

# The House That Robert A. Kehoe Built

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## Laying the Foundation

IT ALL BEGAN in May of 1924, when deeply troubled Chemist Thomas Midgley, Jr., working under the direction of Charles F. Kettering, came to the Medical College of the University of Cincinnati to consult Dr. Martin H. Fischer, Head of the Department of Physiology, and Assistant Professor Robert A. Kehoe. Thomas Midgley's long and painstaking search for an effective and practical antiknock additive to automotive and aeronautical gasolines, carried out for the General Motors Research Corporation, then located in Dayton, Ohio, had come to a fruitful end with the discovery that tetraethyllead met these requirements, only to open up a new and far more serious problem. There had been no foreknowledge of this. None of the research men, exposed to the compound, had experienced ill effects of any note, nor were they aware of its potential danger. It was only when the ethyl fluid mixture—which contains halogenated hydrocarbon scavengers to remove residues of lead forming on parts of the motors—came into semicommercial manufacture and was handled in bulk by nontechnical personnel, that trouble arose. There were two deaths in Dayton and some 30 cases of poisoning. Dr. Midgley had not anticipated this difficulty, although he had been concerned earlier with the possible hazard to public health by introducing a substance such as lead, already known for its potential danger, to that inherent in gasoline and its decomposition products. At his request, the US Bureau of Mines Experimental Station in Pittsburgh

was already investigating this aspect of the problem.

Thomas Midgley hoped that Dr. Kehoe would be interested in assisting him in the care of the employees of the General Motors Chemical Company and in investigating the toxicity and mode of action of tetraethyllead. The two men had met through the American Chemical Society, and Dr. Midgley knew of Dr. Kehoe's earlier work on heavy metal poisoning. Dr. Kehoe was interested and ready almost at once—as the school year was about to close—to begin work in quarters made available to him in a building of the General Motors Research Corporation. He moved his family near Dayton, and during the following school year he traveled to Cincinnati for his Monday and Wednesday classes.

The clinical work—the investigation and care of the ill men—and the means by which the antiknock agent could be manufactured safely were resolved, at least in principle, fairly promptly. The information obtained in the first phase of the toxicologic investigations, that is, the determination of the paths of absorption—through the skin, by way of the digestive tract, and the lungs—and the establishment of the approximate lethal doses of tetraethyllead, had enabled the engineers of the General Motors Chemical Company to design equipment for the safe blending of ethyl fluid.\* The first investigations by the

\* Dr. Kehoe described the clinical symptoms and signs of the cases under his care, the treatment and its results (*JAMA* 85:108-110 [July 11] 1925). In an issue of the *JOURNAL* that appeared just two months earlier (84:1481-1486, May 16) we read the alarming report by Alice Hamilton of the casualties that had resulted from the manufacture of tetraethyllead. It was indeed alarming, for in the period from September 1923 to November 1924 there had been ten deaths, including the two that had occurred in Dayton in mid-1924, and some 60 to 70 cases of poisoning. Three deaths had occurred at E. I. du Pont and de Nemours & Co.

(Continued on following page)

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Bureau of Mines, mentioned earlier, neared completion at the end of July 1924. Dr. Kehoe participated as a consultant, and conferred frequently with Drs. R. R. Sayers and W. P. Yant of the Bureau, Thomas Midgley, Graham Edgar, Director of Research of the Ethyl Gasoline Corporation, and Dr. Emery Hayhurst of Ohio State University, all of whom advised the extension of the investigations to include the effects of ethyl fluid when inhaled as a vapor or when absorbed through the skin.

In the spring of 1925, Dr. Kehoe was named Medical Director of Ethyl Gasoline Corporation (later Ethyl Corporation). On his advice, the Corporation decided to limit the sale and distribution of the antiknock compound to the refiners of gasoline so as to confine to a minimum the number of sites where it was to be added to gasoline. His prime responsibility was to aid in the development of plans for safe mixing operations. At about the same time Dr. Kehoe became a consultant to E. I. du Pont de Nemours & Co. (the sole manufacturer of tetraethyllead in the United States of America, under contract with Ethyl Gasoline Corporation), helping to set up procedures for the medical and hygienic surveillance of the manufacturing operations.

The widely publicized accidents, fatal and nonfatal, that had occurred not only in Dayton, but in the eastern states, had caused great public alarm and anxiety by public officials.† The distribution of tetraethyllead was stopped in May 1925, and the sale of

and five at Standard Oil Co. in New Jersey. In February of 1925, one more death occurred at du Pont and one man at Standard Oil had become insane. The repercussion of the prompt controls initiated in Dayton is clearly evident in Dr. Hamilton's description of investigations by the state officials following the accidents. She says that the representatives of the Ohio Factory Inspection Department "found that at the time the two fatal accidents occurred, unskilled laborers were employed without skilled supervision, the arrangements for handling the product were crude, the mixing and bottling were carried on under an ordinary laboratory hood, and although the men were given gloves and respirators, they discarded them. At the time of their visit, however, an excellent building and equipment had been provided as well as working clothes, washing facilities, etc. for the men. 'Since the installation of the new filling and blending arrangements with the downward exhaust, no symptoms have been experienced by the workmen, whereas previously complaint of sleeplessness, headache, loss of weight and appetite were quite common.'"

† As is typical of incidents of public excitement, exposure to ethyl gasoline and its vapors was accused in numerous cases as the cause of various types of illnesses. Such instances are documented in the report of the investigations carried out by the Public Health Service and evaluated by the Committee appointed by the Surgeon General (Public Health Service Bulletin 163, 1926).

gasoline containing ethyl fluid was discontinued in the East and in some midwestern states. Not only was the public aroused, but the Unions of Automobile and Aircraft Mechanics, Teamsters and Chauffeurs also became concerned about the possible dangers of occupational exposure to lead-containing gasoline. Aware of the situation, the Surgeon General of the Public Health Service of the United States called a conference on May 20, 1925, to consider the "public health questions in the manufacture, distribution or use of tetraethyllead gasoline." Dr. Kehoe, as one of the representatives of the Ethyl Gasoline Corporation attending the Conference, reported the findings of his and Dr. Edgar's preliminary investigations. From the introduction to the report of investigations by the Public Health Service that followed this Conference, we may gather that among the studies reported, only those conducted at Dayton included human observations. Significant as these were, the data were not sufficient for the derivation of definite conclusions. This led the Surgeon General to appoint a committee to investigate the hazards of the use of tetraethyllead-containing gasoline and to formulate regulations for the various situations of exposure, from the manufacture of the concentrated product to the user of the gasoline. The findings of this investigation, on a broader and most importantly on an official basis, confirmed those obtained by Drs. Kehoe and Edgar. While the Committee was satisfied that evidence of immediate danger to the public health did not exist, it recommended further investigations at the expense of the industry.

