Control of the Environment For the Health of Mankind

A symposium of nine addresses at the dedication ceremonies opening the Public Health Service's Robert A. Taft Sanitary Engineering Center at Cincinnati, April 8–9, 1954. Each speech is presented in slightly abridged form.

A Tribute to the Traditions Of Scientific Proficiency

PHR brief

The Public Health Service is honored because the distinguished guests who are participating in the dedication of the Robert A. Taft Sanitary Engineering Center represent every part of our national life which has an interest in the past, the present, and the future of the Public Health Service in general—and of our sanitary engineering mission in particular. This means that there are present at this ceremony representatives of industry and of government—national, State, and local—representatives of the public health and engineering professions; representatives of education and of scientific research.

The Public Health Service is also honored because the completion of this new research center is really a tribute to the traditions of scientific proficiency and administrative integrity under which the Public Health Service was founded and in which it serves the Nation today.

Forty-two years ago, President William Howard Taft signed the act which gave the Public Health Service its present name and also its first basic authority to range in its research efforts beyond the realm of "infectious and contagious diseases." Within a year after President Taft approved this law, the Public Health Service had set up its Stream Pollution Investigations Station in Cincinnati.

At that time the field of sanitary engineering was emerging in response to the needs of a Nation in transition from rural to urban life. Over the past four decades, sanitary engineering has made significant contributions to the conquest of many common communicable diseases. It has dealt with the health-related problems of water, food, shelter, and air. Today, in a rapidly changing technology, the environmental health problems are much broader and much more complex. This laboratory provides for the first time a national facility so urgently needed to probe the new environmental stresses and their effects on man.

Is it not fitting, therefore, that the research

By Leonard A. Scheele, M.D., Surgeon General of the Public Health Service.

set in motion more than 40 years ago by the signature of a distinguished father should now be conducted in a modern laboratory building sponsored by, and named for, his distinguished son?

A Dedication to the Health Of Future Generations

In addition to honoring the memory of the late Senator Taft, we are dedicating a structure and reaffirming an idea. The structure is a place of science designed to probe and to test and to seek out answers. The idea is that the health of man is inseparably tied to the conditions of his environment. The health problems of our present environment are highly complex. They call for the knowledge of a special branch of science, the skills of a special corps of workers, the facilities of a special kind of building.

The opening of the Robert A. Taft Sanitary Engineering Center represents the fruition of that idea in today's world. It will be the Nation's headquarters for research in the science of public health engineering. It will be a focal point for inquiry and investigation into all the external factors which affect human health. It will be a center where men and women in the professions of engineering, chemistry, biology, physics, medicine, mathematics, and many other disciplines work together to develop and apply knowledge.

Engineering and Everyday Life

Many people associate engineering with highways and bridges and great industrial machinery. Yet, from the beginning of recorded time, man has applied engineering principles to the necessities of everyday life. Sanitary engineering had its origins in the first crude efforts to gather and store rainwater for drinking purposes or to dispose of wastes effectively. Manpower and simple machines accomplished such feats of engineering skill as the water systems of ancient Egypt and Babylon.

But the early efforts were aimed largely at civic betterment and public pride. Only when the transition to urban life became pronounced did we recognize that sanitary conditions are associated with the public health.

In our own Nation, as we moved swiftly from a rural to an urban mode of life, the need became sharp and compelling. One of the first tasks undertaken by organized public health services in this country was that of cleaning and safeguarding the physical environment. For a long time, however, we proceeded on an empirical, trial-and-error basis. Only within recent times has a recognized branch of engineering developed to deal with the sanitary sciences. The people of this country owe a great debt to workers in this field. The debt is all the greater because we accept the literal wonders they have worked as commonplace.

It is a sobering fact that in many parts of the world today, such necessities of life as water and food are common bearers of disease and death. The grim shadow of pestilence lurks in every pool of stagnant water, in the squalid streets and homes. In this country, we drink water from a tap without a second thought, secure in the knowledge that the water is free from disease-bearing germs. Most Americans live in homes and work in offices and plants that are safe and comfortable and provided with decent sanitary facilities.

The science of sanitary engineering has, to a considerable extent, made this possible. Engineering has produced and shaped the facilities which protect millions of people against epidemics of typhoid fever, dysentery, and cholera. The control of insects, vermin, and rodents has contributed to the diminishing incidence of malaria and plague.

The water and drainage systems, the control of on-the-job hazards, the countless machines and installations built to protect the public health—all are monuments to the achievements and potential of engineering research and prac-

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By Oveta Culp Hobby, Secretary of Health, Education, and Welfare.

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tice. More than 40 years ago, Public Health Service workers set forth the fundamental relationship between typhoid fever and polluted waters. Many of their studies were made in this laboratory—first established in 1913, in the old Kilgour mansion in Cincinnati.

New Problems, New Challenges

We live in an age of change. Man's relation to his environment is affected not only by change itself but by the speed of change. Not so long ago it was quite apt to apply a metaphorical label to a period of time, and call it the era of coal, or steam, or of power. Today, changes come in such bewildering succession that it is difficult to pinpoint anything except the fact of change itself. We live in a chemical age, an atomic age, and an age of jet power all at the same time.

The effects of change on our physical and social environment, of course, have been tremendous. We are buffeted by noise, subjected to internal and external tensions, harried by the increasing tempos of our civilization. The air we breathe, the food we eat, the water we drink now contain chemicals and synthetic materials undreamed of a few decades ago.

In the last 50 years, the population of the United States has doubled, and is increasing at the rate of 2 million a year. The urban population has tripled since 1900. The output of industry and agriculture has increased sevenfold. Literally tens of thousands of separate organic chemicals are among the wastes now dumped into water supplies by our expanding industries and cities.

The dangers implicit to the health of the people in this enormous growth cannot be ignored. More people, more cities, and bigger industry mean more wastes discharged into the lakes and streams. How will this affect the supplies of water for drinking, for agriculture, for industry, for wildlife, and for recreation? There is no longer certainty that present treatment methods can continue to cope with the wastes and byproducts of new technology.

The use of atomic materials has brought another entirely new set of environmental problems. President Eisenhower, in his December 1953 speech to the United Nations, clearly marked the course of this Nation in harnessing the power of the atom for peaceful purposes. And in his February 17, 1954, message to the Congress on the Atomic Energy Act, he envisioned wide industrial participation in the uses of atomic energy for the production of civilian goods and services.

But we must make sure that the expanded use of atomic substances does not injure the public health and safety. How can radioactive wastes, for example, be disposed of safely and

The White House,
Washington, D. C., April 2, 1954.

The Honorable Oveta Culp Hobby,
The Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

My best wishes to you and the staff of the Department of Health, Education, and Welfare on the opening of the Robert A. Taft Sanitary Engineering Center. In giving Senator Taft's name to a center dedicated to a healthier America, we remember a great American in a most fitting way. During the course of his brilliant public career, Senator Taft worked unceasingly for the better health of the American people. Few areas of research are more important than man's relations with his environment—his home, his place of work, his food and water, the very air he breathes. These days the employment of substances and materials, completely new or hitherto little known, is rapidly increasing. Health—and sometimes lives—depends on wise and prudent use of them. Research, consequently, is more necessary than ever before. We must continue to develop techniques that will protect the public health and at the same time foster industrial and community growth and improved living conditions. This is the mission of the Robert A. Taft Sanitary Engineering Center—a mission that does honor to the man whose name it bears, and to the 80th Congress that conceived and supported the project. I wish you and your associates every success in this important undertaking.

Dwight D. Eisenhower.

surely? The scientists of this laboratory will have a vital part in developing the knowledge that will protect the people of this Nation as they use the atom for peace and prosperity.

There are a host of other problems growing out of our modern, urban, highly industrialized society. Air pollution, for example, is not only a 20th century nuisance but may be a real menace to human health. The tragedy at Donora, Pa., in which 20 people died and half the town's population were ill during a 4-day smog, brought this home with dramatic intensity. Across the country—in New York, Charleston, W. Va., St. Louis, Los Angeles—irritations of the eyes, nose, and throat have been traced to polluted atmosphere.

The Dedication

We look with high hope to this laboratory to obtain the information which is so essential to the Nation's health. We are confident that it will live up to the expectations of the Congress, whose concern with the health problems of our environment made this center possible.

