7 January 1972, Volume 175, Number 4017 SCIENCE

Education and Science in China

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In late April and early May 1971, we were in Hanoi on a scientific visit to the Democratic Republic of Vietnam (*1*). In view of the unexpected invitation of the American table tennis team to the People's Republic of China early in April, we had decided to try to visit China ourselves. Accordingly we applied to the Chinese Embassy in Ottawa just before leaving the United States, and then sought visas at the Chinese Embassy in Hanoi. We were rather surprised when they were granted without much ado. Apparently we are the first American scientists to have visited the People's Republic of China in over 20 years. In recognition of this fact, we were granted a 2½-hour interview with Premier Chou En-lai in the Great Hall of the People on Tien An Men Square in Peking. We also had a lengthy visit in Shanghai with Prince Norodom Sihanouk, deposed Cambodian head of state.

We flew from Hanoi to Nanning on 10 May 1971, then spent 2 days in Canton, 7½ days in Peking, and 4½ days in Shanghai visiting scientific establishments, talking with Chinese scientists and seeing the country until our departure by way of Canton and Hong Kong on 25 May. We found that, under the impetus of the Cultural Revolution, the Chinese are experimenting with new ways of organizing science and medicine. They are trying to integrate scientific research more closely with the immediate needs of industry and agriculture, to broaden the scope of medical care so that it reaches as much of the population as possible, and to do away with institutional and social customs that used to keep intellectuals and professionals as elite classes culturally distinct from ordinary people.

Our formal scientific visits included three universities (Chungsan in Canton, Peking University, and Futan in Shanghai), four research institutes affiliated with the Academia Sinica (Botanical and Microbiological Institutes in Peking, Plant Physiological and Biochemical Institutes in Shanghai), and a hospital. We also visited two factories and a commune that included clinics and some research activity; a school for deaf-mute children; the Canton Trade Fair, where we saw many scientific and technical instruments of Chinese manufacture; the Forbidden (Imperial) City, containing priceless art relics of the Ming and Ching dynasties, a film ("Red Detachment of Women"), an opera ("Taking Tiger Mountain by Strategy"), and a ballet ("The White Haired Girl").

We learned much from two botanists Galston had known some years ago in the United States, and whose names he had mentioned when filling out his visa application in Hanoi. One, Loo Shih-wei, was a graduate student in plant physiology at the California Institute of Technology when Galston was there as a postdoctoral fellow during 1943–44. After postdoctoral years at Columbia and Iowa State, Loo had returned to China just before the victory of the Communists over the Kuomintang in 1949 and had taken a post at the Plant Physiological Institute of the Academia Sinica in Shanghai. He and Galston had exchanged Christmas cards, reprints, and letters until about 5 years ago, when the Cultural Revolution reduced contact between China and the outside world. Galston's other acquaintance was Lee Cheng-li, a plant anatomist-morphologist who had done postdoctoral work at Yale from 1955 to 1957. His wife, Shen Shu-chin, trained at Women's Medical College (now Pennsylvania Medical College) in Philadelphia, worked as a pediatrician at the Hospital of St. Raphael in New Haven. Lee is now a professor of botany at Peking University, and his wife is a member of a medical brigade. Both Lee and Loo met us as we arrived in their respective cities and were free to accompany us wherever we wanted to go. We visited not only their laboratories but also their homes, where we met their wives and families, and enjoyed conversing frankly in English in the absence of interpreters or anyone else.

Our immediate and lasting impression was that the Chinese people today are well fed, healthy, adequately clothed and housed, extremely hardworking, and loyal to the present government. The streets are clean and orderly, and the cities, despite their crowded and busy condition, appear peaceful and free of tension. We were never warned about sections into which we should not venture, and we saw no obviously depressed areas. We were free to wander by ourselves and to snap any photographs at will. It is worth recalling for comparison that starvation, disease, alternating flood and drought, crime, drug addiction, prostitution, and sale of children were frequently described as standard features of life in China before 1949 when the present government took power. The present obvious Chinese national pride and outspoken support of their government and leaders must result, in some measure at least, from their greatly improved standard of living.

Everywhere we went we saw portraits of Chairman Mao Tse-tung, together with billboards highlighting his quotations. Many of these are quite uncom-

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plimentary to the United States, such as "Unite and fight to defeat the U.S. imperialist aggressors and all their running dogs." However, almost everyone we met, whether in the streets, in universities, or at official receptions, expressed an extremely friendly attitude toward Americans. There seems to be a popular feeling fostered by the government that, despite the foreign policy of the U.S. government over the last 22 years, the American people are friends of the Chinese people. Other billboards denounce "revisionists," a reference to the Soviet Union. Relations between the U.S.S.R. and China seem very strained, especially since the border disputes of several years ago, and we were told that the massive air raid shelter construction program is, in part at least, a response to that strain.

The Cultural Revolution

During the years 1966–69, all aspects of life in China were convulsed by an upheaval called the Great Proletarian Cultural Revolution. For example, the universities were closed as formal instructional units, while professors, students, and political cadres worked out new basic policies and procedures. Some of the universities have now reopened and admitted their first groups of new students. However, neither the students, nor their professors, nor the subjects they study resemble closely what they were before. The Cultural Revolution appears to involve a rejection of the organizational systems of both the individualistic, competitive capitalist West and the autocratic, bureaucratic Soviet Union. Its aim is to push China away from the bureaucracy and elitism that pervaded the society up until 1965, allegedly under the influence of former head of state Liu Shao-chi. The present goal is the egalitarian society espoused by Mao Tse-tung, with its stress on equal opportunity for all and faith in group wisdom and accomplishment.

Much of the blame for the conditions that necessitated the Cultural Revolution is laid on the Soviet Union. The present "revisionist" Soviet government is described as having "taken the capitalist road" and as having come to depend on bureaucracy and privileged elite classes rather than "the masses." Liu Shao-chi, now called a "renegade, hidden traitor, and scab," tried to lead China along this path and make it dependent on the Soviet Union; this forced Chairman Mao to respond with the Cultural Revolution.

