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KARL FRIEDRICH MEYER

1884—1974

A Biographical Memoir by

ALBERT D. SABIN

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Biographical Memoir

KARL FRIEDRICH MEYER

May 19, 1884–April 27, 1974

BY ALBERT D. SABIN*

KF MEYER (henceforth "KF," as he was affectionately called by his colleagues) was an outstanding bacteriologist, experimental pathologist, virologist, epidemiologist, ecologist, brilliant and inspiring teacher, and a prototype of the scientist in the service of society. In the tradition of Pasteur and Koch, his scientific studies invariably involved the acquisition of knowledge for the understanding and solution of important practical problems in the field of human and animal diseases. In 1951, when KF was sixty-seven years young, the American Public Health Association presented him a Lasker Award with the following citation that aptly expressed the esteem of his colleagues and summarized his major contributions to science and public health:

> Brilliant scientist, dynamic teacher, inspired humanitarian. His influence now extends over two generations of students of medicine, biology,

*In writing this biographical memoir, I tried whenever possible to let K. F. Meyer talk for himself in his own colorful, inimitable manner. I am indebted to the director of the Bancroft Library of the University of California, Berkeley, for permission to quote from Dr. Meyer's oral history memoir entitled *Medical Research and Public Health* (Berkeley: University of California, 1976), a transcript of a 1961–1962 unedited tape-recorded oral interview by Edna Tartaul Daniel, Regional Oral History Office, The Bancroft Library. This oral history was also the source of much of my information that is not available elsewhere. Since Dr. Meyer continued to be too busy to read this transcript, I corrected the spelling of some of the names and checked the dates of certain events.

and the allièd health sciences. His research and leadership have benefited all classes of people for four decades. . . .

Among his accomplishments is a major share of responsibility for the control of botulism, and for a classification and international identification center for the clostridia; for our recognition that plague is sylvatic, not merely rat-borne; for understanding of the broad spectrum of brucellosis rather than restricted goat-borne Malta-fever; for the concept of ornithosis rather than psittacosis; for elucidating the role of the arthropod vector in western equine encephalomyelitis; for showing that western ticks are also responsible for relapsing fever; for studying the dinoflagellate causing mussel poisoning; for increasing our knowledge of leptospirosis; for valuable assistance with investigations of Q fever.

No ivory tower recluse, Karl Meyer has responded promptly and gratis to calls for help from physicians, scientists, health officers, farmers, fishermen, canners, the Military and the United States Government.

Inherent in his research is its application. To both he has applied himself with boundless energy and humanitarian generosity, to the great good of mankind.

KF continued his important work and enjoyment of life in his inimitable manner until a brief illness ended his life only twenty-two days before his ninetieth birthday.

FAMILY BACKGROUND AND EARLY LIFE IN SWITZERLAND

KF was born in Basel, Switzerland, the son of Theodor and Sophie (Lichtenhahn) Meyer zum Pfeil van Büren. Both parents were members of old, upper-middle-class Basel families, and KF noted that he traced his family tree back to the fourteenth century. His father was a relatively affluent merchant who imported fine cigars from Cuba and Indonesia for sale throughout Central Europe. His father's hobbies included reading, hunting, fencing, and long walks in the Swiss Alps. His mother taught in elementary school before her marriage, and did much to develop KF's intellectual curiosity in his pre-school years. KF had two sisters, both younger than he. His early years were spent in a large, well-appointed old house overlooking the Rhine River, just off the principal Basel Cathedral Square.

KF attended a private elementary Evangelische Volkschule of the Swiss Zwingli reformed church. After four years of elementary school, he entered Gymnasium where languages (Latin, Greek, classical German, French, and English), history, mathematics, and, to a lesser extent, the sciences were the main components of the curriculum. KF's special interest in the natural sciences led him to spend the last two years in the Realgymnasium where there was greater emphasis on and better teaching of the sciences, especially chemistry, physics, and biology. According to KF's own recollection, he was a pain in the neck to his teachers and a "bête noir," full of mischief and tricks in the classroom right up to the end of his Realgymnasium days. His lifelong impatience with what he regarded as "nonsense," illogical, or factually unproven was already fully developed in his late Gymnasium years, and he apparently never let his teachers get away with what he regarded as questionable statements. Despite this and his propensity for neglecting homework, he graduated second in his Realgymnasium class in 1902 when he was eighteen years old.

KF recalled that physically he was in "fantastic shape" during those years. He fenced, rode horseback, rowed on the Rhine River, and walked a lot. He did not share his father's love for hunting. KF was very popular with his classmates and he put on school plays such as Molière's *Le Malade Imaginaire* and Rostand's *Cyrano de Bergerac.* His extracurricular reading during those days included mostly adventure books, the *Illustrated London Times,* the Swiss daily newspapers, with their "superb editorials," and the German encyclopedia *Conversations Lexicone.*

UNIVERSITY EDUCATION

KF's university education included one-half year (1902) in Basel, two years (1903, 1904) in Zürich, one year (1905) in Munich, and about two and one-half years (1906–1908) of course and thesis work in Bern. At Basel, he was tremendously attracted to zoology, more to the abnormal than to the normal, and was particularly fascinated by the newly emerging protozoology with the recent discoveries of the malarial parasites and the flagellated trypanosomes. KF's recollections of Professor Friedrich Zschokke, the "topnotch" zoology teacher in Switzerland at the time, included all those attributes that later characterized KF's own teaching methods—the "fantastically" prepared and orderly presented lectures followed by dissections and gross and microscopic demonstrations in the laboratory, the Saturday field trips that ended in vivid discussions over steins of beer in an outdoor beer garden. "Bon vivant" KF first joined the Helvetia Fencing Club, where the rapier fencing was too much of a bloody affair for him, and, ultimately, the extensive alcohol consumption also became too much. He then switched to one of the oldest color fraternities, the Zofingia. The independent KF's dislike of being pushed around by the older members of the Zofingia corps, and the heavy beer-drinking and all-night parties, strongly disapproved by his father, led to the decision to move away from Basel.

His move to the University of Zürich was influenced not only by his desire to "get away from the house," but also by the fact that there were many more good departments in Zürich, especially the great departments of comparative anatomy and chemistry. Although his great interest was in zoology, he also worked hard in botany, chemistry, and physics, in which he had to pass examinations for admission to the subsequent studies he wished to pursue. KF recalled that his later career was determined by the recommendation of his professor of comparative anatomy that he continue his studies with Heinrich Zangger, a professor of comparative physiology and pathology at the Veterinary School. KF described Zangger as a "perfectly fabulous individual from the standpoint of what he knew in chemistry and the way he looked at life."* Zangger treated KF as if he were a graduate student and gave him a corner in his laboratory where he could work in his spare time.

KF accepted Zangger's recommendation that he enroll in the Veterinary School where he could learn a great deal about animals. KF also studied human anatomy, physiology, and biochemistry in the medical section of the University. After two years at the University of Zürich, KF passed his examinations with "flying colors." Zangger then steered him to the University of Munich and continued to have a most important influence on KF's career and general outlook on life. KF later said about Zangger: "In my life, he was *the* man." Zangger's concern about human beings and what happened in society, evidenced by his subsequent activities in forensic medicine, in industrial hygiene in the rapidly evolving Swiss chemical industry, and in preventive medicine in industry, led KF to say: "This gave me my social consciousness which I always try to hammer home—social consciousness. You are part of the society and you have to make your contribution."†

KF spent his year in Munich working in the laboratory of Professor Friedrich von Müller in the University's Department of Medicine and in the pathological institute of Hermann Dürck. During the first weeks in Munich, KF again indulged in a great deal of heavy drinking and carousing, often without a stop from Friday night to Monday morning.

**Medical Research and Public Health,* p. 31.

†*Ibid.*, p. 39.

He soon realized that this was no good and changed his entire way of living. Thereafter, he would leave Friday evening for skiing in the mountains and also enjoyed the superb theatres and concerts in Munich. He was more attracted to the theatre than to music and was especially moved by Ibsen's plays portraying "the dark side of Europe at that time."

Upon completion of his studies in Munich, KF, again on Professor Zangger's advice, went to Bern to complete various required courses at the Veterinary School. But he wanted more than stereotyped lecture and laboratory courses. He wanted to do something by himself as he had done during all of his student days. He always had a little corner where he could work. KF asked the great pathologist, Paul Langerhans, who discovered the "islets of Langerhans," for a few feet of space in his laboratory, saying that he had his own microtome, his own paraffin oven, etc., but was turned away. A few days later he watched Langerhans perform an autopsy on a baby with a tumor of the jaw. KF suspected that the tumor was a teratoma and, when Langerhans was not looking, "snatched" a piece of the tumor; within forty-eight hours KF found liver cells in the stained sections of the tumor. Langerhans confirmed KF's diagnosis and was so impressed by the beautifully stained sections that he offered to help him. Langerhans recommended KF to Professor Wilhelm Kolle, a former pupil and assistant of Robert Koch, at the Institute for Infectious Diseases in Bern. It is here that KF did his work on his thesis that dealt with an interesting intestinal, paratuberculosis infection in cattle. The thesis, completed in 1908, was sent for approval to the veterinary faculty in Zürich, where he originally enrolled as a regular student in the Veterinary School. Thus, although the graduate work was done in Bern, KF received his doctorate in veterinary medicine from Zürich in 1909.

During his period in Bern, KF apparently travelled to other centers of learning and accumulated experiences that greatly influenced his subsequent career. In his acceptance of the Water Reed Medal of 1956 (*American Journal of Tropical Medicine and Hygiene,* 6:341, 1957), KF recalled the opportunity he had of studying the illustrated monograph of Battista Grassi showing the complete life cycle of the human malarial parasite in *Anopheles* and of seeing Grassi's original preparations during a holiday visit in Rome. Also impressed on KF's memory were conversations with Dr. George Nuttall, Professor of Biology at Cambridge University in 1906, recalled at the acceptance ceremony:

> Professor Nuttall planted ideas in my mind that were decisive as a basis for understanding many tropical diseases. He made it clear that topography, climate, vegetation, and other environmental factors determine whether an area will be likely to sustain the malarial parasite. When I was learning what was known about the factors that cause trypanosomiasis to flourish—about the tsetse fly, trees, shade, proximity to water and cattle and wild game—Professor Nuttall intimated that animals might well serve as reservoir hosts of the parasite. He foresaw many of the relationships between animal and man bridged by an insect vector. That this interplay was profoundly involved in the development and public health of Africa was amply emphasized. The implications of conversations with this able scientist haunted me during the next fifty years. They haunt me still.