The nonpartisan character of the legislation which authorized the Robert A. Taft Sanitary Engineering Center—the Water Pollution Control Act of 1948—illustrates the unity of purpose in protecting the health of our people. For many years, the late Senator Taft—distinguished son of Cincinnati—worked to bring about legislation to safeguard our national sources of water supply against pollution. In many ways, this center can stand as a monument—one among very many—to the untiring struggle for better health for the American people which he carried on during his public career.

President Eisenhower, in his health message of January 18, 1954, made special mention of this center and the possibilities it has in store for American health.

To dedicate, in its classical sense, means to declare or set aside. We set aside this center for study of the environment of man. We set it aside to serve the comfort and health and well-being of all Americans.

We declare it a partner in a broad alliance with industry, our schools and universities, and private and public organizations. We declare it a training center for sanitary sciences throughout the Nation and as a source of advice and assistance for State and local communities. We set this center aside as a place of scientific inquiry and as a source of the practical application of knowledge. In all humility, we dedicate it, in the tradition of American democracy, to the service of man and to the health of future generations.

Our Twofold Responsibility In Sanitary Engineering

PHR brief

The ability of man to effect some degree of control over his environment is one of the major characteristics which distinguish him from other biological forms. It is this ability which accounts in large part for man's predominance over other life forms on the earth. Historically, attempts to control factors of the environment in the interest of health are by no means new, but the great impetus to the development of community sanitation practices has come in the last century—derived from the discoveries of science in that period.

In the United States we are blessed with the fruits of the practice of the sanitary sciences as developed to date—a freedom from the occurrence of previously common devastating epidemics of communicable diseases—a freedom which is still lacking over most of the earth's surface. We are at the same time face-to-face with a fast-growing and increasingly complex industrial development and urbanization; these are contributing to our increasing standard of living but are also producing problems with respect to the safety of our environment—the air we breathe, the water we drink, the food we eat. We must keep pace with these developments as

By Vernon G. MacKenzie, B.S., officer in charge, Robert A. Taft Sanitary Engineering Center, Cincinnati.

they occur, for without such progress, we do not merely stand still, we retrogress.

Our responsibility, then, in the field of sanitary science is twofold: to continue, by support of the basic sciences and engineering application, the development of practices to solve the increasingly complex problems of environmental health hazards; and, in keeping with our present global position, to provide to the less fortunate people of the world the stimulus to permit them to make real progress in their aspirations to control their environmental health problems.

There are many who say that man's ability to control his environment will react disastrously to him—not only, for example, through misuse of nuclear energy but also through the application of modern health practices in the so-called undeveloped areas of the world. The gloomy prophecies of Malthus have not yet proved themselves with respect to human populations in industrial areas, but some believe that such catastrophe has only been postponed. All these fears are only symptoms of an obligation which must be met; namely, the development of the social sciences and their application in comparable manner to our material sciences. Only in this way can we be assured that full advantage can be taken of our material well-being in national and world communities.

Buildings Do Not Think But Men Do

PHR brief The new building for environmental hygiene research marks a great milestone in the long and distinguished history of the Public Health Service in reducing mortality and in preventing the incidence of disease. In these accomplishments, remarkable in quality and in quantity, control of the environment along the joint fronts of engineering, biology, and chemistry has had an equally fine record.

By Abel Wolman, Dr.Eng., professor of sanitary engineering, Johns Hopkins University.

It is timely to recall the thought of Charles A. McCuen, of the General Motors Co.: "Neither elaborate equipment nor well-appointed laboratories can think. These inanimate things make research possible, but creative values from these things can result only from questioning, analytical minds of men."

This center, dedicated in the words of Vergil, to "the noblest motive—the public good," will rise to new heights of accomplishment or fall to the depths of mediocrity dependent on the skillful choice and the freedom of mind of its scientific staff. It renews its work with the benefit of a great heritage of previous scientific contribution. It is to till a field, national and international in scope, which is still plagued by the ancient diseases as well as those more recently added to mortality tables.

What kind of people are these scientists who breathe life into a building? How does one find and capture them? How does one measure their so-called units of work? Upon what food do they feed?

In the Footsteps of the Giants

Josiah Willard Gibbs, Henry A. Rowland, and Ira Remsen—three men long dead—revolutionized the world in industry, in electricity, and in chemistry. A courageous statistician recently evaluated their worth to society in terms of billions of dollars. What is the nature of the scientific problem with which such men deal? Viewed by their contemporaries, they seemed to struggle with the esoteric—the useless. The importance of so-called "useless" knowledge, developed by the imaginative mind, cannot be overestimated. Faraday's comment, "How can one estimate the value of a new-born babe?" gives a universal clue to the eternal necessity of providing an opportunity for scientific work by the strange, the "crazy," the peculiar, and the unorthodox worker.

The area of the greatest opportunity for this center is to devote its best brains to unmasking the unresolved issues of a basic nature, rather than to run the risk of permitting its energies to be frittered away in the myriads of minor development activities so easy to list and so seductive to pursue. Its field of inquiry, since disease is universal and no respecter of geography, politics, culture, or economics, although locally explored, will forever have worldwide application and significance. The stakes, as well as the fruits, are high.

That the Cincinnati workers will be placed on their mettle no one can or should want to deny. To follow in the footsteps of the giants is uncomfortable, but the warmth of their spirit likewise has an important stimulating quality. History teaches us that the great of the past can be surpassed by the great of the present. These men—Frost, Phelps, Hoskins, Crohurst, Butterfield, Streeter, Purdy, Tarbett, Hommon, Frank, and Ruchhoft—would be the first to say they only precede but do not exceed.

The Role of Engineering

PHR brief

From its beginning as an organized profession, engineering has been aware of its responsibility for providing the social capital that spells the developing of available resources—both human and material.

For more than a century, the association of engineers with public health has been close and fruitful, and, in general, harmonious. To be sure, leaders of both professions have not always seen eye to eye, principally, when the sources and modes of spread of infectious diseases were not known or understood; when both engineering and public health were striving for a place in society; and when the lack of scientific knowledge was overshadowed by the partisanship of those who defended inadequate theories.

By Gordon M. Fair, Dr. Ing., Abbott and James Lawrence professor of engineering and Gordon McKay professor of sanitary engineering, Harvard University.

History of the Sanitary Engineer

In the catechism of engineering, the question which asks for the four essentials of human existence is answered by the words, "air, water, food, and shelter." Of these, air and water are elemental and among Thomas Tredgold's "great sources of power in Nature" that the engineer is to direct "for the use and convenience of mankind." It is these great sources, and water specifically, that brought the engineer into the public health field. Food and shelter are in a sense derivative, certainly more or less individualistic in their need, and in general are less amenable to management by engineering means.

The engineer who has to concern himself specifically with the control of the environment for the health of man—the sanitary engineer—did not become established in his profession until the late 19th century, and as a unique American creation. The reason for his origin, in the Massachusetts State Board of Health, was an 1886 act of the Massachusetts General Court entitled, "An Act to Protect the Purity of Inland Waters." The vision behind his origin was that of Hiram Francis Mills, a member of the State board of health and chief engineer of the Essex Company, which owned and managed the locks and canals of industrial Lawrence.

In order to carry out the provisions of this act, an engineering department was set up in the Massachusetts State Board of Health, and a zestful group of chemists and biologists was drawn into association with the engineers of the department. At the same time, Mills offered the use of his hydraulic laboratory in Lawrence for experimentation upon the best practicable methods for purifying sewage and disposing of manufacturing refuse. This laboratory was renamed the Lawrence Experiment Station and has continued its useful existence to this day.

The impact of these developments on the evolution of public health and on engineering practice in America made the engineer a responsible member of the public health team of physician, engineer, and (later) nurse; gave the engineer the key position in a team of his own composed of engineer, chemist, and biologist; and made sanitary engineering investigation a responsibility of public authority.

About 25 years after the events in Massachusetts, need for the control of pollution of the international boundary waters between the United States and Canada and of the great interstate streams of the United States directed the interests also of the Public Health Service into engineering channels. The Massachusetts act of 1886 had its counterpart in the act of Congress of 1912 which extended the function of the Public Health Service to include investigating sanitation and sewage and pollution of the navigable streams and lakes of the United States.

The survey of the pollution and natural purification of the Ohio River, begun in 1913, led the Public Health Service to establish a laboratory at Cincinnati. Thus, a small frame building on the banks of the Merrimack River, the Lawrence Experiment Station, became the prototype of the Robert A. Taft Sanitary Engineering Center of the Public Health Service, the great building on the wide Ohio.

