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Frank John Fenner 1914–2010[1]

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Frank Fenner made major contributions to our understanding of viruses through his research on ectromelia and on the co-evolution of the myxoma virus and its rabbit host. Then in later life he applied his formidable administrative skills to promoting the study of the environment as the first Director of the Centre for Resource and Environmental Studies at the Australian National University. Fenner was a key member of the World Health Organization team behind the eradication of smallpox. He made a very impressive contribution to the literature in microbiology and his textbooks on virology are used throughout the world.

Early Years

Frank Fenner's rich and amazingly productive life began in Ballarat, Victoria, on 21 December 1914. He was the second of five children of Charles and Peggy. The family moved to Adelaide in 1916.

Frank's father had graduated from Melbourne Teachers' College with honours in biology and geology in 1912, and he received a Diploma in Education in 1913. It was while he was there that he met and married Emma Louse Hirt (whom he later called Peggy). After a brief period as Principal of the Ballarat School of Mines, 1915–6, he was appointed Superintendent of Technical Education in South Australia. He wrote several text books at different levels on the geography of South Australia. Frank described him as 'a gifted 'science communicator', both in writing and orally', and recalled with pleasure how, on family trips in the car, Charles would describe the geological, botanical, and historical features of the countryside. Frank included a biography of his father in his last book, *Nature, Nurture and Chance: the Lives of Frank and Charles Fenner.*

Frank described his childhood as a very happy one. He attended Rose Park Primary School, which was said to be one of the best in the State. He then went to the Thebarton Technical High School for four years before going to Adelaide High School for two years in the hope of obtaining one of the dozen bursaries available for university study. Unfortunately he failed to do so.

Nevertheless, on leaving school in 1933 Frank enrolled at the University of Adelaide. He was hoping to become a geologist but his father advised against it and recommended that he study medicine. Frank followed this advice. He did well academically and was disappointed when he came third in the final examinations. He gained a University Blue for hockey in 1936

[1]A similar memoir will appear in *Biographical Memoirs of Fellows of the Royal Society of London*, vol. 59, 2013.

and was captain of the university hockey team in 1937 and 1938.

Frank Fenner's scientific career was striking in terms of its diversity and length. In his second year at university, he developed an interest in physical anthropology and in 1934, 1936 and 1939 he went on field anthropological expeditions to Central Australia undertaken by the University and the South Australian Museum. His first paper, in 1935, resulted from a Museum expedition to Kangaroo Island in December 1934 and concerned diprotodon fossils (1). Then followed several physical anthropology papers based on skeletons of Australian Aborigines held in the collections of the South Australian Museum and the Australian Institute of Anatomy in Canberra (2–6). This work earned him an MD degree in 1942.

The War

The second, short phase of Frank's science was in clinical medicine. He completed his MB BS degrees in Adelaide in 1938 and his hospital residency in 1939, and then went to Sydney to do a Diploma Course in Tropical Medicine before returning to Adelaide.

In 1940 Frank joined the Australian Army in the medical corps, initially as a Captain. He served in Palestine, Egypt, New Guinea, and Borneo. His first clinical publication in the *Medical Journal of Australia* in 1941 concerned an experimental treatment of gas gangrene with local implantation of sulphanilamide (8), written before his posting to the Middle East where he encountered malaria, which was a significant disease among the troops. With Japan's entry into the war in December 1941, Frank was appointed as pathologist in an army tent hospital north of Brisbane. Casualties from New Guinea gave him the opportunity to study cases of malaria and bacterial dysentery, resulting in a handful of clinical papers (11–14).

Two chance events while Frank Fenner was in the army had a profound and positive influence on his future. The first was the posting in 1942 of an extremely competent blood transfusion sister to do malaria diagnosis in his pathology operation in the tent hospital. Her name was Margaret Ellen Roberts, nicknamed 'Bobbie', and she impressed Frank in more ways than one. They were married in November 1944.

The second chance event occurred when, after he had spent eighteen months in New Guinea, the Army, in its wisdom, decided that Frank needed recreational leave and he was sent to Melbourne for six weeks to work in the Walter and Eliza Hall Institute where F. M. Burnet was director. This contact would ultimately lead to Frank's first involvement with the orthopox viruses and arguably his most important experimental work. However, the war demanded another stint in New Guinea, Borneo and Labuan before he returned to Australia in October 1945 as pathologist at the Heidelberg Military Hospital in Melbourne. Frank published three papers on *Salmonella blegdam* (15, 19, 30) and wrote a report on malaria in the Lau-Finschafen campaign in New Guinea. His malaria work resulted in the award of an MBE in 1945.

