wilson delivered a bold stroke indeed. He brought in house-moving equipment and literally picked up scores of the now vacant houses of Weston village and rearranged them to suit the needs of the laboratory. Many of these houses were left as they were, providing individual domiciles for such small-scale operations as public information; but for the central directorate itself 17 of the houses were pushed together and joined as a single structure. When funds did become available to begin the high-rise building, its first floor was already being used as a cafeteria and for office space before the concrete had even been poured for the fourth floor.

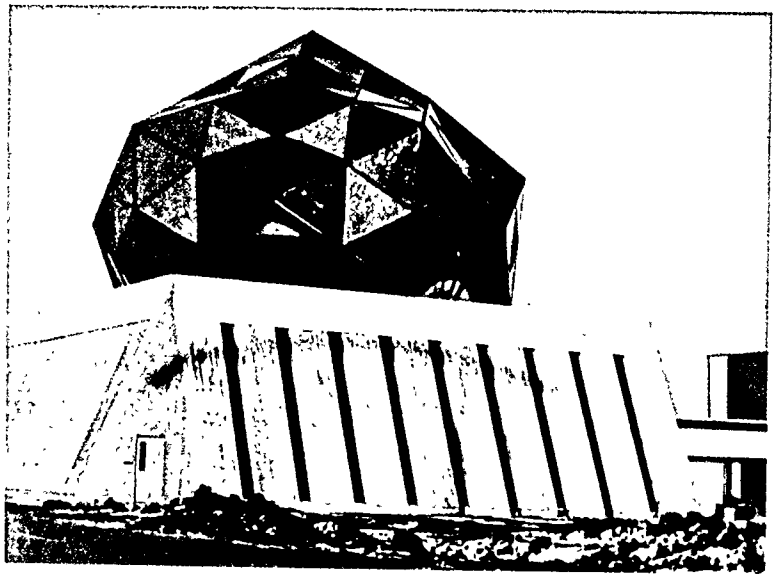
The accelerator in 1972

But no matter how chancy the venture looked from time to time as authorizations or appropriations were withheld, the construction of the accelerator moved along briskly from one improvisation to the next. By 1972, there were four major sections completed that were used to accelerate protons to the next higher level of speed. A relatively small pre-accelerator, much like the one originally invented by Cockcroft and Walton, generated protons by stripping electrons from hydrogen atoms and then gave them their first kick of 750,000 electron volts. The protons were then fed into a 500-foot-long linear accelerator in which nine similar banks of high-frequency voltage apparatus propel the protons to 200 MeV. From there they enter a miniature version of the accelerator itself, a rapid-cycling synchroton approximately 500 feet in diameter. In this instrument, which works on the same principle as the machines at Brookhaven and Serpukhov, the protons are accelerated around their prescribed circle at close to the speed of light, receiving 750,000-electron-volt boosts with each circling. Upon reaching energies of 8 GeV, the speeding pulses of protons are fed into the main ring. Less than a second is required for this operation.



In the bubble chamber area of the neutrino laboratory, the silver building at the lower left contains the 15-foot chamber, and the red building at the right houses the 30-inch device.

At this point the full energy of the installation



Geodesic dome atop a building in the bubble chamber area of the neutrino laboratory consists of reinforced polyester fiberglass panels containing discarded beverage cans.

is brought to bear on the whirling proton pulses. Contained in a 2 inch × 5 inch vacuum chamber fashioned into a ring four miles in circumference, the protons make 70,000 laps around the course, picking up 2.8 MeV with each revolution. The 280,000-mile trip inside the main ring is completed in 1.6 seconds, within a hair of the speed of light.

When the proton packages—each containing a billion or more—have been accelerated to the desired energy level, they are ejected from the main ring along tangential paths a mile or more long to the experimental areas. There, a variety of instruments will derive data from the protons themselves or from the secondary beams of other particles created when the protons collide with a variety of targets.

The first activity in the experimental area was designed to make use of a 30-inch hydrogen bubble chamber, recently transferred from the Argonne (Ill.) National Laboratory. The bubble chamber, which won a Nobel Prize for its inventor, Donald A. Glaser, is a remarkably simple device. When a volume of liquid hydrogen in a chamber is raised to a superheated condition for only a fraction of a second, the content of the chamber is in a state in which a speeding particle creates a boiling path during its brief penetration of the medium. This path of tiny bubbles, visible only for an instant, is photographed in the brilliant light of a stroboscopic camera. These photographs, in the hundreds of thousands, are then studied and analyzed.

During the summer of 1972, an even larger bubble chamber was placed in operation, permitting a track length of 15 feet. As the protons come speeding into the liquid hydrogen, collisions with their constituent atoms will splatter them into a variety of particles and sub-particles. Work already performed on similar instruments elsewhere revealed the presence of 130 different energy particles within the structure of the atom.

Accelerator experiments

The search for a simplifying theory in particle physics has preoccupied many physicists since the great variety of so-called "strange particles" began to come to light. Again a Nobel Prize for Physics was awarded for innovative work in this field, this time to Murray Gell-Mann for his theoretical work in postulating a classified structure for these sub-atomic particles. A central postulate of this theory is that there are three *really* elementary particles, which he named "quarks." By assigning certain properties to each of three varieties of quarks, says Gell-Mann, one would be able to construct the entire array of the 130 known particles.

The search for quarks will surely benefit from the extraordinary devices at the National Accelerator Laboratory. Some of the possibilities were explained by Father Timothy E. Toohig, a physicist and a Jesuit priest;

One of the things we shall be able to do with this accelerator is generate very-high-energy muons, which have the special value of being sensitive only to electromagnetic force rather than the nuclear force itself. With these muons, we shall be able to probe the electromagnetic structure of the nucleus and see whether it is a simple thing with a charge on the outside of it, or whether it is actually a collection of very small charges, like a pudding with the charges embedded in it. Then we would be able to study the deeper structure of the nucleus just as Rutherford studied the grosser structure of the atom.

Father Toohig is, however, far more involved with the central focus of his laboratory, which is the study of neutrinos. These particles have negligible mass and no electrical charge. Because they are so small and are not affected by magnetic fields, they pass through objects like the earth as if they were not there. Muons and neutrinos are created simultaneously by the decay of other products of proton bombardment. To separate the two, the neutrino laboratory at Batavia uses, among other more sophisticated devices, 1,000 yards of earth. Almost all the muons, it is hoped, will be stopped by the earthworks as they veer off the main ring; the neutrinos will slip through to the laboratory. There they will encounter an ingenious apparatus that consists primarily of a spark chamber sandwiched by two high-speed scintillators.

The apparatus works as follows: Since neutrinos carry no charge, they are impossible to detect directly. But one can, in a bubble chamber or a spark chamber, detect the products of an impact between a speeding neutrino and another object, such as a proton or neutron. Spark chambers will display the passage of collision products for a thousandth of a second or longer; the scintillators work in millionths of a second. Therefore, if the rear scintillator signals the passage of a charged particle when the front one does not, logic dictates that the charged particles have originated in a neutrino collision. And the millisecond duration of the traced passage in the spark chamber is long enough for high-speed film to record the event.

There are three experimental facilities located about half a mile or more from that point at which the particles they deal with are flung out of the accelerator ring. In addition to the neutrino laboratory, which includes the work with the muons, there are the meson laboratory and the proton laboratory. By 1975, it is expected that approximately 350 researchers from the United States and abroad will be swarming over these experimental laboratories at any given time. Competition for the privilege of utilizing the product of the accelerator for an experiment is as keen as it was among astronomers when the 200-inch telescope of Mount Palomar first went into action.

Who can use the accelerator?

Who will be allowed to use this unique instrument? Ultimately, that is the decision of director Wilson, but he does not decide alone. With one exception, all the experiments that have been accepted by the laboratory have resulted from proposals submitted by individuals outside the directorate of the facility. All are reviewed by a program advisory committee, chaired in 1972 by Robert G. Sachs, director of the Enrico Fermi Institute of Nuclear Studies at the University of Chicago. Periodically the committee submits its recommendations to the director on which proposals might be accepted and suggests priorities. Once a proposal is accepted, the laboratory staff works closely with the experimental group in arranging scheduling, developing cost estimates, and reviewing logistical needs.

By the spring of 1972, approximately 170 proposals had been received and about 60 had been accepted by the laboratory. Although the directorate of the laboratory sought not to impose its own criteria on the applicants, there is a general strategy of research that Ned Goldwasser described in some detail:

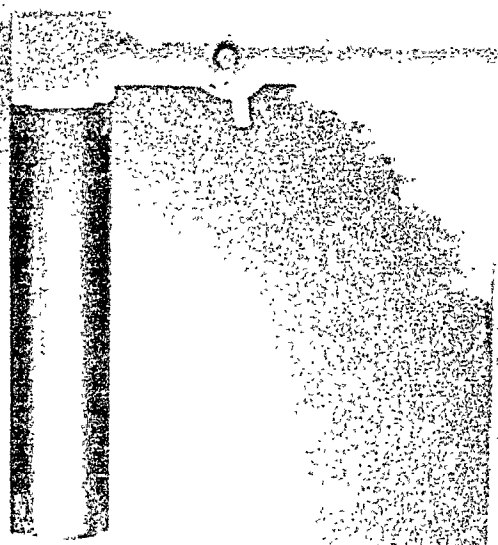
> When you enter a new world, as we shall be doing with this new instrument, you really have two basic choices. You can continue to do much the same kinds of experiments you have been doing, simply trying to attain more precise measurements of known phenomena in this new region of energy; or you can look upon this as an opportunity to explore an entirely new world, to look around to see what is here that wasn't known to exist in the former domain. On the whole, putting together the research program we have approved, we have put the highest priority on the second category. Take the rough look first. In my view, it would be nonsense and trivial to continue what we've done before. When the bevatron was built, it was designed specifically to produce an anti-proton. What they actually found was the whole new world of strange particles that no one had any reason to suspect existed before. Ninety percent of the time of that instrument has been spent in the study of these new particles. If anyone had made out a research program before that accelerator went into operation, he would either have had to have the courage to cancel what they had arranged to do too early or to trudge ahead with a very uninteresting program because of inertia. In actual fact, they were more flexible in those days and were able to respond to the new discoveries that were made. Here we're explicitly making that decision, I hope!

The genius of the men at Batavia has already produced a 200-GeV accelerator at a lower cost and in less time than anyone else had thought possible. But these scientists hold out still greater promises. With modest additions to present equipment, an increased power supply, and increased cooling capacity, they are confident that they can reach 500 GeV, two and a half times the previously rated capacity.