Water—A Human Essential

Since the collaboration of engineers with medical men as well as with chemists and biologists was born of the needs of a developing industrial civilization to preserve the integrity of its water resources, let us first examine the role of the engineer in the control of water for the health of man. This control, correctly anticipated by Tredgold, has been exerted in three directions: the provision of safe, adequate, and economical water supplies; the utilization of these supplies to carry away safely and economically the wastes of household and industry; and the preservation of natural waters for the use and enjoyment of man.

To these purposes, engineers have built works, some of which rival in their complexity the greatest feats of engineering in human history. The water supplies include dams that store great depths of water behind them in impoundages of vast volume, conduits that carry the collected water over hundreds of miles of hill and valley, tunnels that are many times longer than the most famous railroad tunnels in the world and that drop, in at least one instance, more than a thousand feet below the earth's surface to pass beneath rivers in their way. They include pumping stations to lift the water to communities, works for the purification of the collected water, and networks of pipes that distribute the water necessary to prevent serious conflagrations. Delivered to the piping system of the consumer, the cost to him has nevertheless been held to a few cents a ton.

The Safety of Waste Water

But water engineering does not stop there. Most of the water supplied must be removed from the premises as spent or waste water. This has required the construction of other networks of conduits through which the waste waters flow as in underground streams to sweep away waste products that are imposed upon the carrying water. That these Augean streams may not destroy the lakes, ponds, and streams or the tidal estuaries into which most of them must discharge, treatment works of ever-increasing effectiveness have been built to make the waste waters safe for disposal. What has been done for municipal sewage has been repeated in ever-increasing volume for industrial waste waters, too.

The satisfaction for the construction of these water supply and waste-water disposal systems has accrued to many kinds of engineers, but foremost to civil and sanitary engineers. Some of them have excelled in structural design, others in hydraulics, others in foundations, yet others in purification-process designs. The civil and sanitary engineers, in turn, have called upon the services of other engineers and of scientists: mechanical and electrical engineers for pumping water and waste water and for measuring and regulating its flow; geologists for locating dams, tunnels, conduits, and ground water; and chemists and biologists for controlling the quality of the water supplied and the waste water discharged.

Closely related to engineering activities concerned with the control of water and waste water have been sanitary engineering interests—in swimming pools and bathing places, in the harvesting of shellfish and other useful aquatic life, in crops irrigated with sewage or fertilized with sewage sludge or other municipal wastes, and in breeding places for mosquitoes that are vectors of disease or purveyors of nuisance.

Air and the Engineer

Early interest in the control of the atmosphere and of indoor air for the health of man was erroneously directed towards noxious odors, miasmas, or malarias that were believed to be responsible for the dissemination of contagion. Not until the miasmatic theory of disease had been dispelled and the physiological relationships of air to man had been adequately explored was the engineer able to devise rational means for controlling the air of public buildings, workshops, and private dwelling houses.

Like water, air is subject to chemical and biological contamination. But its climatological condition may be such by itself that it is inimical to human health and comfort. As a result, the control of air has involved multifarious engineering responsibilities. To prevent or hold in check the pollution of the atmosphere over great cities and industrial areas, engineering designs and operations have had to concern themselves with the proper combustion of fuels and with the management of almost numberless industrial operations from which airborne waste products are released into the atmosphere. The natural reservoir of air in the earth's envelope is so great and the substance itself is so fluid that the effects of everyday air pollution have generally not been sufficiently intense to be diagnosed with precision, and catastrophes such as those in Donora, Pa., and London have been mercifully few.

The control of indoor air has been the responsibility of mechanical engineers concerned with air-conditioning, heating, ventilation, and extremes of heat and atmospheric pressure, and of chemical engineers concerned with dusts, fumes, and gases that arise from manufacturing processes and from mining and related operations. Their knowledge is often shared by sanitary engineers who have made air rather than water their principal interest. Air-conditioning, heating, and ventilation systems are designed to satisfy the physiological requirements of the occupants of enclosed spaces. These systems have contributed widely to human comfort and presumably to better health. Disinfection of the air for the control of communicable diseases spread by close contact between individuals has not yet proved itself under normal conditions of space occupancy. The control of industrial operations, however, has reduced occupational diseases markedly.

Food and Food Wastes

Numerous health hazards are connected with the production, conditioning, preservation, storage, preparation, and serving of foods. Among these, the large-scale operations of conditioning, preservation, and storage of food have lent themselves best to control by engineering means. As manufacturing processes, they have been principally matters of heat engineering. The canning and freezing of foods and the large-scale pasteurization and bottling of milk are examples. Although these operations are conducted in a great number and a large variety of installations, the equipment used has become a product of engineering analysis, design, and production. These together with the self-regulation of industry, have made for a high degree of accomplishment in health protection. Contrariwise, the preparation and sale or serving of foods in restaurants, foodshops, and the like require so many small-scale operations that they cannot be subjected, economically, to engineering control other than that inherent in available "household appliances." As a consequence, the number of foodborne epidemics has remained extraordinarily high.

Collection and disposal of garbage and food wastes normally proceed along with the collection of other solid municipal refuse. The numerous engineering opportunities in this area include the design of the vehicles employed for the transportation of the refuse and of the means for disposal such as landfills, grinding stations, incinerators, and composting stations. The feeding of garbage to swine is less amenable to engineering control; it presents a health menace through the possible spread of trichinosis.

Shelter, Its Present Relationship

Basic designs for human shelter are of an engineering nature. Consideration must be given to the properties of materials, heating, ventilation, lighting, the control of noise, the provision of water, the removal of waste water and refuse, the control of vermin, and the control of accidents. Except for large-scale housing operations that require the services of engineers both in planning and execution, the principal contribution of engineers has been in the provision of suitable materials of construction and of useful mechanical equipment. Problems of a sociological nature have, as yet, not been resolved by engineering means, and possibly never will be, although there are factors in the environment that impinge upon them.

Public Health Engineering

In America, engineering has been given important administrative responsibilities in public health and related agencies of government. Where strong sanitary engineering units have been developed in such agencies, the public has been well served; opportunities to promote the public health have been seized; and there has been good support by the engineering profession and by the general public for sanitary improvements and needed sanitary works. Where engineering units in public health agencies have been weak, there has been a splintering of responsibilities among other governmental bodies. This has not made for perspective, leadership, and experimentation. Although there has been progress, it has been emulative rather than exemplary, on the whole slow, often inadequate.

By assuming administrative responsibilities, engineers have been able to exercise important functions, among them: determination of the sanitary needs of urban and rural communities and of industrial enterprises; interpretation of these needs to responsible governmental agencies and civic groups to insure the construction of the requisite engineering works; cooperation with practicing engineers and industries in the application of modern health concepts; supervision over existing works and their effective management; assistance to legislative bodies in the preparation of sanitary laws, rules, and regulations, and arbitration of their enforcement; participation in emergency operations for disaster relief and for the prevention of epidemics allied to environmental factors; and direction of researches and investigations by which the control of the environment for the health of man has made important progress.

In these researches and investigations, as well as in many of their other undertakings, engineers have had the cooperation of chemists and biologists. Without such teamwork, progress would have been much slower.

Social and Economic Change And Health Engineering

PHR brief

A glimpse of what sanitation was like a century ago in our own country may be had when we travel the underdeveloped countries of the world. Open water courses are used for drinking purposes, washing the body, scrubbing clothes, disposal of human excreta, and as a place for ducks and children to swim.

Lack of attention and control of environmental sanitation are in evidence in both rural and urban areas. The need for improvement in environmental health is self-evident, even to the casual observer.

Diffusion of Cultural Patterns

Most underdeveloped areas in the world are that way because of their inability to make effective use of their natural resources. Recently, diffusion of cultural patterns from well-developed areas has proved to be a powerful stimulus to backward nations to improve their social and economic status. Global warfare, as one of its few benefits, has contributed significantly to the intermingling of people of diverse cultures and has brought about a new concept of health and well-being among the underprivileged

By Herman E. Hilleboe, M.D., commissioner, New York State Department of Health, and president-elect, American Public Health Association.

people who comprise the majority of the world's population.

The people of the "have not" areas have awakened to the fact that it is possible to speed up the evolution of their living standards, and they are impatient to get under way. Many have come to the United States for assistance—technical, fiscal, and administrative—in their efforts to achieve new social and economic benefits. For our own ultimate survival, we must help these people to help themselves, not, as some propose, by revolution that could destroy all of us, but by a scientific process that will speed up the development of their nations in an orderly manner.

