

## TELFORD H. WORK—A TRIBUTE<sup>1,2</sup>

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**ABSTRACT.** The major contributions of Telford H. Work to the field of arbovirology and epidemiology of arthropod-transmitted diseases are detailed. The human aspects of his life are mentioned in this memorial address.

Those of you who knew Telford Hindley Work, M.D., D.T.M. & H., M.P.H., will know that I am, as Howard Cosell would have said, "Telling it like it is." Those of you who did not have the opportunity to meet Tel will simply have to take it on faith that I am giving a fair account of his career and of his many strengths and few frailties.

A second generation Californian, Tel was born July 11, 1921, in Selma, the "raisin capital of the world," in the San Joaquin Valley of California. He attended Los Angeles City primary and secondary schools, in Pacific Palisades and at University High School near the then newly established University of California at Los Angeles, respectively. He was always busy with school and amateur studies of biology but found time for long-distance running, winning a state championship. Growing up in what was at that time the natural beauty of peripheral Los Angeles, his love of the biological sciences led to entry at Stanford University, where he majored in biological sciences, beginning in 1938. While there, he published his first scientific paper, "The nest life of the turkey vulture" (Work and Wool 1942).

This constant exposure to nature resulted in continuing field studies and interest in endangered species of California birds, particularly the California condor (*Gymnogyps californianus*), for which he had a warm spot in his heart to the end of his remarkable life (Fig. 1). His films of that period and his publication on the life history of these now endangered birds are still unique. Throughout his career he applied these field techniques to problems intrinsic to the study of arbovirus ecology, including studies of St. Louis encephalitis and Murray Valley encephalitis viruses in wild birds.

After moving to Stanford University Medical School, and by studying the year around, he obtained an M.D. degree in 1945, immediately going on active duty in the U.S. Navy and spending his first months training in surgery and management of war-related psychiatric disorders (Fig. 2). His first assignment was aboard the *U.S. Monongahela*, an oil tanker, which took him to the Persian Gulf, Sri Lanka (Fig. 3), and Japan, through the Suez Canal to the east coast of New York, and from Venezuela to Cuba.

Released from service in 1948, Tel dynamically pursued his interests in tropical medicine and exotic diseases. His concept of the population as the patient was expressed in his desire to become involved in epidemiologic studies, at which he was later to excel. I like to think that Tel viewed epidemiology in much the same way as the French poet Andre Breton defined surrealism: "The juxtaposition of the familiar with the fantastic."

After a pivotal meeting with Dr. Hugh Smith of the Rockefeller Foundation, Tel's instincts were fortified and he enrolled in the London School of Hygiene and Tropical Medicine, earning a Doctorate in Tropical Medicine and Hygiene in 1949 but taking 15 days to follow and film the spring roundup of reindeer by Finnish Lapps (Fig. 4).

Tel then spent two years with Sir Philip Manson-Bahr in Fiji, studying clinical, laboratory, and field investigations of the treatment, epidemiology, and control of filariasis (Fig. 5) and, as he put it, "to learn to think like a mosquito." This work made it obvious to him that he would need additional training, and he applied for and was awarded a Rockefeller Foundation Fellowship, receiving a Master of Public Health degree at Johns Hopkins University School of Hygiene and Public Health in 1952.

Five months after being appointed to the staff of the Rockefeller Foundation arbovirus research program he was assigned to work with Richard Moreland Taylor at the Naval Medical Research Unit 3 in Cairo, Egypt (Fig. 6). He was involved in the isolation of West Nile virus from birds in the Nile delta (Work et al. 1953) and

<sup>1</sup> Seventeenth Annual AMCA Memorial Lecture delivered at the 62nd Annual Meeting of the American Mosquito Control Association, Norfolk, Virginia, March 25, 1996.

<sup>2</sup> Acknowledgment is made to the Lowndes Engineering Company for their participation in sponsoring the 1996 Memorial Lecture.



Fig. 1. Telford Work (on the right) and A. J. Wool with condors, 1940.



Fig. 2. Telford Work as a Medical Officer, U.S. Navy, 1943.

the isolation of Sindbis virus from *Culex univittatus* mosquitoes (Taylor et al. 1955b), and helped formulate the role of wild birds in the ecology and distribution of West Nile virus (Work et al. 1955, Taylor et al. 1956). By that time Davis (1932) and Bates and Roca-Garcia (1945, 1946) had provided the first evidence for a relationship between temperature and vector



Fig. 3. The back of this photo is inscribed "13 May 1947. This is a live cobra, defanged and depoisoned. Borrowed from a Colombo snake charmer for this picture."