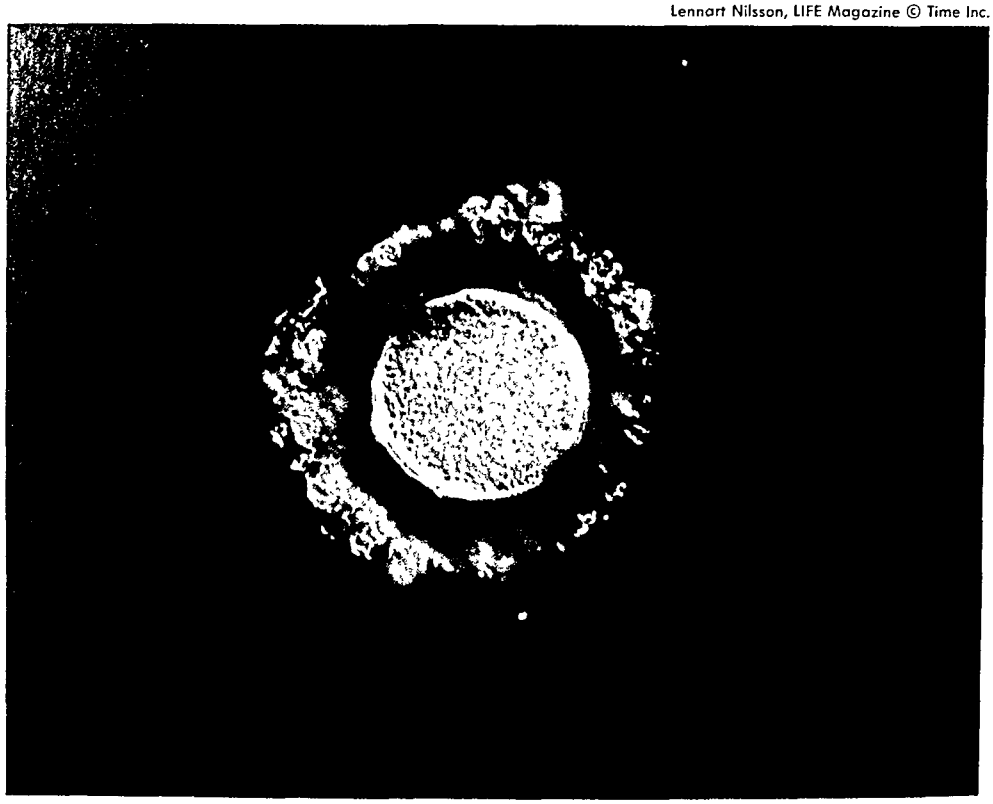
And, in the manner of scientists, they are looking still farther ahead—to the day when it will be possible by the use of jackets of liquid helium to arrange an additional ring of superconducting magnets above the present ring. This addition, they believe, will raise energy levels available at Batavia to an incredible one trillion electron volts—and very probably open up doors to knowledge that no man can now imagine.

Test-Tube Baby

by W[illegible]



Lennart Nilsson, LIFE Magazine © Time Inc.





To date, every human being that has ever lived has been conceived in vivo, within a living organism. This seemingly unalterable necessity may soon be dispensed with. A baby—someday soon—will be conceived in a test tube. It will result from a female egg being fertilized by a male sperm cell in laboratory glassware—in vitro. The embryo then will be returned to its mother's womb for the normal nine-month development period. It is possible that such an event will happen this year or the next. Very few births in the history of man will be watched so closely or will create more controversy, fear, apprehension, and, perhaps, hope.

The proposal for such an experiment has come from a group of scientists at the University of Cambridge, in England, led by physiologist Robert G. Edwards.

If Edwards accomplishes such a feat, it will not be without courage, for he has been brought to task for even suggesting so daring an experiment. The language of Edwards' critics is harsh. His work has been described by one outspoken opponent as immoral and a stunt. The tone of this criticism is extreme for the scientific world, but then the issues raised by the possible success of such a venture are profound. The two principal questions raised in the controversy are these:

1. If the technique works (and the protagonists are divided as to whether it will), does the world really need it? Will the way have been opened to the production of a dehumanized, test-tube baby society described by Aldous Huxley in his *Brave New World*?

2. Is the guilt and concern felt by many scientists about past discoveries (such as nuclear weapons and the chemical processes responsible, unwittingly, for much pollution) leading to a rigid new conservatism that may stifle freedom of research? Will scientists be saying, in effect, "It is good to know this and bad to know that"?

It is particularly appropriate that the proposal arose where it did. Indeed, Cambridge was the site also of the crystallization of the idea that suggested the mechanism of transmission of genetic information via the complex deoxyribonucleic acid (DNA) molecule. From such studies emerged the DNA model, deduced by J. D. Watson, Maurice Wilkins, and F. H. C. Crick (see *1969 Britannica Yearbook of Science and the Future:* THE LANGUAGE OF LIFE, pages 122–139), which suggested that DNA operates as precisely and predictably as a machine —and like a machine, it can be adjusted, modified, overhauled. As DNA is manipulable, so is life.

Tampering with nature

In the two decades since the deduction of the Watson-Crick DNA model, biologists have begun to tamper with nature in ways that earlier generations would have left to evolution. By 1971, when Edwards' studies began to become widely known, the life sciences were already producing startling results.

The genetic code—the arrangement of subunits of DNA and RNA (ribonucleic acid, another important molecule) into informational bits

The mature human egg (opposite page, top) is the largest cell in the body, typically measuring 0.1 mm in diameter. Magnified over 50 times, it appears as a granular mass hiding its nucleus. The cell is surrounded by the zona pellucida, a protective material. The sperm, seen in large numbers circling an egg (bottom), are among the smallest cells, averaging 0.06 mm in length. Each has a rounded head containing tightly massed chromosomes, a midpiece containing other cellular bodies, and a long tail that gives the cell great mobility. The sperm developed as a result of meiosis, a unique form of cell division. Only one sperm will penetrate and fertilize the egg. The egg is midway through meiosis. It has divided once into a large cell and a very small one (a polar body), which is later discarded. It will divide again in the same way after the sperm has entered.

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that call for the chemical construction of cell components—was broken. A gene—a group of these subunits responsible for a particular trait of an organism—was created in the laboratory with off-the-shelf chemicals. It was demonstrated that one type of cell could be converted into another. Laboratory animals were cloned, a procedure that involves taking one animal and producing other animals that are its genetic duplicates. Giant atlases were being prepared to map and identify genes as to their function and their location along the DNA molecule. Methods were being developed to separate and identify sperm cells that, upon fertilization of an egg, could produce progeny of predetermined sex. Fruit flies (long a favorite experimental animal of geneticists) were altered in their DNA composition, and those changes were passed along to future generations. And methods for using harmless viruses to carry alien DNA into cells, incorporating it into the cell's DNA and thereby producing a change (a process referred to as genetic "surgery" or genetic "engineering") were reported.

Ironically, all these events—including the fundamental Watson-Crick work on DNA—were the results of a totally free spirit of scientific inquiry. The guiding maxim behind the work was, in effect: "It is better to know than not to know." Indeed, that has been an idea underpinning science since the Renaissance.

It was within this framework of events and ideas that one of the world's best-known scientists—Watson himself—criticized Edwards' experiments. At a science symposium in the United States, Watson urged Edwards to abandon the idea of reimplanting a test-tube embryo in a uterus because not enough is known to predict whether or not the resulting infant—if it should survive—would be permanently damaged by the procedure.

Late in the fall of 1971, Max Perutz commented on Watson's remarks. Perutz, a senior chemist at the Medical Research Council, the British equivalent of the U.S. National Institutes of Health, and a Nobel laureate, joined with Watson in the belief that scientists must be held responsible for the social ramifications of their otherwise morally neutral discoveries. Perutz' remarks concerning Edwards went even further than those of Watson. Initially, he supported one of Edwards' stated aims for conducting the research—to make visible an otherwise hidden process, to record in fine detail the way a sperm cell penetrates an egg, the way the egg then begins to divide, and the order in which the cells of the baby-to-be are then produced. Perutz felt that an attempt to understand the early development of the human embryo was entirely justified, both scientifically and ethically, but he continued his remarks in a different vein: "His [Edwards'] second aim was to fertilize ova in the test tube and to re-implant these ova into infertile women. I agree with Dr. Watson that this is far too great a risk. Even if only a single abnormal baby is born and has to be kept alive as an invalid for the rest of its life, Dr. Edwards would have a terrible guilt on his shoulders. The idea that this might happen on a larger scale—a new thalidomide catastrophe—is horrifying."

Perutz noted that while he had not read Edwards' scientific papers, such as those published in the widely respected British journal *Nature*, he had read an article prepared for laymen by Edwards and Ruth E. Fowler and published in the December 1970 *Scientific American*. And although he was not familiar with the details of Edwards' experiments, he felt that there was something dangerous here—even to science itself. For if an infant was born that proved to be a freak or monster, public reaction might saddle all of science with the blame. Such backlash would further weaken the already shaky support structure for the basic sciences in a number of countries, Perutz predicted.

By 1972, in the wake of considerable controversy about him, Edwards was remaining silent. Although he had written and spoken extensively since 1965 about his plans to bring an implanted human embryo to term, he was no longer presenting defenses of himself. His last public statement after the controversy erupted was simply, "The work will continue."

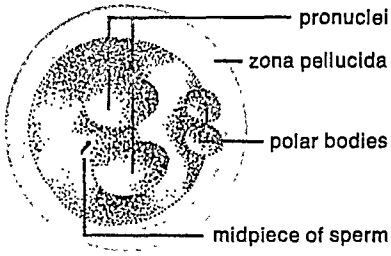
Significance of the work

Among the defenders of Edwards' work was his administrative superior at the Physiological Laboratory in Cambridge, Colin Austin. "I'm entirely in favor of the work," Austin stated. "Much thought has gone into each step of it. There is much data from similar experiments in animals; none of it suggests that Edwards is taking any particularly unusual risk." And it is a relatively small step from animals to man, he contended. Actually, there are fewer chances for deformities to occur in the embryo in its first five or six days after conception—roughly the period in which it will be in vitro—than in later stages of development. The defects associated with thalidomide, for example, did not develop until much later in pregnancy.