Modern engineering makes it possible, John Logan, an engineer with global experience, observes, to alter completely the social and economic status of any area in the world, assuming, of course, adequate provision of health, educational, and nutritional services, public acceptance and support of the objectives, and availability of human and natural resources. An important segment of future global engineering comes within the sphere of activity of the sanitary engineer. The universal desire for health mandates the services of the sanitary engineer; he is an integral member of the health team that will have the task of improving the personal and physical environment so necessary for productivity and improved well-being.

The Robert A. Taft Sanitary Engineering Center can contribute materially to the improvement of underdeveloped countries by training research scientists for these areas and disseminating knowledge of environmental engineering. Sanitary engineers can aid in the conservation and wise use of human resources, the most potent factor in the development of backward countries.

Environment and Health

Sanitation practices can no longer be narrowed by custom to milk, food, water, and sewage, and the prevention of spread of communicable diseases by indirect methods. There is need to extend the knowledge and influence of sanitary science into the broad fields of housing, home and traffic accidents, rodent and insect control, and atmospheric pollution. The threat to health, both mental and physical, of slum districts and poorly contrived housing projects is no longer questioned. High standards for ventilation, heating, lighting, and living space are a necessary part of advanced planning in the home, on the farm, in the shop, and in the factory.

Both adults and children need space and safe equipment for recreation and leisure activities. Mental and physical fatigue associated with the tedium of daily labor is favorably affected by rest and recreation away from the scene of economic struggle. The attainment of such recreation areas can help realize a high level of security and productiveness. To obtain these facilities, adequate funds are necessary.

Experience has taught public health workers that most legislators and most taxpayers are not very much impressed with the amount of money saved by preventive services in public health. To gain the acceptance and support of the people for our environmental health programs, we must try to express savings in understandable terms of social and economic benefits to the community.

Civil Defense

Out of the fears created by the incredible potency of the hydrogen bomb comes a grave concern for the protection of the public health in the event of an enemy attack. An atomic blast upon a major city would create enormous havoc; care of the injured and dying would absorb all available human and physical resources.

The engineering profession has been called upon to serve as leaders, along with physicians, dentists, nurses, and other professional personnel. Provision of emergency water and food supplies, sewage and refuse disposal, decontamination of persons and material exposed to nuclear fission products—these are essential services that will help bring order out of chaos following a disaster. Optimum public health services must be maintained and even expanded to meet the threats of atomic, gas, and germ warfare. The challenges of survival stimulate group activity, in which the environmental engineer has an important role, both as engineer and as citizen.

Problems in the use of nuclear energy in peace as well as in war are heavily laden with social and economic overtones in the public health field. Technological advances in the production of electricity from radioactive strontium, the irradiation of food for its preservation, and the use, distribution, and disposal of radioactive isotopes challenge the ingenuity of sanitary engineers.

Water and Atmospheric Pollution

After 3 years of intensive study by legislators and experts in health, engineering, and industry, a comprehensive water pollution control law was enacted in New York State in 1949. This created the New York State Water Pollution Control Board and gave it far-reaching authority and responsibility to prevent and abate pollution of the waters of the State. Included on the board are the State commissioners of agriculture and markets, commerce, conservation, health, and public works. A sanitary engineer from the New York State Health Department serves full time as the board's executive officer. An ex officio member presents industry's viewpoint in the planning stages of the programs.

The board's activities demonstrate that the social and economic life of our people can be favorably influenced by the prevention and abatement of water pollution. This is the kind of successful approach that States can use to attack water pollution problems, large or small, rural or urban, industrial or municipal.

Recent experiences in several American cities have drawn attention to the dangers of air pollution. Not only is the health of individuals threatened but also the social and economic status of the community. No one willfully comes to live in a smog-ridden city or metropolitan area overladen with smoke, noxious gases, or irritating chemicals that may become deadly without warning. The losses to agriculture are costly in areas where industry unwittingly or carelessly contaminates the air with dangerous pollutants.

In the field of atmospheric pollution, there is an unequaled opportunity for the sanitary scientist, the epidemiologist, the laboratory worker, and the industrialist to join in a combined operation to insure a more healthful environment. The dividends will accumulate in the form of better health and standards of living and a deep sense of community accomplishment for industries and municipalities.

Tooth Decay and Water Fluoridation

Dental science has made significant progress in the control of tooth decay. The most promising development is the mass reduction of dental caries by fluoridation of public water supplies—a field in which dentists and sanitary engineers have combined their knowledge and skills to improve health and well-being, especially for growing children.

When chlorine was first added to public water supplies to prevent waterborne diseases, there was much objection to its use. Gradually, as experience taught that it was absolutely harmless in the small amounts employed and that countless lives were saved by preventing infection with deadly germs, the practice was accepted. That minimum amounts of fluoride added to drinking water effectively prevent tooth decay has been demonstrated. In such small amounts, this substance is harmless, its cost nominal, and rigidly controlled application easily accomplished.

Experts in sanitary engineering are in key positions to explain to their nonprofessional colleagues that dental decay is cheaper and easier to prevent than to treat. People understand the economics of family dental bills; no charts or graphs are necessary to convince them of the value of this public health program.

Traffic Accidents

Radio, television, exhibits, and other means of communication all stress the safest ways to operate motor vehicles. Community organization of safety clubs, teen-age driver classes, and traffic courtesy instruction help to obtain understanding and support of the citizens for traffic safety programs. Safer highways and more efficient systems of traffic control and enforcement contribute significantly to safety on the road. No one questions the continuing need for education, engineering, and enforcement in the campaign to reduce death and disability on the highway. But the high tide of traffic deaths and costly disabilities that engulfs an increasing number of the driving public is morbid evidence that many accident problems still remain unsolved.

That ample knowledge exists to cut down the toll from traffic accidents may be true about highway systems and motor vehicles, but, tragically, it does not apply to the driver of the automobile. Why is dangerous driving a symbol of male prowess to so many men? Why do some drivers behave as they do when behind the wheel of a machine that can be transformed in a flash into a lethal weapon?

Several medical and allied research groups are studying driver behavior, the health of drivers, the effects of various drugs on driving ability, and the dangers of fatigue and fumes in the air. Drivers with such diseases as epilepsy, heart disease, and diabetes, and excessive users of alcohol are being investigated in their role of highway hazards.

But not enough research is initiated and financed to permit full investigation of the human behavior of some drivers. The public health aspects of motor vehicle accidents deserve much more attention in highway safety programs than they have received in the past, for public health research is capable of solving many of the riddles of driver behavior. The same epidemiological techniques used so successfully in the study of communicable diseases are directly applicable to the sociological, emotional, and physical disturbances associated with accidents. The environmental engineer can team up with his colleagues in public works and with medical and social scientists to study the interaction of the driver, the road, and the vehicle.

Social Science and Public Health

The social scientist has much to contribute to the solution of environmental engineering problems. Some of our best-laid plans fail because of social blocks that so often impede our efforts. The new type of social scientist—adequately trained and capable of doing first-class scientific studies—may be called a cultural anthropologist, rural sociologist, social psychologist, or just research social scientist, but his training in the better schools is as rigidly disciplined as that of the biological or engineering scientists.

There is a place for the social scientist in the expanding field of public health. We need to know more about human relations in a changing world that is faced with an aging population, a surplus of chronic diseases, and an environment complicated by the effects of nuclear energy; to accumulate more exact knowledge of the changes occurring in society so that the best use can be made of our resources to protect and improve the public's health; and to discover how to influence human behavior so that people will more readily take advantage of health resources.

In this pioneering field, a social scientist on the staff of the New York State Health Department is applying his special knowledge and skills in such diverse fields of study as motor vehicle accidents, the problem of community resistance to fluoridation of water supplies, and the effects of stress on illnesses and absenteeism in industry.

The addition of social science technique can reduce the lag between the discoveries in the biological and physical sciences and their application in medicine and public health. The fruitfulness of the union between public health and social science should become increasingly evident to public health workers as they successfully complete major projects that lighten social and economic burdens.

Service, Research, and Teaching

Service, research, and teaching are the three interdependent components that comprise a modern public health program. The Robert A. Taft Sanitary Engineering Center has an opportunity and a responsibility to combine research and training so that the service that springs from such a partnership will have the quality essential for permanent benefits.