As early as 1952, Chen Po-ta, then vice president of the Chinese Academy of Sciences, spelled out the essentials of Chairman Mao's science policy (*2*). Science is conceived of as a collective group activity, in which theory and practice must always be united to serve production. The masses (workers, peasants, and members of the People's Liberation Army) are the ultimate source of discovery and verification of a scientific generalization, under the guidance of the Communist Party and the new generation of Communist-educated scientific cadres. The "revisionist" influence of Liu Shao-chi presumably prevented the application of this policy, but the Cultural Revolution has now instituted a number of reforms to put it into practice. The formal education process has been shortened: secondary school from 6 to 4 years and university from 5 to 3 years. Students and their teachers spend about 1 to 2 months each year working and studying production processes in farm and factory, and throughout the year a definite amount of time is spent studying political ideology, especially the philosophy of Chairman Mao. The universities are said to de-emphasize grades and to stress cooperation rather than competition.

The Organization of the University

Until the Cultural Revolution, the universities were run by experts who were developing them along Soviet lines. Futan University, for instance, was being turned into a "Moscow University of the Orient." Because Soviet influence "divorced the universities from the masses," Chairman Mao declared in 1966 that "bourgeois intellectuals" should no longer run the university. As a result of the ensuing Cultural Revolution, effective control was transferred to the hands of the masses. Ideological guidance for the transformation of the University was provided by activist Mao Tse-tung Thought Propaganda teams, including People's Liberation Army (PLA) teams sent out in 1967 and Workers' teams sent out in 1968. By 1969 the teams supervised the elections of the new governing bodies called Revolutionary Committees, which now run all enterprises, including universities.

The Revolutionary Committees seem designed at least partly to bring ordinary people into decision-making positions and thereby to minimize elitism. They are organized according to two "3 in 1" policies. First, each Revolutionary Committee must have representation from (i) "cadres" (managers or officials usually although not always members of the Communist Party), (ii) the masses (students, professors, workers in the university), and (iii) the PLA, or the militia. (We were told, incidentally, that the PLA is not purely military; it seems to be a national service organization embodying characteristics of our Army, Vista, Peace Corps, Civilian Conservation Corps, and Public Health Service. It is said to be politically oriented, and its representation on Revolutionary Committees is probably for the purpose of insuring control by the government.) The second 3 in 1 policy requires representation from the old, the middle-aged, and the young. There is also a strong move to give women equal representation in all areas, including policy-making bodies. Wherever we inquired, we found in fact that women were present but underrepresented on Revolutionary Committees. In explanation, our hosts reminded us that not so long ago women were not represented at all, and that rapid progress toward equality is being made. To eliminate discrimination against working women with children, the Chinese have instituted a widespread system of crèches and nursery schools in universities, factories, and communes. Many meals are eaten in canteens at the place of work, in order to further free women from the chores of shopping, cooking, serving, and cleaning up.

Election of Revolutionary Committees seems to have been a complicated procedure. At a factory we were told that it took place during several weeks of open meetings where nominees were discussed collectively until a final slate was agreed upon and elections were held. The term of office is apparently indefinite, but committee members may be removed by a superior Revolutionary Committees for personal or ideological reasons. We were told that at most institutions the chairman of the Revolutionary Committee is a political cadre, usually a member of the Communist Party. The actual running of a university, for example, would then be left to the vice chairman of the Revolutionary Committee, who is usually a senior professor elected by the Revolu-

tionary Committee. At Peking University, 12,700 students, faculty, and staff elected 39 members: 13 were from the local activist "Mao Tse-tung Propaganda Teams" (including seven PLA members and six workers); six were political cadres, nine were teachers, seven were students, three were workers from the university-run factory, and one was a representative of faculty and staff families. The vice chairman is Professor Chou Pei-yuan, a physicist who studied at California Institute of Technology from 1924 to 1928; he was vice rector of Peking University until 1965. He almost lost his position during the stormy days of ideological battling between different Red Guard factions but managed ultimately to help reconcile the factions.

Peking University, founded in 1898, is situated in a gracious parklike campus on the northern edge of the city; it is a university of arts and sciences with emphasis on the arts (*3*). Chungsan University, whose pleasant wooded campus is in suburban Canton, was formerly Lingnan Christian University. In 1924, Sun Yat Sen reorganized it into Canton University, and when he died in 1926 the name was changed to honor him (he was also known as Sun Chung-san). The university now specializes in the sciences (*4*). Futan University, which we visited briefly, is on the outskirts of Shanghai (*5*).

In the fall of 1970 all three universities admitted their first classes since the Cultural Revolution: 2667 at Peking, 547 at Chungsan, and 1136 at Futan. Enrollment is eventually expected to reach the former levels of nearly 10,000 at Peking, of more than 4,000 at Chungsan, and of 6,000 at Futan. But we were told that the admissions procedure is now very different from what it used to be.

To be admitted, students must be at least 20 years old, in good health, and qualified in political ideology, as shown by "mastery of Mao Tse-tung's philosophy, application of Mao's thought to forge close links with the masses, and demonstrated willingness to serve the people." They must have completed at least 2 years of secondary school. However, instead of going directly from secondary school to university, all students must first have at least several years' experience in agriculture, industry, or the army. Furthermore students no longer take a competitive matriculation examination. Instead each "production unit" (agricultural commune, factory, or army unit) may nominate candidates for the university after collective discussion. The students chosen will generally be outstanding production workers—intelligent and physically and ideologically qualified. A student may also apply individually for a university but must still obtain approval of his production unit or of officials in the region. The university assigns the new students to departments according to government quotas, respecting individual preference where possible. Once admitted to the university, students receive a government stipend of about one-third of the average worker's salary (19.5 yuan per month) for food and pocket money in addition to free tuition, board, and medical care. A worker coming to the university after 10 or more years on the production line receives full salary from the work unit on which he served.

At Peking University the student's daily schedule is very tight for 6 days of the week. Specifically, 6 a.m., rise and physical exercise, either organized or free; 7 a.m., breakfast; 7:30 to 11:30 a.m., classes; 11:30 a.m., lunch; 12 to 2:30 p.m., rest; 2:30 to 5:30 p.m., classes or study; 5:30 to 6:30 p.m., recreation; 6:30; dinner; 7 to 8 p.m., free; 8 to 9:30 p.m., study; 10 p.m., bedtime. Sundays are free. In a free-wheeling discussion with about 40 students in a dormitory, we were assured that competition among students does not exist. Examinations are given to permit the student and teacher to learn what the student does not know so that the deficiency may be corrected, but grades are not recorded. No student ever fails; all cooperate to make sure that "not a single classmate is left behind." When outstanding students need to be chosen to fill important positions in the university or in a production unit, the decision is made collectively.