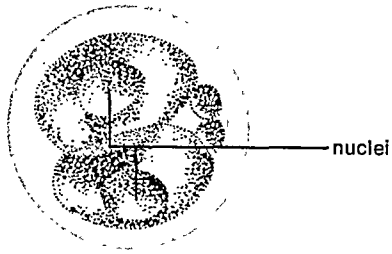
"The tone of the criticism the Edwards work is drawing is not particularly justified—in fact, I'm incensed by it," Austin continued. "A number of women who are donating eggs to the experiments, and who may carry them to full term after the in vitro fertilization, are nurses, doctors, or the wives of doctors. They are fully informed about the risks, yet are willing to go through with it. As to the 'morality' of the experiments, they have considerable humanitarian promise. The Edwards technique not only would permit previously infertile women to have their own children, but also offers the opportunity of separating some types of deformed embryos from normal ones while they are in vitro."

Who is Edwards? Exactly what is he doing? Robert G. Edwards is an intense, articulate man in his forties. He is a transatlantic scholar, having held research positions not only in Great Britain (Cambridge for the past seven years, and universities in Glasgow, Edinburgh, and Wales) but also in the U.S. at the California Institute of Technology, Johns Hopkins University, and the University of North Carolina. He has received U.S. research funds in the form of grants from the Ford Foundation.

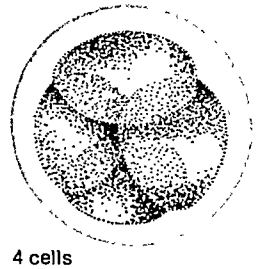
His interest in reproductive physiology, the early developmental



zygote



first cleavage



4 cells

The earliest stages of human growth, diagramed in sequence on these pages, can be duplicated in the test tube. A fertilized egg cell, or zygote, (top) has two polar bodies, showing meiosis is complete; two pronuclei, one the egg's and the other a result of expansion of the sperm's head; and the sperm's discarded midpiece. Before the cell divides, the pronuclei will join, so that in the first cleavage and all cell divisions thereafter all cells will have the full chromosome number. The external form of the egg remains unchanged as the cells, all of equal size, divide within it.

Adapted from "Human Embryos in the Laboratory" by R. G. Edwards and Ruth E. Fowler. Copyright © 1970 by Scientific American, Inc. All rights reserved.

stages of the embryo, and in certain birth defects was expressed as early as 1957 in experiments on mice, rabbits, and other laboratory animals. By the mid-1960s, he was publishing articles suggesting the value of conducting such research on the human level. Of central interest was the egg, both animal and human.

At birth, each woman possesses in her ovaries a lifetime supply of eggs. At the onset of menstruation, usually only one egg matures at a time and begins its journey through the oviduct to the uterus. If it is not fertilized, it disintegrates and passes out of the body. But if fertilization by sperm occurs—an event that takes place within the oviduct—the egg starts on a long process of division, or cleavage, and initial development of the embryo has begun.

By the time the fertilized egg has entered the uterus, it has divided into 16 or more cells and has been transformed into a structure called a blastocyst. If the blastocyst attaches itself to the wall of the uterus, pregnancy has begun. A placenta is then formed to nourish the embryo, and the nine-month period of development (during which are formed all of the organs and supporting systems necessary for human life outside the womb) is under way.

All of this, of course, is a hidden process. Edwards wants to know what stages and events the egg undergoes between its maturation and implantation in the uterine wall. Are eggs released in any particular order? (Or, as he says, "Does each egg have a number assigned to it, and if so, why?") What hormone systems work to ripen an individual egg? What are the first steps involved in a single cell, the egg, becoming an organism composed of untold trillions of cells—and what might go wrong? What chemical changes does a sperm undergo to enable it to penetrate an egg? And what better way to observe such events than to let them occur in a test tube, subject to full visual and microscopic analysis?

Even before he began such work with humans, Edwards was aware of the controversial aspect of the project as well as of the fears that such tampering with natural processes might draw from the public. In speeches and papers he began to outline his "defense," contending that nothing is worth doing in the laboratory unless it is socially valuable. He considers the socially valuable aspects of his project as the following:

An accurate knowledge of the early events in reproduction can help achieve two goals that at first appear to be contradictory. It could suggest much more effective means of contraception and thereby help to achieve world population control. At the same time, many men and women who want children desperately cannot have them because of physiological barriers. A common barrier in women is a blockage of the oviduct. Some men, on the other hand, generate very low volumes of healthy sperm. To retrieve eggs surgically and to fertilize one under controlled laboratory conditions with what healthy sperm cells can be obtained from the husband would be one way of overcoming such types of infertility.

The research timetable

In collaboration with Patrick Steptoe, a senior clinician at Oldham General Hospital in Lancashire, Edwards' group began the long transition from animal to human reproductive studies in the mid-1960s. Eventually, a group of about 50 women volunteered for the experiments—most of them in expectation of overcoming infertility. Previous animal experiments indicated that an egg must be at a precise state of maturity before it can be fertilized in vitro. Early work with the volunteers, consequently, was devoted to "gaining control" of the ovulatory cycle (by hormonal injections) so that the eggs could be taken at precisely the right stage of development. A standard surgical technique called laparoscopy—the insertion of a needlelike instrument with an optical viewing attachment through the volunteer's navel into the egg sack—was used to extract the eggs. (The Edwards group plans to implant an in vitro-fertilized egg into a uterus by the same route.)

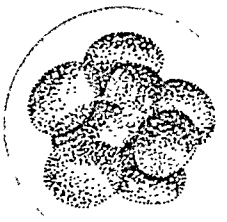
Several different types of culture media (solutions of salts, proteins, and other nutrients) had already been used successfully in animal in vitro-fertilization experiments, and were tested for their applicability to the human eggs. In September 1970, Edwards and his co-workers published in *Nature* a report stating that a number of the human eggs had not only begun dividing in these test-tube solutions but had been carried as far as the 16-cell stage of development. A *Nature* paper of January 1971 contained evidence that the group had later mastered the in vitro culture media and had indeed gone far beyond the blastocyst stage—to embryos with 110 or more cells—in the test tube.

By late 1971, Edwards was already well into his policy of public silence. Word from his laboratory, however, revealed that no more than a minor alteration or two to the culture media was needed before a laboratory-grown blastocyst would be implanted in its natural mother. When that happens—if it has not already happened—the embryo will be on his or her way to birth.

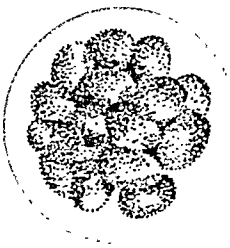
Both Edwards and his supporters contend that there is far less risk in producing a deformed infant than the critics predict. Edwards, who has been speaking of his work on an international scientific tour circuit, stated that every expert he has met in this general field has assured him he is right—and safe enough—to move ahead to implantation. Furthermore, there are proven techniques for detecting malformations well before birth. Taking samples of the fluid from the sac enveloping the baby, for example, and analyzing the contained cells for genetic or other abnormalities is one such approach.

As Edwards has written: "Bringing such embryos into the light of day provokes various thoughts and opinions: The beginning of test-tube babies, armies of carefully planned robots, playing at God in the laboratory. . . . But every stage of clinical research must be questioned, and care taken to ensure that it is related to social needs and is not stimulated by its own impetus." Edwards states he has no other interests in altering natural embryonic development processes than to overcome

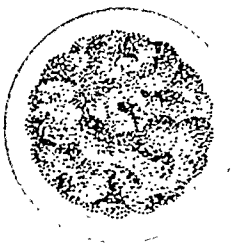
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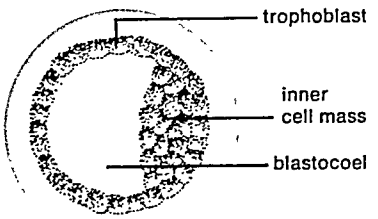
8 cells



16 cells



morula



blastocyst

When the morula is reached, there are about 32 cells and indications of unequal internal cell development. The egg soon becomes a hollow sphere (blastocyst) with a one-cell-thick wall, the trophoblast, which will become the parts of the placenta not contributed by the mother, and, heaped to one side, an inner cell mass, which will become the embryo proper.

Pioneering work

The earliest accounts of test-tube conception date back to 1944 when John Rock and M. F. Menkin of Harvard University Medical School achieved this experimental fertilization of human ova outside the body. They obtained ripe eggs from female patients and then exposed them to sperm in a test tube. No special medium was used to incubate the eggs, and success was slight. But these experiments marked the beginning of the elucidation of one of nature's prime phenomena.

In 1952, Landrum B. Shettles, a biologist, obstetrician, and gynecologist in the College of Physicians and Surgeons, Columbia University, began refining the experiments of Rock and Menkin. He demonstrated conclusively that in vitro fertilization of human ova is possible. In the course of performing various operations requiring abdominal incision into the peritoneal cavity of a woman, he pierced the ovarian follicles with a needle, causing some of the eggs in their follicular fluid to aspirate into a syringe. At the same time, without harming the patient, he excised tiny pieces of the tubal fimbrae, the fingerlike projections at the end of the Fallopian tubes that receive the egg when it is released from the ovary, and aspirated some of the mucosa that abounds within the tubes. From all this, he formulated the culture medium in which the eggs could mature and become ready for fertilization in the test tube.

When the egg, bathed in the follicular fluid, was ready for fertilization, it was placed in a sterile petri dish containing another oxygenated culture medium. There the prime ingredient was ovulation mucus taken from the midcervical canal of the woman who provided the egg. Into this Shettles unleashed millions of sperm cells and let them migrate to the egg just as they would in nature. At the right moment, he added the tubal mucosa and tiny bits of fimbrae in order, again, to provide the chemical components that the sperm normally encounter when they pass from the uterus into the tubes.

Thus, Shettles first witnessed the drama of human fertilization. The first report was in the *Federation Proceedings*, 1953, and 29 subsequent publications appeared on in vitro fertilization and the earliest steps of human development. He watched the ovum, glowing like a distant but bright-yellow sun on the microscope as it was pummeled by hundreds of sperm striving for penetration into its interior. The spectacle that was unfolding before him continued for hours while the sperm, their heads firmly against the outer membrane of the ovum, lashed their tails furiously, rotating the egg a full 360° every 15 seconds. At last, one penetrated into the interior of the cell proper, there to merge with its nucleus and thus achieve fertilization.