The role of government in research has assumed considerable stature within the last decade. Continued success in this role is dependent upon the establishment and maintenance of certain safeguards to insure freedom of action in both applied and fundamental research. Government research often carries with it strong pressures—pressures that may tempt research workers to balance their programs to the detriment of work that might prove more productive.

Praiseworthy as the intentions behind such guided governmental support may be, damage to the quality of research can be done, and the true intent and purpose of scientific investigation can be misdirected. The goal of the research scientist is primarily the discovery of truths in nature, and secondarily the practical application of the results of his efforts. Attempts to dictate areas of research investigation and too great emphasis on predictable consequences will inevitably have the effect of stultifying creative imagination and reducing the scientist to the level of a technician.

Large-scale group research, another trend in modern scientific investigation, can be either fruitful or futile. Properly utilized, it can lead to results as significant as atomic fission. Improperly undertaken, it can lead to an enormous waste of brains and funds. The scientific members of a community can best decide when and under what conditions closely coordinated group research is appropriate and promising of fruitful issue.

The great scientific discoveries of the past have occurred in atmospheres of freedom and were made by men of imagination who had liberty to follow their informed hunches, guided only by the beckoning shadows cast by the evasive luminosity of truth. This is the everlasting right of men driven by intellectual curiosity, and any tendencies that might imperil this right are threats to the progress of mankind.

Therefore, government can exercise its true responsibility in research by creating conditions under which the imagination and initiative of scientists are given the widest scope and by providing adequate support, free of arbitrary provisions imposed by the exigencies of governmental policies. Acceptance of this principle will permit a greater expenditure of public funds for research without endangering the fundamental right of unfettered inquiry.

Many other problems in environmental sanitation await exploration by sanitary engineers and their associates in the sanitary sciences. Their precise methods of scientific analysis and synthesis are ideally suited to strengthen and refine program planning, execution, and evaluation in the broadening field of public health. The environmental engineer whose activities extend into the social and economic as well as the physical aspects of the community will bring credit to his profession, enlarge his own horizons, and serve the people to his full capacity.

The Biological Sciences

In science, there can surely be but one world. In discussing the contributions of the biological sciences, I would want it understood that their interdependence with many other disciplines is to be assumed. Good fences may make good neighbors, but they don't make good scientists.

It is through the biosciences in particular that man has gained a fair understanding of himself, what he is, how his body functions, what his needs are, what constitutes a state of health in terms of internal processes. Man doubtless finds himself more interesting than any other species and has devoted perhaps as much attention to himself as to all other species combined. Yet, much more knowledge and understanding are needed. We must keep in mind that if man is to control the environment, he must first control himself.

Dependency on Surroundings

Man's surroundings contain many plant and animal species, both domesticated and wild, both gross and microscopic, which influence him directly or indirectly. Man has come to appreciate that his very existence depends on the activities of many other living forms; that the carbon and nitrogen cycles of nature make his own life possible; that the remains of dead plant and animal life would mount to high

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heaven if Nature's forces of dissolution, largely biological, were not continuously active. Man has learned that he is utterly dependent on other species for food and energy supplies, being unable directly to convert the sun's energy to his own uses internally, or to synthesize certain of the organic compounds of which his tissues are composed.

Man collectively is an important element of the environment for man individually. And although this is the realm of the social disciplines, the behavioristic sciences, society is certainly a collection of individuals; again, it is man himself who is doing the behaving or misbehaving, presumably reacting to external stimuli by way of internal mechanisms.

All sciences are dependent on a biological creature, man the scientist. Useful information does not flow through the senses automatically and in an organized, intelligible form. It is inevitably conditioned by the media through which it must pass and the receptors on which it impinges. Even such an abstract science as mathematics cannot deny this relationship—the decimal system presumably had origin in the fact that man happens to have 10 fingers.

In the Darwinian era, much was said of the adaptation of life to the environment; the survival of species as a function of their fitness in relation to competing species. The grand concepts of evolution were formulated, and the foundation for a science of genetics was laid. More recently, as the environment came to be understood in precise physicochemical terms, it was recognized that fitness of the environment is equally as essential as the fitness ascribed to living forms and emerging during the course of organic evolution.

Internal and External Environment

The environment, when closely examined, is indeed found to be marvelously fitted for life on this planet. This is notable particularly in the properties of water and carbonic acid. Among all known possible compounds, these appear to be almost uniquely suitable, not only as prime constituents of the physical world, but in maintaining that world in a state compatible with life. They serve a similarly important role for the "internal environment," the fluid medium in which man's body tissues develop and function.

While the external environment must hold to a narrow range of conditions if life is to continue, even more rigorous standards are required for the internal menstruum. Constancy of temperature, pressure, acidity, osmotic tension, and of many other properties is critically important to health and to mere survival. And while attention today is focused on the external world, it is abundantly clear that maintenance of the vital and more intimate environment within requires a continuous interchange with the outer world. Health is a matter of delicate equilibrium between the body tissues and fluids and the external surroundings. Man can get along without food—grossly ingested—for several months, because of internal stores. He can live without imbibing water for a few days. But he carries almost no stockpile of oxygen. Without it, he will die within a few minutes. Unconsciousness can be produced in a few seconds if the flow of blood to the brain is interrupted. But little can be done to alter the essential physical properties of the environment to which living tissues are so nicely adapted.

With the flowering of the biological and medical sciences beginning in the latter part of the 19th century, man acquired more understanding of infectious diseases than all the preceding centuries had afforded. Superstition and witchcraft waned; the gods and the constellations were exculpated; and empiricism in medicine—the classification and treatment of diseases on the basis of symptoms—was supplanted by sound methods based on knowledge of cause and mechanism. A rational approach to prevention of disease became possible as facts began to accumulate concerning reservoirs of disease agents, carriers and vectors, portals of entry and egress, and the properties of the agents themselves.

Endless Environmental Problems

Ironically, man's successes have brought him new problems. The technological complexities of the machine age place him in dire jeopardy if any vital element falters even momentarily. When disaster strikes locally in the form of earthquake, hurricane, or flood, there is immediately grave concern about food, water, medical supplies, and shelter.

Although the mechanism of most infectious diseases is now known, the greater mobility and density of population make control more difficult and more costly. Agents of disease can now be borne not only on the wings of mosquitoes and tsetseflies, but also on the wings of swiftly speeding aircraft. Within a matter of hours, exotic diseases can be transported from remote places and introduced into dense aggregations of susceptible people.

The tremendous reduction in infant mortality has brought a much larger proportion of the population through to the older age groups, presenting problems of health and adjustment about which we are not well informed. The machine age has introduced new occupational hazards and diseases. More decibels of noise and more quanta of hurry and confusion confront us all. The automobile has displaced the horse on city streets, thus eliminating the principal source of tetanus spores, but leaving a no less noxious trail of carbon monoxide.

Keeping Pace With Technology

To meet the growing demand for food from a finite acreage of arable land, agriculture has resorted to the wholesale use of insecticides and thus has raised some serious problems of toxicity for man. Could it be that the worm we fail to find in the apple has been repelled by pesticides which we also should shun? More information is needed about the effects of some of the insecticides, especially compounds which can accumulate in soil and in plant and animal tissue. Meantime, new insect pests are appearing, and resistant strains of well-known species are developing selectively, so that new insecticides and new formulas must be sought continually.

Industrial wastes in ever greater amount and variety pollute surface waters. More information is needed about the biological effects of many of these compounds and how to reduce or remove them. The disposal of sanitary wastes too is becoming increasingly difficult and costly as demands for water continue to mount and the supplies of this precious resource, once thought of as boundless, shrink before our very eyes. Here knowledge, biologically at least, seems reasonably adequate, but disposal facilities scarcely keep up with the increasing load.

The industries which are largely responsible for contamination of the atmosphere will be concerned with improvement of equipment and processes to minimize it, but it is the biologists who will continue to wrestle with the problem of effects on plant, animal, and human life. Much more knowledge is needed about the results of repeated minimal exposures and the effects on different age groups and on those already suffering from respiratory or cardiac disease. It has been suggested recently that the high incidence of lung cancer in urban areas might be related in some degree to these irritants. Only long-term studies in the laboratory and the field can give valid answers to problems of this kind.

Some thought now must be given to radioactive elements in the atmosphere and in surface waters as the result of accidental or incidental contamination. Physicists and engineers will put them there, but biologists will be called on to interpret and minimize the effects on living tissue. More information is needed about the long-term effects of ionizing radiation. It is known that the rate of genetic mutations can be increased by radiation. Cumulative effects in large populations might be very significant.