To return to the temporal sequence of this account, some time late in 1925, the entire investigative program, begun in Dayton, was moved to Cincinnati to the Eichberg Laboratory of Physiology in the College of Medicine, to form the nucleus—or the foundation—of what later became known as the Kettering Laboratory. The investigations from that time on dealt with the distribution of lead in the tissues of animals following the absorption of tetraethyllead, along with the development and constant improvement of methods for the determination of trace quantities of lead in biological materials and

in the air. The normal distribution of lead was established. Various criteria for the recognition of poisoning both by tetraethyllead and inorganic lead compounds were clearly defined. Elaborate investigations were made of the lead hazards associated with the distribution and use of tetraethyllead-containing gasoline by comparing the findings on filling station attendants, tank wagon handlers, garage mechanics, and other exposed persons, with similar groups handling gasoline that contained no tetraethyllead. All these investigations were designed to contribute to the solution of the serious problems which had been raised at the Conference called by the Surgeon General: the mixing of ethyl fluid with gasoline by methods that would insure the safety of men handling the concentrated mixture; the determination of the degree of hazard in the handling of gasoline containing (as of that time) 3 ml of tetraethyllead per American gallon (through contact with the skin and through the inhalation of tetraethyllead vapors given off from gasoline); and the degree of hazard associated with the contamination of the air by the exhausts of automobile engines. The findings of these investigations were communicated periodically to the Public Health Service and were published in detail, together with additional observations, in 1936.

With official sanction given to the use of tetraethyllead-containing gasoline in January 1926, plans for its enlarged manufacture and use on a large scale were set in motion soon thereafter. It was up to Dr. Kehoe to lay out the program for medical surveillance and technical supervision of the personnel at the mixing plants of the petroleum industry. The precautionary methods developed by him and his associates, the formulation of regulations for the handling of ethyl fluid, the education of personnel exposed to it during manufacture, its transport, mixing with gasoline, and the cleaning of tanks used to transport and store the leaded gasoline have been included from that time on in every contract of sale of the antiknock product to refineries. That the impact of these preventive measures should have become far-reaching, extending to every part of the globe, is understandable. The cooperation achieved internationally in

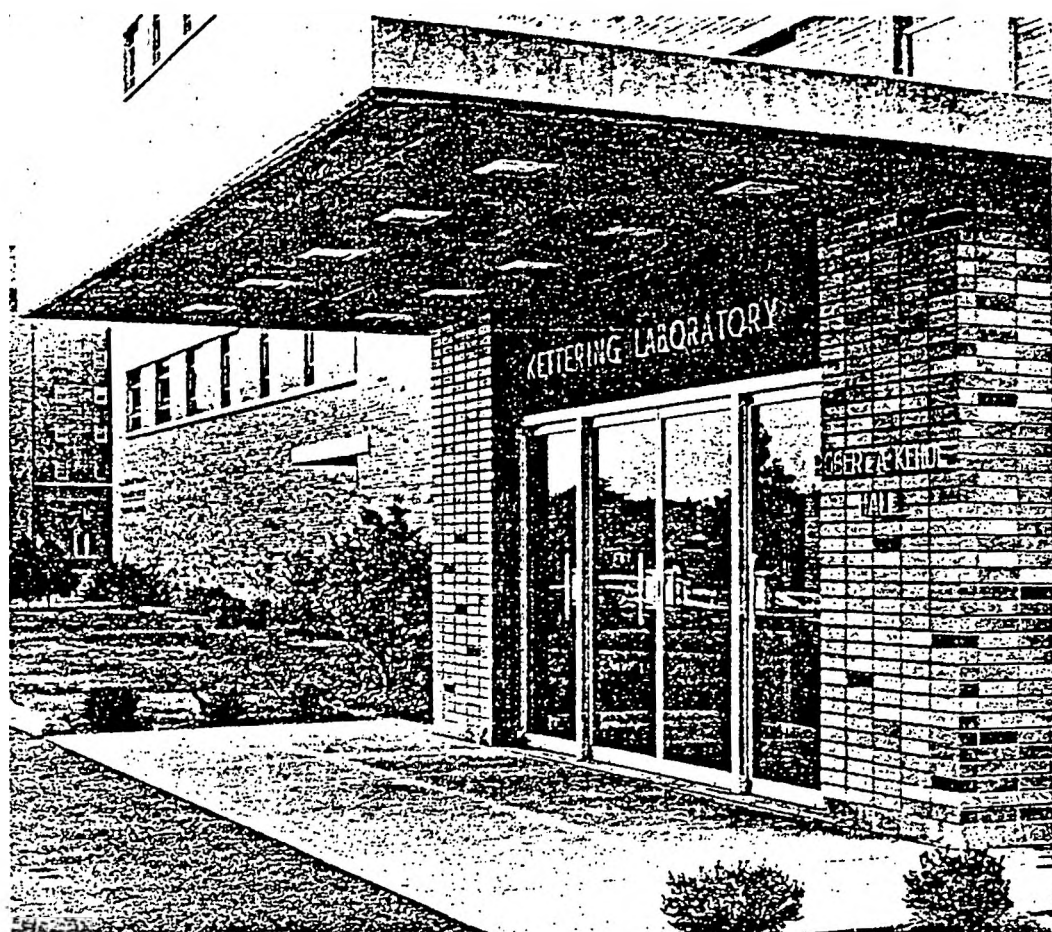
controlling this industrial hazard is a matter of record. It is significant that no case of tetraethyllead poisoning has ever occurred in connection with these mixing operations in the United States and Canada, nor is believed to have occurred in other countries in which the prescribed regimen has been followed consistently.‡

It may be pertinent to note here that in spite of continued search over the past 40 years for a less toxic antiknock additive, none has been found to equal the effectiveness of the alkyl lead compounds. The vigilance against any possible effects on the health of workmen and of the general public has been evidenced throughout the years by surveys carried out from time to time as to the absorption of lead by large groups of people and of the concentrations of lead in urban atmospheres.