In the course of these experiments, various criteria were established for successful test-tube fertilization that have since become standard for the researchers in this field. These include the observation of both sperm head and tail within the egg proper, the elimination of excess female chromosomes in the second polar body (a minute cell that separates from the egg during maturation), the pairing of the male and

Courtesy, Dr. Landrum B. Shettles, Columbia University



A human egg cell, still within its zona pellucida, shows two polar bodies released below it, indication that a sperm has entered the egg to begin fertilizing it.

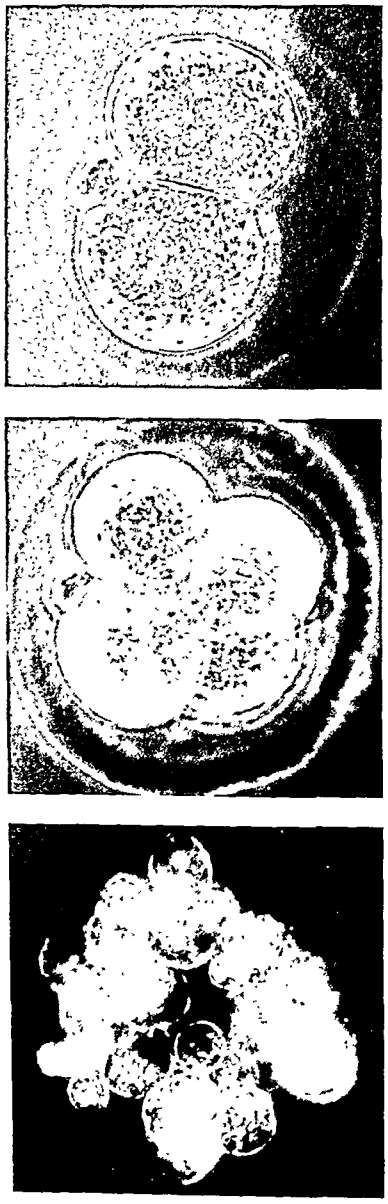
female pronuclei, and the actual division of the fertilized cell, showing that the embryo is growing and developing normally.

All of these criteria were repeatedly satisfied, and several of the fertilized ova were grown to the blastocyst stage, with more than 100 cells. At this time, in a woman's body the dividing egg would normally start to attach itself to the lining of the uterus. When experiments were first begun, however, too little was known to attempt implanting one of the test-tube embryos in the uterus.

Since then, a further step has been taken. Shettles aspirated a nearly mature egg from its follicle in the ovary of a woman undergoing an operation to correct a defect in one of the Fallopian tubes. The egg was matured in vitro, fertilized with sperm from the woman's husband, grown in culture for five days to the blastocyst stage, and then implanted into the uterus of a second individual scheduled for surgery. The menstrual cycles of the two women were synchronized, affording a hospitable environment for the transplanted embryo. Two days after the transplant, the previously scheduled hysterectomy was performed on the recipient. The implanting embryo was then located, with a dissecting microscope, on the upper, posterior lining of the excised uterus. An examination showed that it was implanting properly and consisted of several hundred cells. The objective of the procedure was not to produce a full-term baby but to ascertain whether implantation could occur, given the circumstances of in vitro fertilization, and to provide further information before proceeding to the final transplant.

—L. B. Shettles

Courtesy, Dr. Landrum B. Shettles, Columbia University



The first steps of human development can be seen in photomicrographs of an egg fertilized in vitro: top, the two-cell stage, 30 hours after fertilization; middle, a four-cell egg 40 hours after fertilization; and bottom, a forming blastocyst, the state of a $4\frac{1}{2}$-day-old embryo. To develop further, the blastocyst must become attached to the wall of the uterus.

continued from page 405

infertility or to ensure contraception and to perfect means for spotting defective embryos very early in pregnancy. He sees no point to developing human cloning methods—to use one set of "desirable" human genes to produce many living "desirable" duplicates. Also, keeping the baby in vitro for five or six days is quite enough to accomplish his socially valuable purposes. There is no justification for attempting to develop a baby for the full nine-month term in test-tube conditions, he states. (Austin, incidentally, estimates that such an accomplishment, at the present rate of advances in embryology, is still about a decade away. A major barrier currently is lack of knowledge about growing a placenta in vitro for such an embryo.)

Yet . . . are Edwards' good intentions enough?

Edwards' work is not literally "genetic engineering"—that is, producing changes in DNA in order to alter an undesirable physical trait or induce a desirable one. The prospect of such developments is actually what frightens Watson, Perutz, and many other knowledgeable men: who will decide what is desirable? But the Edwards' in vitro technique could conceivably make it much easier to shape the physical traits and eventually the behavioral characteristics of a baby through genetic or other types of manipulation.

John M. Thoday, chairman of the genetics department at Cambridge, notes that determining the physical characteristics of a baby before birth is a long step toward fixing its behavior as well. Certain physical types could be isolated that are much easier to "condition" than others, he speculates. And sooner or later, such methods might conceivably be employed to satisfy a despotic leader with designs to create and control an entire race of beings.

Are there indeed some things that it is better *not* to know? M. R. Pollock of the University of Edinburgh's molecular biology department writes: "I do not believe there is, has been, or could ever be, a scientific discovery potentially of benefit to humanity that might not be exploited to some degree *against* mankind, if people want to do so."

Scientific results

The basic scientific advances stemming from the Edwards work to date, according to his supporters, are (1) confirmation of the fact that the early development of the human embryo—from conception to blastocyst stage—is very much like that of the widely used laboratory animals, (2) isolation of the key hormone actions governing the maturation of the human egg and its release into the oviduct and (3) determination of the proper conditions for permitting early embryos to develop outside the womb. As to how such knowledge, and other knowledge that Edwards' experiments might produce, may be used, the debate is wide open. Some possibilities include:

- Coupling the Edwards information with that of the many other geneticists and life scientists for the purpose of remedying widely

recognized pathological defects occurring before birth. Perutz supports such an approach, noting that at least 1,000 recorded pathological syndromes are now classed as being associated with genetic errors during the prebirth period. A broad-scale public monitoring of even this goal might be warranted, however, to ensure that "pathological" is not interpreted in a political or racial sense.

• Using Edwards' technique, or something that might succeed it, to clone a genetic blueprint. The usual response to such a possibility is that cloning (1) is no longer interesting for basic scientific reasons since it can be done so readily in animals, (2) is unpredictable, since environmental conditions may lead one intelligent clone into one path of choices and another in a separate direction, and (3) is not necessary if reproducing high intelligence is the goal of cloning (as Edwards says, "There is so much brilliance around today that it is not necessary to copy genetically one form of it").

Speculation can take one much further than such alternatives. For example, would it be better to design people to perform certain jobs —working underwater with lungs that could extract oxygen from its liquid form, or adapting humans to life in other worlds with different gravitational or chemical conditions—or would it be more humane to use contemporary man's considerable technological skill for dealing with such specialized existences? Or, more feasible under the Hippocratic Oath of medical ethics, would it be worthwhile to try to encode DNA to produce brain cells that would regenerate after their normal "life" as do other cells, thus averting loss of memory and senility, which have long created a fear of normal human aging; to produce hearts, kidneys, and livers that could endure more strain, with less damage, than is the case now; or to produce breasts and uteruses that were not so highly prone to cancer?

Such questions will not be resolved by deciding whether Edwards' socially valuable goals are worth as much as his critics' moral ones, dictated as they are by the environments of science and politics today and by the lives of the individuals proclaiming these goals. Perhaps the answers will come into clearer focus when an embryo conceived in vitro is born.

FOR ADDITIONAL READING:

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The Nobel Science Prizes

by William Kirk

Although generally considered the most important and prestigious awards in science, the Nobel Prizes have not recognized many significant achievements. How are the winners chosen? Should the system be modified?

Probably the greatest honor a scientist can receive in his lifetime is a Nobel Prize. And to many scholars and laymen, the Nobel Prize *is* science. There are three science prizes—one for outstanding research in chemistry, one in physics, and one for either physiology or medicine. (Nobel Prizes also are awarded for high achievement in literature and for contributions to world peace, and in 1969 a Nobel Memorial Prize was awarded for research in economics.) No other science prize has been so highly regarded by the world—and particularly by the United States—for so long a time. Since the prizes were first awarded in 1901, winners have returned from the lavish award ceremonies in Stockholm, to find that they are national heroes. Almost everything they ask for in money or equipment for further research is granted by a grateful nation or university. They are sought after as government advisors, as university presidents, as general savants who can make the unknown knowable. André Lwoff, who shared the 1965 prize in physiology/medicine with two other French geneticists, Jacques Monod and François Jacob, summed it up this way: "We have gone from zero to the condition of movie stars."

Not the least of a Nobel laureate's rewards is prize money that may reach $90,000 or more, but the amount of cash associated with the prizes is only one reason for the Nobel prestige. Equally as important is Sweden's reputation as a nation that values objectivity and high intellectual achievement—and the widely held respect for the standards of judgment used by Swedish scientists who select the winners.


ALEX.
NOBILI
NAT.
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XXXIII
OB.
MDCCC
XCVI

For reasons such as these, the casual remarks of a young Swedish geneticist, chatting with a visitor in the summer of 1971, came as a shock. For most of his professional life, the geneticist had been used to the very best in science. He was the protégé of a Nobel Prize judge. It was his privilege to work in the laboratories of one of the world's leading centers for research in life sciences, Sweden's Royal Caroline Medico-Chirurgical Institute with a faculty that not only includes Nobel laureates but which also has the final say each year on who wins the physiology/medicine prize. And in the middle of a conversation about the significance and standards of the prize, he was to say: "Who cares? Nobel prizes aren't all that important. I doubt that it is useful to continue to hand out the prizes. It was all right earlier in the century when there were very few scientists who needed all the encouragement they could get. But much of the best research in science and technology today is not eligible for prize consideration. Very few of the younger scientists here pay any attention to it at all. The prize simply does not affect their lives."

This was one of the more critical remarks encountered during recent interviews with Nobel officials and judges and a cross-section of Swedish governmental and academic figures. Some of these men had equally surprising responses. "So much modern science is excluded from Nobel consideration," remarked Gösta Funke, secretary-general of the Swedish government's two principal organizations for financing research in the life sciences, physics, and mathematics. "It's a pity. There should be several more prizes. In fact, I discussed this need with the Ford Foundation people several years ago, but nothing came of it —our Nobel officials simply said they did not want a Ford prize."