When students graduate, the current plan is that most of them will return to their former positions on the production line in industry or agriculture, although a few will go on to teaching, research, graduate study, or other specialized positions. Those who have studied applied sciences will be able to use their newly acquired knowledge directly, but it is less clear what students in arts and letters will do. We were told they will do exactly what they were doing before but will serve as centers for the diffusion of knowledge about their specialty. Almost all students we questioned about their future answered at first that they would do "whatever the country needs."

This system is just being put into practice after several years of planning; we were cautioned that it is considered still experimental, but it is clearly a radical change in education policy. Its aim is to keep the working classes in direct touch with skills, knowledge, and expertise; hopefully they will never again be in the position of having to trust a privileged class of educated "experts" who know all about things that are beyond their comprehension. With education distributed among the working classes, the expectation is that the culturally isolated intellectual and expert classes will gradually disappear from society.

The university curriculum is also being altered to "integrate with production." The biology department at Chungsan University (*6*) formerly had two specialties, zoology and botany; now there are three: industrial biology, agricultural biology, and Chinese medical herbs. In order "to combine research, teaching, and production," the department operates several factories including one producing tetracycline antibiotics. This unit was built and is run cooperatively by students and teachers and sells the prepared antibiotic ampoules to the government at a profit. A new and better-equipped factory and laboratory is now being built with these profits, and new enterprises are being undertaken. For example, in collaboration with neighboring communes, both crude and crystalline gibberellic acid for agricultural use are being produced from the mold *Gibberella*. The practical problems require collaboration among various disciplines (biology, chemistry, physics, engineering, economics) and serve as proving ground and laboratory for both faculty and students.

We were told that before the Cultural Revolution university curricula were redundant and overlapping; these deficiencies have now been removed. At Number 3 Affiliated Hospital of Peking Medical College the medical curriculum, which is at the university rather than the postgraduate level, has been shortened from 6 to 3 years, and it has been streamlined, according to the principle of "fewer and more efficient." Formal basic course work terminates at the end of the first 10 months (*7*). Next follow 6 to 8 months of clinical training in affiliated hospitals, after which the students are sent to the fac-

tory or the countryside with their teachers for 8 months more of practical training. Finally, they return to the hospital for advanced clinical and theoretical training. Some of the doctors may later go on to specialize, "if the people in their departments feel they need it."

The new emphasis placed by the Cultural Revolution on "production," on the working classes, and on the policy of disestablishing the intellectual classes, will obviously require that the university faculties change their attitudes drastically. Despite the difficulties inherent in such a process, we were told that no faculty or staff members were discharged because of the changes wrought by the Cultural Revolution. Some of the older ones were pensioned off; others who were repudiated by the new Revolutionary Committee were sent off to be "reeducated" and to have their social points of view altered by contact with working people in a special school ("May 7 Cadre School"), a commune or a factory. After varying periods of time, such people returned to the university and were reinstated to their former positions, apparently having been reoriented along accepted pathways. We saw and heard no evidence of executions or imprisonment of dissident intellectuals. This conclusion has recently been confirmed by Professor C. N. Yang of the State University of New York at Stony Brook (personal communication), who recently returned from a visit to China. Well acquainted with Tsinghua University in Peking, where he lived as a boy and young man, he was able to account for all of the pre-Cultural Revolution members of the faculty.

The three intellectuals with whom we were able to discuss the matter at length had very positive attitudes toward the readjustments entailed in their "reeducation." Galston's friend Lee Cheng-li, still a professor at Peking University, looked bronzed, lean, and healthy and insisted that he feels much better now that he spends some time in the fields doing manual labor. His scientific work has shifted from plant morphology to palynology in connection with explorations for petroleum. His wife, Shen Shu-chin, a pediatrician, as mentioned earlier, trained in the United States, set up practice in Peking when they returned to China in 1957. She felt that she was doing her part for society, and when the Cultural Revolution began she didn't think its exhortations applied to her. But she later became convinced that by staying in Peking she had been working only for her own satisfaction and taking the easy and comfortable path. Heeding Mao's call "to bring medicine to all the people," she joined a medical brigade, which at the time of our visit had just returned from 18 months in the countryside. She spent this time ministering to sick children, helping to establish clinical centers in each village, hamlet, and commune, and training paraprofessionals ("barefoot doctors") in first aid and similar fundamentals. She saw her family only sporadically during these 18 months, but now feels that she has truly served the people, and she is preparing to return to the countryside. She wore proudly a pin that reads "Serve the People" and presented such a pin to each of us upon our departure. Their older son, now 18 years old, is with a workers' brigade on the frontier in the northwest; their younger son, aged 12, wants to become a laborer.

Galston's friend Loo Shih-wei, now 64 years old, is still a plant physiologist at the Institute of the Academia Sinica in Shanghai. He used to work in the laboratory on the effects of plant hormones on growth and on the development of agriculturally important plants. Since the Cultural Revolution he has been working on similar problems, but now he works in collaboration with members of a production unit at the Malu People's Agricultural Commune just outside Shanghai. Like other Western trained plant physiologists, he knew that the hormone gibberellin applied to seedlings increases the rate of plant growth but frequently not the final yield. However, at the suggestion of some of the peasants at the commune he tried applying it to barley at the flowering stage instead and found a 20 percent increase in the yield of grain. Since purified gibberellin is expensive, he and the commune members together worked out a new technique, using a cheap, crude gibberellin preparation that they could make themselves (*8*). This crude gibberellin is also used to increase yield of rapeseed, to prevent premature cotton boll abscission and (experimentally) to increase rice yields. Loo says that he has felt much more socially useful since his "reorientation" and is enjoying his work more. He cites his own case as evidence that scientists can frequently receive good suggestions from relatively untrained workers whose common sense has been sharpened by practical experience. He maintains that this did not happen before the Cultural Revolution because of the separation of intellectuals from average people.

Scientific Research

Like the universities, the research institutes of the Academia Sinica are run by elected Revolutionary Committees, whose chairman is a political cadre and whose vice chairman is a practicing scientist. They, too, have undergone profound transformations since the Cultural Revolution. Work has certainly been interrupted and dislocated during the past few years, and even in the West we can see evidence of this in the fact that publication of well-known scientific journals has stopped. However, the laboratories we visited seemed to be operating at a reasonable level. We were told that research would soon be in full swing again and that journals are soon to reappear.