CHOICE OF CAREER

The choice was between going into practice and into an academic career. For KF, veterinary practice had no appeal because it was against his nature to ask a fee for services rendered. On completion of his thesis, Professor Kolle advised KF to embark on an academic career, and while he offered him a laboratory, he told him he could not pay him anything. The first step at that time in an academic career was to become a "privat dozent" at the university. Unfortunately the income for such a post was unpredictable, since it came from the modest fees paid by students who might be attracted to the dozent's lectures. The opportunities for ultimately getting a professorship at one of the five Swiss universities were very slim. So when KF, at age twenty-four, told his father that he had chosen an academic career, he recalls his father telling him: "Do you think I'm going to feed you until you're fifty-six?"* In the end, Professor Kolle offered to find a job for KF, and several weeks later informed him of an opening for a pathologist at a big new institute in South Africa under Arnold Theiler (later Sir Arnold Theiler, the father of Nobel Laureate Max Theiler), a Swiss who wished to have a Swiss for this post. The salary was 600 pounds sterling ($3,000—a lot of money at the time), free round-trip transportation, and a contract for three years. Kolle, who had worked in South Africa with Robert Koch, told KF that scientifically it was a "fantastic" opportunity because (as KF recalled it) "you can look under the microscope at any blood sample and find a new parasite." KF accepted; his father outfitted him for the trip and even arranged for the best British tailor to make his clothing as he passed through London on his way to South Africa. Thus was KF's career launched at twenty-four years of age.

SOUTH AFRICA (1908–1910)

A magnificent new Institute, just outside of Pretoria, had been built for Arnold Theiler because of his important contributions to the understanding and control of livestock diseases in the preceding twenty years, and was opened only a few months before KF's arrival. The Institute had a large operating budget by the standards of the time (about $200,000), and much experimental work was in progress

*Ibid., p. 41.

there on the nature, transmission, and prevention of diseases of cattle and horses that were of great economic importance to South Africa, such as rinderpest, African horse sickness, East Coast fever, red-water (Texas) fever, bovine pleuropneumonia, anthrax, glanders, and other obscure parasitic and bacterial infections.

The official title of KF's new post was pathologist, Transvaal Department of Agriculture, Onderstepoort, Union of South Africa. His duties included making rabies vaccine, doing autopsies on the hundreds of large animals that were used in experiments or were brought to the Institute by farmers, and diagnostic work involving hundreds of blood smears. This routine work, full of challenges to KF's inquisitive and prepared mind, occupied most of his regular workday from 7 a.m. to 5:30 p.m. He then went horseback riding in the hilly country around the Institute, had his dinner at the hostelry where the unmarried Institute staff members took their meals, and then invariably returned to the laboratory to work until midnight on problems he wished to elucidate.

His routine responsibility for the contagious bovine pleuropneumonia vaccine led him to carry out classic studies on the pathologic anatomy of the disease, which were published in 1909. He also discovered a strain of pleuropneumonia organism that produced arthritis in cattle. (About thirty years later I accidentally discovered a mouse pleuropneumonia strain that produced an experimental arthritis in mice similar to human rheumatoid arthritis.)

The challenging, unsolved problems of African East Coast fever, which had been under study at the Institute for many years, and had previously brought both Robert Koch and Wilhelm Kolle (KF's mentor in Bern) to East and South Africa, soon engaged KF's interest. His work resulted in an important elucidation of the life cycle of *Piroplasma (Theileria) parvum,* which was present in large numbers in the erythrocytes of cattle suffering from the disease. The mystery was that the blood of these diseased cattle failed to transmit the disease to susceptible cattle, although it was already established that certain blood-sucking ticks were effective transmitters of the infection. KF soon demonstrated that while as much as one liter of blood was not infectious, suspensions of the spleen and lymph nodes transmitted the disease. The explanation emerged from a study of the life cycle of the parasite carried out by KF and Institute entomologists. In his 1956 Walter Reed Medal acceptance speech (mentioned earlier), KF described these studies as follows:

> A study of the life cycle of the protozoan disclosed that asexual and sexual multiplication, manifestations of which were seen by Koch and described as Koch's granules, takes place in the cytoplasm of the lymphocytes and endothelial cells. This stage terminates in the formation of gametocytes, and it is these that invade the erythrocytes. In its erythrocytic phase in the mammalian host the parasite cannot multiply further. In time it degenerates in the blood and organs or even when transferred to another susceptible bovine host. However, when, through a blood meal, the parasite is taken into the intestinal tract of *Rhipicephalus appendiculatus* or other ticks capable of transmitting the parasite the gametocyte transforms to zygote, ookinete and finally into sporoblasts. The sporoblast, when introduced into a new host with the saliva of the tick, initiates infection.

The relations between Arnold Theiler and KF were difficult from the beginning. KF recalled that Theiler "was a typical Lucerne squarehead, and a Lucerne squarehead cannot get along very well with a Basel squarehead."* KF's work on the transmission of East Coast fever to susceptible cattle by means of lymph node and spleen suspensions first led Theiler to accuse KF of failing to guard against intercurrent infection by ticks. And when KF repeated his work in more cattle during Theiler's absence from the country, and then showed Theiler a short article he prepared for publication,

**Ibid.*, p. 46.

Theiler said: "Have one thing understood; anything which is done in the institute, *I* have done. *I* wrote this paper."* KF said he did not see it that way, and published this work under his own name in 1909 both in the *Zeitschrift für Infektionskrankheiten* and in the *Journal of Comparative Pathology and Therapeutics.* After that encounter, Theiler and KF did not talk to each other and their only contact was by written communications. KF continued to work until close to the end of his contract in 1910, but it is no exaggeration to conclude that KF and Theiler hated each other, each committing unfriendly acts against the other. In later years KF admitted that while "Theiler made a lot of mistakes . . . he helped a lot in elucidating causes for East Coast fever; he developed the dipping procedure for getting rid of the ticks; and some immunization procedures which were pretty good."† Nevertheless, KF recalled that when Sir Arnold Theiler met him nineteen years later at a meeting in Switzerland, he politely and respectfully addressed him as "Herr Kollege," invited him to lunch, and in response to a question on botulism at the meeting Sir Arnold deferred to his "honorable colleague Meyer."‡

When KF decided to leave South Africa in 1910, he returned to Basel with the resolution to "behave himself" and, now that he had saved enough money to be independent for a while, to work in Kolle's laboratory in Bern again. He recalls, however, that when he walked through the main street in Basel, some of his friends said to him "Are *you* back *again*?" and that "this was just like a stilletto."§ He got to feeling that he no longer fit very well in Switzerland. During this feeling

**Ibid.*, p. 50.

†*Ibid.*, p. 53.

‡I must admit to a certain amount of personal feelings as I write these words because I came to know Sir Arnold's son Max and his work on yellow fever quite well in the 1930's and was the first to recommend Max Theiler for a Nobel Prize in 1947, which he finally received in 1951.

§*Ibid.*, p. 60.

of depression he was invited by an ambassador to Austria, whose wife and daughter KF had met and entertained in South Africa, to spend two weeks with them in a castle. KF had a fine time and opportunities for serious discussions with the ambassador who believed that the United States was the country of the future and that KF should go there. But how? The ambassador happened to have an honorary Doctor of Laws from the University of Pennsylvania and eight weeks later informed KF that there was a position for an assistant professor of pathology and bacteriology at the University of Pennsylvania's School of Veterinary Medicine and that they would like to have a European. The salary was only $1,800, but KF accepted.

UNIVERSITY OF PENNSYLVANIA SCHOOL OF VETERINARY MEDICINE (1910–1913)

KF's mentor in Philadelphia was Dr. Richard M. Pearce, professor of pathology at the University of Pennsylvania School of Medicine. He also met other important faculty members who made him feel welcome, and he quickly became a member of the Philadelphia Pathological Society and a participant in the meetings of the Interurban Clinical Club. Despite these auspicious beginnings, KF soon became very unhappy with the poor preparation and background of the students he had to teach. When he became openly critical of his students, the rumor reached him that faculty reaction to his criticism was: "Don't these foreigners make you sick?"* KF determined to make them even sicker and at the next examination flunked 70 percent of the class. The provost of the University told him: "We don't do things like this around here, because we need the tuition fee."† KF's outspoken criticisms also ruffled feathers at the Philadelphia Patho-

**Ibid.*, p. 63.
†*Ibid.*

logical Society. At one of the meetings of the society after a lecture on the mechanism of immunity in streptococcic infections by John Kolmer, professor of immunology, which was loudly applauded by the audience, KF dissected the presentation with a sharp knife. He felt a chill in the audience, which remained perfectly silent after he finished. The chairman of the meeting, Dr. Richard Pearce, who was KF's mentor, on the way out told him: "You know, we don't do things like this.* When KF reacted to this blow by saying he was only doing what should be done at such meetings, Pearce advised him not to talk any more at these meetings until he was asked to talk. Three months later he was asked to talk on some interesting studies he just carried out on sporotrichosis.

KF got a feeling of the basic fairness of his American mentor when Dr. Pearce helped him become a member of the American Association of Pathologists and Bacteriologists only five months after his arrival in the United States and took him to the 1911 national meeting in Chicago to present a paper on the life cycles of blood parasites in South Africa. The appreciation of these studies publicly expressed by Frederick Novy, the great American microbiologist of the University of Michigan, was salve for KF's bruised ego. When Novy and the University of Michigan's distinguished pathologist Alfred S. Warthin then invited him to spend the long Easter weekend with them at Ann Arbor on his way back to Philadelphia, KF felt that he was at last appreciated in the United States, and by men whose scientific work and philosophy he could admire. Despite the Easter holiday, KF and his hosts spent much time in the laboratories, where KF also met Paul de Kruif and Victor Vaughan, the pioneering professor of hygiene. Many years later, KF credited Novy's account of his studies on plague in kindling his own subsequent lifelong

*Ibid., p. 64.

interest in this infection. Many years later, KF remarked: "I must say these three days in Ann Arbor restored my confidence that this is a country where something is going on. This is worth staying around for."* The warm and stimulating experience at Ann Arbor, where, in KF's words, he "was promptly accepted as being somebody," led him later to express his feelings about Philadelphia in the following perceptive words:

> Well, perhaps they recognized the background of my training, but they did not like the way I made use of it. I was too darned critical; I had too sharp a tongue, and I never cloaked anything in a lot of praises when I knew perfectly that the work which was done was a five-cent kind of hash piece. That they didn't like.†

Based on my own familiarity with KF in later years, he did not change, but his colleagues adapted themselves to this aspect of KF's character, because his "darned critical" comments were invariably well founded. Apparently this was also the case in Philadelphia, because he was promoted to full professor in 1911, when he was only twenty-seven years old, and was also appointed director of the Laboratory and Experimental Farm of the Pennsylvania Livestock Sanitary Board—with an increase in salary from $1,800 to $4,000. The diagnostic work and research on animal diseases that KF carried out during the two years at this Laboratory resulted in publications on glanders, biliary fever in dogs, contagious abortion of cattle, paratuberculous enteritis of cattle in America, epizootic abortion in mares, and coccidiosis in chickens. In his review on filterable viruses, he referred to his studies on the possible viral cause of equine encephalitis, work that he brilliantly resumed seventeen years later in California.