Two of the most influential Nobel judges, Erik Rudberg and the late Arne Tiselius, expressed similar views. "Too often we are regarded as the world's supreme court in science," said Tiselius, a Nobel laureate himself (chemistry, 1948), a former president of the principal administrative and financing body for the prizes, the Nobel Foundation, and at the time the chairman of the chemistry prize committee, "This is unfortunate. We operate on much too narrow a base to reward all of the remarkable people in science today." And Rudberg, who is chairman of the physics prize committee as well as the permanent secretary of the Royal Swedish Academy of Sciences, made this statement: "There is a long list of scientific and technical achievements that will never get the prize, at least as long as it remains in its present form. Such exclusions do raise a legitimate question about the relevance of the prize."

Exclusions?

If archaeologists 1,000 years from now were attempting to piece together an accurate picture of 20th century science and technology, using only the minutes, reports, and written conclusions of the Nobel prize awarding bodies, what a strange society these records would reveal. These documents would show that 20th century society was

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unquestionably advanced: that 20th century scientists possessed an excellent basic understanding of how the atomic nucleus was organized; of how genetic molecules encode and pass along the physical traits of all forms of life from generation to generation; of how chemical elements are "fused" within the interior of the sun and other stars to produce vast amounts of thermonuclear heat for the warming of such planets as earth; of how nerve cells exchange information chemically and electrically; of vaccines and vitamins; of lasers, transistors, and wireless communication. Many other discoveries of similar importance would demonstrate that the 20th century scientists were extremely clever in extracting information from a reluctant, secretive nature.

Yet how limited 20th century scientists would appear to be in other areas. The Nobel documents provide no evidence of computers, no indication of the existence of a program or means for exploring space —or even the oceans; nothing showing 20th century knowledge of the physical history of the planet—of how mountains grew, how oceans were formed, or how massive supercontinents sundered and drifted apart to form Antarctica, Europe, Africa, Asia, and the Americas. There is not even a hint that scientists of the era knew how atmospheric pressure systems and fronts shaped the weather; or how to measure the distance to a star; or of the existence of exploding non-stars outside the galaxy; or how animals, including humans, communicate or reproduce. The only medicines mentioned are penicillin, the sulfa drugs, and a handful of antibiotics, and the only synthetic fiber, rayon. And on the disciplines of psychiatry and psychology—nothing, a blank. The evident crudity of 20th century science would be much more heavily underscored, however, by the omissions of the sure signs of an advanced civilization—the development of a body of "pure" mathematics. The Nobel documents give no evidence of the existence of such knowledge.

These future archaeologists also would find no trace of certain seminal figures in 20th century science and technology. There is nothing about Mendeleyev bringing the chaotic science of chemistry into predictable order with a periodic table of chemical elements; no mention of Thomas Edison or electric lights or recording machines; nothing on the Wright brothers and airplanes or on K. E. Tsiolkovski, Robert H. Goddard, and Wernher von Braun and the development of rocketry; and no hint of Henry Ford or the transformation of the 20th century by the development of the techniques of mass production.

And although these future archaeologists would find some names of scientists that would be recognizable to most 20th century schoolchildren, these scientists would not always be cited for their most important accomplishments. Albert Einstein is there, honored for describing how a ray of light releases electrons from the metallic surface it strikes (the photoelectric effect)—good solid physics but certainly not the product of a mind capable of suggesting how gravity might give shape to the universe, or how time itself may in some way be related to the speed of light, or how matter and energy are inter-

The Bettmann Archive



Albert Einstein, winner of the Nobel Prize for Physics in 1921 for his "services to theoretical physics," leads an informal seminar at the Institute for Advanced Study at Princeton, N.J. Einstein worked at the institute from 1933 until his death in 1955.

The Bettmann Archive



Ivan Pavlov (center, with beard) conducts an operation on a dog at his institute in Leningrad. A Russian physiologist, Pavlov won the Nobel Prize for Physiology or Medicine in 1904 for his work on the action of the digestive glands, but he became best known for his studies of conditioned reflexes in dogs and other animals.

changeable. And yes, there is Ivan Pavlov, honored for his studies of gastric juice secretion. Could that possibly be the same man whose discoveries of conditioned reflexes would have profound impact on the development of experimental psychology and the understanding of mental illness? The Nobel documents do not say.

It would also appear that 20th century scientists did not work together in large groups as indicated by the fact that the Nobel documents show that a prize was never awarded to more than three people. Would future archaeologists conclude this to be at least part of the reason for the apparent lapses in 20th century scientific creativity? They might consider this the reason that scientists were unable to send vehicles into space or to harness nuclear and thermonuclear energy, all impossible undertakings without large research and development teams.

There is no doubt, the archaeologists would probably conclude, that 20th century scientific knowledge was very unevenly developed. Based on the evidence provided in the Nobel documents, its gaps were more remarkable than its achievements.

A defense of prize selection procedures

Almost all of the Nobel judges interviewed were aware, in varying degree, of such criticism and of the resulting charges that the prize is narrow, irrelevant, and obsolete. One Nobel judge, Börje Uvnäs, chairman of Sweden's Royal Caroline Institute's pharmacology department, made this remark: "I'm surprised how highly appraised the prizes are. It is difficult to understand. Of course we need criticism on our choices of winners, but the criticism we get is usually very mild."

But in defense of prize selection procedures the judges offered a number of arguments:

1. *Do not confuse science with technology.* Nobel Prizes are designed to reward discoveries about the organization and function of living and inanimate matter. How such discoveries may be applied to create computers, rockets, or better mouse traps—is outside of our scope. Besides, the men who developed the great technological and industrial inventions such as the telephone, the wide variety of pharmaceuticals, and the like were amply rewarded by the economy and have no need for our prize money.

2. *The will of Alfred Nobel, drafted in 1895, which is the basis for the prizes, excludes several of the established basic sciences and, of course, many of the newer behavioral sciences.* That is why there have been no prizes in astronomy or geology, for example (even though these might be considered to be branches of physics) or in "pure" mathematics. Mathematics is of Nobel prize interest only when it is *applied* in making fundamental discoveries within chemistry, physics, medicine, and physiology.

3. *The statutes of the Nobel Foundation, formed to carry out Nobel's will, limit the number of winners of a single prize to three.* This is why such things as the space program and the computer are not eligible for the prize. Each development required the efforts of thousands of people, and the Nobel committees were unable to single out the three most important individuals.

4. *Sometimes it takes years for a scientific discovery to be confirmed, found useful, and generally accepted by other scientists.* Many of the "gaps" the future archaeologists might find, based on interpretation of Nobel records, are in this category. Some of them will doubtlessly receive future prizes, but more solid evidence of their value is needed first. Unfortunately, by the time such general acceptance comes, some of the scientists will be dead. That is why Mendeleyev, for example, who was nominated several times, received no prize. And for Einstein's theories of general and special relativity still more confirmation is needed, although such confirmations are still gradually being made. And even if the theories are completely upheld, Einstein is dead too.

5. *There are simply too many good scientists today and too few prizes.* Each year some 10 to 20 men are judged by the Nobel committees to be worthy of winning *each* of the three prizes. Again, only a maximum of three scientists may be named for each prize. All of the prizeworthy candidates may be outstanding but may represent scientific fields that are impossible to compare. In medicine, for example, which is more important—a basic discovery in genetics or cell function, a spectacular surgical technique, or an important vaccine? The difficulty of answering such questions makes it a foregone conclusion that much good work will not receive Nobel recognition.

6. *Admittedly, there are inconsistencies and even errors in the prizes awarded over the past 71 years.* The selection committees are human and subject to error. There are also legitimate philosophical

differences among Nobel judges even now on what scientific excellence might be. Even the three Nobel science prize committees have views and procedures that differ from each other.

7. If the world has an overinflated view of the science prizes, that is not the fault of the Nobel committees or the Nobel Foundation. Probably the most representative defense of the prize record was given by Carl Gustave Bernhard, also a Nobel judge and a recent president of the Royal Swedish Academy of Sciences. As he writes in the 1971 edition of the Nobel Foundation's official book on the prizes, *Nobel: The Man and His Prizes:* "That the Nobel Prizes, in spite of these restrictions have come to be regarded as the highest scientific distinctions in the whole world, can therefore only mean that *certain well-defined discoveries* (emphasis added) have in fact been of paramount importance to the general progress of science."

Alfred Nobel's will

Accepting such restrictions, what are the standards used to separate the scientific wheat from the chaff? How are prize candidates found and examined? What *is* a discovery and when is it of benefit to mankind?

Most Nobel judges and officials continually refer to the will, the statutes, and the wishes of Alfred Nobel as explained by his friends' memories of his actions, conversations, and letters in defending prize selection procedure. With those guidelines, the explanation of the Nobel prize standards of excellence in science begins.

Nobel's will was very brief and general. On a single sheet, he wrote only that his vast estate should be invested safely with the resulting interest to be distributed annually "to those who, during the preceding year, shall have conferred the greatest benefit on mankind." His specific instructions were that the interest be divided five ways, with three of these earmarked for physics, chemistry, and physiology or medicine (the other two for literature and peace); that each science prize was to go to the person making "the most important discovery" in the three fields (as well as for "inventions" in physics and "improvements" in chemistry); that the Royal Swedish Academy of Sciences would select the winners of the chemistry and physics awards, while physiology/medicine would be the province of Sweden's Royal Caroline Institute; and that the winners might be of any nationality.

The will created much initial confusion among disappointed relatives and business associates, among the governments of the various nations where Nobel occasionally lived or operated his business empire, and among the membership of the science academy and the Royal Caroline Institute (some of whom feared that administration of the awards would bring political pressures and lobbying into their quiet havens of research). However, influential Swedish academics and industrialists—with the willing assistance of the Swedish King Oscar II—brought about an agreement, established the parent Nobel Foundation, and wrote the statutes.

The Nobel statutes

The statutes, which are much more detailed than Nobel's will, contained several interesting changes. Whereas Nobel wrote that each prize should go to a "person," presumably meaning one individual, the statutes specified that three—but no more—could share it. Apparently the intent was twofold. The statute writers recognized that an outstanding scientific work was seldom the work of one man, but to divide the prize money more than three ways would produce sums so small that the winners could finance very little future research. The unwitting effect of this provision, however, was forever to exclude discoveries made by large research groups. Also discarded from the will was the directive that the prize be awarded for a scientific achievement made during "the preceding year." The way of science is to treat discoveries very cautiously—to first publish them in a respected professional journal, to allow other scientists to check every detail in search of error or over-enthusiastic claims, to see if they survive the test of time. Decades can roll by before scientific discoveries are accepted as valid. (The most interesting example of this was the case of Francis Peyton Rous of the United States, who received the Nobel Prize in Physiology or Medicine in 1966 for experiments demonstrating that cancer can be transmitted by a virus. The experiments were first reported in 1910!)