Just a few years after Dr. Kehoe was approached to help solve the problem surrounding the antiknock compound, another problem—and in this case one directly concerning public health as well as industrial health—was brought to the Laboratory. The source of it was the household electrical refrigerator. Fatalities and accidents had occurred due to the escape of methyl chloride, methyl bromide, and sulfur dioxide, then widely used as refrigerants. The Frigidaire Corporation, which used sulfur dioxide exclusively, requested an investigation of the toxicity of this gas. The first phase of this work was again, as in the investigations involving tetraethyllead, a careful survey of the health of the workers in the industry. Meanwhile, Thomas Midgley was asked by Charles F. Kettering to develop a nontoxic,

‡ Some of the early history of leaded gasoline, and the procedures developed to control whatever hazards might occur at every step from the transport of the concentrated fluid to the ultimate use of the gasoline, were reviewed recently by Dr. Kehoe (*Arch Environ Health* 8:378-383 [March] 1964).

Again, it is interesting to refer to Dr. Hamilton's report, published in 1925, in which she describes the addition of ethyl fluid to gasoline by operators of service stations, to which it was then sold in 1-quart steel receptacles, and the attendant dangers. She mentions that having become cognizant of this danger, the manufacturers of the antiknock fluid had decided that "in the future, sales of tetraethyllead would be made only to refineries, where it will be mixed with gasoline by specially trained employees and then distributed to service stations." She adds, "this provision, however, is purely voluntary on the part of the manufacturers, and in no state is it a regulation with the force of a law behind it." There can be no doubt that the record of safety achieved, as stated above, has been responsible for the absence of specific legal regulations.



Main entrance to Kettering Laboratory

nonirritant, and nonflammable refrigerant. This Midgley and his associates accomplished in a remarkably short time, upon Midgley's even more remarkable prediction that the combination of the highly flammable gas, methane, with two highly toxic gases, chlorine and fluorine, would form dichlorodifluoromethane, a nontoxic and nonflammable compound—being the first of the class of fluorinated hydrocarbons, so widely used today not only as refrigerants, but also as propellants of aerosols in numerous applications.

The extensive investigations of the safety of the new refrigerants under Dr. Kehoe's direction were designed to test their use under the worst imaginable conditions, such as what would happen if the escaping gas were to come in contact with heated surfaces or with open flames. The nature of the decomposition products arising under such

conditions, and their toxicity, were established, even though the organic compound itself was nontoxic under usual situations. The lack of toxicity of the fluorinated hydrocarbons as such had been determined in animal experimentation and some preliminary studies of the decomposition products had been carried out by Kinetic Chemicals, Inc., that had first prepared the compounds, and by the Bureau of Mines, to which Dr. Kehoe also contributed.

#### The Family

The conduct of the investigations, above described, could not, of course, be accomplished by one man alone. As his associates within the "small research unit" or "nucleus of the Kettering Laboratory" (in his own terms), Dr. Kehoe had physicians Lester W. Sanders, Karl V. Kitzmiller, R. L. Crudgington, Willard F. Machle, and Leslie J.

Schradin; chemical engineers Frederick Thamann and Jacob Cholak, and capable technicians Daniel Duvall and Ben Hancock. For epidemiologic studies and statistical evaluation, he sought the collaboration of Professor Thomas LeBlanc, Head of the Department of Preventive Medicine. And somewhat later, aware of the need of being advised of all published information, insofar as it could be gathered, Dr. Kehoe asked Nell Conway, knowledgeable in languages and medical terminology, to join the staff as "information specialist" (in the modern term of this activity).

With the growth of the Laboratory, many others joined the "family," quite a number of whom gained enviable reputations in their own right.

#### Building Upward

While the investigations that were destined to become the foundation of the Kettering Laboratory were underway, the need for more space became acutely evident. The details of investigative programs of industrial and public health, as followed by Dr. Kehoe from the beginning, need no spelling out for those in the know: the necessity of examining man in his actual environment, as well as the environment to which man is exposed, be it in the workplace, the home, or the community; the number and types of biological material that need to be collected and examined, and the types of analyses that must be carried out to establish the cause of an industrial or environmental ailment; the importance of determining the normal intake and output of certain ubiquitous trace ions, for example lead and fluoride that also arise in the decomposition products of the lead alkyls and fluorinated hydrocarbons, before the abnormal concentrations can be ascertained.

In recognition of the work to be done, Ethyl Gasoline Corporation, E. I. du Pont de Nemours & Co., and Frigidaire Corporation contributed jointly a sum of money (\$130,000) to the University of Cincinnati to build and equip a laboratory. The first unit was completed in December of 1930 and was named The Kettering Laboratory of

Applied Physiology in honor of Charles F. Kettering, the "father" of the antiknock agent and of the modern refrigerants.

Investigations of several of the fluorinated refrigerants were carried out in the first few years of the thirties. These led, in turn, to practical as well as toxicologic research on the effects of hydrofluoric acid, used in the manufacture of, and occurring in vapor form as a decomposition product of the fluorinated hydrocarbons, then to the natural occurrence, effects, and metabolism of the fluoride ion. The success of the Laboratory in the solution of hygienic problems, by establishing means of controlling them, in two major industries, led other industries to bring their troubles to it. At that time such investigative facilities were sadly lacking in the United States. It was essential that such investigations be impartial—in other words, that they be done preferably in a laboratory free of bias, affiliated with a university or governmental agency. Some substantial work of this type had been carried out from time to time at several American universities, but not as a primary function or to the comprehensiveness of the work at the Kettering Laboratory. Among the governmental agencies, for example, the Bureau of Mines Experimental Station was deprived of the right to accept industrial funds for investigative work shortly after it completed its studies of the refrigerants, and only considerably later did the Public Health Service develop a group for such services at Bethesda, Maryland, under the direction of Dr. Paul Neal.