**Ibid.*, p. 68.
†*Ibid.*, p. 66.

During the Philadelphia period, KF also met Dr. Theobald Smith, then professor of comparative pathology at Harvard, at a meeting in Boston where both presented papers on *Bacillus abortus* (later called Brucella on KF's initiative), the cause of infectious abortion of cattle. After the meeting Theobald Smith invited him to the laboratory and home to dinner. The whole experience left an indelible impression that KF later described as follows:

> I went to the laboratory and here this gentleman unrolled before me one of the most fantastic stories in science. The philosophies which he expounded later on tremendously influenced my way of thinking. One remark I will not forget: He said, "You know, one must always get these infections either human or animal, into small laboratory animals. Then we can study them, because it's too expensive to study them in larger animals. Besides with this present desire to control, to eradicate, they frequently eradicate a disease before we understand it." Only too true.*

Despite his meetings with leading bacteriologists and pathologists who appreciated his work, KF was basically disappointed in his post at Pennsylvania and even considered returning to Europe. Early in 1913, Dr. Richard Pearce told KF that he did not fit into the set-up in Philadelphia and advised him to go west to California. Dr. Pearce had just come back from Berkeley where he learned that there would soon be an opening in the Department of Pathology at the Medical School and that the University of California had just received a large gift from Mrs. Hooper to establish an Institute for Medical Research that could become the Rockefeller Institute of the West. KF recalls that Simon Flexner told him: "If you go to California, you will disappear in the Pacific Ocean, because the intelligentsia of the United States lives within a hundred miles from New York."† After considerable hag-

**Ibid.*, p. 70.
†*Ibid.*, p. 74.

gling with Dr. Frederick P. Gay, who was the head of the Department of Pathology and Bacteriology at Berkeley, KF accepted an appointment as associate professor of bacteriology and protozoology at a salary of $3,000 per annum, with the understanding that he would be promoted to full professor the following year.

After acceptance of this appointment, KF married Mary Elizabeth Lindsay, whom he met during his popular man-about-town activities in Philadelphia, and went off to Europe for several months before going to California in October.

CALIFORNIA (1913–1974)

It was in California that KF finally, despite many tribulations, was able to fulfill his life's goals and find his gratifications from students who inspired him with their eagerness to learn, from fighting battles that he sometimes lost but more often won, and from a citizenry who appreciated his concern for their welfare and his well-directed studies for the solution of some of their serious problems. California also supplied him ample opportunities for enjoying the many nonprofessional aspects of life that were always also very important to KF.

KF's early years in California were devoted largely to the development of his own distinctive teaching programs; their excellence soon won KF a reputation as an exacting, demanding, unique, but brilliant and enchanting teacher. He soon had 286 students in microbiology with laboratory space for only sixty-five, and he remembered that the Bunsen burner was kept burning from 8 a.m. to 10 p.m. He constantly insisted that things be done right or not at all, and his students never forgot him—and their numbers grew over the years. When Dr. David R. Goddard, Home Secretary of the Academy, wrote me in 1978 about my agreement to write KF's story for the Academy's *Biographical Memoirs,* he did not fail to mention that as an undergraduate student at Berkeley he had "the good fortune in taking a course in animal pathology from Dr. Meyer." Dr. Dorothy M. Horstmann, professor of epidemiology and pediatrics at the Yale University School of Medicine, who took the bacteriology course from Dr. Meyer while she was a second-year medical student in California, wrote me: "The lectures started on Fridays at 1 p.m. and ended anytime between 4 and 6 p.m. But he was always interesting to listen to—and gave scholarly yet colorful lectures. Their main impact for me was due to his tremendous knowledge of pathology and pathogenesis. It was this that stimulated my interest in infectious diseases, and directed my course from then on. I owe Dr. Meyer a great deal!" Dr. Edward B. Shaw, emeritus professor of pediatrics at the University of California, San Francisco, wrote me: "I started to work with him about 1918 and got a great deal of my medical education from him as a preceptor. He was always so generous; he put my name on publications when I was still a medical student. . . . You know well that I could go on and on about all he has meant to me and to many others." One of KF's later students and co-workers on brucellosis, Sanford S. Elberg (subsequently professor of immunology and medical microbiology at the School of Public Health and dean, Graduate Studies Division, University of California at Berkeley), described in vivid language (*American Society of Microbiology News,* 40, September 1974) the unique qualities of KF as a teacher. Elberg said that KF "was a walking encyclopaedia of information about theory and practice of bacteriology in those days and withal a master of showmanship and sense of drama, and a great platform speaker. . . . The material in the course over the weeks gradually began to take shape in student minds as a dynamic entity that seemed to unfold in an orderly way. Occasionally the session ended with a burst of applause and students would flock to the lecture bench to ask him questions and follow him to his tiny office. . . . K. F. Meyer was one of the very greatest teachers, especially for large classes, in the history of the University of California and on that score alone is one of the University's immortals."*

KF's own recollections were that "the relationship with the students was perfectly marvelous, the echo from them was unbelievable; it was perfect."† Julius Schachter (now professor of epidemiology and acting director of the Hooper Foundation) became his last student in 1960, when KF was seventy-six, and then continued as his co-worker for the remaining fourteen years of KF's life. Schachter, who shares the affection and dedication of KF's earlier students, provided an insight on what it was like to work with KF (*Bull. Schweiz. Akad. Med. Wiss.*, 33: 187–99, 1977):

> Meyer was never easy on graduate students, and I suspect that I was fortunate in coming along when he had mellowed. Our modus operandi for differing experimental approaches was simple. Meyer always let me do the experiments my way—as long as I also did them his way. Successful experiments had to be repeated again and again. . . . During the years when I was a student of Meyer's I could receive phone calls at all hours of the night from him informing me that one of my animals looked sick and I better get up to the laboratory and do something about it. . . . Not only would Meyer call the staff at home about a problem, but if you worked at the Hooper Foundation it was impossible to go to a meeting and be out of Karl Meyer's reach. . . . I remember one instance in the early 1960's when I was in New Orleans on the second day of a five-day meeting. I was paged at breakfast to receive a telegram which said: "Had discussions with Albert Sabin yesterday. He had some interesting ideas. Meet him in Cincinnati tomorrow." Of course I went. . . . Meyer was a man of dignity and courtesy. Even when I was a lowly graduate student he always introduced me as his "colleague." . . . All of us have had our lives enriched by his presence. . . . What we regret is that we have no more like him.

Lucille Foster (B.A. in bacteriology, University of Cali-

*Ibid., p. 374–75.
†Ibid., p. 76.

fornia at Berkeley, 1932), who was KF's senior laboratory assistant until his death in 1974, affectionately recalled: "When he was young, we were all scared to death of him. He really yelled. He mellowed considerably as he grew older. . . . He was a very fair boss. He never stayed angry."*

In 1914 George F. Whipple (later Nobel Laureate in medicine) came from Johns Hopkins to become the first director of the George Williams Hooper Foundation for Medical Research with laboratories in San Francisco. On recommendation of Dr. Richard Pearce (KF's critical Philadelphia mentor), Whipple invited KF to join the Hooper Foundation as associate professor of tropical medicine in charge of the section on infectious diseases and immunology. KF accepted and in January 1915 moved from Berkeley to San Francisco and then commuted to Berkeley three or four times a week for teaching. The Hooper Foundation was the research center for the medical school. KF's appointment at the Hooper provided him more time and better facilities for research.

He was public health conscious from the beginning and quickly became involved in San Francisco and California State Health Department activities. All his subsequent studies on typhoid, brucellosis, botulism, plague, ornithosis, and equine and human encephalomyelitis stemmed directly from his involvement with the public health activities in California. KF served as director of the Hooper Foundation for Medical Research for thirty years, from 1924 to 1954, but continued to work for another twenty years.

At the same time he organized the Departments of Bacteriology at the Medical School in San Francisco and in the College of Letters and Science at Berkeley, and was chairman of both from 1924 to 1948. Thereafter until his "retirement"

*Ibid., p. 387.

at age seventy in 1954, he was professor of experimental pathology.

BOTULISM

KF's involvement in research on botulism in 1919 was largely in response to the serious threat to the billion-dollar canning industry in California. This highly fatal disease first aroused special public and professional concern during the eighteenth century in Germany after a number of human outbreaks of so-called blood sausage (Latin *botulus*) poisoning. For a long time, human botulism was believed to be associated with uncooked, inadequately cured, contaminated meats and other foodstuffs containing animal protein. Although eleven fatal cases of typical botulism occurred among twelve persons who ate a wax-bean salad in Germany in 1904, it was an outbreak of botulism in California involving twelve persons who consumed a string-bean salad at a sorority party at Stanford University in November 1913 that focused attention on canned vegetables as a possible source of this neurotoxin. The disease at Stanford was diagnosed as botulism by Dr. Ray Lyman Wilbur, who saw some of the botulism patients in Germany in 1904, even though the preserved string beans in the Stanford sorority salad were known to have been boiled for one hour on three successive days as was then recommended by the U.S. Department of Agriculture. Although it had been established by then that human botulism followed the ingestion of a highly fatal neurotoxin that was formed in food in which *Clostridium botulinum* had multiplied, the conditions that led to the appearance of this neurotoxin in preserved boiled food were still poorly understood. Following the 1913 Stanford outbreak, Dr. Wilbur, president of Stanford University, induced Dr. Ernest Dickson to study this problem. Dr. Dickson soon found that *C. botulinum* spores could not be sterilized by the recommended procedure for home canning. By 1919, commercial food processing had become a big industry in the United States, and especially so in California. During the ten-year period from 1910 to 1919 there were forty-eight botulism outbreaks attributed to home processed food and fourteen to commercially processed food. The number of cases in the United States was never very large (only 957 reported deaths during the entire seventy-one-year period of 1899 to 1969—E. J. Gangarosa et al., *American Journal of Epidemiology,* 93: 93, 1971), but the panic and impact of one small outbreak could be enormous.

It was just such an event in 1919 that forced the California canning industry and the National Canners Association to seek help. Between August and November 1919, there were twenty-eight cases of botulism with seventeen deaths in Ohio, Michigan, and Montana, all of which were traced to the ingestion of olives canned in California. The California canning industry was faced with a possible embargo on their olives. KF, who had no previous experience with botulism but already had a reputation as a bacteriologist concerned with public health, and Dr. Dickson, who had been working on the problem at Stanford University for a number of years, were asked for advice on what to do. KF told the canning industry executives that based on Dickson's work, asparagus, corn, spinach, and string beans—not only olives—were apt to cause trouble. He frankly told them that nobody could tell the industry what to do to avoid trouble on the basis of existing knowledge. He believed that only a comprehensive research program involving studies in the field where the vegetables and fruits are harvested, in the factories where they are processed, and of the special factors in outbreaks of human botulism might provide the knowledge for a truly scientific rather than empirical technology for the canning industry. Such a research program would undoubtedly cost a lot more money than they ever spent before. KF later recalled that if they would have objected to the size of his proposed budget he was prepared to tell them: "No money, no research, no salvation of the canning industry."*

The canning industry was wise enough to settle for new knowledge and provided the money KF requested. A program was then developed for collaborative studies at the Hooper Foundation of the University of California and at Stanford University. Dickson was to continue with the toxin studies, including heat resistance, at Stanford University. KF reserved for himself and associates at the Hooper the epidemiologic investigations, the determination of where the organism was in nature, the studies on the metabolism of the various strains, the heat penetration for various products in the cans, and the like.