The Nobel will says nothing about the cloaking of the prize selection procedure—the sorting out of the winners from the losers—in secrecy. The statutes, however, make selection off limits to outside scrutiny. Minutes of meetings by the three prize committees were directed to be extremely brief and to contain no evidence of disagreement among individual committee members over who should or should not win. Votes are not recorded, the names of all of the scientists considered for the prize in any one year are not released, and the lengthy special reports prepared on the scientific merit of the dozens of nominees are available for inspection only by members of the faculty of the Royal Caroline Institute and the Royal Swedish Academy of Sciences. For some 70 years, then, the nitty-gritty of determining who is "prize-worthy" and who is not, the fine detail of the value judgments rendered on what is good, bad, or indifferent in science has remained a well-kept secret.

The statute makers no doubt were motivated by the best of intentions. To conduct the selection in the open would subject Nobel judges to political influence and lobbying on behalf of particular scientist-candidates, thus destroying the objectivity of the scientific approach, they reasoned. The practice is still defended by Nobel judges who add that it would be unkind to reveal to the world the names of those candidates found to be unqualified for the prize. And the fact that the prizes are still highly regarded throughout the world today in many scientific and governmental circles reflects favorably, the judges believe, not only on the high quality of accomplishment by the prize winners over the past seven decades, but also on the policy of not airing the selection controversies (or the opinions behind value judgments) in public.

The Bettmann Archive



Alfred Nobel willed the bulk of his vast estate to establish the prizes that bear his name. A Swedish chemist and engineer, Nobel amassed his fortune by the invention and manufacture of dynamite and other explosives and by investments in oil fields.

Ironically, the Nobel judges themselves suffer from the secrecy mandate in the statutes. Stockholm conversations can be counted upon to produce rumors that such secrecy conceals prejudice or incompetence among the judges. The policy of secrecy also encourages the Swedish political left to suggest frequently in print that Marcus Wallenberg, one of the four members of the Nobel Foundation's governing board and a Rothschild-like figure with great influence in Swedish banking and industrial circles, may also influence prize awards. This is one reason, the left will argue, that the prizes frequently go to scientists of Western anti-Communist nations. (Through 1971, 84 science prizes had been awarded to the United States, 46 to Germany, 50 to Great Britain, 21 to France, and only 9 to the Soviet Union—out of a total of 278 for all nations over the 71 years. Scientists of the People's Republic of China have declined to submit prize nominations on the grounds that they do not believe in prizes awarded on an individual, non-collective basis.) The judges themselves shrug off such attacks as unfounded and generally unworthy of reply. Since the judges cannot produce Nobel records and minutes to defend their choices and actions, however, the rumors continue.

But a far more serious ramification of the secrecy policy is that it might result in the wrong man winning the prize. One old tradition, stemming from the early days of the statutes, is to avoid letting a science nominee know he is being considered for the prize. Yet the judges are committed to conduct as thorough an investigation as possible of the nominee's scientific work, not only to determine its merit as a "discovery" but also to see if he was the first or most important contributor to it. One senior Nobel judge, Sven Gard, commented that the policy forces Nobel investigators to operate so obliquely—trying not to tip off the nominee—that an erroneous assessment of a candidate's work might result.

A case can be made, according to most judges interviewed, that the secrecy policy denies the world's scholars access to civilization's longest and most complete record of science criticism and analysis. Perhaps the most valuable of these records are the lengthy investigations on scores of nominees each year. In a world where the vast majority of people understand little of the methods and goals of science —and increasingly attribute sinister purposes to it—the opening of the Nobel archives might, at the very least, produce a much more accurate picture of just what science can or cannot do.

That the secrecy policy has remained unchallenged for seven decades is particularly bizarre in Sweden. For more than 200 years, Sweden has operated under a government documents act that permits anyone to demand letters, memoranda, reports, and general documents on civil governmental affairs—and to have them produced by the civil servant approached *on the spot.* Swedish universities are nationalized, and since all Nobel judges are university men who are considered government employees, there is a question of whether they could deny access to the archives if such access were requested.

But perhaps the most important element of the statutes was clearly to invest prize decision powers in the hands of university professors specializing not in engineering or the applied sciences but in the fundamental sciences. Their decisions over seven decades have generally favored the basic scientific discovery—which often appears at first to be of no more than intellectual or cultural interest—at the expense of many of the revolutionary technological developments of the century (although occasionally machines or "practical" processes have been honored). Nobel himself was vitally interested in such basic science and wanted to give impetus to its development. Ironically, however, Nobel was also one of the 19th century's supreme industrial technologists.

Finally, the statutes roughly outlined how the judges were to go about canvassing the world for prizeworthy scientists. By 1971, these general instructions had been refined into a set procedure (*see* "How Nobel prizewinners are selected," pages 420–421).

What constitutes a "discovery?"

Language is full of words like "discovery," the meaning of which everyone is quite sure he understands. However, one often finds that the world is no more agreed on its meaning than it is on "good." There is no doubt that the meaning was clear to Alfred Nobel when he used the word in his will. It is probably very clear in meaning to his successors, the judges, although they are rather vague in discussing its significance with outsiders. When asked about what they considered "discovery" to mean in a Nobel context, the judges responded:

—"Something unexpected."

—"A big step."

—"A development which opens an entire new field of research."

Slightly more detailed is this definition by Nobel judge Gard: "If a scientist has followed a systematic research theme throughout his career that has at last answered a set of complex questions, he has made a discovery." Nobel laureate Ulf von Euler (who is also the son of a Nobel laureate): "It is something that no one believes at first because it departs too sharply from the norm. If it were good average work, it would be believed." And Nobel laureate Axel Hugo Theorell: "A discovery can be the result of a quick, simple experiment that yields an answer so clear and obvious that it is unnecessary for others to check or repeat the experiment."

According to classic scientific practice, the minimum requirement for a discovery is that it be published in a respected scientific journal. A great development kept secret—not presented before a scientific audience for a period of checking and confirmation—is simply not a "discovery." If a considerable number of scientists drop what they are doing to verify a development by another person—and find it is correct and interesting enough to enter that field themselves —it is indeed a valuable discovery.

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How Nobel prizewinners are selected

The Nobel awards complex is to Sweden as the Vatican is to Italy. It is autonomous and international. The judges constitute their own parliament, and preside over an elaborate diplomatic and scientific intelligence network. This Nobel nation begins a new year's activities each fall, and it is also then that the intelligence network is the most active.

The three science prize committees begin the new annual cycle by sending out 2,000 to 3,000 confidential letters. The purpose of the letters is to ask network members for suggestions about top candidates for the prizes. The identity of the letter recipients is not revealed outside of Nobel circles. It is generally known, however, that they are senior academics. Their ranks, of course, include all the members of the Royal Swedish Academy of Sciences and the senior faculty of the Royal Caroline Medico-Chirurgical Institute (each of whom are encouraged to informally contact their own colleagues abroad in search of nominees), senior professors at all the major Scandinavian universities, and leading scientists from two to three universities in each of the scientifically developed European and Asian nations as well as from perhaps a dozen U.S. universities. The principal science academies throughout the world, including the Soviet Academy of Sciences, are contacted, as are the principal officials of major research installations such as the European Organization for Nuclear Research (CERN), a high-energy physics laboratory in Switzerland; Great Britain's Jodrell Bank astrophysical observatory; the U.S. government National Institutes of Health; and the U.S. National Accelerator Laboratory in Batavia, Ill. Final key elements of this intelligence gathering network are the previously chosen Nobel laureates.



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The members of the Royal Swedish Academy of Sciences meet annually to select the winners of the prizes in physics and chemistry. This 1964 gathering chose Dorothy Crowfoot Hodgkin to receive the chemistry award and Charles H. Townes, Nikolai G. Basov, and Aleksandr M. Prokhorov to share the honor in physics.

The network then informs Stockholm on the prospects that look best that year. The letters of nomination they return are in themselves fairly detailed investigations of individual candidates that spell out clearly the nature of a scientist's work.

No further nominations are accepted after the following February 1. Then, the prize activities once more become an exclusively Swedish show. A rough weeding out is performed by members of the three committees. Immediately discarded are the names of scientists who nominate themselves (including those names sent by a candidate's loving wife—which actually has happened). The judges live by a kind of Robert's Rules of Order that cherishes merit coupled with modesty and is offended by what appear to be pressure tactics involving lobbying and publicity. An outstanding scientist may prejudice himself in the eyes of the judges by appearing to be trying too hard to win the prize. Finally, the best candidates must have a large body of published scientific work to their credit that can be read and checked in detail by the judges.

By summer, each committee has narrowed the list down to between 10 to 20 candidates. These are selected for the intensive investigations mentioned earlier. Senior judges sometimes are asked to prepare as many as 8 or 10 such reports. On occasion, a young outsider (not a judge or a person affiliated with the awards machinery) is asked to conduct an investigation. In this phase, selected members of the international intelligence network may again be contacted for much more detailed information on a candidate. Judges attend international scientific conferences, inquiring discreetly about this or that candidate but always, of course, denying that anyone actually is a candidate.

In an average year, the name of the winner is usually known by the judges by July. The remainder of the summer is spent in committee meetings and the writing of the final "Committee Report and Recommendations." The reports, containing all the investigations plus a recommendation for a winner, are formally presented to the full membership of the Royal Caroline senior faculty and the Royal Swedish Academy of Sciences in fall meetings (a year after the annual cycle began). On these meeting days, members of the two organizations file into a large auditorium and are presented a golden Nobel medal—or about $25 in cash if they already have enough medals—for attending the debate and vote. Usually, the debate is brief, and the voters endorse the committee recommendations (although judges commented that such recommendations have been altered or ignored on three or four occasions since World War II).

Then, the press is informed of the identity of the winners, and the world is presented its new Siegfrieds of science. All that remains is for the winners to come to Stockholm in December to deliver their Nobel addresses, to be congratulated by the King of Sweden, and to pick up their checks. But by then, the Nobel committees are well into the next cycle of activity, receiving nominations, keeping in touch with their network, pondering the next year's prizewinners.

Culver Pictures



Marie Curie, a Polish-born French physicist, won Nobel prizes in 1903 and 1911. She shared the first award, in physics, with her husband Pierre and Antoine Becquerel for their pioneering investigations into the nature of radioactivity. The 1911 prize, in chemistry, was for the isolation of pure radium.