At least some of the laboratories have considerable access to Western science. For example, the library attached jointly to the Biochemistry and Plant Physiology Institutes in Shanghai would grace any American university. It has all the standard scientific journals we could think of, most of them complete up to about 3 months before our visit, and a large number of books. There is also a special reading room for studying Mao Tse-tung Thought, to which most professional workers are said to devote about an hour each day. The university libraries seemed fairly well stocked, too. Individual laboratories all had a number of Chinese books and usually also several foreign texts, often quite up to date, interspersed with copies of the "little red book," *Quotations from Chairman Mao*.

The Biochemical Institute of the Academia Sinica in Shanghai impressed the scientific world in 1965 by its accomplishment of the total synthesis of biologically active insulin. There are now groups working on protein structure and function, on the mechanism of action of enzymes, on nucleic acids, and on metabolism (*9*). The Plant Physiological Institute in Shanghai includes laboratories of photosynthesis, plant hormones, and agricultural microbiology (*10*). The Botanical Institute in Peking does research on taxonomy of medicinal plants; geobotany, paleobotany, and palynology; development of plant resources; and research on herbicides, plant hormones, fruit and vegetable storage, and general plant physiology (*11*). At the Microbiological Institute in Peking we saw studies on microbial taxonomy and preservation of cultures; microbial genetics and breeding of useful strains; and micro-

bial physiology and enzymology (*12*). We also visited research laboratories of entomology, industrial microbiology, pharmacology, and electron microscopy at Chungsan University (*13*). While we can hardly claim to have surveyed all of Chinese science, we did see a number of features that seemed to be unlike those of science elsewhere, specifically because of the Cultural Revolution.

A change that will have very far-reaching effects on Chinese science is the decision to concentrate on applied rather than basic research. This policy was instituted during the Cultural Revolution as part of the general policy of "integrating with production" and "serving the people." The Chinese maintain that they are not against theoretical research, but that industrial and agricultural production should be the source of knowledge used to construct theories. Even very "long-term, exploratory research" is acceptable, they say, although "we must still handle correctly its relationship to production" (*14*). Presumably this means some basic research is still supported. However, all the biological scientists we met who were formerly doing basic research are now doing applied work and "participating in production." Fossil and evolutionary botanists are now working on the geobotany of pollen grains, useful in petroleum prospecting; taxonomists are now concentrating on industrially useful bacterial and medically useful plant strains; bacterial geneticists formerly doing pure research are now developing new strains with better growth characteristics and higher yield for industry; entomologists have switched from physiological studies to combating plant pests; and botanists who were studying basic plant physiology are now working to increase agricultural production.

The insulin group at the Biochemical Institute in Shanghai was an interesting example. We first asked why they had decided to synthesize the hormone back in 1958. Hu Shi-chuan, the head of the Institute, answered: "Our great leader Engels said that protein is a form of life. By synthesizing it from simple chemicals we proved the correctness of materialism and discredited idealism, which holds that biological substances can only be obtained from living matter." (This was a rather unexpected answer, but resembled somewhat the attitude of American scientists who have recently synthesized biologically active nucleic acid molecules.) "Also," he continued, "we wanted ultimately to be able to synthesize insulins with amino acid substitutions in order to study the relationship of protein structure and function." His answer was typical of many we received, both in science and elsewhere, in giving a practical reason together with an ideological framework and justification. But when we asked if they were still working on insulin, he said there was really no urgent need for doing so. Instead they are now adapting the methodology to the industrial synthesis, for medical use, of the small peptide hormones oxytocin and angiotensin. Thus, like most of the other research groups we met who have shifted from basic to applied work, the insulin group has not embarked on a totally new project, but has rather shifted the focus of its work enough for it to have some application in production.

The new research policy often involves scientists working closely with a specific factory or agricultural commune. Thus, in order to coordinate the joint effort, the insulin group began their shift by first going to the factory that was to synthesize the peptide hormones, and have maintained the contact since. Groups at the Microbiological Institute in Peking studying microbial synthesis of glutamic acid for production of monosodium glutamate and enzymic conversion of cornstarch to glucose for intravenous feeding also work closely with the appropriate factories. Scientists at the Botanical Institute in Peking, who are purifying a novel growth factor from water chestnuts, cooperate with an agricultural commune where it is tested and will hopefully be used to increase crop yields. They are also investigating the use of hydrolyzed yeast (grown on agricultural wastes) in increasing yield. Entomologists at Chungsan University, having developed a way of fighting a litchi wasp with insect parasites, are raising the parasites at 40 different communes. And Loo Shih-wei's group at the Plant Physiological Institute in Shanghai, formerly studying the mechanism of action of plant hormones, has moved to a commune outside the city to develop the agricultural use of these substances.

Conversely, factory workers and peasants have begun spending a few weeks or months in the appropriate research laboratory to learn techniques. At the Department of Biology in Chungsan University, a factory team has come to study the extraction of pharmacologically active substances from medicinal plants. After their exposure to research and development at the University, they plan to return to the factory to begin large-scale production. In another laboratory, workers from an iron refinery are collaborating with microbiologists in studying the use of sulfur-metabolizing bacteria to remove sulfur from low grade iron ore. Production workers are also said to be invited to research seminars in the laboratories.

Workers and peasants, particularly in agricultural communes, are being encouraged to set up their own simple laboratory facilities. At the Malu People's Commune in Shanghai, a small factory was turning out a crude preparation of the hormone gibberellin from a water extract of fungal mycelia (*8*). Nearly all the equipment was primitive and homemade—the incubator room for growing the fungus, for example, was heated by a hot plate nailed up in each corner of the ceiling. Next door was a thatch-roofed hut containing a white-tiled laboratory for microbiological work and for quality testing of sodium sulfite, made for sale by the commune from sodium carbonate and flowers of sulfur bought outside. And in the back room of the pharmacy at the small clinic in the housing project of the Number Three Cotton Textile Mill in Peking, we were surprised to find, among the stocks of traditional and Western medicines, a large ion-exchange column being used to purify the anesthetic procaine.