The years between the formal establishment of the Kettering Laboratory in 1930 and World War II saw, in addition to the continuing basic research on the normal and abnormal metabolism of lead and of the fluoride ion, both in experimental animals and in man, investigations, in the laboratory and in the field, of numerous air pollution and industrial problems, such as the nitroparaffins, the phenols, solvents of various types, and many other industrial products. The war years brought important assignments from all branches of the armed forces. These years also revealed numerous problems created by the increased production demanded by the emergency: the occupational,

as well as the public health hazards of the contamination of the atmosphere and water by the effluents from the aluminum, atomic energy, beryllium, magnesium, petroleum, steel, and other industries, some of which involved exposure to inorganic lead, and all of which required careful examination and recommendations for their control. Thereafter came investigations, begun during the war, of the toxicity of pesticides and of the propellants for them, food additives, and plastics for various purposes including the wrapping and preservation of food, first needed to supply the armed forces. The extension of these products, born in the war years to sustain and protect the armed forces, for the benefit and convenience of the general public required further investigation to meet the requirements of the US Food and Drug Administration and of the World Health Organization. The Laboratory investigated and is still investigating the toxicity of many of these materials, as well as of new ones as they are constantly being developed, in the laboratory and as they affect those who are exposed to them either occupationally or as consumers. Extensive surveys were carried out of the atmosphere of many communities, some in collaboration with the Public Health Service, as for example, of the urban atmosphere of the metropolitan area of Cincinnati and of a number of other cities of the United States. Several trace metals were added to the basic studies, as well as investigations of the physiology of the human skin and the mechanisms of absorption, secretion, and sensitization. The carcinogenesis of various petroleum distillates and other substances has also been examined. Since 1947, through an arrangement with the Coroner of Hamilton County, the Laboratory has been responsible for the pathologic and toxicologic investigation of deaths by violence. Throughout the years, various members of the staff have served as consultants to national organizations, governmental agencies, and industries; they have also contributed to undergraduate instruction, services to local hospitals in cases of poisoning of adults and children through careless use or storage of various products, and in cases of occupational diseases.

The need for more space was inevitable, and so in 1941, the original building was remodeled and a small addition was constructed to accommodate research essential to the war effort. A new and fully equipped wing was added in 1948-1949, made possible by a total contribution of about \$640,000 by 15 industrial sponsors. In 1949, the Laboratory was united with the Department of Preventive Medicine to create the Department of Preventive Medicine and Industrial Health under the chairmanship of Dr. Robert A. Kehoe, and the name of the Laboratory was shortened to that of Kettering Laboratory.

At that time, the Department and the Laboratory within it were organized into six divisions representing their principal functions: Preventive Medicine; Clinical Medicine; Toxicology; Forensic Pathology; Industrial Hygiene Technology; and Bibliographic Research including the library. To the functions represented by these divisions, that of Biometrics, was developed more recently to become the Medical Computing Center in the University.

The educational activities of the Department which will be described under the next heading, required still a further expansion in space. Another wing was completed by the end of 1963 and was dedicated on April 1, 1964, as the Robert A. Kehoe Hall. Its cost of more than \$1,500,000 was met by contributions from industry, a matching grant from the US Public Health Service, and an additional sum from Hamilton County, Ohio, whose Coroner's office, morgue, and laboratories are housed on part of the ground floor of this structure.

The results of all these developments have been that the "family," its activities, and the "house" have grown by 1965 from a nucleus of 11 members, active in two major investigations sponsored by two industries, and occupying a few rooms in the late twenties, to a staff of nearly 150 people engaged in research and field investigations sponsored through these years by more than 100 industries and governmental agencies, in a building covering about 100,000 square feet.

The investigative work of the Laboratory has been entirely self-supporting. The work,

undertaken by it, is by agreement between the industries or governmental agencies and the Board of Directors of the University. The public responsibilities and academic rights of the University are set forth and protected in these agreements. In its relationship with its sponsors, the Laboratory, as part of the Medical College, acts on the same basis as that of a physician to his patient. The results of the work are published at the discretion of the staff of the Laboratory. As of July 1965, 635 publications have appeared in professional periodicals, texts, and monographs, and around 700 reports have been submitted to sponsors.

As a reflection of the modern concept of the activities of the entire department, its name has been changed, effective July 1, 1965, to the Department of Environmental Health, the name of the laboratory within it remaining the same, the Kettering Laboratory.

#### Education of the New Generation

The years of growth of the Laboratory coincided with the years of the most rapid technologic developments since the turn of the century. The materialization of these developments through industrial production exposed the workman to an environment of chemical and physical forces never encountered before—an environment which was also constantly changing as methods of production were being varied. The problems brought to the Kettering Laboratory and to other laboratories of the same type clearly pointed to what needed to be done and how it should be done if the well-being of the increasing industrial population were to be preserved. Dr. Kehoe, together with a number of prominent industrial physicians, had long been concerned about the lack of recognition by the medical profession as a whole of what constitutes the sound practice of industrial medicine and of the qualities and capabilities that the industrial physician must possess. They were even more concerned with the lack of physicians properly trained in the assessment of the environment in the various work places, and in the recognition of the effects of the ever growing number of

chemical and physical stresses to which workmen are subjected. Short courses in occupational medicine had been offered from time to time in several universities, but they were inadequate to give the required broad basis of knowledge and experience which could be gained only through full-time graduate training in this specialized field, analogous to that required for other medical specialties.