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The most commonly mentioned examples of great discoveries, in the opinion of those judges who will discuss the subject, are Wilhelm Röntgen's discovery of X rays and the Antoine Henri Becquerel and Marie and Pierre Curie discovery and exploration of the nature of radioactivity. These were revelations of a fundamental property of matter which took the scientific world by surprise, opened vast new fields of research, and were applied in solving a huge variety of practical and scientific problems. Concerning more recent awards, the entire string of prizes given for genetics research since the 1950s is cited by the judges as examples of key discoveries. In that area, the name most frequently mentioned is that of Marshall W. Nirenberg, who shared the 1968 prize with Robert W. Holley and H. Gobind Khorana for work in deciphering the genetic code.

Erik Rudberg provided a more detailed analysis on what constitutes a Nobel-level discovery. He labeled most of his comments "personal opinions" that may or may not be shared by other judges. The first type of prizeworthy discovery he mentioned was in the class of "an advanced experimental technique or instrument that makes it possible for science to measure a phenomenon for the first time." Examples in physics include the cyclotron developed by Ernest Lawrence of the United States, the 1939 laureate. The cyclotron represented an entirely new approach at that time for probing the atomic nucleus with beams of high-energy electrons. Another example cited is the hydrogen bubble chamber developed by Donald Glaser of the United States (and honored by the physics award in 1960). The device permits a photographic record to be made of fragments broken from an atomic nucleus by a beam of probing particles.

"On the other hand, I would also give special consideration to a Nobel prize candidate who made an important finding with less-than-adequate instruments," Rudberg said. "That would be more impressive than the scientist who made a finding simply by pressing a button on a very sophisticated device." An example in point, he added, was the 1964 award to Charles H. Townes of the United States and to Nikolai G. Basov and Aleksandr M. Prokhorov of the Soviet Union for discovering the principles of the maser, and, indirectly, the laser. The two Soviet scientists worked in much more primitive laboratory conditions than Townes, but still managed to produce valuable and relevant results. (The award, incidentally, was delayed for several years, said Rudberg, because of the difficulty of obtaining information on the Soviet work.)

It is often a frustrating job to determine whether a discovery is something totally new or is merely a continuation of work done by others. One could argue philosophically, for example, that many 20th-century discoveries were simply continuations of work started by Archimedes or Democritus. Consequently, the Nobel judge looks principally for something Rudberg describes as the "sudden jump." Previous findings plotted on a graph, for example, would describe no more than a gently rising curve when compared to the sharp upward rise of the Nobel-level

discovery. An example is the 1969 physics award to Murray Gell-Mann of the United States for his theories on how the components of the atomic nucleus are organized. His "symmetry scheme" of nuclear components was later largely confirmed when a research team discovered a particle, the Omega Minus, which his theory had predicted. Another example of the sudden jump was in the field of semiconductors and transistors, which had drawn the attention of many physicists. The contributions of the U.S. team of William Shockley, John Bardeen, and Walter Brattain were sufficiently more precise and dramatic to justify the award of the 1956 physics prize to them, said Rudberg.

One recent award suggests an interesting change in traditional Nobel discovery standards and one that eventually may make findings by large research groups eligible. Luis W. Alvarez of the United States received the 1968 physics prize for his work in directing the accelerator team that confirmed the theories of Gell-Mann. The development of new experimental techniques and instruments was one reason for the award, explained Rudberg, as were the achievements of Alvarez in analyzing the extremely complex information obtained from the experiments. But for probably the first time, the judges also recognized a researcher's ability to administrate, to organize, and to coordinate a large team working on a difficult problem.

The discovery then remains a term of multiple definitions. In most cases, other judges said, when there is disagreement on which of a number of findings is the most legitimate, the contest is usually decided on the basis of which has brought more "benefit to mankind." The vagueness leaves the judges much room for maneuver in making award selections. Do they ever abuse this flexibility and allow prejudice to influence their choices? Rudberg's reply was generally echoed by other judges interviewed. "To my knowledge, very definitely not. I believe that to be the case for all the science prizes. However, in a critical international situation, for example, the wording of the award citation may be dampened a bit for other than purely scientific reasons."

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King Gustavus V of Sweden (left) congratulates Irène Joliot-Curie, daughter of Pierre and Marie Curie, for winning the 1935 Nobel Prize for Chemistry with her husband Frédéric, standing behind her. The Joliot-Curies won the award for synthesizing artificial radioactive elements.

Conclusion

The awarding of the prizes, then, has served high purposes over the past seven decades in stimulating the growth of certain of the basic sciences. The award activity has probably been more fair and objective in the hands of honest and qualified men from a small, neutral country such as Sweden than it might have been under the control of men from more nationalistic and politically ambitious governments. The discoveries honored by the prizes do not, in any sense, represent all of the best that has been produced in science and technology by 20th century man. Errors have been made, but scores of important scientists who might otherwise have been overlooked or mercilessly exploited for financial reasons have been allowed to bask in the glow of world admiration and to develop according to their own lights. That alone—although the prizes appear to many to be entirely too narrow in scope today—may be enough to fulfill Alfred Nobel's good intentions.

Too Many Scientists?

by Charles V. Kidd

After many years of not having enough manpower in science, the United States now shows signs of having too much. Have we trained too many scientists?

For nearly 30 years—from the beginning of World War II until the end of the 1960s—the United States faced continuing shortages of all kinds of manpower with advanced training, and particularly scientists and engineers. Only brief episodes in specialized fields disturbed the picture of demand that exceeded supply. All of the signs of shortage were present during this period: salaries rose rapidly; recruitment of both new holders of advanced degrees and older workers ranged from active to frantic; employers offered attractive fringe benefits, perquisites, and amenities to supplement salaries; the output of Ph.D.s rose rapidly in response to high demand; highly-trained foreigners relocated in the United States at a rate sufficient to generate heated debates in the United Nations with charges that the United States was draining from other nations the brains that they needed for economic and social progress; and, finally, mobility was high—virtually always leading to better jobs.

But, over the past several years there was a sharp reversal of the shortages that this nation had grown to accept as facts of life. Newspapers, magazines, and professional journals were full of stories of unemployed scientists and engineers and of the bleak future they faced. What caused this sudden shift? What is the real situation? Is unemployment a passing phenomenon or a warning signal of long-range trouble? Are we overproducing Ph.D.s? What is wise public policy, now and for the future? This essay examines these questions as they relate to the top cut of the nation's scientific and engineering manpower—those with a Ph.D. degree—and it includes social scientists as well as those in the physical and biological sciences.

Unemployment among scientists and engineers

Unemployment among scientists and engineers is so novel that exaggerated stories have been circulated widely. The actual unemployment rate among scientists in the spring of 1971 was 2.6%, as compared with 1.5% in the spring of 1970. The unemployment rate among the entire labor force for the spring of 1971 was 6.5%. So for scientists as a whole, the unemployment rate remained quite low. The general impression that unemployment was higher probably rested on the existence of pockets of unemployment in particular age groups, geographical areas, disciplines, and levels of training. For example, in the spring of 1971, in Seattle, Wash., a city hard hit by the reduction of work in aerospace companies, 5.6% of all scientists were unemployed. Nationwide, 5.3% of all scientists under the age of 29, 3.9% of the physicists, and 3.8% of the sociologists were unemployed. Most significantly the unemployment rate among those scientists with only a bachelor's degree was 4.1%, while only 1.4% of those with a doctorate were unemployed. The idea that there was widespread unemployment among Ph.D.s in science, or in any field, was contrary to fact. Moreover, even among the recent graduates, unemployment rates for holders of Ph.D.s in science were low. In the early months of 1971, only 0.5% of those who received a Ph.D. degree in science in 1969 and 1.1% of those who received the degree in 1970 were unemployed. The unemployment rates were only slightly higher among those with degrees from the less prestigious institutions. New Ph.D.s had to look harder and longer for jobs, and while they were looking, they were unemployed. After a long search, many of them did not land the job they preferred, but few—only 1.2%—took jobs that did not adequately make use of their graduate training.

Unemployment at this level certainly did not indicate that the country had trained too many scientists and engineers. Changes in a dynamic economy are certain to produce unemployment as emphasis shifts from one field to another. However, those unemployment levels may presage a long-range situation in which a degree of unemployment among scientists and engineers will continue, and in which many scientists and engineers may be forced to take jobs that are neither in universities nor in research and development.

What happened?

The output of Ph.D.s in science and engineering jumped fantastically in recent years, and then the demand for their services slackened. This produced unemployment. Let us look at each development in some detail.

There were as many Ph.D.s in science and engineering produced in the United States in the decade of the 1960s (112,000) as were graduated in the nation's entire prior history (111,000, *see* Table). This tremendous acceleration of output, which was roughly equal in all fields of science, engineering, and the nonsciences, required a continuing rapid growth of the capacity of the economy to absorb Ph.D.s.

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Ph.D.s graduated in the United States 1880–1974

year	total	scientists and engineers	scientists and engineers as % of total
1880–1929	23,000	15,000	65
1930–39	26,000	18,000	70
1940–44	15,000	10,000	66
1945–49	16,000	11,000	70
1950–54	40,000	27,000	67
1955–59	45,000	30,000	66
1960–64	60,000	41,000	66
1965–69	100,000	71,000	70
1970–74	160,000	101,000	63

Until 1968, the absorptive capacity did expand at the rate required to provide jobs for the new Ph.D.s. College and university enrollments, including enrollment in graduate science and engineering, doubled from three million to six million between 1960 and 1969. This generated a demand for new faculty members, and full-time faculty in colleges and universities increased from 170,000 in 1960 to 290,000 in 1969. Federal research and development expenditures grew steadily. From 1953 through 1961, the average annual growth rate of federal research and development expenditures was 16.3%, and private research and development expenditures rose by 10.1% a year. The comparable rates from 1961 through 1966 were 8.6 and 9.4%.

But between 1966 and 1968 things began to change. For example, from 1966 through 1971, federal research and development expenditures rose by only 1% a year and in real terms they declined by 3% a year. The aerospace cuts were particularly hard on engineers. Then came the general economic slowdown, with a 3% reduction in industrial research and development expenditures from industrial sources in 1970. These downward pressures were augmented by difficulties in the academic field. Universities, the prime academic employers of Ph.D.s, ran into steadily mounting financial difficulties. Graduate schools were particularly hard hit because of the federal slowdown in research and development expenditures and in their reduced support of graduate students. All of these factors combined explain the painful adjustments in the labor market.