KF recalled that this kind of industrial research at a university was regarded by some faculty members as a "prostitution of science." KF could not see why studies on the behavior of a microorganism under artificial conditions in test tubes in the laboratory constituted "appropriate" science, while studies on the behavior of bacteria in cans or in nature, or the acquisition of new knowledge required for the understanding and control of practically important industrial processes, did not constitute a scientific activity that was appropriate for a university. He was deeply hurt by this criticism, especially since Pasteur's contributions to industrial fermentations were generally regarded as great science.

The methodical basic approach to the problem by KF and his co-workers is reflected in the titles of the numerous publications (especially in the *Journal of Infectious Diseases*) that appeared from 1922 to 1924:

1. An experimental study of the methods available for the enrichment, demonstration, and isolation of *B. botulinus*

**Ibid.*, p. 99.

in specimens of soil and its products, in suspected food, and in clinical and in necropsy material.

2. The distribution of the spores of *B. botulinus* in California, in the United States, in the Territory of Alaska, in the Dominion of Canada, in Belgium, Denmark, England, the Netherlands, and Switzerland, and in the Hawaiian Islands and China. It was during the course of these global studies that it became apparent that the dusty, dry soil of California at harvest time forced *B. botulinus* into the resting spore state and thus everything that became contaminated with the dust contained large numbers of spores.

3. Some observations on the pathogenicity of *B. botulinus*.

4. The heat resistance of the spores of *B. botulinus* and allied anaerobes.

5. Toxin production and signs of spoilage in commercially canned vegetables and fruits inoculated with detoxified spores of *B. botulinus*.

6. Effect of glucose on biochemical activities, including growth and toxin production of *B. botulinus*. Studies on metabolism of anaerobic bacteria.

7. Studies on serologic classification of *B. botulinus*.

8. Occurrence of *B. botulinus* in human and animal excreta.

9. Effect of direct sunlight, diffuse daylight, and heat on potency of botulinus toxin in culture media and vegetable products.

10. The epidemiology of botulism.

From these and other fundamental studies in subsequent years, and from the analysis of special processing problems related to specific foods such as spinach, fish, and the like, emerged a body of knowledge that provided a scientific basis for protective measures against botulism. Writing on "The

Rise and Fall of Botulism" in the May 1973 issue of *California Medicine,* KF noted (pp. 63–64):

> Scientifically established sterilization standards replaced former procedures as the result of experiments exposing the spores of 107 different strains of *C. botulinum* (Types A and B) to five different heating temperatures and demonstrating that thermal destruction of the most resistant pathogens required a four-minute exposure at 248°F and 330 minutes at 212°F. The time and temperature essential for the destruction of heat-resistant spores were calculated from the heat-penetration and thermal-time slopes. The [botulism] commission recommended that olives and spinach be processed under pressure in retorts. The regulations merely coped with an emergency—without specifying the type and means of operating of equipment nor insisting on rigid, continuous inspection of the packing and processing procedures. Therefore unsterilized, commercially packed food continued to cause botulism.

KF soon discovered that merely having a body of knowledge for proper regulations was not enough; without continued inspection and control, botulism problems would not be eliminated. Since KF was not one to be satisfied merely with the acquisition of knowledge but was concerned with its proper utilization, he was involved for many years in establishing methods of inspection and control. Botulism did not disappear from the United States, but home processed foods were responsible for most of the outbreaks. During the twenty-year period from 1910 to 1929, commercially processed foods accounted for 32 percent of the 125 outbreaks of known source, but for only 3.3 percent of the 305 outbreaks of known source during the subsequent thirty years (1930–1959). The necessity for ongoing laboratory activities—not only for surveillance but also for studies of emerging new problems—resulted in the establishment of an ongoing Laboratory for Research in the Canning Industries at the University of California, of which KF was the director from 1926 to 1930. KF remained a consultant to the canning industry for the remainder of his life.

BRUCELLOSIS

Brucellosis is now recognized as a worldwide infection and disease of many different species of animals that is transmissible to human beings, in whom, depending on the species and strain of the microorganism, the infection is either inapparent, mild and unrecognized, or severe. In 1887 David Bruce isolated a bacterium he called *Micrococcus melitensis* from the spleen of a patient who died of Malta Fever, a disease that affected many British military and naval personnel on Malta. Shortly thereafter it was also recognized in North Africa, South Africa, and the United States. In 1905 Zammit of the British Mediterranean Fever Commission, searching for the cause of this human disease, accidentally found this bacterium in goat milk. When consumption of raw goat's milk was stopped, the disease quickly declined in the British personnel—but not in the native population that continued to drink raw goat's milk. In 1897 Bang isolated an organism, *Bacillus abortus bovinus,* from cattle with infectious, epizootic abortion, an organism whose relationship to *M. melitensis* in goats was discovered only later.

It was in this context that KF's interest in this zoonosis was first aroused in South Africa in 1908 and 1909, when he isolated *M. melitensis* from a human illness. When KF moved to Philadelphia he was soon involved in studies on contagious abortion in cattle (first publication in 1912), which at that time was an important problem in the dairy industry, and in etiologic studies on epizootic abortion of mares (publication in 1913). In 1911, KF first met Theobald Smith at a meeting in Boston, where both presented papers on *Bacillus abortus bovinus.* It was after this meeting that Theobald Smith showed KF how he accidentally (in guinea pigs used to test for tubercle bacilli in milk) discovered that *B. abortus* was eliminated in cow's milk and suggested to KF the possibility of a relationship between the "*Micrococcus melitensis*" of goats and *B. abor-*

tus of cattle. Soon after KF's arrival in California and his early association with the San Francisco Milk Commission, he learned of Dr. E. C. Fleischner's finding (to use KF's own words) "this abortion organism in the certified, high-class milk of San Francisco, and we then became interested to find out if it was transmissible to man."* After several years (1915–1918) of hard work, they failed to demonstrate any illness attributable to this organism among infants and children who drank such contaminated milk. This was the beginning of the ultimate realization that the bovine abortion organism was not very virulent for human beings and especially for infants and children. At about this time, Alice Evans showed a close biologic relationship between the melitensis organisms of goats and the abortion organisms of cattle (first published in 1918). The studies by KF and his student E. B. Shaw (later professor of pediatrics at the University of California in San Francisco) on the morphologic, cultural, and biochemical characteristics of *B. abortus* and *B. melitensis* led them to establish the new genus of *Brucella* for these and related organisms (first publication in 1920).

After his all-absorbing involvement in studies on botulism, KF left the field of brucellosis in 1920 for about seven years. His later activities were very largely concerned with the practical problems of eradication of *B. abortus* from cattle in the United States, including vaccination of calves with the live, attenuated strain 19 of *B. abortus* isolated in the United States by Buck in 1923. In 1951 the first of a series of studies on immunization against brucella infection by Elberg, KF, and associates was published—studies that were continued in considerable depth by Sanford Elberg and his associates in subsequent years.

**Ibid.*, p. 127.

WESTERN EQUINE ENCEPHALITIS

KF's work on Western equine encephalitis was a real trailblazer not only because of the isolation of a totally new kind of virus, but because the methods used soon led to the discovery of similar viruses as the causative agents of certain types of human encephalitis in different parts of the world as part of a complex ecological cycle involving mosquito transmission from inapparently infected hosts. KF recalled his involvement in the following words:

> In July of 1930 a large number of horses were reported dying in the San Joaquin Valley from botulism. Well, the moment that word is mentioned I have to investigate, and I had my theoretical reservations because in summertime you couldn't have botulism, there would not be an adequate amount of moisture in the feed to permit [C.] botulinus to grow and produce its toxin.*

Dr. J. C. Geiger, who was sent by KF to a ranch where the disease was occurring, reported that the horses were partly paralyzed, and when they were still able to get around, they walked in circles. The two horse heads Geiger brought back were highly contaminated and were suitable only for microscopic examination, which revealed lesions that convinced KF that they died of encephalitis and not of botulism. KF went out into the field, carried out autopsies by careful aseptic methods, and inoculated brain suspensions in horses and rabbits, and nothing happened. KF later recalled:

> By that time, it was the latter part of October and the number of cases became less and less, and I was afraid this would begin to disappear with no solution. . . . My failure to isolate this agent [the hypothetical virus] out of the brain was perhaps attributable to the fact that I used only the brains of dead horses. . . . I said we must get a horse which has the first signs of

**Ibid.*, p. 213.

it. [Such a horse was located, but they telephoned KF that the farmer said] "I won't sell the horse, and if you ever do anything to the horse, I shoot you." . . . I went down and I had a $20 bill in my pocket. This was a depression year and I was sure they would be glad to get rid of the horse for $20. [KF was warned not to talk to the farmer, and he said:] "I'm not going to talk to him. I'm going to talk to his wife." I said, "Look here, this horse is going to die anyhow, and when it's dead you haven't anything. It just goes to the rendering plant and you get a couple of dollars. On the other hand, you see, you could contribute to the knowledge of what this is and perhaps to its prevention." "Well," she said, "My husband is just irate about this." I said, "Yes, I can readily understand, but look here, suppose I trust you, and I give you $20 and the next morning you will find in the backyard the horse without a head?" "How are you going to do this?" "Look here, about nine o'clock at night when it is dark, I'll be over here behind some bushes . . . [where] I can see the window of your house. When your husband is sound asleep you lift up the shade." . . . I had a syringe with strychnine, I had a good sharp knife, and I sat around there and smoked a pipe, and sure enough about twenty minutes past nine the shade went up. Within about two minutes I was over the fence and in another two minutes the strychnine was under the skin of the horse and in another two or three minutes, the horse went down, and in another five minutes the head was off.

It was a heavy head, but I threw it over the fence and wrapped it up in burlap and we vanished as fast as we could to the most remote corner on the other side of the town of Merced where Haring [C. M. Haring, Chief, Division of Veterinary Science, College of Agriculture, University of California at Berkeley] had located an old abandoned chicken coop, and there with the help of flashlights I did a careful dissection of the brain and wrapped it up so it was not contaminated, etc. This was all done and we were about ready to go home by midnight. We drove back, and I tell you, naturally, I was fantastically excited. . . .