The concern by Dr. Kehoe and his colleagues about the need for specialized training and recognition of the specialty of industrial medicine by certification is well portrayed in the numerous published addresses at professional meetings and other publications beginning in the earlier forties. In an address in 1945 in London (*Med Press* 215:41-45 [Jan 16] 1946) Dr. Kehoe succinctly defined real industrial medicine as "preventive medicine—when it is effective and adequate—with attention focused on the environment rather than on the patient," albeit the study and care of industrial casualties is necessary and must be done well. He further defined it as one involving "a series of professional activities that require intimate knowledge of industrial processes, conditions and personnel, as well as sound medical judgment and clinical experience." At that time he outlined the essential structure of a course of instruction of the type needed, which "should be in a laboratory of industrial hygiene and toxicology that is an integral part of a university center for medical training and practice."

In the next two years the embryonic plans were further developed with the assistance of Dr. William F. Ashe, and the Institute of Industrial Health of the University of Cincinnati came into being in 1947. It was organized under the academic authority of the Graduate School of Arts and Sciences. Instruction was and continues to be provided by several departments of the Colleges of Medicine, Engineering, and Law, by appropriate personnel of the Robert A. Taft Sanitary Engineering Center, the Occupational Health Research and Training Facility of the Public Health Service, and of several industries. In-school experience is rounded out by weekly seminars to which prominent

industrial physicians, hygienists, toxicologists, and others are invited as speakers, by clinical conferences presented both by students and faculty, and by field trips.

The course offered to physicians, which is accredited by the Council on Medical Education and Hospitals of the American Medical Association, leads to the following degrees: Master of Science, requiring at least one year of study in residence; Doctor of Industrial Medicine, with two years of study in residence and a year of industrial medical training and practice in an industry or in another setting with approved facilities; and Doctor of Science in Industrial Medicine after three years of study in residence.

Since an effective program for safeguarding the health of the working population requires close collaboration between the physician and the industrial technologist, a training course was begun in 1956 for engineers and graduates of schools of science who wished to prepare themselves for careers in environmental hygiene in industry, in research, or who desired to serve as educators in their specialty. The degrees awarded to them are Master of Science upon completion of at least one year of study in residence and Doctor of Science in Industrial Health, after three years in residence. Appropriate theses or dissertations are demanded of all candidates for degrees. For special students, the Institute offers training in epidemiology and biometry, leading to the degree of Doctor of Philosophy. Finally, certificates are granted to professional persons who do not seek training for periods or purposes for which degrees are awarded.

The full-time postgraduate training course in industrial medicine was the second such course to have been established in the United States, the first having been developed and initiated just a year or so earlier by Dr. T. Lyle Hazlett at the University of Pittsburgh.

Several years were to elapse before the final goal, that of official recognition of the specialty of occupational medicine could be achieved. Dr. Kehoe participated actively toward this goal, serving as Chairman of

an Interim Board to petition and to present evidence to the American Medical Association Council on Medical Education and Hospitals. Occupational Medicine, a discipline of preventive medicine, was officially recognized as a specialty by the American Board of Preventive Medicine in 1955, and Dr. Kehoe served as the first Vice Chairman of this Board.

### The Progeny

The first degrees of Doctor of Industrial Medicine were conferred by the Graduate School of the University of Cincinnati in 1950 upon Drs. Arthur M. Edwards and Ian Maclachlan. Since then, doctoral degrees, the degree of Master of Science, and certificates have been conferred upon 125 physicians, engineers, and graduates of other disciplines. Students have come from all parts of the United States and 25 have come from foreign lands. The responsible positions assumed by those who have had their specialized training in the Institute can perhaps be best exemplified by the following enumeration: of 86 physicians, 38 serve industry, 27 are in government service, 8 have become educators, and 13 are in private practice. Twenty-three of the physicians have assumed medical directorships of industries, some of which are among the largest in the country, or have become chief medical officers of important governmental agencies. Among the 38 environmental hygienists and one biostatistician who received the first PhD granted by the Institute, 7 are in industry, 25 are with the government, and 7 are teachers. Perhaps, also, it may be a tribute to the Institute that most of the alumni have kept in close touch and have organized as the "Kettering Laboratory Alumni Association."

### Epilogue

The history of the Kettering Laboratory until the present time reflects, understandably, in large measure the many activities, accomplishments, and farsightedness of Robert A. Kehoe. If the first investigations have been described in some detail, this has been done deliberately, for they are a dra-

matic evidence of his broad vision—as early as 1924—of the concept of industrial (or occupational, or environmental) medicine and technology: that the effective surveillance of the health of the working population can be accomplished only by the practice of preventive medicine by a team consisting of practitioners of medicine and allied sciences and those of the physical sciences and engineering, rather than relying on therapeutic means. In the investigation of troubles brought to the Laboratory in subsequent years, the same principles of thoroughness first applied by him in the successful solution of the problems of two very important industries have been followed. More significantly, in his teaching, Dr. Kehoe has impressed upon his students his ideals in the safeguarding of man against exposure to an ever increasing number of, as well as changing, environmental hazards.

Thus, it is not merely a laboratory or a school that Dr. Kehoe has built, but a living structure—a house—the members of whose household have worked both inside and outside it, as well as having learned and taught. From this house he has sent disciples into

the world to cope with existing and new problems of modern civilization which is man-made and man-desired.

#### Postscript

As raconteuse of the history of the Kettering Laboratory, I cannot resist the temptation of saying that from another part of the University Campus, I had been aware of Dr. Kehoe's Laboratory almost since its beginning. Starting first as student assistant in 1926 in the Office of the Vice President in Charge of Business Administration, to which nothing is secret, and to which sooner or later all faculty come for assistance, I had learned bit by bit some of the history. The story of why the Laboratory was part of the University particularly fascinated me, and I wished to include it in this historical sketch. Understandably, I had to learn the true sequence of events, for these are not on record, and only one man could help me. This he did graciously and generously. For this I wish to thank him, as I thank him for his constant understanding and encouragement throughout the years since I joined his staff in the mid-forties.