In this era of cold war or tepid peace, there is ever present the possibility of hot war. If another world war were to break out, it must be assumed that hostile forces might seek to exploit knowledge of the agencies of disease in order to make our environment as unhealthful as possible. The very sciences which helped man master many of the transmissible diseases of men, animals, and plants might thus be turned against him openly or covertly, adding immeasurably to the burden of our health services and possibly setting us back many years in our progress toward a more healthful world. This negative or destructive role in which science is sometimes found is deporable, but it cannot honestly or prudently be overlooked.

The problem of man and his environment thus is a never ending one, requiring that he be eternally vigilant and progressively adaptable.

The Physical Sciences

By control of the environment for the health of man, in its broadest sense, is meant the control of every aspect of the universe surrounding a man which might conceivably affect his internal well-being. A very great number of physical, chemical, biological, personal, and spiritual elements of an individual's environment can affect his health.

The role of the physical sciences in the control of man's environment is too broad a problem to be dealt with adequately. Rather than catalog the examples of the ways in which the physical sciences have contributed to the material well-being of man, it would be more constructive to pick out some single example, such as certain aspects of the conscious control of tuberculosis, and to trace how the physical sciences have contributed to this control. The main method of prevention is one of limiting the individual's contacts with the tubercle bacillus, or, one of controlling man's biological environment. I have chosen this example because of the clarity with which the contribution of the physical sciences to public health can be seen.

A large variety of factors have contributed to the decline in the death rate from tuberculosis, but the Framingham, Mass., experiment demonstrated that the application of specific control measures can reduce the rate still further. When it was found that careful examination by X-rays of presumably well people is required to find tuberculosis cases in early stages, it became a known fact that the mass chest X-ray survey is a powerful method for controlling man's environment.

In many concentrated population areas today, mass chest photoradiography surveys have been conducted and are being conducted. It is practically possible to do this only because of the availability of methods for recording chest radiograms on small-sized photographic film. I want to examine here those fundamental findings in the physical sciences which make possible this particular control of man's environment. All of the important physical principles which make mass photoradiography possible today were known before the end of the 19th century.

The photoradiograms used in mass surveys are made by photographing on a small film a fluoroscope pattern of the examined area of the body. These small film images are then used as a screening device. Experience has shown that approximately 6 percent of supposedly healthy individuals show on the small photoradiograms shadows which require investigation by direct roentgenography, using the large-sized film. Approximately 2 percent of the population examined show ultimate evidence of tuberculous lesions.

When we analyze the apparatus used in obtaining a small film photoradiograph, we find that there are three elements involved. One is an X-ray generator, another is a fluorescent screen, and the third is a photographic camera. Thus, our ability to conduct such a survey is grounded on our knowledge of X-rays, of fluorescence, and of photography.

The History of the X-Ray

X-rays were discovered by Wilhelm Konrad Roentgen, who held professorships of physics in three German universities, Giessen, Würzburg, and Munich. Late Friday evening, after all of the research assistants had gone home, Roentgen remained in his laboratory at Würzburg. This was November 8, 1895. He was studying the properties of the cathode rays obtained when an electric current is discharged through a gas at reduced pressure. He had completely enclosed the discharge tube in an opaque covering, and yet he observed that, when the current was discharged through the tube, some fluorescent material nearby emitted a faint glow. Roentgen realized the implications of this observation. He must have worked furiously the next few weeks, because his findings were announced in the December 1895 issue of the *Sitzungsberichte der Würzburger Physikalischen-Medicinischen Gesellschaft*, and this

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was followed in March 1896 by a second communication giving further details. The following are quoted directly from a translation of Roentgen's own announcement:

"If the discharge of a fairly large induction coil be made to pass through a Hittorf vacuum tube or through a Lenard tube, a Crookes tube or other similar apparatus, which has been sufficiently exhausted, the tube being covered with thin, black cardboard which fits it with tolerable closeness, and if the whole apparatus be placed in a completely darkened room, there is observed at each discharge a bright illumination of a paper screen covered with barium platino-cyanide, placed in the vicinity of the induction coil, the fluorescence thus produced being entirely independent of the fact whether the coated or the plain surface is turned toward the discharge tube. This fluorescence is visible even when the paper screen is at a distance of two meters from the apparatus. . . . We soon discover that all bodies are transparent to this agent, though in very different degrees. . . . A single sheet of tin foil is . . . scarcely perceptible; it is only after several layers have been placed over one another that their shadow is distinctly seen on the screen. . . . If the hand be held between the discharge tube and the screen, the darker shadow of the bones is seen within the slight dark shadow-image of the hand itself. . . . Lead of a thickness of 1.5 mm. is practically opaque; and on account of this property this metal is frequently most useful. . . . Of special significance in many respects is the fact that photographic dry plates are sensitive to the X-rays."

Description of the New Rays

It is amazing how much is contained in this first report. First of all, it is obvious that in the discovery of X-rays, Roentgen made use of the previous studies of Hittorf, Crookes, and Lenard or the discharge of an electric current through rarified gases, and he also made use of the phenomenon of fluorescence previously investigated by Stokes. He reported the effect on a photographic plate of X-rays, and he describes the first roentgen-ray shadowgram, namely that of the bones in the human hand. In spite of this, his announcement contains no comment upon the possible medical implications of this use of X-rays.

Roentgen was apparently more interested in elucidating the properties of these newly discovered rays. I illustrate this by some more quotations from his first two publications:

"X-rays cannot be concentrated by lenses; neither a large lens of hard rubber nor a glass lens having any influence upon them. . . . It is well known that Lenard came to the conclusion from the results of his beautiful experiments on the transmission of the cathode rays of Hittorf through a thin sheet of aluminum, that these rays are a phenomenon of the ether and that they diffuse themselves through all bodies. We can say the same of our rays. . . . Other substances behave in general like air; they are more transparent to X-rays than to cathode rays. . . . A further difference, and a most important one, between the behavior of cathode rays and X-rays lies in the fact that I have not succeeded, in spite of many attempts, in obtaining a deflection of the X-rays by a magnet, even in very intense fields. The possibility of deflection by a magnet has, up to the present time, served as a characteristic property of the cathode ray. . . . I, therefore, reached the conclusion that the X-rays are not identical with the cathode rays, but that they are produced by the cathode rays at the glass wall of the discharge apparatus. This production does not take place in glass alone but as I have been able to observe in apparatus closed by a plate of aluminum 2 mm. thick, in this metal also."

Discovery Probably Accidental

From a reading of Roentgen's original announcement, it seems probable that the discovery of X-rays was purely accidental; that he was simply trying to investigate further some properties of cathode rays studied earlier by Crookes, Hittorf, and Lenard.

Indeed, this conclusion is attested to by one of his students. Once he discovered these rays, his first concern was obviously to understand their nature. While he himself made the first practical application of his rays, he described this in one sentence. It is also interesting to observe that all of the scientific principles involved in present day small film photoradiography were known to Roentgen himself at the time of his first publication. He knew how to produce X-rays; he knew that shadows could be produced by human tissues of varying densities; and he knew that these shadows could be observed either on a fluorescent screen or by direct action on a photographic plate. There is no evidence that Roentgen profited directly in any way as a result of the enormous use to which X-rays were put, almost immediately. He apparently took out no patents and entered into no commission agreements with apparatus manufacturers. He did, of course, receive the first Nobel Prize in physics.

Other Great Contributors

It was Roentgen's interest in the fascinating phenomena accompanying the passage of an electric current through a gas under reduced pressures which led him to the accidental discovery of X-rays. These prior phenomena were described lucidly by Johann Wilhelm Hittorf, professor of physics and chemistry at Münster in *Annalen der Physik und Chemie* in 1869. Another person who had studied this same intriguing physical problem was Sir William Crookes, the British physicist. In 1879, he published his Bakerian lecture entitled, "On the Illumination of Lines of Electrical Pressure and the Trajectory of Molecules" in the *Philosophical Transactions* and described his own researches in this field. Another investigator whose work was known to Roentgen was Philipp Lenard. His researches in this field led him, in 1900, to a correct interpretation of the photoelectric current.