During the Cultural Revolution chairman Mao emphasized Chinese self-reliance, partly because China had become too dependent on foreign countries, particularly the Soviet Union. We saw evidence of this policy in the abundant jars of chemicals of Chinese manufacture lining the shelves of all the laboratories we visited. The biochemistry group in Shanghai, having decided to synthesize insulin, said they chose first to start a new factory for chemically synthesizing the component amino acids rather than buying them abroad. And although we saw some foreign items (dating mostly from before 1949), most of the equipment—*p*H meters, photometers, electron and light microscopes, refrigerated centrifuges, an electrophoresis apparatus, microbiological incubators, and all the hospital operating room equipment—was made in China, and appeared to be of high quality. The laboratories themselves, scrupulously clean and neat, were furnished modestly, and very much resembled photographs of biology and chemistry

laboratories in the United States in the 1920's and 1930's. This was true even in the laboratory where insulin was synthesized.

Much of Chinese taxonomy is now being done in relation to economically important plants and microorganisms which, insofar as possible, are local strains. Self-reliance, we were told, also means that, although the Chinese are prepared to learn from foreigners and welcome our suggestions and advice, few (if any) Chinese scientists have gone abroad for training since the Cultural Revolution. The ones who had previously done so—at the Microbiological Institute in Peking, about 20 out of 300, both group leaders and ordinary scientists—had generally gone to the United States and Europe before 1949, but after 1949 to the Soviet Union. In response to our question, we were told that the Chinese are prepared to send representatives to international scientific meetings, but not if scientists from Taiwan are also present.

Besides the shift to applied research, the emphasis on production, and the stress on self-reliance, an additional factor impressed us as particularly different and characteristic of Chinese science since the Cultural Revolution. This is a strong, determined attempt to alter the social framework in which scientific research is done in order to reduce elitism, narrow the gap between experts and average workers, and disestablish intellectuals and technical experts as a privileged social class. We have already described the Revolutionary Committees, which bring average workers into positions of responsibility, and the "re-education" which intellectuals have undergone since the Cultural Revolution.

In order to increase contact with workers and peasants, at Peking University each faculty member rotates periodically among teaching, research, and manual labor in a production unit. In addition, scientists now do part of their research work at factories and communes, and workers and peasants spend time in laboratories working on projects related to their needs. Intellectuals are officially encouraged to pay close attention to suggestions from ordinary, untrained people, and several scientists offered us unsolicited instances from their own experiences. Above, we described Loo Shih-wei's experience of receiving useful suggestions from commune peasants regarding the use of gibberellin. At the Microbiological Institute in Peking (*12*), it was a visiting worker who suggested correctly that the efficiency of the industrial enzymic process converting starch to glucose could be improved by making the enzyme insoluble. Other scientists working there on contamination of industrial bacterial cultures with several viruses were having trouble obtaining multiply resistant strains, but following the suggestion of a factory worker seemed to succeed by using instead mixed cultures of singly resistant strains. And when scientists began going to the factories to find out about production problems, the experienced workers took pains to help them learn. These examples were quoted, not to give the impression that peasants and workers are automatically always correct, nor that uneducated people are necessarily smarter than educated ones, but, rather, to emphasize the current notion that suggestions should be evaluated only on merit, and that even uneducated people can make valuable commonsense suggestions. Before the Cultural Revolution, we were told, experts and intellectuals would not deign to accept advice from uneducated people.

A similar leveling process is said to be occurring within the research groups. At the Microbiological Institute in Peking the title of professor has officially been abolished (although it seems still to be used deferentially for older scientists), and all the scientists are considered research workers at the same level. There are still heads of research groups; but, whereas they used to make all decisions, now "bright young persons can insist on the truth, which is sometimes in the hands of the minority." Thus anyone, including workers, can suggest a research project to the group for discussion, although the final decision on adoption rests with the Revolutionary Committee of the Institute or with even a higher authority. We were told that the criterion for authorizing a research project is "the needs of the people."

We were quite aware of the absence of one kind of elitism during our tours of institutes and universities and the formal interviews that always preceded them. While those in authority were treated with respect and deference, people of the rank and file showed no hesitation or self-consciousness in interrupting the conversation or in contradicting their superiors when they had something to say; nor did these contributions seem to be taken amiss.

In Peking we lectured on our specialties before about 75 scientists and students in reception rooms on the sixth floor of the Peking Hotel, just off the Tien An Men square where large public demonstrations are held. Galston spoke on the physical and chemical control of plant growth to a group that came mainly from the Botanical Institute and the University, and Signer spoke on the genetics of bacteriophage to a group mainly from the Microbiological Institute. Our interpreters—Professors Tsui Cheng and S. I. Lu, respectively—had learned English years ago while studying in the United States. They were both excellent, despite the fact that Professor Tsui said that he hadn't spoken English in 20 years. One surprise was their use of Chinese words for even very technical terms—such as ribosome, aneuploid, and heterozygote—presumably another instance of self-reliance. During the lively discussions that followed our talks we answered some questions that indicated familiarity with recent advances in Western science on the part of most, and more detailed knowledge on the part of the few specialists.

Medical Care

Although more than 80 percent of the Chinese people have lived in rural areas, medical care used to be heavily concentrated in the cities. Redressing this imbalance seems to be one of the main goals of the Cultural Revolution (*15*). At the Number 3 Affiliated Hospital of Peking Medical College (*16*) Kuo Fa-shang, head of the Revolutionary Committee, told us that one-third of the staff has now moved permanently to the countryside. There they will "care for the peasants and train 'barefoot doctors' [paramedical personnel]," as Dr. Shen Shu-chin, whom we described above, had done. The remaining two-thirds of the staff, besides picking up the slack at the Hospital, are also organized in mobile teams that occasionally go to the neighboring districts and countryside to give medical care and lessons in preventive medicine. Chairman Mao's instruction, "In medicine, put stress on the rural areas," is apparently being taken to heart.

Medical care for workers and peasants is either free or covered by cooperative medical plans costing very little (a few tenths of a percent of an average salary), although dependents must pay half the costs of medicines and hospitalization. Care is generally administered through the factory or agricultural commune. A clinic at the Number 3

Cotton Textile Mill in Peking, although in modest quarters, seemed well organized (*17*).

Birth control is being encouraged in an attempt to reduce the rate of population growth, said to be about 2 percent yearly, to 1 percent. The methods include voluntary sterilization of both men and women, intrauterine devices, and a contraceptive pill developed in China. In addition, traditional herbal remedies are being investigated.