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#### RELATIONSHIP OF CARCINOMA TO BREAST FEEDING

We have more solid information regarding the relationship of carcinoma to breast feeding. It is well known that this disease occurs more frequently in nulliparous women. In a number of countries where breast feeding is more generally practiced, the incidence of breast carcinoma is much lower than it is here. For example, the disease is about five times as frequent here as it is in Japan. Such differences may, of course, be due to genetic or other factors, but the most obvious explanation is the degree to which the breasts function to produce milk. An unchallengeable answer to this question of whether or not breast feeding protects mothers against breast cancer can come only from a careful study of the problem in a society where (1) a complete cancer registry has been functioning for a good many years, (2) a large enough proportion of women have nursed their babies to provide controls for those who have not, (3) the population is comparatively uniform genetically, and (4) matching groups of women of similar social and economic strata who have and have not nursed their babies are available. At the present time these requirements can only be met in Denmark, but such a study has not yet been conducted.—Haagensen, C.D., editorial, *Breast Feeding and Breast Disease*, *J Amer Med Wom Assoc* 20:956-957 (Oct) 1965.

## Robert Arthur Kehoe, MD

WILLIAM F. ASHE, MD † COLUMBUS, OHIO

ALTHOUGH he became a very unusual man, Robert Arthur Kehoe was born on Nov 18, 1893, in the usual fashion to Jeremiah and Jesse Kehoe in Georgetown, Ohio. It is to be presumed that some day he will die. But having long since passed the biblical statute of limitations, three score and ten, and now shows almost none of the ravages of the aging process, we suspect he will be around a long while pursuing his life work—industrial hygiene—in the true Greek meaning of the word *hygieinos*.

Young Robert's university education began at Ohio State before World War I and was completed at the University of Cincinnati thereafter. Upon receipt of his MD degree in 1920, he married Lucile Marshall and to them was born one child, Kathleen.

Except for more than her share of allergic respiratory disorders which have led to innumerable bouts of severe asthma and pneumonia, Mrs. Kehoe's life has been full and happy as she pursued her interests in the arts of painting, sculpture, and music while her husband pursued the sciences of biology and chemistry.

Dr. Kehoe treated his child more as a son than a daughter, teaching her early to love rugged packhorse camping trips in the Rocky Mountains and fly fishing for trout. After she left home, she joined UNESCO and has spent most of her adult life in Europe where she sees her father often.

During World War I, Dr. Kehoe was a member of the Students Army Training Corps while attending medical school and learning to march and perform the manual of arms. About this experience he says: "I have never seen any set of more demoralized people than we were, being neither good

students nor good soldiers. It was a heart-breaking experience."

Dr. Kehoe began his professional life as a pathologist at the Cincinnati General and Jewish hospitals in Cincinnati, but soon switched his interests to Dr. Martin Fisher's Department of Physiology at the University of Cincinnati College of Medicine.

During this period Mr. Tom Midgley, working under the direction of Mr. Charles Kettering of General Motors' fame, had learned how to make and use tetraethyl lead mixed with ethylene dibromide and ethylene dichloride (called Ethyl Fluid) as an anti-knock compound in gasoline for reciprocating engines. Soon, however, a great discovery got him into trouble because this highly toxic mixture killed several people with a new form of acute lead encephalopathy. This problem caused Mr. Kettering to visit his old friend, Dr. Martin Fisher, in quest of a solution. Fisher in turn introduced him to a young \$110-a-month instructor in physiology by the name of Robert A. Kehoe who was working on the mechanism of the denaturation of protein by toxic materials, particularly heavy metals. That day Dr. Kehoe's real life work began.

Working with Mr. Midgley in laboratories in Cincinnati and Dayton, Dr. Kehoe tackled the study of the nature and mechanism of Ethyl Fluid toxicity and the means by which it could be handled safely by all makers and users. Although Ethyl Fluid was taken off the market in late 1924 and early 1925 at the request of the US Public Health Service, many will remember the sign in all Standard Oil gasoline stations which appeared in 1927: "Ethyl Is Back." In this short period of time, Dr. Kehoe had learned that tetraethyl lead, the primary toxic agent in Ethyl Fluid, is readily absorbed through the intact skin, through the respiratory tract, and through the gastrointestinal tract, something of the probable order of magnitude of the toxic and

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† Dr. Ashe died Feb 27, 1966.

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lethal exposure doses for animals and man and from these had formulated a plan by which the material could be safely manufactured, safely mixed with bulk gasoline by trained workmen properly clothed with impervious clothing and airline respirators, and how safely to clean 100,000 to 1,000,000 gallon mixing tanks without risk to the especially trained workmen who did the job. He also set up a medical surveillance program whereby the maintenance of good health could be assured in all who made, mixed, and distributed ethyl gasoline. This program brought him into contact with Dr. George Gehrman, the first full-time medical director of the E. I. DuPont de Nemours and Company, the first commercial maker of Ethyl Fluid. They became fast friends who shared their ever increasing interest in the health of workers in all occupations.

What Dr. Kehoe had done literally was to put what was to become a billion dollar-a-year industry in business. Quite naturally, the newly formed Ethyl Corporation which took over production and distribution from DuPont did not wish to lose the services of this valuable man and tried hard to obtain his full-time services as their full-time medical director, first in Dayton and later in Detroit and New York. Dr. Kehoe said "no." He would continue his work for them and assume the responsibilities of their medical needs only if he could remain in academic medicine in Cincinnati. He thereby turned down the opportunity to become many times a millionaire and it is characteristic of the man that while he never lacked for money and was well paid for his services, he never took any job because of the personal financial gain it might bring to him. This caused him some anguish years later when he learned to his sorrow that not all doctors thought as he did and would often take advantage of him and put into their own pockets monies which should have gone into the laboratory's research and teaching activities. Dr. Kehoe also talked the company into building him a laboratory to his specifications in back of the medical school in which to carry on his work. This first building was jointly financed by the Ethyl Gasoline Corporation, later called the Ethyl Corporation, the DuPont Company, and Frigidaire Corporation.

While the laboratory was being built, Dr. Kehoe found it necessary to learn about the

metabolism of naturally occurring lead in man. This study took him to some very primitive farming villages in Mexico where he studied the lead content of water, soil, plants, and pottery used in cooking and the lead content of the blood, urine, and feces of Mexican peasants. Later he studied the occurrence of lead in the air, soil, water, and plants the world over and no data on the subject compares in accuracy or in volume with that obtained by Dr. Kehoe.