Roentgen needed to know more than the experiments of Hittorf, Crookes, and Lenard on the passage of electric currents through gases. He needed to understand the induction coil and, of course, he made use of a fluorescent screen in his initial observation. Michael Faraday, the director of the Royal Institution, was the man who investigated induced currents and invented the induction coil. He described his work on electromagnetic induction in a paper published in *Philosophical Transactions* in 1832. But, of course, Faraday's studies were carried out with full knowledge of the work of those great contributors to the physics of electricity who had preceded him. Among them were Ohm, Ampère, Oersted, Volta, Galvani, Coulomb, and Franklin.

The Use of Fluorescence

Roentgen used fluorescence in his discovery of X-rays, and this same phenomenon is involved in microfilm procedures for mass X-ray surveys. Fluorescence was first described in detail by Sir George Gabriel Stokes of Cambridge University. His studies were published in the *Proceedings of the Royal Society* in 1852. The following are quotations:

"The author was lead into the researches detailed in this paper by considering a very singular phenomenon which Sir John Herschel had discovered in the case of a weak solution of sulfate of quinine, and various other salts of the same alkaloid. This fluid appears colorless and transparent, like water, when viewed by transmitted light, but exhibits in certain aspects a peculiar blue color. Sir John Herschel found that when the fluid was illuminated by a beam of ordinary daylight, blue light was produced only throughout a very thin stratum of fluid adjacent to the surface by which the light entered. . . . Several years before Sir David Brewster had discovered in the case of an alcoholic solution of the green coloring matter of leaves a very remarkable phenomenon, which he has designated as internal dispersion. . . . After having repeated some of the experiments of Sir David Brewster and Sir John Herschel, the author could not fail to take a most lively interest in the phenomenon."

Thus, it is shown in his introduction that Stokes was merely following up some interesting observations made by predecessors. Stokes went on to show that not only many solutions of naturally occurring compounds but also dried paper, previously soaked in these solutions, exhibited the phenomenon of fluorescence. He investigated rather thoroughly exactly what took place. The following quotations summarize some of his findings:

"There is one law relating to the change in refrangibility which appears to be quite universal, namely, that the refrangibility of light is always lowered by internal dispersion. The incident rays being homogeneous, the dispersed light is found to be more or less composite. Its color depends simply on its refrangibility, having no relation to the color of the incident light, or to the circumstance that the incident rays were visible or invisible. The dispersed light appears to emanate in all directions, as if the solid or fluid were self-luminous while under the influence of the incident rays. . . . The appearance which the rays from an electric spark produce in a solution of sulfate of quinine shows that the spark is very rich in invisible rays of excessively high refrangibility, such as would plainly put them far beyond the limits of the maps which have hitherto been made of the fixed lines in the chemical part of the solar spectrum."

Stokes, of course, made use of his knowledge of the relationship between color of light and its refrangibility, or in more modern terms, its index of refraction. This was first pointed out clearly by Sir Isaac Newton in a paper entitled, "Theory about Lights and Colors," published in *Philosophical Transactions* in 1672.

The Photographic Camera

The third and final element of the photoradiograph is, of course, the camera. To have a camera one really needs to know only two things, namely how to produce an image with a lens and how to record that image on a photographic emulsion. Knowledge of lenses and image formation actually antedate what we might consider the scientific era. The Arabian, Alhazen, described the lens system of the human eye about 1000 A. D., and Ptolemy of Alexandria, who lived between 70 and 147 A. D., wrote about the diffraction of light by lenses.

Recording images on photographic emulsions depends on more recent discoveries. In 1727, a German physician, Schultze, made the observation that a suspension of chalk in silver nitrate solution turned dark when exposed to sunlight. At a later date, Karl Wilhelm Scheele, the noted Swedish chemist, found that paper coated with a layer of silver chloride would be darkened by exposing it to sunlight. Credit for the first use of this blackening reaction for recording images is usually given to Thomas Wedgwood, the son of the famous potter, Josiah Wedgwood. Wedgwood knew the experiments of Schultze and of Scheele and of others who had preceded him in this study. By 1802, he had succeeded in making prints on paper coated with silver chloride from paintings on glass. This required extremely long exposure. He also tried to make photographs using the camera obscura, but failed because he could not get enough light to form an image. He published his findings jointly with Sir Humphry Davy, the English chemist, in 1802. The title of their paper was "An Account of a Method of Copying Paintings on Glass, and Making Profiles, by the Agency of Light upon Nitrate of Silver." One of the difficulties with these images was that they were not fixed; that is, on exposure to additional light the undarkened portions also darkened. Sir John Herschel pointed out in 1839 that sodium thiosulfate, or hypo, which he had discovered, could dissolve the unaltered silver salts and leave only the blackened portion. As we know, to this day hypo is used as a fixing agent in photography.

The next big step in the history of photography was the discovery of what we now call development. In 1840, Talbot, an Englishman, discovered that silver iodide in the presence of gallic acid and silver nitrate was far more sensitive to light than silver chloride. He found that it was not necessary to expose the paper until the image is formed, but that he could develop the image by applying gallic acid and silver nitrate to the paper after only a very brief exposure. Gallic acid is, of course, a reducing agent, and the photographic developers which we know today are reducers. The only thing remaining was to discover how to produce the present day type of dry gelatin emulsion for coating photographic films and plates. This development came gradually. By 1877, Wratten and Wainwright advertised dry photographic plates with gelatin emulsions.

The Byproducts of Research

Several things are fairly clear from this historical survey. The first is that the scientific knowledge necessary for mass photoradiography was available at the time that Roentgen discovered X-rays, before the beginning of the present century. Yet, it took 30 years before this method was developed to the point that it gained any acceptance at all, and even today, more than half a century later, mass photoradiography is still something of a novelty.

Another observation one can make from this historical survey is that not a single one of the essential basic scientific discoveries was made as the result of a deliberate attempt to find a method for the control of tuberculosis or of any other disease. Most of them were made by professors apparently trying to understand something else. Surely, if Roentgen had had a contract from some agency of the government to find a method for the control of tuberculosis, he would never have dreamed of fooling around with a Crookes tube. He wouldn't have done this even if he had been looking for some radiation more penetrating than ordinary light, because it is a fact, known even at that time, that the cathode rays obtained in the Crookes tube have very low penetrating powers. Had Stokes been working on a contract to find a method of controlling tuberculosis, he couldn't possibly have justified wasting his time trying to understand the cause of the queer blue color seen at the surface of a quinine sulfate solution when exposed to daylight. What possible connection could have been seen by a review panel between this obscure laboratory curiosity and the control of man's environment? Yet, as we have already seen, Stokes' pioneering studies on fluorescence were necessary for Roentgen's discovery. The same can be said of most of the other workers whose contributions, we know today, were absolutely essential for this control measure. Had these individuals been under contracts to find a means of detecting tuberculosis, they would undoubtedly have lost their contracts in short order.

The Lag Before Practical Application

Obviously, the important thing for us to worry about is not how the physical sciences have been used in the past to help with the problem of control of man's environment, but rather how can they be used most wisely in the future. Our study of the past is valuable only insofar as it gives us insight into this more pressing problem.

One of the things we learned in our consideration of the past was the extremely long lag between discovery of the physical principles underlying mass photoradiography and the actual use of the method. A good many people died of tuberculosis unnecessarily in the half century between the discovery of these principles and the present time. To know how to speed up application, one would have to know something about the reasons why the present methods were not accepted earlier by the medical profession. I would venture to guess that one reason is that the method is complicated. It involves the simultaneous application of three physical phenomena, namely roentgen-ray generation, fluorescence, and photography. In order for one to make full use of a scientific principle, it is absolutely essential that he appreciate its limitations; otherwise, he will expect the impossible and be discouraged by the actual results. To appreciate fully the limitations of photoradiography, an individual needs to know a great deal about both physical science and human biology. For the future, I would seriously recommend more thorough training in mathematics, physics, and chemistry as an entrance requirement to schools of medicine.

However, merely speeding up the development of methods based on scientific discoveries to the stage where their use is accepted by the medical profession is not sufficient to insure the best possible utilization of the physical sciences for the future control of man's environment. It is necessary also to discover new basic scientific principles which can be put to use in the future.

Support of Project Research

I think it safe to say that most people look to the universities as the source of new discoveries in basic science. The public probably feels fairly secure when it reflects upon the rather considerable financial support being given to scientific studies in universities today. Since 1940, we have witnessed a tremendous increase of academic research sponsored by the Federal Government and by various special foundations dedicated to the solution of specific problems. In addition to this, some of the great charitable trusts have also been supporting academic research.