Fig. 4. Telford Work (on the right) with Aslak, a reindeer herder at camp in Lapland, Finland, summer 1949.

competence and Hurlbut was undertaking experimental infections of mosquitoes and other arthropods (Hurlbut and Thomas 1969). Eventually, these works led to the concept of infection rates (Chamberlain et al. 1954a, 1954b; Chamberlain and Sudia 1955; Chiang and Reeves 1962). At the same time, the memorable, cigar-smoking Harry Hoogstraal was cataloging a plethora of ticks, from which, among others, Quarantil and Chenuda viruses were isolated (Taylor et al. 1966, Hoogstraal 1988).

In light of the disease focus of the Egyptian studies, the isolation of Sindbis virus might have been considered a throwaway, mere icing on the cake; however, Tel considered nothing extrane-

ous. He filed specimens and bits and pieces of information: virus strain numbers, sera from camels, lists of N.I.H. *ad hoc* subcommittee members from decades ago, annual reports of Ministries of Health—anything and everything. He tossed nothing, either physically or mentally, as anyone who waded through his library can attest. He was a meticulous cataloguer of what to some of us may seem trivial, but he could dredge up, years later, a germane pair of serum samples, a fact, an observation, a name, or a scientific article. Since working for Tel I have never thrown away anything; this has not been a mistake. When Tel put two and two together, most of the time he arrived at four, unless he felt





Fig. 5. Telford Work enjoying himself, as usual, and entertaining some Fiji Islanders, 1950.

that these were extremely large values of two, in which event he might imperiously state that in this particular instance the sum is five, and that was supposed to be that.

Emerson spoke of "life's compensations"; in essence that if each of us is shorthanded in one department, we have other areas in which to make contributions. Tel's persistence, his "big picture" view, and his unwillingness to publish before every last piece of information was in hand and repeated certainly were annoying characteristics to others but I believe they were touchstones of his life and of his career. The 76 publications listed in his curriculum vitae included the usual descriptive ones a person in science adds to the scientific record. Included, however, were some exceptionally insightful and penetrating papers comprising overviews supported by details rather than just the details themselves.

He obtained passports at the last minute, was usually last on board a plane, lost manuscripts (in the days when manuscripts were not on disks), called staff meetings for 5:00 p.m., invited people to his home without first notifying the cook, and sent people into the field to gain experience, as he had done. In 1967 he thought I should have a try at fieldwork and sent me to the village of Pilottown, Louisiana, to help Rex

Lord collect birds. I stayed there for two weeks, living on a houseboat in the Mississippi River delta 60 miles south of New Orleans, poaching fish and crabs to survive. Needless to say, that is not what I had in mind, but Tel, as always, thought otherwise. One result of that study was the isolation of two strains of South American variety EEE virus from birds flying north from their wintering grounds in Latin America (Calisher et al. 1971).

Isaiah Berlin suggested that "greatness is the ability to transform paradox into platitude." Tel had the opposite ability. I do not mean this as denigration; what to many are accepted facts, even gospel, were to Tel still unproven. He accumulated piles of data, not doing anything with them for years, feeling that something was missing, that the paper was not yet ripe, the thought not yet complete, the chain missing a link.

If luck is that which occurs to one passively, that is one thing. If luck is an advantage taken, conferred upon an individual by probability, that is surely another. Having searched for overwintering and interepidemic mechanisms of West Nile virus, work involving argasid ticks, pigeon houses, and cattle egret rookeries in Egypt, having spent 1954 searching for enzootic yellow fever virus activity in Sudan (Taylor et al. 1955a), which served as schooling in field investigations



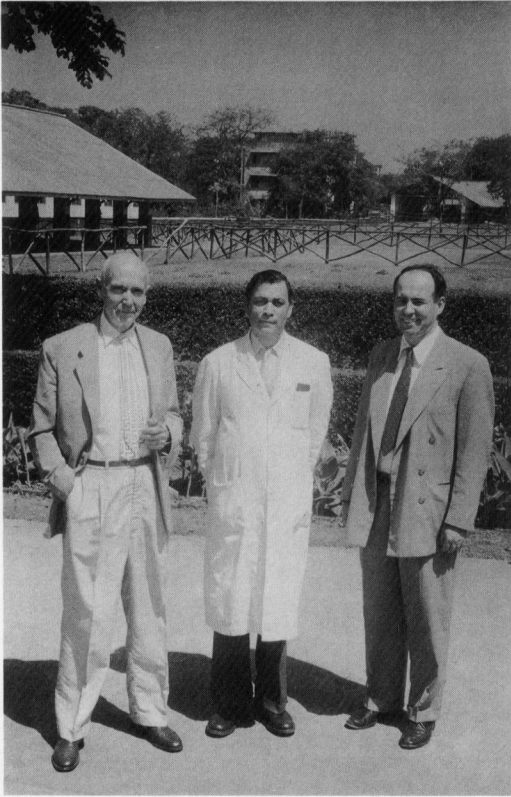


Fig. 6. Telford Work (right), W. Sumars (center), and Richard M. Taylor (left) at the Naval Medical Research Unit 3 in Cairo, Egypt.

of primates, the background was laid for a great stroke of luck in India.