Traditional medicines appear to be taken very seriously in China, a consequence of Chairman Mao's instruction: "Chinese medicine and pharmacology are a great treasure house. Efforts should be made to exploit them and elevate them to a high level." The Chinese are teaching the peasants, particularly the "barefoot doctors," to recognize, grow, and handle medicinal herbs. Since the Cultural Revolution began, the taxonomists at the Botanical Institutes and in the university departments of biology have been preparing manuals to help identify them. Scientists are trying to extract the active principles from many of these, as at Chungsan University where we saw students testing preparations used to stop bleeding. Furthermore, Western-trained doctors are encouraged to study traditional medicine and combine the two systems.

Perhaps the most remarkable traditional medical technique is acupuncture, the ancient Chinese practice of ameliorating pain by inserting very fine needles into one or several discrete points of the body. Although this practice has long been known in the Western world it has never found favor here, mainly because no rational explanation has yet been provided for the effects of the needles inserted at the various locations. Chinese doctors told us that some points are correlated with nerve-muscle junctions, but others are not. Although they are trying to find a physiological basis for the phenomenon they have not yet succeeded.

We saw acupuncture used in two ways. The first was in the treatment of children that had become deaf as a result of early childhood infections. Every 10 days needles are inserted and twisted in place below the ear and above the wrist. We saw such acupuncture performed in the classroom by a teacher and a member of a PLA team at one of the four schools for deaf-mute children in Peking. It was alleged that this treatment restored at least some hearing to 90 percent of the deaf children treated. Six out of 230 were said to have improved enough over the past 3 years to be sent on to regular school, with another eight planned for transfer soon. Of course, we had no way of verifying these statistics or comparing them with the spontaneous remission rate. However, we did see a class of pupils who were formerly totally deaf repeating syllables pronounced loudly and distinctly by the teacher, and some of them then put on recitations and brief skits for us.

Much more spectacular and immediately verifiable was our observation of four simultaneous major operations performed at the Affiliated Hospital. The only anesthetic was electroacupuncture —a new application of the ancient technique. We witnessed the preparation of patients for removal of duodenal ulcer, removal of thyroid tumor, removal of an ovarian cyst, and repair of an inguinal hernia. In all cases, two or three pairs of bilaterally placed needles were deftly inserted into the body. For the three abdominal operations the needles were placed in the calves at different points; the hernia operation had an additional pair placed at the site of incision; and the thyroid operation required needles in the neck and the backs of the wrists in addition to ordinary surface electrodes taped to the upper chest. The needles were connected to a small (5 volt), direct current electrical unit, and a pulsed current of 0.5 milliampere was permitted to flow for 20 minutes. After 20 minutes the affected part was completely anesthetized, and we were told that operations lasting as long as 9 hours could then be performed. We personally witnessed the incisions being made and operations performed. To the best of our knowledge the patients had no other anesthesia and had not been hypnotized. All were alert and talked to us before and during the operation. Three of the four were cheerful and relaxed, although the hernia patient was nervous and clutched a copy of Chairman Mao's sayings to his breast throughout. By contrast, the woman whose baseball-sized ovarian cyst had just been removed asked to see it, and we photographed her smiling at it as it was held up to her in a dish, while her abdomen was being sewed up. In Shanghai we met Audrey Topping of the *New York Times*, who had just witnessed open-heart surgery on a patient given acupuncture anesthesia. She reported (*18*) that the patient was awake and alert throughout the operation, and even sipped orange juice while her heart was exposed. Since then, several groups of American physicians have also witnessed similar operations performed under acupuncture anesthesia (*19*).

Traditional medicines are also combined with modern ones in psychiatry. Depending on the symptoms, we were told, acupuncture and herbal medicines may be combined with vitamins and insulin therapy, or electric shock treatment (discontinued at the Affiliated Hospital). But the main treatment is discussion therapy—not based on Freud or other "idealistic Western theories," but rather on dialectical materialism and the philosophy of Chairman Mao.

General Comments

It is important to keep in mind the limitations of our visit. Besides lacking the time to see many things, we had to generalize from a very small number of examples and accept many facts second hand. Furthermore, we were observing a frankly experimental shift in policy that is still in its early stages, and it seems far too soon to tell how permanent or successful will be the changes instituted as part of the Cultural Revolution. However, we were completely free to walk, observe, and photograph wherever we wished in the cities we visited, and we could talk frankly and in isolation with English-speaking friends.

The quality of most of the scientific research we saw was modest. This is not surprising considering for instance that when China emerged from feudalism as recently as 1949, there were only 125,000 college-trained people in the entire country [there are now said to be over 2 million (*20*)]. From that point of view progress has been quite remarkable. Furthermore there were significant exceptions such as the synthesis of insulin, the production of a birth control pill, and the use of gibberellin to increase plant yield. The Chinese have also made great strides in the physical sciences (*21*).

The extent to which scientific research has resumed after the upheavals of the Cultural Revolution is difficult to judge; the laboratories we visited appeared fully staffed and running at a reasonable level. China has obviously suffered a short-term loss in scientific productivity, but the Chinese feel that this will be more than compensated for by the long-term benefits that are expected to result from the reforms of the Cultural Revolution.

These reforms will probably make Chinese scientific research rather different from that elsewhere. Clearly, applied research will predominate, although some basic research may also be supported. The emphasis on research closely integrated with agricultural and industrial production will presumably be accompanied by emphasis on the education of workers and peasants. This policy will also be reinforced, in parallel with large-scale science in research institutes, by the development of science on a small scale in factories and communes—part of Chairman Mao's general policy of "walk on two legs."

The Chinese will probably continue to rely to some degree on foreign basic science, which seems sensible in view of the extent to which this has been developed in the West. Nevertheless self-reliance and independence of foreign influence are obviously very important to the Chinese, probably resulting in part from the hostility of the United States since 1949 and the Soviet Union since 1960. Thus the Chinese will probably attempt to become self-sufficient as quickly as possible in those areas that they consider important.

Potentially the most far-reaching reform is the attempt to eliminate elitism from scientific, technical, and intellectual activity. The priorities and attitudes of scientists may already be affected by the emphasis on workers and peasants, or practical commonsense knowledge, and on "serving the people." No doubt there was a good deal of opposition on the part of intellectuals to their loss of class privileges and deference status, and of course we did not expect to be introduced to opponents of the policy. However, most of the scientists we met seemed very much in sympathy with this sort of egalitarianism. If the policy is successful, Chinese scientists and intellectuals may come to see themselves, and be seen, simply as useful members of society rather than as an elite class of mandarins.