We got back to the lab about six o'clock in the morning. I immediately got busy and made a suspension of the brain material. I was over in Berkeley about 9:30 and by ten o'clock I had made two inoculations. I inoculated the suspension directly into the eye of a horse and another part of the suspension I put into the brain of the horse. . . . The rest of the brain was prepared by Miss [Beatrice] Howitt, who was with me and who was very, very good, and we had agreed that instead of merely using rabbits we would use mice, we would use guinea pigs, and we would even use monkeys and we would put the material directly into the brain. This gave us the virus.*

Such a "microbe hunter" was Karl F. Meyer! The description of the disease and the isolation and identification of this virus were reported (without the dramatic episodes described above) by Meyer, Haring, and Howitt in the August 28, 1931 issue of *Science*. Using similar procedures, the virus of human St. Louis encephalitis was isolated in 1933 by Ralph Muckenfuss et al. in monkeys and by Leslie Webster and G. L. Fite in mice; and the virus of human Japanese B encephalitis was isolated in 1934 in monkeys and in 1935 in mice. When KF studied the epidemiology of the equine encephalitis in California in 1930, he was struck by a concurrent increase in cases of "poliomyelitis" from rural areas that were admitted to the Kern County Hospital, and he noted that clinically these cases had the manifestations of encephalitis rather than poliomyelitis. Studies in subsequent years proved that the virus of Western equine encephalitis caused encephalitis in human beings. When KF mapped the horse encephalitis cases in 1930, he "began to see one crazy thing, that most of the cases were in an irrigated area. The moment you went in the foothills, no cases,"† and this led him to suspect mosquito transmission. When an epidemic of human encephalitis hit St. Louis in 1933, KF went there, among other things, to study the distribution of the cases and found that all the cases lived in the outlying suburban areas where "the mosquitoes were perfectly scandalous."‡ After a few additional personal studies with this virus, KF became deeply involved in wide-ranging studies on psittacosis and sylvatic plague, and left the job of working out the intricate ecological cycle and proof of

***Ibid.*, pp. 215–17.
†*Ibid.*, p. 218.
‡*Ibid.*, p. 219.

mosquito transmission of the Western equine encephalitis and St. Louis encephalitis viruses to Dr. William McD. Hammon and entomologist Dr. William C. Reeves, whom he brought to the Hooper Foundation laboratories. KF later had this to say about their work:

> These two [each of whom in turn later became Dean of the School of Public Health of the University of California at Berkeley] have filled out the complete story and have shown that the infection is doubtless originally picked up by one species of mosquitoes, namely, culex tarsalis, early in spring and probably from migratory birds. This culex [Culex] tarsalis prefers to feed on birds and frequently brings it to human habitations by feeding on chickens. . . . Then they showed beautifully that in the chickens for four or five days this virus circulates in the blood in sufficient concentration to give the mosquito a chance to get infected; therefore, gradually during the summer there is an enormous build-up of infected mosquitoes and then [when the numbers are large enough] it naturally slops over to human beings and to horses. The cycle is, therefore a bird-mosquito cycle which has operated probably in this state [California] since time immemorial, but it never came to light until man began to irrigate and created vegetation and humidity adequate to build up an enormous mosquito population. Man, together with his work-horse, had the misfortune of being susceptible. The bird population is susceptible, yes, but they never get sick. Their infection is not apparent.*

PSITTACOSIS—ORNITHOSIS
LYMPHOGRANULOMA VENEREUM

The cause of psittacosis, a human infectious disease resulting from contact with parrots, was isolated from parrots and patients in 1930 and erroneously identified as a virus for many years. It was later shown to be a very small, obligately parasitic, intracellular bacterium. The information at the time led to the assumption that diseased parrots were the only source of the infectious agent. KF's work with this new animal source of human disease began with the death of three el-

*Ibid., p. 221.

derly ladies within a period of five to ten days in December 1930, after they had all been at a home in Grass Valley, California. It was an involvement that continued for more than forty years. Since the diagnosis was "typhoid pneumonia," an older name for psittacosis, KF asked the state health officer to look for a sick or dead parrot. The health officer telephoned back that evening to say that there was a healthy parakeet hanging in a cage over the table where the dead ladies had gathered for coffee, that another parakeet in that cage had died and was buried, and that the husband in this household was now in the hospital with the same illness. KF asked for blood and sputum from the patient, for the live parakeet, and if possible the carcass of the dead one. The specimens arrived at ten o'clock that night, the sputum and blood were promptly inoculated into animals, and the psittacosis agents were isolated. KF then showed that rice birds (finches) that were put into a clean jar with the live parakeet died of psittacosis, thus, "proving conclusively what had not been known until that time, that parakeets were really shedding the virus in the droppings."*

But KF was not a bench-bound microbiologist. He wanted to know where these parakeets came from. He learned from the hospitalized husband, just before he died of psittacosis, that he had bought the pair of parakeets from an itinerant peddler called Meyer. The highway patrol located this man and brought him to KF for an interview. The peddler at first said that the parakeets came from Japan, but when more human cases began to be reported from other parts of the state where the same peddler had sold parakeets, KF grilled him again and discovered that he got them from Los Angeles where thousands of parakeets were being bred by poor people who were trying to make a living during the depression.

**Ibid.*, p. 150.

Just about that time, cases of psittacosis began to be reported from Los Angeles. KF pursued the problem to Los Angeles and within about a month he had evidence that practically every one of the aviaries contained locally bred psittacosis-infected parakeets, that other birds in the aviaries acquired the infection, and that more and more exposed people were getting the disease. His request that the health department put an embargo on the export of these birds was resisted for a long time. The birds continued to be exported to other states, and soon there were many psittacosis cases that were traced to the birds imported from California. Among these cases happened to be Senator Borah's wife. The senator "raised cain" with the Public Health Service and convinced President Hoover to put an interstate embargo on the export of parakeets.

KF's concern for the people who were losing money as a result of this embargo led him to offer to establish certified psittacosis-free aviaries in California by testing 10 to 20 percent of the breeding stock that would be sacrificed for isolation of the psittacosis agent by mouse inoculation. The Public Health Service agreed, and soon this became the main activity in this field at the Hooper Foundation. By 1934, 25,000 to 30,000 parakeets had been tested, and about 185 aviaries were found to be free of psittacosis. In the 1930's the Hooper Foundation laboratory was the only place in the United States where psittacosis work was being done on a large scale. Amidst all of this activity the first scientific publication by KF and his devoted co-worker, Bernice Eddie, appeared in 1933, reporting on spontaneous psittacosis infections of the canary and butterfly finch. KF became severely ill with psittacosis, and he wrote it up as an infection in a laboratory worker in a publication that appeared in 1936.

It became apparent in the subsequent work that the national reservoir of psittacosis was not just in parrots, and in sick parrots at that, as was assumed when KF began his field and laboratory investigations. The discovery of the extensive reservoir in extrapsittacine birds brought forth the term "ornithosis" to describe the psittacosis infections in these birds. Published reports of KF and Eddie implicated pigeons (1942), chickens (1942), ducks (1952), turkeys (1953), and pheasants (1956). As a rule the infections in these birds were inapparent, although occasional epizootics by virulent strains brought heavy direct and indirect losses to poultry raising and processing industries. The inapparent infections in these birds, however, constituted reservoirs of occasional serious, even fatal, occupational hazards for human beings. The turkey ornithosis agent was considerably more virulent for human beings, and turkey ranching and processing procedures presented special problems for investigation by KF and his co-workers.

Other investigators found infectious agents in a great variety of mammals (e.g., sheep, goat, cattle, cat, mouse, hamster, guinea pig) that are biologically and antigenically related to the agents of psittacosis and ornithosis, but these turned out to be of very low virulence and almost never seen in human infections. However, the strictly human agent that is responsible for the veneral disease called lymphogranuloma venereum was shown in 1938 to be another member of this group of obligately parasitic, intracellular, very small bacteria. Subsequently J. W. Moulder and KF created the genus *Bedsonia*. The name honored S. P. Bedson, who with J. O. W. Bland first described the developmental cycle of the psittacosis "virus" in 1932 and subsequently made important fundamental contributions to our understanding of the nature of this agent. In subsequent years, the genus *Chlamydia* replaced *Bedsonia* to accommodate the biologically related agents of human trachoma and inclusion conjunctivitis, and in 1970 KF published a paper on antigens in *Chlamydia psit-*

taci. From 1966 to 1975, there appeared a whole series of publications by Julius Schachter (currently acting director of the Hooper Foundation), KF et al., elucidating the nature of the agent of lymphogranuloma venereum and other *Chlamydia* organisms and their role in human disease.

James H. Steele, in his biographical notes on K. F. Meyer (checked by KF just before his death) published in the supplement to the May 1974 issue of the *Journal of Infectious Diseases*, noted (p. 57):

> With the advent of broad-spectrum antibiotics (i.e., tetracycline), psittacosis was no longer the dangerous disease it had been, although it was a serious occupational disease among turkey producers and processors from 1948 to 1961. It could, however, be controlled by tetracyclines in turkey feed, and the disease in humans could be abated by treatment with tetracyclines. K. F. was to have an important role in all of these developments. Today public health and animal health officials ask what happened to psittacosis and ornithosis; all one can say is that these diseases are no longer the problems they were 20 years ago, thanks to the work of K. F., his colleagues, and other investigators influenced by him, who worked out the epidemiology of the disease and developed control procedures.

PLAGUE

In a chapter on plague KF said: "For centuries the Black Death found a highly susceptible population living in poverty, congestion and ignorance in Europe and took an appalling toll, justifying all of its somber aliases and the awe in which it has always been held."*

A Swiss, Alexander Yersin, discovered the plague bacillus in 1894. The role of rats and rat fleas was already known at the beginning of the twentieth century. At the end of the nineteenth century and during the early years of the twentieth, extensive epidemics were occurring in India, and

***Bacterial and Mycotic Infections of Man*, ed. R. J. Dubos and J. G. Hirsch, 4th ed. (Philadelphia: J. B. Lippincott, 1965), p. 664.

plague was being disseminated by rat-infested ships to seaports around the world, including San Francisco. Evidence that rodents, other than rats, were infected was found in Mongolia (1895), India (1898), South Africa (1906–1908), and California (1908). When KF arrived in California in 1913, he found Dr. George McCoy in the U.S. Public Health Service laboratory in San Francisco "engaged in methodically unravelling the complex interplay between wild rodents and commensal rats." In 1915 the Public Health Service announced that plague had been eradicated from California.

In 1919 KF was asked to advise on an outbreak of pneumonic plague (which can spread from man to man when a rodent–flea-transmitted human infection involves the lungs) affecting thirteen persons, including two physicians, that suddenly appeared in Oakland, California. An epidemiologic study traced these cases to a primary case of bubonic plague in a person who had been hunting in the Berkeley hills. The question that led KF to begin laboratory work on plague was one of pure curiosity—why were there so many pneumonic cases? Was it possible that there may be special pneumotropic strains of the plague bacillus? The work that he began in 1919 continued for the remainder of his life. In the special May 1974 issue of the *Journal of Infectious Diseases*, published in honor of his ninetieth birthday and devoted entirely to plague, KF was the first author or coauthor of ten of the twelve original communications.

KF did not publish anything on plague from 1919 to 1925—that was the period of intensive work on botulism. Another outbreak of thirty-one cases of pneumonic plague in the Mexican quarter of Los Angeles in 1924 got KF to work on plague again. He went to Los Angeles, accompanied the survey crews in their search for possible sources of infection, and was there when the first infected rat was found under a staircase leading up to a grocery store in the Mexican quarter.

He attended autopsies on the fatal cases, obtained a lot of cultures, and became intensely interested "in how this thing established itself in Los Angeles." His studies showed that the rat infection could not have come from the port. However, rats in the areas around Los Angeles were found to have ground squirrel fleas on them, and KF visualized an infection chain from ground squirrels to rats to humans, and from humans with lung involvement to other humans. These observations became the basis for the extensive subsequent field and laboratory work on wild rodents and their fleas that revealed a reservoir of plague bacillus infection in squirrels and chipmunks—the beginning of his more extensive studies on "sylvatic plague" in California. After a while, KF realized that the best place to look for plague bacilli was not in the organs of wild rodents, but in the fleas that were combed from them. The survey crews then found sylvatic plague in the states of Oregon, Washington, Montana, and Nevada. KF recalled: "Without asking for it, we realized that plague suddenly was all over the landscape,"* although only rare sporadic cases were occurring in human beings.