Transferred to the Rockefeller Foundation's Virus Research Institute in Poona (now Pune) as a junior staff member, by an odd series of circumstances he became its Director within a year, the beneficiary of a Rockefeller Foundation commitment to the newly independent nation of India (Fig. 7). The Poona laboratories developed C6/36 cells, investigated a New Delhi epidemic of hepatitis, now believed to have been caused by hepatitis E virus, studied Jamshedpour fever, the first recognized outbreak of what is now known as Reyes syndrome, discovered the presence of Japanese encephalitis in south India (Work and Shah 1956), elucidated the geographic interface between Japanese encephalitis and West Nile viruses (Work 1971), and then discovered Kyasanur Forest disease (KFD) virus.

On March 27, 1957, a virus was isolated from a black-faced langur (*Presbytis entellus*) monkey, which had been brought moribund to the laboratories from a forest in Mysore District,



Fig. 7. Telford Work with Lady Mountbatten when she visited the Poona laboratories, 1955. Apparently, Jawaharlal Nehru, India's Prime Minister, had planned to visit the laboratories but was unable to do so and sent Lady Mountbatten in his place. Harold Trapido is seen on the far right.

southern India. Initially it was speculated that yellow fever virus had at last been isolated in Asia. Tel showed otherwise, identifying the virus as a new one, KFD virus, and isolating it from *Haemaphysalis intermedia* ticks (Work and Trapido 1957) and, with his collaborators in the New York laboratories, showing that it was related to Russian spring–summer encephalitis, Central European encephalitis, Powassan, and other viruses of the tick-borne encephalitis complex of flaviviruses. They also showed that protection against KFD virus, which can cause a fatal hemorrhagic fever in humans and monkeys, was not conferred by vaccination with Russian spring–summer encephalitis virus (Aniker et al. 1962). The epidemiologic studies of KFD were filmed and used extensively by Tel for the benefit of generations of medical and other public health students. That excellent film is still available.

In 1962, Tel returned to the New York laboratories long enough to establish the *Arbovirus Information Exchange* with Dr. Taylor and became the first editor of that successful newsletter.

In 1967 he was appointed by Congress to

head the Virology Section of the Centers for Disease Control (CDC) in Atlanta. Having detected antibodies to Venezuelan equine encephalitis virus in Native Americans living in the Everglades of south Florida (Work 1964), Tel established a program of arbovirus studies in Everglades National Park, established national and international surveillance systems for arboviruses and other viruses, and oversaw the discovery and identification of Everglades virus, Venezuelan equine encephalitis virus type II (Chamberlain et al. 1964), and numerous other newly recognized viruses from mosquitoes and rodents, including the arenavirus Tamiami (Calisher et al. 1970). Those studies showed that the virologic fauna of south Florida was related to the virologic fauna of subtropical and tropical areas of Central and South America, laying the groundwork for our later studies of bunyavirus evolution (Calisher 1988).

Under his direction, the CDC conducted studies to determine whether the Venezuelan equine encephalitis TC-83 vaccine could be transmitted between humans, done with volunteer personnel of the Arbovirus Unit at CDC.

He led studies of dengue in Jamaica and Puerto Rico, and of St. Louis encephalitis in Florida (Coleman et al. 1968; Fig. 8), Houston (Sudia et al. 1967), and in other urban centers in Texas and elsewhere (Kokernot et al. 1967). Also while at CDC, Tel established a program to study the role of migrating birds in carrying arboviruses between the Americas (Work and Lord 1972) and guided the federal government in establishing a national support program for the study of La Crosse encephalitis as well as for other diseases with arboviral etiologies.

Because of the expertise gained from his Indian experiences, he was asked by the great Russian virologist-epidemiologist Mikhail Chumakov to participate in six joint U.S.-U.S.S.R. discussions of tick-borne encephalitides (Fig. 9). In addition to Tel, the U.S. side included Jordi Casals, Alex Shelokov, Karl Johnson, Ned Wiebenga, and Harry Hoogstraal, as idiosyncratic a group of people as might ever have been gathered (Casals et al. 1966).