The scientific reforms seem to be only part of the larger efforts of the Cultural Revolution to change the values of Chinese society. At the universities, as elsewhere, average working people are being brought at least to some extent into positions of responsibility. The admissions and curriculum reforms will probably result in university graduates continuing to identify themselves as workers and peasants, from whose ranks they entered, instead of becoming a separate social class. Reforms similar in principle are making medical care available to many more people and elevating traditional folk remedies to a respectable status.

Since our visit, an increasing number of Americans are being invited to the People's Republic of China. We can only hope that exchanges of scientists in both directions will become part of the regular scientific scene. There is much to be gained by both parties from a reopening of the channels linking our two countries.

References and Notes

1. A. W. Galston and E. Signer, *Science* **174**, 379 (1971).
2. R. P. Suttmeier, *China Quarterly*, October/December 1970, p. 146.
3. There are 17 departments, 10 of which are in arts and 7 in sciences. These are subdivided into 42 specialties, as well as university-run factories and experimental farms. There are 201 professors and 700 active teachers present on the campus, out of a total teaching staff of 2134. The remainder are either doing research, training in the field, or are performing some task in a production unit in factory or farm.
4. The university has nine departments: electronics, optics, metals, dynamics, chemistry, biology, geography, political science, and Chinese literature. There used to be 4500 students; this number dwindled to zero during the Cultural Revolution, and the first class admitted in December 1970 had 547 students. The aim is an enrollment of more than 4000. There are 1900 employees at the university, including 66 professors, 34 associate professors, 163 lecturers, and 646 assistants; the rest are staff and political cadres. Much of what we learned about this university was told to us by the vice chairman of the Revolutionary Committee, Huang Sen, through an interpreter, but we also obtained much direct information in English from Pu Chih Lung and his wife Lee Tsui Ying. Both are insect physiologists who earned Ph.D. degrees at the University of Minnesota in 1946 and 1949, respectively, and have been in China ever since the revolution.
5. We had an interesting question and answer session with a large group, including Professor C. C. Tan, a *Drosophila* geneticist who studied at Caltech and knew many American biologists, and with Professor Hwang Kai Ji, a plant morphologist. The remainder were students and staff workers in various categories. The meeting began with a recital of the history and recent transformation of the University by a student member of the Revolutionary Committee who belongs to both the Mao Tse-tung Thought Propaganda Team and the Communist Party. He explained that the University was founded in 1905 as part of a French mission with a faculty and student body of about 400 people. There has been gradual and considerable expansion since 1949. Before the Cultural Revolution, there were 2500 staff and 650 students; now there are 107 professors, 235 lecturers, 948 assistants, 400 other staff members, 379 workers, and 290 postgraduates still in the school. There are 13 departments, including the following six in the sciences: electronics, optics, nuclear physics, mathematics, chemistry, and biology. The arts departments are Chinese literature, general literature, international politics, economics, philosophy, history, and foreign languages. There has been no change in the departmental structure here as a result of the Cultural Revolution.
6. The biology department, headed by a woman, has 12 professors, 36 lecturers, and 150 students; plans call for a student body of about 500.
7. The college and its four hospitals can accommodate 2800 students, and, as elsewhere, the present class of 750 is the first since the Cultural Revolution began. Although secondary education is the customary requirement, many of these students have apparently substituted training as "barefoot doctors" (see below) and "practical experience." First-year courses include anatomy, physiology, biochemistry, pathology, histology, embryology, microbiology, pharmacology, parasitology, epidemiology, and preventive medicine. Graduate doctors are expected to be proficient in diagnosis and treatment of common diseases, routine major surgery, obstetrics, and diagnostic bacteriology and parasitology.
8. The workers at the commune decided to manufacture and use gibberellins agriculturally. Cooperatively, and with scientific guidance, they worked out a method for using such agricultural wastes as rice and barley chaff, supplemented by some corn flour, as a growth medium. Cultures are started in glass bottles in incubators; these are then used to inoculate open trays kept in large enclosed racks. When the mycelium of the fungus has overgrown the tray it is removed as a mat, dried in the sun, reduced to a powder, mixed with water, and filtered over a locally obtained, washed, kaolinite type of clay. The clay decolorizes the preparation and also removes some interfering inhibitory compounds, such as fusaric acid. The resulting clear preparation could be easily standardized for gibberellin content by fluorometry and bioassay at the commune, and could also be then directly applied to the crops.
9. The Biochemical Institute also includes workshops for the repair of equipment and preparation of reagents as well as two attached factories. Since January 1968, the laboratory has been attempting to direct its research toward better serving the people.
10. The Plant Physiological Institute was founded in 1953 with a staff of 43 people; it now numbers 341 researchers. The hormone laboratory includes 26 people working on gibberellins and new microbiological products that influence plant growth. The herbicide laboratory was working with trichlorobenzothiadiazole for rice and cotton weeding. Other compounds synthesized and studied were 2,4-D, CMU (3-*p*-chlorophenyl-1,1-dimethylurea), dichloropropionanilide, and prometryne. Among the personnel in this laboratory who studied in America are Loo Shih-wei and Tang Yu-wei. The photosynthesis laboratory, started in 1964, includes 30 people working on such problems as photophosphorylation, quantum requirement, velocity of the dark reaction, development of activity during greening, uncoupling in diffuse light, and intermediary products in photophosphorylation. Most of the excellent equipment in this laboratory was Chinese, although some of the older instruments were British (Unicam) and German (Zeiss).
11. The Botanical Institute was established in 1949. It represented an enlargement and transformation of two older taxonomical institutes with a combined staff of 20; it now has over 200 workers. We visited a herbarium with more than 1 million specimens of some 30,000 higher plant species and 2000 ferns, staffed by six professionals equipped to identify specimens. This group had produced a manual of the medicinal plants of Hopei province, some monographs, and the three-volume *Flora of China* published in 1958, 1961, and 1963. A group working on a tomato storage project, directed by Liu Chung Tri, had figured out an optimum régime for control, in plastic containers, of temperature, O_2, and CO_2. Basically, tomatoes ripen rapidly if the temperature is high, O_2 is available, and CO_2 is low. A new hormone is being extracted from water chestnuts by Miss S. P. Liu in collaboration with Tsui Cheng, a former graduate student of Dr. Folke Skoog at the University of Wisconsin. This compound seems not to have conventional gibberellin, auxin, or cytokinin activity, yet it makes callus tissue cultures grow and produces buds in such cultures. There has been considerable progress in its extraction, purification, and partial identification. Other hormone work includes the use of gibberellin to improve grain weight in rice, the use of CCC (chlorocholine chloride) to retard stem growth and promote flowering in cotton and wheat, and the use of nucleic acid hydrolyzates (obtained from yeast grown on agricultural wastes) to improve rapid development of cotton

seedlings. Much of this work is being done in collaboration with peasant colleagues on communes. A paleobotany laboratory is doing work on fossil ginkgos and also palynological work in connection with oil exploration.