About 1940, when many military installations were being established in California, there was concern about plague and KF was again asked for advice. After his advice on how to get rid of the ground squirrels and their fleas proved successful, KF made the important discovery that plague infection was widespread in all sorts of field mice and their fleas. He later recalled:

> Well, this threw an entirely different light on the whole question, namely, that you were dealing here with a very mobile, migratory species of animal which easily could slop it over miles. Furthermore, the average resistance of these field voles was very high. It didn't kill, as it did in rats, 80 to 90 percent of them. Sometimes it only killed 20 percent. It looked to

*_Medical Research and Public Health_, p. 181.

me, and I hypothecated, that the persistence of plague in certain areas is entirely conditioned by the amount of resistance in the wild rodents. If they are resistant they can maintain infected fleas, because if all the rodents would die naturally with it, infection would get wiped out, as happened with rats. But with these wild rodents there is always a possibility that an infected flea will get a meal and during the wintertime maintain the infection and then start it all up in the springtime, which was always the case here.*

He was then helped by Air Force crews that gathered material for him from widespread areas, and "practically every day, there would be an icebox coming in with bottles full of fleas," all of which were ground up and inoculated into guinea pigs. At that time about 50 percent of the Hooper Foundation funds were spent on the laboratory work with plague. Most of the work was done by graduate students working for their Ph.D.'s. Miss Bernice Eddie worked along with them, often till midnight and on Saturdays and Sundays because of her great interest in the work. All of this plague work was done in a special isolation building that was built after 1936 with funds KF obtained from the Rosenberg Foundation, because there were fears about work with the "Black Death" bacteria on the San Francisco campus. It was in this building that KF had a big room with a "mouse village" where he scattered infected fleas in two sections—in one the mice were receiving sulfanilamide in their diet and in the other, only the regular diet. All mice on the regular diet died, while all on the sulfanilamide diet remained well.

During World War II it was evident that American military personnel would have to operate in areas of the world where plague was a potential threat. Accordingly, KF and his associates began to work on immunity and effective vaccination against plague. Except for sulfadiazine, the highly effec-

*_Ibid._, p. 183.

tive therapeutic antibiotics (streptomycin, tetracycline, chloramphenicol) did not become available till later. Special aspects of the metabolism, physiology, and antigens of the plague bacillus had to be studied. Animal models for reliable potency testing and serologic tests that would measure the immune response in humans had to be developed. While all this was going on, there was a request to produce twenty-six million doses of the best vaccine that could be prepared for use in the military forces—and mass production of the vaccine could be carried out only in the special plague isolation building of the Hooper Foundation. A formalin-killed vaccine, which had to be given in multiple doses every six months, was developed and produced. For whatever reasons (because multiple control procedures were used), KF and McCoy reported in 1964 that no cases of plague occurred among the U.S. Armed Forces, although they operated in areas in which small numbers of cases were occurring in the native population and also in some members of the British Armed Forces. KF and his associates continued work on immunization against plague for many years, as the reports in the May 1974 issue of the *Journal of Infectious Diseases* testify. While there is no place for immunization of the general population in the worldwide vigilance against plague, a practically useful, effective method of immunization could be a valuable component in the total strategy for the protection of persons who may be at special risk during limited periods of time.

K. F. MEYER, THE PERSON

To have known KF was an unforgettable, enriching experience. Julius Schachter (now acting director of the Hooper Foundation) said in a recent article:*

**Bulletin der Schweizerischen Akademie der Medizinischen Wissenschaften*, 33 (1977): 187.

The enthusiasm and application that Meyer showed in his professional career were also expressed in a great appetite for life's pleasures. In the spring he seemed to get reports straight from the farms on the progress of the first asparagus of the season. He would later discuss with great gusto the quality of the year's crop. Similar enthusiasm was shown for a recently discovered restaurant, wildflower display, or a new film that did a better job of showing the texture of redwood bark or the colors of the wild flowers.

I personally recall with great pleasure the many good times we had together. I remember especially the gourmet dinners we had at his "Family Club" in San Francisco, and the time he gave me a package of luscious asparagus and special sauce to take home to Cincinnati. I shall also long remember the experiences we shared in a night on the town in Istanbul (escorted by a Turkish police officer) during the 1954 International Congress of Tropical Medicine. J. B. de C. M. Saunders and Edward B. Shaw, colleagues and friends over many decades, concluded their March 1976 University of California "In Memoriam" as follows:

Science and friends alike will miss his rugged personality, his directness, his genius, his bonhomie, his love of company and conversation, and his graciousness. He was an accomplished photographer, fascinated by radio in its early days, loved good conversation, good company, and good wine. Those who knew him at close hand rejoiced in his friendship. His lifelong devoted support was a priceless boon to those who had worked with him—the "hand on the shoulder" for many years.

Karl Meyer married Mary Elizabeth Lindsay at Philadelphia in 1913 and to this union was born his only daughter, Charlotte (Mrs. Bartley P. Cardon). The first Mrs. Meyer died [in 1958] following a prolonged illness in which her husband gave her every care and attention. In 1960, he married Marion Lewis, a happy and blissful union of which "God hath no better praise."

KF's marriage to Marion Lewis—by all accounts a delightful person—brought him great happiness during the last fourteen years of his life. She wrote me: "The last fourteen years of his life were, indeed, the happiest of all of mine. He was a warm, passionate, affectionate man; perhaps one could simply say we were two fortunate people who were blessed with the privilege of sharing in a perfect union. Humbly, I am glad it was me!"

KF's deep concern for the course of human events in the world scene is reflected in the quotation with which he concluded his "Acceptance of the Walter Reed Medal" in 1956 (*American Journal of Tropical Medicine and Hygiene,* 6:341, 1957). The quotation was from comments made by Dr. Hans Zinsser in 1935 at the Second International Congress for Microbiology in London:

> And may some political Leeuwenhoek discover a microscope by which he can see and define the little animalculae of enmity and hatred and savagery, so that at last, in International Congresses assembled, wise men may sit in peaceful assembly planning research into the virulence of human stupidity and consider measures of active immunization, chlorination and delousing for international politics as we do this for infectious disease.

HONORS AND DISTINCTIONS

DEGREES

A.B., University of Zurich, 1905
D.V.M., University of Zurich, 1909
Ph.D., University of Zurich, 1924

HONORARY DEGREES

M.D., College of Medical Evangelists, Los Angeles, 1936
Dr. Med., h.c., University of Zurich, 1937
LL.D., University of Southern California, 1946
D.V.M., h.c., University of Zurich, 1949
Dr. Med., h.c., University of Basel, 1952
D.V.M., h.c., Tierärztliche Hochschule, Hanover, 1953
LL.D., h.c., University of California, 1958
D. Sc., University of Ohio, 1958
D. Sc., University of Pennsylvania, 1959

PROFESSIONAL APPOINTMENTS

Pathologist, Transvaal Department of Agriculture, Onderstepoort, Union of South Africa, 1908–1910
Assistant Professor of Pathology and Bacteriology, School of Veterinary Medicine, University of Pennsylvania, 1910–1911
Professor of Pathology and Bacteriology, School of Veterinary Medicine, University of Pennsylvania, 1911–1913
Director, Laboratory and Experimental Farm, Pennsylvania Livestock Sanitary Board, Philadelphia, 1911–1913

University of California:
- Associate Professor of Bacteriology and Protozoology, 1913–1914
- Professor of Bacteriology and Protozoology, 1914–1915
- Associate Professor of Tropical Medicine, George Williams Hooper Foundation for Medical Research, 1915–1924
- Acting Director, George Williams Hooper Foundation for Medical Research, 1921–1924
- Director, George Williams Hooper Foundation for Medical Research, 1924–1954
- Professor of Bacteriology, 1924–1948
- Director, Laboratory for Research in the Canning Industries, 1926–1930

Director, Public Health Curricula, 1936–1939
Professor of Experimental Pathology, 1948–1954
Director Emeritus, George Williams Hooper Foundation for Medical Research, 1954–1974
Professor Emeritus of Experimental Pathology, 1954–1974

CONSULTANCIES

Consultant in Bacteriology, Board of Public Health, State of California
General Consultant, Board of Public Health, State of California, 1948–1974
Consultant on Public Health, Southern Pacific Railway, 1920–1974
Chief Consultant, California State Department of Public Health, 1927–1947
Consultant in Bacteriology, Department of Health, City and County of San Francisco, 1935–1945
Consultant to the Board of Health, Chicago, 1939–1950
Consultant on Epidemic Diseases, Secretary of War, 1942–1945, 1948
Consultant to Department of Clinical Laboratories, Mount Zion Hospital, San Francisco
Consultant on Tropical Medicine, Secretary of War, 1942
Consulting Bacteriologist, Langley Porter Clinic, San Francisco
Consultant, Office of The Surgeon General, Medical Research and Development Board (appointed 1951–1974)
Member, National Advisory Health Council, 1940–1950
Member, Study Section on Microbiology and Immunology, Grants Division, United States Public Health Service
Scientific Advisory Board of Consultants to the Armed Forces Institute of Pathology, 1952–1974
Consultant to the Communicable Disease Center, United States Public Health Service, Atlanta, Georgia, 1949–1974
Senior Civilian Consultant on Clinical Pathology (appointed by The Surgeon General, 1953–1974)

COMMITTEES, BOARDS, COMMISSIONS

National Research Council, various committees
Committee on Sylvatic Plague, American Public Health Association

World's Fair Advisory Commission, 1939
Commission on Virus Research, National Foundation for Infantile Paralysis, 1938–1948
Commission on Epidemics and Public Health, National Foundation for Infantile Paralysis, 1938–1948
National Advisory Health Council, National Institutes of Health, United States Public Health Service, 1941–1945; 1946–1974
Commission on Tropical Diseases, 1942–1945
Respiratory Disease Advisory Council, California Board of Public Health, 1943
Army Epidemiological Board, 1946–1948
Commission on Immunization, Committee on Plague, Armed Forces Epidemiological Board, 1949–1974
Board of Trustees, Langley Porter Clinic, 1945–1974
Committee on Medical Research and Therapy, American Trudeau Society, Medical Section of the National Tuberculosis Association, 1953–1954
Committee on Social Research, National Tuberculosis Association, 1952–1974
Expert Advisory Panel on Plague, World Health Organization, 1949–1974
Expert Advisory Panel on Zoonoses, World Health Organization, 1952–1974
Temporary Advisor, Technical Discussion Group, World Health Organization, 1954–1974
Inter-American Society of Microbiology Committee, Society of American Bacteriologists, 1952–1974
Advisory Committee, Armed Forces Medical Library, 1952–1974
Medical Advisory Committee, Research Foundation
Committee on Army Medical Library, National Research Council, 1952–1974
Chairman, Standing Committee on Public Health and Medical Science, 9th Pacific Science Congress, 1957; 10th Pacific Science Congress, 1961