Research in Microbiology

Frank's wartime experience led to his decision to do research on infectious diseases, and his brief interlude at the Walter and Eliza Hall Institute convinced him that he should work there with F. M. Burnet. To this end he decided while still in the army at Morotai in 1945 to apply for a fellowship from the National Health and Medical Research Council, but before he could do so he received an offer from Burnet of a Francis Haley Research Fellowship to work at the Hall Institute on ectromelia virus, an orthopoxvirus that specifically infected mice. Frank read as much virology as he could while briefly at Heidelberg Hospital in late 1945 and early 1946 before his discharge from the Army in January 1946. He began work with Burnet in February 1946. Thus began his involvement with viruses, which never really left him and which were his dominant scientific interest for more than 25 years.

While Burnet dictated that Fenner work with ectromelia virus because it was known to be related to the viruses that caused smallpox in humans, he allowed Frank to take the initiative in designing the project. Frank's industriousness and self-discipline, which characterized his entire career, were soon in evidence and a series of papers dealing with various aspects of ectromelia infection in mice was published from 1947 to 1949 (16–18, 20–23, 25–29). Burnet's role was to read and critique the papers before submission for publication and to ask Frank what

he planned to do next. The papers were authored by Frank alone, except for one with Bobbie Fenner as co-author. They dealt with immunization of mice against ectromelia using live vaccinia virus—a parallel to human vaccination against smallpox—and with various aspects of natural transmission, propagation of epidemics, clinical features and pathogenesis. It emerged that mice that survived what was often a lethal infection due to uncontrolled virus growth in the liver developed a rash, thus providing a model for smallpox. A key methodological principle was also illustrated by Frank's approach to this project. He quantified the course of infection in relation to actively and passively acquired antibodies by enumerating infectious virus levels in target organs using the technique of the time, pock counts on the chorioallantoic membranes of embryonated hens' eggs. This principle was fundamental to later work by others that elucidated the role of T-cell-mediated and antibody-mediated immunity in controlling viral and certain bacterial infections. Fenner's 1948 paper in *Lancet* entitled 'The pathogenesis of the acute exanthems' (22), based on his work with ectromelia, became a classic and cemented his place as a respected figure in the field of viral infection research. He was awarded the Syme Prize for Research by the University of Melbourne in 1949. Burnet had picked a winner in his choice of both ectromelia infection of mice as a model and the person to work on it. Burnet was impressed enough by Fenner's achievements to invite him to co-author a review entitled 'Genetics and immunology' (1948) (24) and a book *The Production of Antibodies* (1949) (B1) in which the concept of acquired immunological tolerance was introduced. This concept was to win Burnet a Nobel prize in 1960. Frank often joked about Burnet winning the prize 'for a one-line idea'.

In 1948, Fenner took advantage of his eligibility for a travel grant based upon his war service. Burnet and E. V. Keogh (a senior Melbourne medical researcher of that time) recommended New York to enable networking with many prominent researchers. They settled upon the laboratory of René Dubos at Rockefeller University, where the focus of research was on *Mycobacterium tuberculosis*. There Fenner worked mainly with BCG, the vaccine strain, and developed a method to enable quantitation of bacterial numbers by colony counts in Tween-albumin medium (31, 33–39), a painstaking process that took two weeks for colonies to be big enough to count, while avoiding contamination with faster-growing bacteria and fungi. He also began work with *Mycobacterium ulcerans* which he had brought from Australia (41, 42). In addition to the mentorship of Dubos, Fenner was exposed to diverse areas of research and prominent scientists at Rockefeller including Peyton Rous, later to win a Nobel prize for discovering a virus that caused sarcoma in chickens, Rollin Hotchkiss who was showing that pure DNA was Avery's 'transforming principle' (i.e. the genes of bacteria), and Merrill Chase, the first to transfer delayed-type hypersensitivity with white blood cells.