Recently, I had occasion to review some data provided by the Commission on Financing Higher Education and by the Biennial Survey of Education for 1948–50. By combining a few not quite comparable statistics, I was able to obtain the following approximate picture of the situation at the end of the last decade. Out of an annual academic budget for the whole country of $1.5 billion, 44 percent was spent for instruction, and 15 percent for organized research. The 15 percent can be broken down as follows: 9 percent sponsored by defense agencies of the Government, 1½ percent sponsored by agricultural and medical agencies of the Government, and 4½ percent sponsored by all others, including charitable trusts, special foundations, industry, and universities themselves.

It seems likely that most of the persons responsible for the distribution of research funds consider that grants to universities represent the support of basic research. I would like to examine the question whether this is really so. Most grants to universities are made on a project basis. A university obtains a particular sum of money to investigate a particular question in a particular budget period. There are, of course, a few exceptions, but in general this is true.

Now, what are the effects of the establishment of projects of this sort? Well, obviously, they permit the university to carry out investigations in areas which it couldn't afford to study otherwise. For example, almost no university could build or even operate a cyclotron without substantial outside support. Another effect of project research is that it determines what intellectual areas in the natural sciences are going to be developed. Under the present system, these decisions are made outside the university by the committees who allocate the funds.

Project Management—A Pattern

However, there is a much more serious consequence of the project system. This system tends to preclude discovery of any really remarkable principle in basic science. The whole business of managing a project requires the recipient to follow a certain pattern. As soon as a professor begins work on a project, he usually has to hire highly trained assistants. It then becomes his obligation to guarantee them a certain element of job stability. This means that the professor must make it his first concern to see to it that the chances of renewal are as good as possible. He knows that he will be judged on the basis of whether or not the project has turned up any concrete findings. I hasten to add that most sponsors today are decent enough not to require patentable findings. Now, anybody with a grain of sense knows that the problem of obtaining clean-cut results obeys a sort of inverse square law. The closer you stick to what is already known, the more likely it is that you will obtain specific clean-cut significant results. But this process makes it less likely that anything truly extraordinary will be uncovered.

It is evident from the foregoing that I do not think that the present system of supporting research in the universities is the best way to encourage the development of the basic sciences, either biological or physical. Since I believe that continuing progress in fundamental science is an absolutely essential first step in the effective utilization of such science for the control of man's environment, it follows, then, that I do not believe that our universities are being utilized effectively today in relation to that problem.

Probably most of us agree that our university resources ought to be exploited to the fullest extent possible for the solution of man's pressing practical problems. The question is: What is the best way to do this? Concerning this question, I find that I have some very definite views. I believe that the university can make its best contribution to the solution of the problems of our age by concentrating on education. In fact, I believe that education is the only real business of the university. By education, I mean that which leads the student to a realization of the problems of mankind and to a recognition of his own responsibility with respect to them, and that which induces him to develop the intellectual tools to cope with them. By education, I mean, further, a process which involves, at the highest level, cooperation between the student and the teacher in the creation of new knowledge and in the gaining of new understanding.

I would judge every activity carried on by a university on the basis of the extent to which it contributes to the process of education. In the field of science, I would judge a specific sponsored research project on the basis of whether its pursuit provides a good way to educate students and whether it is apt to lead to any significant advancement in the understanding of nature. I would judge the present-day policy of supporting academic research through the medium of projects on the basis of whether this is a good way to further the educational function of our universities.

I believe that a university neither can nor should attempt to solve within its own walls very many of man's practical problems. This isn't because I am not anxious to see these problems solved: it is only because I believe firmly that pursuing such an aim will prevent a university from realizing its true function. Our job is to provide people with the means to solve these problems; this task alone is overwhelming.

Scientist-Based Research

I feel, further, that it should be the duty and the privilege of university faculties solely to determine what intellectual areas are essential for the education of its students. I certainly recognize that this places an enormous responsibility upon the faculty, and I am fully aware of the inadequacies in the human beings like myself who make up faculties. Nevertheless, I don't think the human beings in the government or anywhere else are any more adequate. This being the case, then, I must oppose any attempt, conscious or unconscious, to direct or shape the intellectual activities of the universities from the outside. This does not mean that universities must not be influenced from the outside. It does mean that professors themselves have an obligation of being fully aware of what goes on in the world, that is, of what man's problems are. It means further that the faculties must be completely free to choose the kinds of intellectual exercises used to prepare students to face these problems.

Please be assured that I am not really advocating irresponsible discontinuation of the present support of science in our universities by the Federal Government and by other agencies. What I am advocating is an honest attempt to find ways of giving this support which will result in the greatest possible advancement of science and, therefore, in the greatest potential good for mankind. Truly fundamental scientific discoveries cannot be planned. They can be made only as the result of the alertness of a highly competent and highly imaginative scientist as he observes the day-to-day progress of his own research. I would advocate a research supporting policy which is based, not upon projects, but upon men. Assume that a certain scientist working in a certain university has demonstrated on the basis of previous performance that he is capable of making significant contributions to basic science. On this basis alone, he should receive research support for an extended period of years with no limitations beyond those normally binding a university professor to his academic duties. There should be no research reports and no visiting committees. The man should be judged only after a long period of time, and then solely upon the basis of the effectiveness of his research published in regular scientific journals. Effectiveness, I remind you, depends on quality and quantity. If this effectiveness is high, then his support should be continued even beyond the original long-term period. And, if it isn't high, then, of course, support should be terminated.

There are many examples which prove that this is a good way to get research done. While it isn't concerned primarily with physical sciences, the Rockefeller Institute for Medical Research has always operated on this system. This institution has had an enormous effect on the development of basic biological and medical science in this country. Most of the great physical and chemical laboratories in Europe and in Britain in the 19th and early part of the 20th century were operated on this same principle, and the enormous development of the physical sciences in these institutions demonstrates clearly the effectiveness of this way of managing research.

I make an urgent plea that we give serious thought to this problem, the problem of insuring the future availability of basic science, both physical and biological, for use in the control of the environment for the health of men.

The Role of the New Center In Scientific Research

PHR brief

The discussions which have been presented at this symposium illustrate the breadth of scientific talent and the nature of the working environment that are required for successful research in sanitary engineering. The discussions have served to point out clearly that there will be no simple formula which can insure success in this field. As we face the complex problems of our environment today, emerging with all their complexities, the prospects for sanitary engineering might be considered as either encouraging or discouraging: discouraging because of the extremely rapid development of problems in so many diverse aspects of environment, many of which will have to be approached without much guiding precedent; encouraging for these very same reasons. It is pioneering that offers a fascinating challenge.

Particularly those of us who will have some part in administering the affairs of the Robert A. Taft Sanitary Engineering Center are grateful for the insight into the technical aspects of its operation, which our speakers have given. My remarks are concerned with those far less precise but perhaps more perplexing problems of administration—problems not amenable to slide rule computation.

Two basic philosophies will become apparent as we move ahead. Much has been said about these directly—much more has been implied: first, that an institution of this type cannot attract and retain and promote scientific competency if it be geared to an assembly-line production schedule; and second, that the authorization that established this center and the public moneys that will support it do not provide for the maintenance of a scientific environment solely for the purpose of stimulating original scientific knowledge.

At the risk of a challenge, these two philosophies need not be incompatible. The problem is to maintain a resultant which represents the proper mean between these two extremes.

Brought out abundantly clear have been the broad and interrelated problems involving the equilibrium between man and his environment. Certainly this center in itself cannot hope to encompass all of these problems. Through close collaboration with the universities and other research resources of the Nation, however, we may jointly stimulate the guiding research so urgently needed to cope with them. We look forward to serving our research colleagues in the States, the universities, and industry in whatever manner will best serve the public interest. The primary energies of the center will be directed toward those problems national or regional in character and generally beyond the resources of individual State institutions and industries.

In developing the pattern of operation for the center, two questions emerge:

How best to develop the atmosphere required to attract and retain the kinds of people necessary to accomplish the center's mission?

How best to develop and maintain coordination between the applied activities of the center and the more basic research carried out by the universities?

The intelligence with which we are able to manage these two problems in a large measure will determine the success of the enterprise.

We in the Public Health Service accept the responsibility for managing this center to meet the challenges described by the previous speakers. We hope we have the potential to develop its capacity to full advantage of the opportunities it provides.

By Mark D. Hollis, C.E., Assistant Surgeon General and chief engineer officer of the Public Health Service.