MEMBERSHIPS

Society of American Bacteriologists (Council; Vice President, 1934; President, 1935)

American Public Health Association, Western Branch (Council; President, 1942)
American Association of Immunologists, (Council; President, 1940)
American Society of Tropical Medicine (Charter Member, 1918; Vice President, 1937)
Northern California Public Health Association (2nd Vice President, 1930)
American Academy of Tropical Medicine (Charter Member; Council, 1945–1948)
American Association of Medical Milk Commissioners (President, 1929)
American Association of Pathologists and Bacteriologists, 1911–1974
American Veterinary Medical Association, 1911–1974
Pathological Society of Philadelphia, 1911–1974
Society for Experimental Biology and Medicine, 1915–1974
American Society for Experimental Pathology
American Therapeutic Society, 1924–1926
Société Helvétique des Sciences Naturelles, 1924–1974
American Epidemiological Society, 1936–1974
Asociacion Fronteriza Mexico Estadounidense de Salubridad Publica (Charter Member)
Inter-American Society for Microbiology
National Society for Medical Research
California Academy of Medicine
Institute of Food Technologists
California Academy of Sciences
New York Academy of Sciences, 1939–1974
National Academy of Sciences, 1940–1974
American Academy of Arts and Sciences
American Philatelic Society
Sigma Xi
Delta Omega
Phi Sigma
Alpha Omega Alpha

HONORARY MEMBERSHIPS

Los Angeles Surgical Society, 1922
National Association of Sanitarians, Inc., 1939–1974

Sigma Kappa Theta, 1940–1974
Swiss Academy of Medical Sciences
Alumni Association, College of Medical Evangelists, Los Angeles
San Francisco County Medical Society, 1951–1974
American Trudeau Society, Medical Section, National Tuberculosis Association, 1953–1974
Harvey Society, 1939–1974
Institute of American Poultry Industries
International Epidemiological Association
American Society for Microbiology
Infectious Diseases Society

FELLOWSHIPS

American Association for the Advancement of Science, 1920–1974
American Academy of Arts and Sciences, 1935–1974
American Public Health Association, 1935–1974
National Academy of Sciences, 1940–1974
Associate Fellow, Academy of Pediatrics, 1941–1974
New York Academy of Sciences, 1941–1974

HONORARY FELLOWSHIPS

American Board of Veterinary Public Health, 1953 (Awarded at the XV International Veterinary Congress, Stockholm, Sweden)

AWARDS AND HONORS

Sedgwick Memorial Medal, 1946
James D. Bruce Medal (Preventive Medicine), 1949
Officier, l'Ordre de la Santé Publique, 1946
U. S. Certificate of Merit (Conduct in Aid of the War Effort, World War II), 1948
Certificate of Appreciation, Bureau of Medicine and Surgery, United States Navy
Tribute, National Canners' Association (Prevention of botulism and development of canning techniques), 1939
Annual Prize, Outdoor Life (Conservation of natural resources), 1931
Honors, American Academy of Tuberculosis Physicians (for promoting scientific medicine and public health), 1950

Lasker Award, Albert and Mary Lasker Foundation at the meeting of the American Public Health Association, 1951

Humanitarian Award, Variety Clubs International, 1953

Borden Award, Association of American Medical Colleges, 1954

Walter Reed Medal, American Society for Tropical Medicine and Hygiene, 1956

Howard L. Ricketts Award, University of Chicago, 1960

Forty-Niners Service Award for the outstanding services to the Canning and Allied Industry, 1961

Jessie Stevenson Kovalenko Medal, National Academy of Sciences (for outstanding contributions to Medical Science as an investigator, teacher, and administrator over a period of half a century), 1961

Award of the "Animal Care Panel," 1961

XII International Veterinary Congress Prize, American Veterinary Medical Association, 1964

The 1964 Special Award, "The Goldheaded Cane," known as "The Karl F. Meyer Award," presented by the Conference of Public Health Veterinarians, Atlanta, 1964

The 1970 Bristol Award for Distinguished Achievement in Infectious Diseases, Infectious Diseases Society of America, 1970

Certificate of Recognition, American Public Health Association, 1972

Certificate of Appreciation for Patriotic Civilian Service, in recognition of years of devoted service as a consultant to the staff of the Surgeon General, Department of the Army, Washington, D.C., 1973

Certificate of Commendation in recognition of services as President of the American Association of Immunologists from 1941 to 1942, 1973

Selected as one of the subjects in a biographical film series "Leaders in American Medicine" made for the Medical Audiovisual Center, National Library of Medicine, Atlanta, Georgia, 1973. The film has been deposited as audiovisual history and will be available as an educational medium

Canners' League Hall of Fame Document, by the Canners' League of California, Sacramento, 1974

SELECTED BIBLIOGRAPHY*

1908

Über die durch säurefeste Bakterien hervorgerufene diffuse Hypertrophie der Darmschleimhaut des Rindes. (Enteritis hypertrophica bovis specifica.) Arb. Inst. Erforschung Infektionskrankheiten Bern Laborator. Schweizer Serum-und Impfinstitutes, 2: 47–153 + 3 plts.

1909

Notes on the pathological anatomy of pleuro-pneumonia contagiosa bovum. In: *Transvaal Department of Agriculture. The Veterinary Bacteriological Laboratories,* pp. 135–64 + 7 plts. Pretoria: Government Printing and Stationery Office.

Zur Übertragung von afrikanischem Küstenfieber auf gesunde Tiere durch intraperitoneale Verimpfung von Milzen und Milzstücken kranker Tiere. Z. Infektionskrankheiten, 6 (5): 374–79.

Preliminary note on the transmission of East Coast fever to cattle by intraperitoneal inoculation of the spleen or portions of the spleen of a sick animal. J. Comp. Pathol. Ther., 22 (3): 213–17.

1911

Beiträge zur Genese und Bedeutung der Kochschen Plasmakugeln in der Pathogenese des afrikanischen Küstenfiebers. Zentralbl. Bakteriol., Abt. I., Orig., 57 (5): 415–32 + 3 plts.

1913

The conjunctival reaction for glanders. (Ophthalmic test.) J. Infect. Dis., 12 (2): 170–90; Am. Vet. Rev., 43: 233–51.

The specific paratuberculous enteritis of cattle in America. J. Med. Res., 29 (2) [n.s., 24 (2)]: 147–89.

With F. Boerner. Studies on the etiology of epizootic abortion in mares. J. Med. Res., 29 (2) [n.s., 24 (2)]: 325–66.

*A complete bibliography of the works of Karl F. Meyer is available from the Archives of the National Academy of Sciences.

1914

Zur chronischen, paratuberkulösen Darmentzundung des Rindes. Schweizer Arch. Tierheilkd., 56 (8/9): 393–403.

Filterable viruses. Am. Vet. Rev., 46 (2): 132–44; 46 (3): 264–80.

1915

The relation of animal to human sporotrichosis: Studies on American sporotrichosis. III. J. Am. Med. Assoc., 65 (7): 579–85.

Epizootic lymphangitis and sporotrichosis: Studies on American sporotrichosis. II. Am. J. Trop. Dis. Prev. Med., 3 (3): 144–63.

The etiology of "symptomatic anthrax" in swine: "Specific gasphlegmon of hogs." J. Infect. Dis., 17 (3): 458–96.

With J. A. Aird. Various sporotricha differentiated by the fermentation of carbohydrates. Studies on American sporotrichosis. I. J. Infect. Dis., 16 (3): 399–409.

1916

With S. H. Hurwitz. Studies on the blood proteins. I. The serum globulins in bacterial infection and immunity. J. Exp. Med., 24 (5): 515–46.

Notes on the occurrence of equine sporotrichosis in Montana and the "blastomycotic" form of *Sporotrichum schencki-beurmanni.* Proc. Soc. Exp. Biol. Med., 14: 23–24.

With J. Traum and C. L. Roadhouse. The *Bacillus enteritidis* as the cause of infectious diarrhea in calves. J. Am. Vet. Med. Assoc., 2 (1): 17–35.

1917

With E. C. Fleischner. Observations on the presence of the *Bacillus abortus bovinus* in certified milk. Preliminary notes. Am. J. Dis. Child., 14: 157–73.

The intracutaneous 'typhoidin' reaction. III. The relation of cutaneous hypersensitiveness to experimental immunity and infection. J. Infect. Dis., 20 (4): 424–41.

1918

With E. C. Fleischner. The bearing of cutaneous hypersensitiveness on the pathogenicity of the *Bacillus abortus bovinus.* Am. J. Dis. Child., 16: 268–73.

With S. H. Hurwitz and L. Taussig. Studies on the blood proteins. III. Albumin-globulin ratio in antitoxic immunity. J. Infect. Dis., 22 (1): 1–27.

1919

With E. C. Fleischner and E. B. Shaw. A résumé of some experimental studies on cutaneous hypersensitiveness. Am. J. Dis. Child., 18: 577–90.

With E. C. Fleischner and E. B. Shaw. The pathogenicity of *Bacterium melitensis* for guinea pigs. Proc. Soc. Exp. Biol. Med., 16: 152–56.

With L. E. McRoberts, J. E. Stockel, H. E. Brown, and J. Wollenberg. A review of our knowledge concerning the etiology of influenza: With notes on the bacterial flora of respiratory cultures of influenza patients in San Francisco, and the value of prophylactic vaccination with *B. influenzae* vaccine. Calif. State J. Med., 17: 216–48.

1920

With M. L. Feusier. Principles in serologic grouping of *B. abortus* and *B. melitensis:* Correlation between absorption and agglutination tests. Studies on the genus Brucella nov. gen. II. J. Infect. Dis., 27 (3): 185–206.

With E. C. Fleischner. Preliminary observations on the pathogenieity for monkeys of the *Bacillus abortus bovinus.* Trans. Am. Pediatr. Soc., 32: 141–56.

With N. M. Neilson. Irregular typhoid strains and the infections caused by them. J. Infect. Dis., 27 (1): 46–71.

With E. B. Shaw. A comparison of the morphologic, cultural and biochemical characteristics of *B. abortus* and *B. melitensis:* Studies of the genus Brucella nov. gen. I. J. Infect. Dis., 27 (3): 173–84.

1921

With C. R. Christiansen and N. M. Neilson. Do "carrier" strains differ from strains isolated from ordinary typhoid cases? Experimental typhoid-paratyphoid carriers. III. J. Infect. Dis., 28 (4): 394–407.

With E. C. Fleischner, M. Vecki, and E. B. Shaw. The pathogenicity of *B. abortus* and *B. melitensis* for monkeys: Studies on the genus Brucella nov. gen. III. J. Infect. Dis., 29 (6): 663–98.

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Some suggestions concerning the bacteriological diagnosis of human botulism. Public Health Rpt., 36 (23): 1313–17.

With N. M. Neilson and M. L. Feusier. A comparative study of the infections produced by intravenous injections of typhoid, paratyphoid A and B bacilli in normal and immunized rabbits: Experimental typhoid-paratyphoid carriers. IV. J. Infect. Dis., 28 (4): 408–55.