When he went to New York, Fenner expected that his immediate future would be at the Hall Institute; Burnet had indicated that he would be very welcome, perhaps as Deputy Director. However, in February 1949, while he was working with Dubos, Fenner unexpectedly received a letter from Sir Howard Florey that was to lead to a dramatically different future and to Fenner's becoming one of the world's most prominent virologists. Florey was Professor of Pathology at Oxford at the time but had been commissioned by the Chifley Labor Government in Australia to set up the John Curtin School of Medical Research at the new Australian National University (ANU) in Canberra. Florey offered Fenner the position of Professor of Microbiology in the new School, and Fenner immediately accepted the formal offer from the ANU Council that followed. In July 1949, Frank and Bobbie left New York and went to Oxford to meet with Florey and the two other newly-appointed professors of the John Curtin School, Hugh Ennor and Adrien Albert. They laid out plans for the building on the ANU campus that would house the new School.

Fenner spent the remainder of 1949 visiting virology and bacteriology laboratories in England and touring Europe before returning in January 1950 to the Hall Institute where the ANU had been lent laboratory space, since none yet existed in Canberra.

Fenner chose to consolidate his work with Mycobacteria and began experiments with *M. ulcerans* and *M. balnei* while writing a review on BCG. However, this interest became a sideline when flooding in the Murray–Darling basin

in south-eastern Australia in the summer of 1950–1 resulted in a significant outbreak of myxomatosis in wild rabbits, giving Fenner a major opportunity to return to virology. In typical fashion, Fenner thoroughly investigated published information pertinent to the outbreak.

Although myxomatosis had been introduced into Australia by the Council for Scientific and Industrial Research in 1937 and reintroduced in 1949 in an attempt at biological control of feral European rabbits, it had limited success until 1950–1. It was known that the Myxoma virus, a poxvirus, could be transmitted by mosquitoes, and the floods of 1950–1 that resulted in widespread mosquito breeding led to the disease outbreak that decimated rabbits across south-eastern Australia. The feral rabbit was in plague proportions before the outbreak, destroying fragile ecosystems and agriculture alike. Thus the outbreak was not only of scientific interest but of great importance to the future of Australia.

Concurrent with the outbreak of myxomatosis in rabbits in the summer of 1950–1, Murray Valley Encephalitis Virus was causing human infections, sometimes lethal. People were blaming myxomatosis for human deaths. To counter this perception, in March 1951 Macfarlane Burnet, Frank Fenner and Ian Clunies Ross, Head of CSIRO, publicly injected themselves with 100 rabbit-infectious doses of myxomatosis virus. They suffered nothing but slight inflammation at the site of injection. The results were announced in Parliament and public concern subsided.

In collaboration with Max Day of CSIRO, Fenner studied mosquito transmission in detail (43, 44). Myxoma virus does not grow in mosquitoes; transmission is mechanical via the virus adhering to mosquito mouthparts, and therefore is dependent upon the concentration of virus in the skin of the donor rabbit. This was to become fundamental to later studies on the evolution of the outbreak (60). Fenner then appointed I. D. Marshall and G. M. Woodroofe to assist him in further work in collaboration with CSIRO's Wildlife Survey Section. A combination of field observations and viruses from CSIRO and laboratory studies of the viruses by Fenner's team led to the discovery that fatality rates of myxomatosis were 99% in the initial outbreak, but after one year, viruses circulating in the field caused fatality rates of only 90% (48). The next decade saw intensive investigation of changes in virus virulence and concurrent increased resistance in rabbits and led to the realisation that co-evolution of the virus and the rabbit was occurring through natural selection. Mutants of the virus with reduced virulence persisted at high levels in the skin of the rabbit for a longer time than the original virulent virus because the latter quickly killed its host. This caused more frequent transmission by mosquitoes of the less virulent virus than of the more virulent virus, with the former ultimately dominating circulation in the field. With their very rapid reproduction rate, rabbits also quickly showed evidence of selection for increased resistance. While there are many examples of viruses causing relatively little harm to their natural hosts but causing severe, often lethal, disease in other accidental hosts, the myxomatosis outbreak was a striking illustration of co-evolution of host and parasite in real time. Over evolutionary time, American rabbits and myxoma virus had co-evolved so that the virus caused a relatively trivial localized fibroma in the skin of the rabbit after mosquito transmission. After introduction into the wild European rabbit population in Australia, myxoma virus caused a rapidly lethal generalized infection. Evidence for the transition to less severe disease was consolidated over the next decade, as summarized in the 1965 book *Myxomatosis* (B2) by Fenner and F. N. Ratcliffe, head of the CSIRO Wildlife Survey Section.