I recall clearly Tel's relating to me the story of the discovery of a La Crosse virus epidemic in Ripley County, southeastern Indiana, in 1964 (Work 1983). He unfolded this tale to me some years after the fact, in his office, after 6:00 p.m., when one could smoke in government buildings. I was not only suffocated with cigar smoke, I was suffocated with details, including the Delta Airline flight number and times of his departure from Atlanta and arrival in Indianapolis, the names of the floor nurses at the hospital, the streets on which lived the widely scattered pa-

tients, etc.; he was remarkable. It once took him two consecutive 18-hour days to answer the simple question I had asked of him: "Why is she no longer your secretary?" Before he was through, I had learned more about filariasis, St. Louis encephalitis, La Crosse encephalitis, dengue, the tick-borne encephalitides, Volvos, and Australian cattle dogs than I wanted to know.

Under his direction, the Arbovirus Unit at CDC was appointed a World Health Organization Collaborating Centre for Arbovirus Reference and Research. To it he recruited a number of outstanding people, to continue the work and legacy of arbovirology: Phillip Coleman, Bernard Fields, Martin Hirsch, Brian Henderson, Blaine Hollinger, Rexford Lord, and Frederick Murphy. Under Coleman, virus identification became routine; the first glimmer of interest in reoviruses shined in Fields's eyes; Henderson studied in detail the epidemiology of St. Louis encephalitis in Dallas; Lord collected, banded, and released birds in British Honduras, now Belize, only to net them when they arrived in Pilottown, Louisiana (try to get that funded today); and Murphy used sophisticated electron microscopic studies to visualize, for the first time, rabies, eastern equine encephalitis, western equine encephalitis, and many more viruses. This was a monumental series of works, leading to a rational basis for the taxonomy of all viruses. This work, and more, was done under Tel's guidance and direction, and "on his watch" as he liked to say.

Tel was a member of numerous public health service and military committees, of the World Health Organization, National Institutes of Health, and National Academy of Sciences panels, of the editorial boards of the *Journal of Medical Entomology* and *American Journal of Tropical Medicine and Hygiene*, tireless proselytizer of students at Harvard, Louisiana State, and other medical schools, from which he lured the likes of Robert Tesh and Thomas Monath, and active member of various scientific societies, including the American Mosquito Control Association and the Society of Vector Ecology.

In 1967 Tel left CDC to become Professor of Tropical Medicine and Infectious Diseases at the University of California at Los Angeles Medical School, where he taught and with his devoted wife and coworker, Martine Jozan Work (Fig. 10), began the search for foci of St. Louis encephalitis and other arboviruses in arid zones of southern California (Jozan and Work 1983; Fig. 11), demonstrating the year-round activity of *Culex tarsalis* in the Imperial Valley. His epidemiologic insight served him well throughout his career but his outspokenness kept some potential allies at arms length. Nonetheless, he



Fig. 8. This photograph, which appeared on the front page of the *St. Petersburg (Florida) Times* on the day the CDC cavalry arrived to aid in studies of the Tampa Bay epidemic of St. Louis encephalitis, shows the unloading of equipment to be used to save the day.

trained or had impact on U.C.L.A. students, including Steve Bowen, Gary Clark, Bruce Knudsen, Mike Nelson, Hazel Wallace, Jim Webb, and Luis Fernandez Zorilla.

In 1969, Tel was elected President of the American Society for Tropical Medicine and Hygiene (Work 1971). He and Martine spent sabbatical years in Australia (1978) where an epidemic of Murray Valley encephalitis was occurring in the northwest Kimberley area, and in Argentina (1988), where dengue was occurring on the border with Paraguay and yellow fever was occurring in Brazil.

In 1966 Tel had elegantly introduced Richard M. Taylor as the first recipient of the Richard M. Taylor Award of the American Committee on Arthropod-borne Viruses. This award, the highest distinction bestowed by that venerable group, of which both Dr. Taylor and Tel were

founders, is presented triennially "for significant contributions to the virology, immunology, entomology, ecology, or epidemiology of arthropod-borne viruses." In 1981, in San Juan, Puerto Rico, I had the honor of presenting that award to Tel. We kept the award a secret from him until the time of the presentation and I can assure you that he was genuinely surprised, honored, and flattered. I am certain that were he present to receive this American Mosquito Control Association award he would have been equally honored and flattered because he had great respect for this group and for the work done by its members.