The bacteriostatic and germicidal properties of bile: Experimental typhoid-paratyphoid carriers. VII. J. Infect. Dis., 28 (4): 542–87.

1922

With G. E. Coleman. Some observations on the pathogenicity of *B. botulinus*. X. J. Infect. Dis., 31 (6): 622–29.

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With J. R. Esty. The heat resistance of the spores of *B. botulinus* and allied anaerobes. XI. J. Infect. Dis., 31:650–63.

With E. B. Shaw and E. C. Fleischner. The pathogenicity of *B. melitensis* and *B. abortus* for guinea-pigs. Studies of the genus Brucella nov. gen. IV. J. Infect. Dis., 31 (2):159–97.

1923

With P. Schoenholz. Studies on serologic classification of *B. botulinus*. 1. Preparation of antiserum. J. Infect. Dis., 32 (6):417–20.

With P. Schoenholz and J. R. Esty. Toxin production and signs of spoilage in commercially canned vegetables and fruits inoculated with detoxified spores of *B. botulinus*. XII. J. Infect. Dis., 33 (4):289–327.

1924

With C. C. Dozier and E. Wagner. Effect of glucose on biochemical activities, including growth and toxin production of *B. botulinus*. Studies on metabolism of anaerobic bacteria. II. J. Infect. Dis., 34 (1):85–102.

With E. J. Easton. Occurrence of *Bacillus botulinus* in human and animal excreta. XXI. J. Infect. Dis., 35 (2):207–12.

With P. Schoenholz. Effect of direct sunlight, diffuse daylight and heat on potency of botulinus toxin in culture mediums and vegetable products. XXIV. J. Infect. Dis., 35 (4):361–89.

1925

With P. Schoenholz. Studies on the serologic classification of *B. botulinus*. II. Agglutination. J. Immunol., 10 (1):1–53.

1926

With A. Batchelder. Local immunization of guinea pigs to cutaneous infection with a pasturella isolated from wild rats. Proc. Soc. Exp. Biol. Med., 23 (8):730–34.

Selective mediums in the diagnosis of rodent plague. Plague studies 1. J. Infect. Dis. 39 (5):370–85.

A disease in wild rats caused by *Pasteurella muricida*, n. sp. Plague studies 2. J. Infect. Dis., 39 (5):386–412.

With E. W. Sommer and H. Sommer. The purification of botulinum toxin. J. Infect. Dis., 39 (5):345–50.

1928

With J. C. Geiger. Experimental food poisoning in white mice with heat stabile paratyphoid poisons. Proc. Soc. Exp. Biol. Med., 26 (2):91–93.

With J. B. Gunnison. Susceptibility of *Macacus rhesus* monkeys to botulinum toxin type B, C and D. Proc. Soc. Exp. Biol. Med., 26 (2):89–90.

With J. B. Gunnison. *Cl. botulinum* type D sp. n. Proc. Soc. Exp. Biol. Med., 26 (2):88–89.

With H. Sommer and P. Schoenholz. Mussel poisoning. J. Prev. Med., 2 (5):365–94.

1929

With H. L. Averill. Cutaneous immunization against *B. aertrycke* in the guinea-pig J. Infect. Dis., 44 (6):495–502.

Further studies on the pathogenicity of *Br. abortus* and *Br. melitensis* for monkeys. Proc. Soc. Exp. Biol. Med., 27 (3):222–24.

With J. B. Gunnison. European strains of *Cl. botulinum*. XXXVI. J. Infect. Dis., 45 (2):96–105.

South African cultures of *Clostridium botulinum* and *parabotulinum*. XXXVII: With a description of *Cl. botulinum* type D, n. sp. J. Infect. Dis., 45 (2):106–18.

1930

With J. B. Gunnison. Susceptibility of monkeys, goats and small animals to oral administration of botulinum toxin, types B, C and D. J. Infect. Dis., 46 (4):335–40.

With B. Howitt. The convalescent serum therapy in poliomyelitis. Calif. State Dep. Public Health, Wkly. Bull., 9 (22):85–86.

With C. E. Zobell. The metabolism of the Brucella group in synthetic media. Science, 72 (1859):176.

Metabolism studies on the Brucella group. II. The fermentation of monosaccharides. Proc. Soc. Exp. Biol. Med., 28 (2):160–62.

1931

With C. M. Haring and B. Howitt. The etiology of epizootic encephalomyelitis of horses in the San Joaquin Valley, 1930. Science, 74 (1913):227–28.

1932

With R. A. Stewart. Isolation of *Coccidioides immitis* (Stiles) from the soil. Proc. Soc. Exp. Biol. Med., 29 (8):937–38.

With C. E. Zobell. Metabolism studies on the Brucella group. V. The production of hydrogen sulphide. J. Infect. Dis., 51:91–98.

Metabolism studies on the Brucella group. VI. Nitrate and nitrite reduction. J. Infect. Dis., 51:99–108.

1933

With B. Eddie. Spontaneous psittacosis infections of the canary and butterfly finch. Proc. Soc. Exp. Biol. Med., 30 (4):481–82.

Latent psittacosis infections in mice. Proc. Soc. Exp. Biol. Med., 30 (4):483–84.

Latent psittacosis infections in shell parakeets. Proc. Soc. Exp. Biol. Med., 30 (4):484–88.

1934

With B. F. Howitt. Tests for cross-immunity between the virus of Borna disease and that of equine encephalomyelitis. J. Infect. Dis., 54:364–67.

With O. Larsell and C. M. Haring. Histological changes in the central nervous system following equine encephalomyelitis. Am. J. Pathol., 10 (3):361–74.

Virus diseases of animals transmissible to man. Ann. Intern. Med., 8 (5):552–69.

The common cold. Calif. West. Med., 41 (6):361–65.

With B. Eddie. Psittacosis in the native Australian budgerigars. Proc. Soc. Exp. Biol. Med., 31 (8):917–20.

Latent psittacosis and Salmonella psittacosis infection in South American parrotlets and conures. Science, 79 (2059):546-48.

With F. Wood, C. M. Haring, and B. Howitt. Susceptibility of non-immune, hyperimmunized horses and goats to Eastern, Western and Argentine virus of equine encephalomyelitis. Proc. Soc. Exp. Biol. Med., 32 (1):56–58.

1935

With B. Eddie. The problem of caprine brucella infections in the United States. J. Am. Vet. Med. Assoc., 86 (3):286–303.

With B. Eddie and L. Foster. Cytology of psittacosis virus in the sparrow (Zonotrichia). Proc. Soc. Exp. Biol. Med., 32 (9): 1656–58.

With C. M. Wheeler and W. B. Herms. A new tick vector of relapsing fever in California. Proc. Soc. Exp. Biol. Med., 32 (8):1290–92.

1936

With J. B. Gunnison and J. R. Cummings. *Clostridium botulinum* type E. Proc. Soc. Exp. Biol. Med., 35 (2):278–80.

Latent infections. J. Bacteriol., 31 (2):109–35.

The therapeutic use of convalescent serum in poliomyelitis. Calif. West. Med., 44 (4):254.

1937

With A. S. Lazarus and B. Eddie. Propagation of variola virus in the developing egg. Proc. Soc. Exp. Biol. Med., 36 (1):7–8.

Ultrafiltration of psittacosis virus. Proc. Soc. Exp. Biol. Med., 36 (4):437–38.

With C. L. Connor, F. S. Smyth, and B. Eddie. Chronic relapsing latent meningeal plague. Arch. Intern. Med., 59 (6):967–80.

With H. Sommer, and the assistance of R. Stohler, N. Sharma, K. Jenkins, H. Mueller, W. F. Whedon, and R. J. Silverberg. Paralytic shell-fish poisoning. Arch. Pathol., 24 (5):560–98.

1938

With B. Eddie. Persistence of sylvatic plague. Proc. Soc. Exp. Biol. Med., 38 (3):333–34.

With B. Eddie and B. Anderson-Stewart. Canine, murine and human leptospirosis in California. Proc. Soc. Exp. Biol. Med., 38 (1):17–19.

1939

With S. S. Elberg. The nutritional requirements of *Clostridium parabotulinum*, A. J. Bacteriol., 37 (4):429–45.

The extracellular proteolytic system of *Clostridium parabotulinum*. J. Bacteriol., 37 (5):541–65.

With J. C. Geiger, A. B. Crowley, and B. U. Eddie. Administrative problems in connection with psittacosis and the importation of Australian parrots. J. Am. Med. Assoc., 113 (16):1479–81.

With A. S. Lazarus. The virus of psittacosis. I. Propagation and developmental cycle in the egg membrane, purification and concentration. J. Bacteriol., 38 (2):121–51.

The virus of psittacosis. II. Centrifugation, filtration and measurement of particle size. J. Bacteriol., 38 (2):153–69.

The virus of psittacosis. III. Serological investigations. J. Bacteriol., 38 (2):171–98.

With B. Eddie. The value of the complement fixation test in the diagnosis of psittacosis. J. Infect. Dis., 65 (3):225–33.

Psittacosis in importations of psittacine birds from the South American and Australian continent. J. Infect. Dis., 65 (3):234–41.

With B. Eddie and H. Yanamura. Complement-fixation test with tissue-culture antigens as aid in recognizing latent avian psittacosis (ornithosis). Proc. Soc. Exp. Biol. Med., 41 (1):173–76.

With B. Stewart-Anderson and B. Eddie. Epidemiology of leptospirosis. Am. J. Public Health, 29 (4):347–53.

Canine leptospirosis in the United States. J. Am. Vet. Med. Assoc., 95 (753):710–29.

1940

The host-parasite relationship in the heterogeneous infection chains. Harvey Lect., 35:91–134.

With J. G. Molner. Jaundice in Detroit. Am. J. Public Health, 30 (5):509–15.

1941

With B. Eddie. Laboratory infections due to Brucella. J. Infect. Dis., 68 (1):24–32.

With H. Y. Yanamura. Studies on the virus of psittacosis cultivated in vitro. J. Infect. Dis., 68 (1):1–15.

1942

The known and the unknown in plague. Am. J. Trop. Med., 22 (1):9–36.

The ecology of plague. Medicine, 21 (2):143–74.

The ecology of psittacosis and ornithosis. Medicine, 21 (2):175–206.

With B. Eddie. Spontaneous ornithosis (psittacosis) in chickens the cause of a human infection. Proc. Soc. Exp. Biol. Med., 49 (4):522–25.

With B. Eddie and H. Y. Yanamura. Ornithosis (psittacosis) in pigeons and its relation to human pneumonitis. Proc. Soc. Exp. Biol. Med., 49 (4):609–15.

Active immunization to the *Microbacterium multiforme psittacosis* in parrakeets and ricebirds. J. Immunol., 44 (3): 211–17.

With H. Y. Yanamura. Active immunity to the *Microbacterium multiforme psittacosis* in the mouse. J. Immunol., 44 (3):195–209.

1943

With E. Jawetz. Avirulent strains of *Pasteurella pestis*. J. Infect. Dis., 73:124–43.

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