In late October and early November 1952 Fenner's team left the Walter and Eliza Hall Institute and occupied temporary laboratories in prefabricated wooden buildings on the ANU campus in Canberra. The permanent building of the John Curtin School of Medical Research was not yet under construction; it was ultimately occupied early in 1957 (Fig. 1).

Fenner continued to investigate various properties of poxviruses but switched to vaccinia instead of myxoma because the latter did not grow well in cultured cells. This resulted in the first example of recombination between DNA viruses of vertebrates, published in 1958 (76). Fenner also investigated the phenomenon of 'transformation' of fibroma virus into myxoma virus, first described in 1936, and showed that it was not 'transformation' but reactivation of heat-inactivated myxoma (85). He then focused

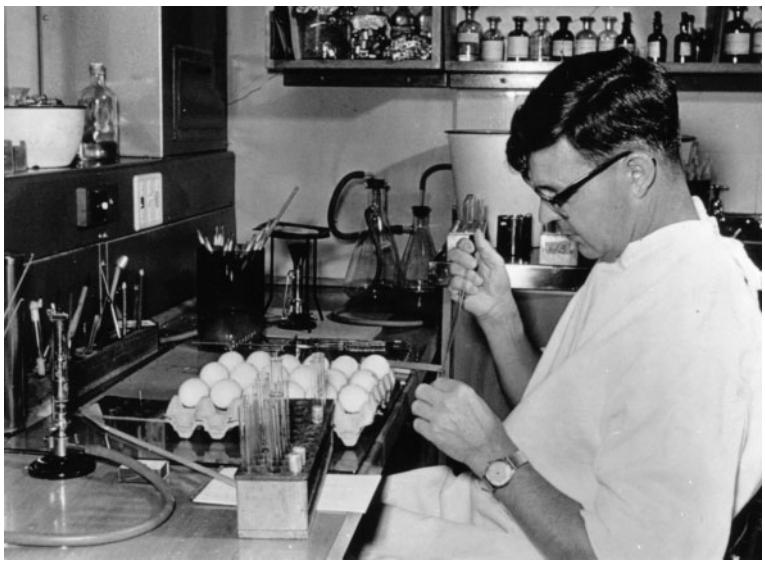

Figure 1. Frank Fenner in his laboratory, 1958.

on different mutants of rabbitpox virus that produced white pocks on the chorioallantoic membrane of embryonated hens' eggs instead of the wild-type red, haemorrhagic pocks. By selecting different white pock mutants, distinguished by the type of lesion, and using them in different combinations to produce different rates of reversion to wild type, he obtained what he termed a rough 'genetic map' of rabbitpox virus (87). The poxvirus genetics phase of Fenner's research ended with the discovery that white pock mutants were unable to produce plaques in PK-2a cells, a particular line of pig kidney cells, and so were termed 'conditional lethal mutants' (107). It was also the end of his laboratory-based research in virology.

Director of the John Curtin School of Medical Research and Author

From mid-1965 to early 1967, most of Frank Fenner's time was spent on the mammoth undertaking of writing the book *The Biology of Animal Viruses* (B3) for Academic Press as a successor to Burnet's *The Principles of Animal Virology*. When complete it ran to 846 pages in two volumes and was published in 1968. It is a compelling illustration of Fenner's work ethic, self-discipline and memory.

Upon the resignation of Hugh Ennor as Dean of the John Curtin School in early 1967, the ANU advertised the position of Director of the School. Fenner was the successful applicant and became Director in September 1967. The administrative demands of the position prevented further experimental work at the bench, so his publications became reviews, book chapters and commentaries on various aspects of virology. During his directorship he also wrote a textbook, *Medical Virology* (B5), with a former PhD student, Professor D. O. White of the University of Melbourne. This was accomplished mainly in the hours between 6 am and 9 am, before the administrative demands of the directorship took precedence. David White spent interludes at the John Curtin School and at Frank Fenner's house on the south coast of New South Wales during their collaboration and told hilarious anecdotes about Frank's work ethic. For example, after days of dawn to dusk writing at the coast, one morning Frank said something like 'What a beautiful day. Let's take a break'. David thought 'At last I get a chance to enjoy this beautiful environment and perhaps get in a bit of birdwatching'. However, after walking on the beach for half an hour or so, Frank said 'That was great. Now let's get back to work'. *Medical Virology* was published by Academic Press in 1970 and was a great success.