In December of 1930, the new laboratory was dedicated, named the Kettering Laboratory of Applied Physiology in honor of Mr. Charles (Boss) Kettering, given to the University of Cincinnati by the Ethyl Corporation, and placed under the direction of Dr. Kehoe.

As the Ethyl Corporation's business became world-wide, so also did Dr. Kehoe's supervisory responsibilities. For 30 years this man's rules controlled the handling of every ounce of Ethyl Fluid ever made and it may be said with reasonable certainty that nowhere since 1925 has there been a case of illness or death from this compound where Dr. Kehoe's rules were properly followed. The meticulousness of the man is clearly shown in this true story.

During World War II, a 55-gallon drum of pure Ethyl Fluid made several trips back and forth across the United States and finally disappeared. Dr. Kehoe set out to find it. He searched everywhere with no results and finally found himself in the office of one General Grove in Washington who told him he wasn't going to find it; the material was in good hands and was being handled per his instructions. No amount of browbeating by Dr. Kehoe nor appeals to higher headquarters right up to General George C. Marshall's office changed the picture and Dr. Kehoe reluctantly gave up. He didn't know then of the Manhattan Project nor of Oak Ridge, Tenn, where the fluid had been sent.

As the laboratory research and service activities grew and Dr. Kehoe's responsibilities increased, more staff had to be added. Dr. Kehoe and Dan Duvall, an excellent technician and animal caretaker, who constituted the original team were no longer enough. The key personnel were Don Hubbard, an analytical chemist whose job it was to develop new ways to reduce biological specimens including whole animals to quantitatively analyzable solutions without gain or

loss of trace metals; Fred Thamann\* and Jacob Cholak, both analytical chemists who worked out methods for mass analyses of hundreds of specimens with the smallest possible error; three physicians—Willard Machle, Lester Sanders, and Lester Schradin—who looked after the supervision of Dr. Kehoe's medical program in the Ethyl Corporation; Dr. Karl Kitzmiller, a pathologist; Iola Sheppard, personal and financial secretary; and Nell Conway, librarian and editor. None of this group ever had any doubts about who the boss was and he was known to all as Doctor Kehoe, not Bob. No report of work accomplished nor any analytical data ever left the Kettering Laboratory without being critically studied by Dr. Kehoe. As the years rolled rapidly by and the work load of the laboratory increased exponentially, this procedure got Dr. Kehoe into hotter and hotter water with his industrial clients. They wanted reports fast and no amount of prodding would get them off Dr. Kehoe's desk until he was ready. Yet industry knew that nowhere else could it get as reliable work so it fumed and fussed to no avail.

Kehoe had another policy about which he was adamant. While he recognized the need and right of industry to keep certain secrets, when his work for them revealed a serious hazard to employees or users of a product, he felt obligated to publish his knowledge in the medical literature whether or not industry liked it. He had many an argument with corporate legal advisors but nearly always won. If they didn't like his work on his terms, they could go elsewhere for it. Some tried the latter approach with disastrous results because they soon found that research work on matters affecting the health of man emanating from their own laboratories was considered by organized labor and by many courts as biased in the company's favor, whereas that done at the University of Cincinnati's Kettering Laboratory was not, and in some instances Dr. Kehoe had to do the work over for them to prove they had been right in the first place.

The work of the laboratory on lead soon increased to include problems from Willard Storage Battery Company, Winchester Rifle Company, General Motors body shops, lead mines in Colorado, and many paint industries. To these were added toxicologic studies

\* The only major accident in the laboratory's 35 years of existence was the death of Dr. Thamann in 1937 due to accidental massive intoxication by hydrogen sulfide gas.

of refrigerants, at first ammonia and sulfur dioxide and later the freons. Arsenic, mercury, chromium, and finally beryllium and uranium problems followed until by 1950, Dr. Kehoe was the world's foremost authority on many matters of industrial toxicology, yet he never lost his primary interest—lead.

As early as 1942, he became vitally interested in the Industrial Medical Association and made strenuous efforts to up-grade the quality of medicine practiced in and on the periphery of American industry. He served from 1946 to 1957 on the Council on Industrial Health of the American Medical Association and was an advisor to it both before and after his term of office. At a recent 25th anniversary dinner of the Council, Dr. E. S. Jones said of his early experience with Kehoe's Council activities: "When we found ourselves with a sticky problem of policy or procedure, Bob Kehoe would always straighten us out—in about an hour."

This foible of sometimes talking too much when he was sure he knew more about a subject than his colleagues was best shown on one occasion when the laboratory sponsored a symposium on lead. It was to have been a five day affair with many speakers covering many phases of the subject. But what actually happened was that Dr. Kehoe talked most of the time, eight hours a day for five consecutive days about lead. Whether one likes it or not, this is a remarkable feat and all who attended recognized who the ultimate authority was.

Dr. Kehoe is also a member of the Ramazzini Society, an informal body of corporate medical directors who meet for 2½ days once a year to have fun and to let the wind out of the sails of any stuffed shirts in the group. On one very wet occasion (both from rain outside and alcohol inside), some of the men were playing pool at one of Fred Waring's establishments at Shawnee-on-the-Delaware. Kehoe and Jim Sterner of Eastman Kodak were watching from the sidelines and commenting vociferously on what the shooter should have done on each shot. Soon one of the purposes of the Rams asserted itself and these two gentlemen were forced into a game between each other. It soon became apparent that neither had ever played much pool and maybe had never handled a pool cue before. When the suddenly augmented audience got through with

them, the word "pool" disappeared permanently from the vocabulary of each and although they return each year to the Rams' meeting, neither has ever again pontificated or held court.

Bob Kehoe is a warm and generous man with an easy smile. It is very doubtful that he ever fired any employee of his even when it was indicated. He loves a story, provided it is clean, and though he does not use profanity himself, he thoroughly enjoys listening to a good cussing-out done by someone else. He says mountain wranglers are the best. Sometimes he has been too generous in his willingness to accept the view of others and has lost some very superior men from his organization because he felt it wrong to try to impose his will to get them to stay. He has occasionally kept a man to his own detriment because he could always see more good in a professional colleague than he could see faults and he knew full well of his own.