12. The Microbiological Institute has 400 workers, including 300 researchers; most are university graduates, and the others are from factories, communes, or the PLA. We were guided on our visit by Professor Fang Sinfang, Associate Professor S. I. Lu, who also acted as interpreter, and Wei Jang Chun, chairman of the Revolutionary Committee. The culture preservation laboratory has 10,000 cultures preserved on agar at 4°C, under mineral oil at 15°C, or by lyophilization. This collection is mainly of organisms isolated in China and is used to supply cultures all over the country. The classification and identification laboratory was mainly concerned with yeasts, for which they were making popular guides for laymen and factory workers. They do some chemical and metabolic studies in their yeast identification. The bacterial identification laboratory was studying mainly spore-forming *Lactobacillus, Pseudomonas,* and *Brevibacterium.* An analytical laboratory had excellent chromatography, electrophoresis, and high-voltage electrophoresis equipment. Their aim is to understand the microbiological resources of their country in chemical terms. The antibiotics laboratory had produced kasugamycin, an antibiotic that protects against rice blast. It is applied at 40 ppm by aerial spray to seedlings or adult plants, which absorb it and translocate it. Its use is becoming extensive, since it does not seem to be toxic and does not get into the rice grain. Its use is economically sound, since one application usually suffices and the cost is only 80 cents (Chinese) per mu (1/6 acre). In another laboratory, improved strains of *Corynebacterium glutamicum* were being used to make monosodium glutamate. At the suggestion of a worker, insoluble enzymes (such as amylase from *Aspergillus niger* coupled to diethylaminoethyl Sephadex) were being used to obtain longer-lasting and more effective conversion of cornstarch to glucose that was destined to be used for intravenous feeding. Recovery of enzyme activity after coupling to the carrier is only 20 percent, but the resulting preparation can be used for nearly 320 hours, and yields a dextrose equivalent of 93 percent. They also diazotize the enzymes and then couple them to other carriers. The bacteriophage laboratory was working with *Bacillus polymyxa,* for which they had obtained four different serological types of phage. Since the Cultural Revolution, they had shifted to *Corynebacterium* and have tried to minimize phage problems in production.

13. At Chungsan University entomologists were studying pest control, the herbarium prepared a collection of useful plants for reference, pharmacologists were testing medical herbs for hemostatic properties, and an electron microscopy laboratory was studying morphology of sulfur-metabolizing bacteria. Student laboratories were testing herbal extracts for hemostatic and anticoagulant activity and studying elementary chemistry.
14. "Integration of Research and Practice," *BBC World Summary Broadcast, Far East,* FE/3586/B/5 [from Peking Home Service, 6 January 1971, translation of broadcast by Chinese Academy of Sciences (Academia Sinica)].
15. J. S. Horn, *Away With All Pests* (Monthly Review Press, New York, 1971).
16. The hospital is one of more than 80 large hospitals in Peking, of which three medical hospitals and one dental hospital are affiliated with the medical college. Founded in 1958 as a polyclinic, it has departments of medicine, surgery, obstetrics, pediatrics, neurology, otorhinolaryngology, and ophthalmology. There are 700 staff, of whom 160 are doctors and 260 are nurses, for the 606 beds. Including barefoot doctors, medical personnel in this district of the city is 1.1 percent of the population.
17. The clinic has a staff of 60 (including 20 doctors) for the 6000 workers. It includes outpatient clinics and patient wards, operating and delivery rooms, diagnostic and x-ray laboratories, and a pharmacy well stocked with both Western and traditional medicines.
18. A. Topping, *New York Times,* 24 May 1971.
19. S. Rosen, *ibid.,* 1 November 1971; E. G. Dimond, *J. Amer. Med. Ass.* **218**, 1558 (1971).
20. J. Sigurdson, *Natural Science and Technology in China,* Report No. 154 (Swedish Academy of Sciences, Stockholm, 1968).
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Health Care Experiment at Many Farms

A technological misfit of health care and disease pattern existed in this Navajo community.

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Medicine and the other health professions are undergoing wide-ranging scrutiny as parts of a total health care system. One part is the system for primary health care (*1*) consisting of a university-connected health center manned full time by physicians and nurses, with the aid of well-trained, indigenous, auxiliary personnel who work both at the center and in the homes. A chance to measure the impact of such a system on the endemic disease pattern of a poverty-stricken, rural, and traditional tribal society was provided as part of a larger series of studies on a Navajo community (*2*). Naturally, the human support components of medical care were heavily involved in this activity. However, these aspects have been purposely excluded from this analysis, which is concerned solely with the influence of the technology. By technology is meant the capability to alter disease in a predictable fashion by such entities as drugs, vaccines, diagnostic equipment, or surgery. In a community with satisfactory health services, those services delivered to the individual and those delivered to the group operate simultaneously; hence it is difficult to separate their respective effects. Such a separation is necessary, however, if rational choices are to be made in setting up systems of medical care in communities where the existing systems are ineffective or nonexistent. In the present study, the circumstances were such that the influence of one of the systems—in which the technology is selectively applied by a clinical physician to one patient at a time—could be evaluated free from significant influence by the other system—in which the technology is applied by a variety of professionals to the community as a group.

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Background and Methods of Study

The Navajo–Cornell Field Health Research Project was organized by the Navajo Tribe, Cornell University Medical College, and the U.S. Public Health Service in 1955, when the responsibility for the health of the U.S. Indian was transferred to the Department of Health, Education, and Welfare. The stated purposes were fourfold: to develop effective methods for the delivery of modern medical services to the Navajo people; to see to what extent these methods could be applied to other people in similar socioeconomic circumstances; to study discrete diseases, particularly in light of their possible shaping by Navajo culture;