Weary of and justifiably disgusted with administrators and bureaucrats, and of having to deal with people he considered somewhat less than appropriately civilized, Tel retired from U.C.L.A. in 1991 to pursue his interests in trav-





Fig. 9. Telford Work and Harry Hoogstraal with a Russian tick expert.



Fig. 11. Telford Work posing as a tourist in an arid area of southern California; the epidemiology or arboviral diseases was never far from his mind.

el, breeding Australian cattle dogs, reading, and film making, but maintained his dedication to arboviral epidemiology (Fig. 12). As are all good teachers, he was proud of his students' accomplishments, no matter how small, so I periodically called him to let him know how I was doing. Even when he was in obvious decline he had the wherewithal to ask piercing scientific questions, inquire as to the well-being of my

wife and children, even ask about our dog, advise me on selecting the proper manifold for a carburetor (as though I was planning to replace one), and otherwise either stick his nose in my business or continue to teach me, depending on your point of view. I always considered him my teacher. Some of our best conversations were about baseball; he was an avid fan, reading and



Fig. 10. Martine and Telford Work, 1971.



Fig. 12. Telford Work at home in Malibu, California.

memorizing the daily box scores, as do I, and we had many warm and laugh-filled conversations. During one conversation he asked me how many publications I had. I told him; he asked, "How many are good ones?" When I told him I thought two or three might stand the test of time, he said that was good, and gave me his views of the proper responsibilities of scientific writers and editors, Heaven and Hell, the appropriate role of the federal government in health care, and other apparent non sequiturs. I accepted each segment of our conversations as small, inexpensive gems.

On February 6, 1995, with his attentive wife Martine at his side, Tel died at his home of complications of congestive heart failure and the inevitable process of aging; one final contribution to science was made after his death. Because he had spent his life as a public servant of this country, which he loved and revered, he was buried with military honors at Riverside National Cemetery. He was a little late for his own funeral, which was apropos.

Tel's eldest son Clemens worked for *US News and World Report* for a time and now is a Professor of Journalism at the University of Mon-

tana, continuing a tradition of the Work family; Tel's father, a newspaper publisher, had introduced computerization to newspaper publishing. One of Tel's daughters, Amrit Kendrick, is a park naturalist and lives in Perth, Australia. Another son, Thierry, is a graduate veterinarian with a Master's degree in veterinary public health and a Master's degree in entomology; he is a wildlife biologist in Hawaii. Daughter Kathleen Collins is a fund raiser for the Colorado Springs symphony orchestra.

As anyone who knew him can verify, Tel was persistent, stubborn, voluble and articulate, demanding, generous, intuitive and rigorous, caring, stimulating and exhausting, amusing, annoying, a dreamer, and a realist. His was a life characterized by accomplishments, and by the application of his talents and intellect, creativity, and calculated eccentricities. The sum total of his wide travels and intellect is a melange of detailed field notes, photographs, motion pictures, and classical additions to the scientific record. I consider him to have been a splendid example of humanity.

I close with comments sent to me by Ian Marshall of Australia National University, himself one of the great arbovirologists of our time. "I recall a time a few months before his first heart attack 20 years ago when Kathleen, the children and I took Tel and his movie cameras on a brief camping trip through the Murray Valley in the summer of 1975. Suddenly, there we were on the side of the Sturt Highway. I was chagrined that my near new station wagon radiator was boiling, but Tel was happily filming the billowing smoke and flames of a bush fire as it consumed a small village in the middle distance of the shimmering Hay plains. I first had met Tel when he came to Canberra about 40 years ago during the throes of designing the Poona labs. Tel wanted to swap ideas with Frank Fenner who was in the process of designing the John Curtin School of Medical Research laboratories. However it was not until the 1960s that I had opportunities to spend time with him and enjoy the warmth of his friendship, be embarrassed by his frank generosity, despair of his lack of punctuality, witness his bouts of crankiness that so upset some of his less-tolerant friends, argue science and politics, and revel in the laughter of his experiences. You and I, and scores of others have been enriched by having known him. The legends Tel engendered will continue to live and multiply as long as there is an international community of arbovirologists." There is no need to add to that.

#### ACKNOWLEDGMENTS

I thank Martine Jozan Work for providing photographs for use in this paper and as slides

in the original presentation in Norfolk. Many thanks also to Carl J. Mitchell, Division of Vector-borne Infectious Diseases, Centers for Disease Control and Prevention, Fort Collins, Colorado, and Roy W. Chamberlain, Centers for Disease Control and Prevention, Atlanta, Georgia (retired), for leading me to and finding certain key references.

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