What does the future hold?

Let us start with an examination of the existing pool of scientists and engineers. The United States now has about 160,000 scientists and engineers with Ph.D. degrees. They are distributed as follows:

Employer	%
Universities and colleges	60
Private industry	25
Government	10
Other	5

Therefore, the question is this: How rapidly will that pool expand over the next decade, and will the expanded pool be productively employed —and if so, where? Answers to such questions involve forecasting, and forecasting is now an imperfect art. One problem is that forecasts in the social sciences are not simply efforts to foretell what will happen. They can and often do influence the course of events. For example, a forecast of overproduction of engineers with Ph.D.s can be one of the factors leading to a decrease in enrollment and eventually in the output of Ph.D.s. The problem is further complicated by the long time required to produce a Ph.D. and by the long working life of the average Ph.D. A student who is pondering whether to become a Ph.D. candidate must, so far as job prospects influence him, consider not the current market but the market when he first looks for a job five years later and the market over the succeeding 30 years of his working life. To the extent that people believe manpower forecasts and act upon them, the forecasts are doomed to error unless those who make them predict the effects of their own forecasts. The more widely the forecasts are publicized the greater the extent to which they become an active factor influencing the trend of events.

Many powerful forces will continue to promote a continuing expansion of all graduate study, including that of the sciences and engineering. University science and engineering departments need graduate programs, and they need graduate students. The complexity of technology will continue to generate substantial demands for doctorates in engineering. Substantial support for students will continue, from one source or another, and large amounts of research money will continue to flow into universities. So, all things considered, there is a great deal of momentum in the system. Those students already in graduate school programs probably will push on to the Ph.D. degree in about the same proportions as in the past.

One would think that most students would shy away from enrolling for graduate work in science because of the stories of current unemployment forecasts and the declining support for science students. Rapid increases in graduate enrollment in science and engineering that characterized the 1960s have indeed slowed down. During the 1960s graduate enrollment in the physical sciences and engineering more than doubled; in mathematics and the biological sciences, enrollment almost tripled. But in the fall of 1970 and again in the fall of 1971,

first time enrollment of full-time graduate students in science and engineering increased by just 5%. Enrollment in science was up by 6% or so and engineering enrollment was unchanged. Total graduate first-year, full-time enrollment slackened off most rapidly in science and engineering in private institutions. The general public disillusionment with science and engineering and decreases in private and public support for graduate students contributed to this change.

While these negative pressures will probably continue, there is one powerful counter force—a continuing increase in the number of bachelor's degrees, including degrees in science and engineering. In 1965, five years before the 29,000 total doctorates of 1970 (17,300 of whom were scientists and engineers), 530,000 students received bachelor's degrees. In 1975, five years before the doctorate group of 1980, there will be about 960,000 bachelor's degrees. If the same proportion of the 1975 bachelor-degree holders proceed to a Ph.D. degree, as was true of their 1965 predecessors, about 52,000 Ph.D. degrees will be granted in all fields (about 32,000 of whom would be scientists and engineers).

A reasonable estimate of the total available supply of scientists and engineers in 1980 (after taking into account not only production, but death, retirement, emigration, and immigration) would be in the range of 315,000 to 340,000, with about 325,000 as a midpoint. These are the assumptions of the National Science Foundation and they are close to the estimates of others who forecast relatively low numbers of scientists and engineers with Ph.D. degrees.

Supply and demand

If one accepts the assumption that the existing pool of about 160,000 Ph.D.s in science and engineering will grow to about 325,000 or so by 1980, what is the prospect that the increased number—more than double the 1969 level—can be productively utilized? Assumptions have to be made to answer questions like this: At what rate will the total economy expand? What proportion of the gross national product will go into research and development? At what rates will enrollment in the sciences and engineering increase at undergraduate and graduate levels? What would be the effect of a really large-scale attack on problems of the environment? What will be the ratio of professors to students, and what proportion of faculty will have a Ph.D.? To what extent will Ph.D.s in science and engineering be absorbed in nonacademic, non-research and development jobs that will use their training reasonably well? What will be the long-run effects of the youth rebellion on advanced training in science?

Such a simple list of the questions that have to be answered in forecasting the demand for Ph.D.s in science and engineering suffices to show the impossibility of making firm and precise forecasts. Nevertheless, there is a fairly wide consensus on the dimensions of future demand for Ph.D.s, and the National Science Foundation projections provide a reasonable set of figures. They indicate that there will be

suitable jobs for 270,000 to 300,000 scientists and engineers in 1980. Employment substantially above these levels would be generated only by implausible rates of increase in the gross national product devoted to research, in undergraduate and graduate enrollment, in the proportion of all college and university faculty with a Ph.D., and in the absorption of Ph.D.s in nontraditional areas requiring high levels of academic preparation.

The total supply of doctorates in 1980 has been predicted to be 325,000. A likely figure for utilization of doctorates in that year would be 285,000. In this circumstance, there would be a gap of 40,000 between supply and utilization. These Ph.D.s would be for the most part underemployed. These figures are not precise but represent calculations based on plausible but not necessarily precise assumptions. In addition, the figures are for all scientists and engineers and do not indicate differences among fields. With these qualifications, the implications of the forecast are clear.

In 1971 most forecasts were less optimistic than they were in earlier years. For example, the National Science Foundation said of its 1971 projections that this "represents a greater likelihood of a future oversupply than the projections developed two years ago." Allan Cartter, who first pointed out that we should be worried about oversupply rather than shortages in 1980, has noted that the time of trouble has arrived sooner than he had originally thought. As of now, the possibility of oversupply should be viewed as a matter of continuing concern and not as a passing aberration.

The rough overall balance of supply and demand disguises some probable imbalance in specific fields. It appears that there may be substantially more engineering Ph.D.s than will find suitable work, although virtually all of them will have jobs. This may also be the case in mathematics and the social sciences, but the imbalance may not be as severe as in the case of engineering. The outlook is for reasonable balance in the physical sciences.

If there is not to be substantial unemployment among scientists and engineers, many more than the current 10%—as many as 15 or 20%—will have to be employed in nonacademic, non-research and development employment. This includes such fields as management, sales, government administration, consultation, and teaching in junior colleges and high schools. Here one faces the question whether such employment proves that there has been "overproduction." I think not, for the reason that these are worthy and productive careers. Moreover, a consistent line of development in this country, and one which has contributed greatly to social mobility and economic growth, has been a steady elevation of the level of education of those in given lines of work. However, this line of argument cannot be pushed too far because at an extreme it offers a way of dismissing any level of overproduction. That is, those not absorbed in academic work in four-year colleges and universities and in nonacademic research and development are simply assumed to be productively employed in other cate-

gories. If the National Science Foundation projections have a weakness it is in the assumption that from 40,000 to 55,000 engineering and science doctorates in the other category would all be suitably employed.

The overall picture of *total* employment also disguises the situation that will be faced by the *new* Ph.D.s. A certain and striking decrease in the proportion of new Ph.D.s who will be employed in universities and colleges is one of the most prominent prospects of the 1970s. This decline will come about as the rate of increase in undergraduate enrollment decreases over the decade and as enrollment actually declines in the 1980s. The proportion of new Ph.D.s in science and engineering who will be employed as faculty in colleges and universities will drop (from 60% during the 1960s) to about 10 to 25% in the last half of the 1970s. This decline will come about even if substantially more Ph.D.s are employed in junior colleges and even if the proportion of faculty with Ph.D.s in all academic institutions increases substantially. On the other hand, the proportion of new Ph.D.s during the 1970s who will be in nonacademic, non-research and development jobs will be 20 to 25%, and the proportion will rise throughout the decade.

Because of the changing job market, a substantial proportion of the Ph.D.s in science and engineering will have to be trained more broadly than is now the case, and with less emphasis on training for academic research. The change in the labor market will generate a debate over the nature of advanced training that will continue for years. If history offers a guide, the necessary adjustments will be made long after the need for them becomes evident.

The bargaining power of Ph.D.s in science and engineering will be less, and the power of employers—academic and nonacademic—will be greater in the present decade than it was during the preceding two decades. Not only jobs but promotions and raises will be harder to come by. To some degree, those with jobs will be in competition with those coming into the market. The average age of faculties will increase, and this will raise acutely the problem of maintaining youthful vigor in research and teaching in fields that will continue to change rapidly. Pressure will be exerted to reduce retirement ages and to modify tenure policies, with resulting financial problems for individuals and institutions.

Overproduction or underproduction?

Given the fact that supply and demand will rarely be in ideal balance, and that forecasts are virtually certain to be wrong in some respects, what general course of action with respect to training of scientists and engineers is appropriate? Should output be restricted on the ground that supply will apparently outrun demand?

The costs to the nation that would be generated by overproduction of scientists and engineers would be far less than those that would be generated by underproduction. The costs of overproduction are of two kinds. First, there are the economic costs of educating those who are "surplus" to the needs of the economy—defining surplus as the num-

ber who are not employed in jobs making reasonably full use of their advanced training. Second, there are the intangible costs to individuals as well as to society when a group of highly intelligent and highly trained people are unable to use their skills fully. However, the costs of overproduction, both to society and the individual, are reduced to a substantial degree by the fact that highly-trained scientists and engineers can perform capably and usefully in many capacities other than those for which they have been specifically trained.

On the other hand, the costs of having too few highly-trained scientists and engineers are extremely high. The inability to staff important segments of the economy with enough highly-trained people will tend to depress the total output of goods and services, retard advances in productivity, decrease the adaptability of the economic system, stifle innovation, and raise prices.

These considerations suggest that when the future is murky, as it generally is, the wisest course is not to take steps designed to achieve a fine balance between current output and anticipated demand, but rather to sustain output at levels somewhat above those that would be indicated if future balance were the goal.

The federal government has overreacted to the short-run situation. From a level of 50,000 graduate students in all fields supported by federal fellowships in 1968, there has been a decline to 30,000 in 1971, and a further decline to 22,000 in 1972 is probable. The cuts in graduate student support in science and engineering have been proportional to the total reduction. This abrupt reversal of federal policy toward support of graduate students threatens to cut the capacity of graduate schools—particularly the best ones—to turn out the highly-trained scientists and engineers needed a decade or more in the future.

If there is a principal lesson to be learned concerning the current changes in the labor market and the responses to them, it is that the U.S. has not yet learned how to combine planning and free choice in a way that will give individuals a reasonable chance to follow their interests while ensuring that the needs of society are reasonably well met.

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