He is an excellent conversationalist because he has, over the years, read widely in the many fields other than his own and he is always keenly and accurately aware of what is going on in the world. But his truly intimate friends are few and carefully selected. They are, like himself, mostly expert trout fishermen and all have his highly developed sense of what is good taste. He lives a good Christian life but makes no public show of religion and is never sanctimonious about what is right and proper.

There are many tales about his sly humor. When a man becomes a legend in his own time, many such stories often lack veracity. One of the best tales involves testimony he was giving in an eastern court regarding an alleged injury from the use of a lactic acid based douche powder. He was an expert witness for the defense and when the plaintiff's attorney was cross-examining him, the lawyer waxed eloquently about the sensitiveness of the human vagina. He turned to Dr. Kehoe and asked if the good doctor didn't agree that the vagina was the most sensitive organ in the human body. Dr. Kehoe's reply: "Did you ever get a squirt of lemon juice in your eye?"

By about 1940, Dr. Kehoe had come to realize that in addition to research and service to industry, the laboratory ought to be training physicians and industrial hygiene engineers for industry. He was timid about starting such a program because there was

none anywhere in this country: he was not sure young men would accept such a program nor that industry would use the trainees, and he knew of the failure of such a program when Dr. Otto Geier, MD, a co-owner of the Cincinnati Milling Machine Company, had tried it and failed miserably shortly after World War I.

The war years of World War II immersed Dr. Kehoe in the problems of industry, government, and all branches of the Armed Forces and somehow, even with a depleted staff, he got the jobs done. Immediately thereafter he was sent with one of the intelligence teams to learn what he could from German experience during the war years. He knew where to look because of prewar contacts through the petroleum and dye industries and brought back large quantities of useful information.

When Dr. Kehoe really gets excited about something, he rocks back and forth in his desk chair in his office or in his rocker at home (he used one long before the late President Kennedy was born). Late in 1946, one of his colleagues came into the office one day and said, "Chief, don't you think it is about time to start a graduate training program for physicians in industrial medicine?" Bob really rocked that afternoon while this young man spelled out his ideas and, grinning from ear to ear, he finally said, "Why not!" During the next year the three-year training program, two at the laboratory and one as a preceptor in industry, was formulated and put into being. The program, as originally designed, today serves as the basis for programs in eight universities leading to the recognized specialty of occupational medicine. Many of his ex-students are now the medical directors of huge corporations and others are filling a vital role in government, both in this country and abroad.

When the Industrial Medical Association showed little interest in furthering education in this field, Dr. Kehoe and Dr. George Gehrman were instrumental in starting the American Academy of Occupational Medicine whose purposes are to upgrade the quality of practice in occupational medicine and to further education and research in this field.

At this same time, 1948-1949, Dr. Kehoe felt that he must double the size of the laboratory to meet the needs of industry. He went to his many sponsors and demanded (not just asked) that they contribute \$640,-

000 for new facilities. When some boards of directors balked, he told them in no uncertain terms that they should be ashamed of themselves. Their very survival required increased research facilities and they'd better ante-up quickly if they wanted his services in the future. They all did. Kehoe's favorite aphorism, "Nothing succeeds like success," was still working.

Increased facilities brought not only increased work to the laboratory but increased academic responsibilities for Dr. Kehoe in the university. He was made professor and chairman of the Department of Preventive Medicine and director of the Institute of Industrial Health (the graduate teaching program) as well as director of the Kettering Laboratory. But his pattern of life changed but little. For 11 months each year he works very hard, but in August each year he forgets it all completely and plays hard, usually somewhere in the back country between New Mexico and Montana with a few intimates and a fly rod.

In addition to Dr. Kehoe's love of the rugged life during playtime, he has two intense loves other than his work which he pursues for the enjoyment they bring him. One is a love of great music, both vocal and instrumental, and his record collection is excellent. The other is the literary society to which he belongs. His critiques and book reviews are always very carefully done and are of high quality. His efforts at creative writing for his own enjoyment and the criticism of his literary society friends gradually became quite excellent. This will come as a bit of a surprise to many professional colleagues who worked with him in the laboratory and whose reports and scientific papers were brutally edited by and in the image of the boss in a manner which the original authors often called "furniture moving." Unfortunately, much of American scientific writing is stilted, stereotyped, devoid of humor, and sorely wanting in easy readability. It very rarely fits the Webster

specific definition of literature: "that part of which is notable for literary form or expression"; what the French call *belles lettres*, beautiful literature.

The post war years brought extension of his work into the fields of industrial hygiene surveys, air pollution studies, studies of the carcinogenicity of petroleum and its by-products, the fluorides, halogenated hydrocarbons of several kinds, the organic solvents, and the pesticides but he always continued probing into lead problems.

The University of Cincinnati has mandatory retirement at age 70. As that age rapidly approached, Dr. Kehoe again felt that the laboratory needed to be enlarged. This time he sought money not only from industry but also from the federal government, the Hamilton County coroner's office for which he had become official toxicologist, and probably also from his own pocket. This final addition was completed on or about his 70th birthday and was dedicated a year later.

Late in his 69th year, the university began to search for an equally competent man to succeed Dr. Kehoe. No more hopeless task has been given to a university faculty committee. By special action of the University Board of Trustees, Dr. Kehoe was asked to stay on one additional year and then a second before his successor was appointed.

Now in retirement and still young and vigorous, his services as a consultant are in demand the world over. At present he is happily engaged in developing research and training facilities at the University of Santiago, Chile, with his long-time friend, J. J. Bloomfield, but his heart is still in the Kettering Laboratory.

The Kettering Laboratory was Dr. Kehoe and Dr. Kehoe was the Kettering Laboratory, the finest industrial medical research and service organization of its kind in the world. It will never be quite the same again but perhaps, though Dr. Kehoe would not agree, the need for his kind of organization is rapidly changing in large part because he did his job so well.