The World Health Organization and Smallpox Eradication

In 1966, Fenner had become a member of the inaugural International Committee of the Nomenclature of Viruses. He was elected President of this Committee for five years. The name was changed from 'Nomenclature' to 'Taxonomy' and Fenner was in the forefront of discussions on virus classification. He had also been a member of the World Health Organization (WHO) Committee on Virus Diseases since 1957, and early in the period of his directorship of the John Curtin School, in 1968, he was invited to be a member of an Informal Group of Monkeypox and Related Virus that met for the first time in Moscow in 1969. This was the origin of the expert committee of virologists advising the Chief of the Smallpox Eradication Unit of WHO on virology. Fenner ultimately became Chair of this committee, which existed in its last phase as the WHO Committee on Orthopoxviruses until 1999. His experience with experimental infection with poxviruses, first ectromelia virus in mice, then myxoma virus in rabbits, plus the field experience with myxomatosis and laboratory work on poxvirus genetics, made him uniquely qualified to advise the WHO on smallpox eradication. Fenner was a member of the International Commission for the Certification of Smallpox Eradication from India and of sister commissions for Malawi and Mozambique. In 1977 he became Chair of a large group of virologists and public health experts termed the 'Consultation on the Worldwide Certification of Smallpox Eradication' which, in 1978, became the 'Global Commission for the Certification of Smallpox Eradication'. It was in his capacity as Chair of this commission that, in May 1980, Frank Fenner informed the World Health Assembly that smallpox had been eradicated. He said this was the proudest moment in his life, announcing this great achievement of science.

Thus, one of the greatest achievements in public health was completed using a cheap, stable, live virus vaccine delivered into the skin with a bifurcated needle, a procedure for which fieldworkers were easily trained. It was basically similar to Edward Jenner's pioneering work on smallpox vaccination in 1798! In the modern western world, fear of the side-effects of vaccination, litigation, and the absurd anti-science campaign against any vaccination procedure means that the successful eradication of smallpox that ended in 1979 might be impossible today. Ironically, despite the dramatic advances in molecular biology of recent years, no other human infectious disease has been eradicated. This irony was not lost on Frank Fenner.

The Environmental Phase

From the early 1960s, Frank became increasingly involved in matters to do with the environment. The Australian Academy of Science played a seminal role in this development. He was Secretary (Biological Sciences) in the Academy from 1958 to 1961 and he said later that this experience greatly broadened his perspectives, and that from then on he became increasingly interested in environmental and conservation issues. He was, of course, to some extent primed by his father's interest in nature.

In 1969, at a conference honouring Macfarlane Burnet's 70th birthday, Frank presented an insightful and thought-provoking paper entitled 'Brahma, Shiva and Vishnu: three faces of science' (115). In this paper he talked about pollution, climate change and the 'population avalanche' and questioned the rationality of continuing economic growth. Foreshadowing his later pessimism about humankind's future, he wrote 'Perhaps, if man the technologist initiates uncontrollable climatic changes ... he will follow the dinosaur to extinction, dragging many other forms of life with him'. He concluded with 'Unless the right steps are taken quickly, man on earth has to face a future of increasing misery, even in an uncluttered country like Australia'.

In 1969 Frank was appointed Chairman of a committee at ANU charged with the task of preparing a submission to the Australian Universities Commission (AUC) for the1973–5 funding triennium, advocating the establishment of a Centre for Natural Resources in the University. The committee initially recommended that the new institution should be called the Centre for Environmental and Resource Studies. However, Frank would tell the story how it was as considered that the acronym—CERS—would be inappropriate, and so it was changed to the Centre for Resource and Environmental Studies (CRES). The committee's recommendations were accepted by the ANU Council on 14 July

1972 and the Centre was subsequently approved by the AUC.

At this time Frank was coming to the end of his stint as Director of the John Curtin School, and in 1972 he made the decision to apply for the directorship of CRES. He was duly appointed and took up office in May 1973, moving into temporary quarters adjacent to the John Curtin School that had been built originally as the nurses' quarters of the original Canberra Hospital. Later CRES was based on the fourth and fifth floors of the Hancock Building, which also housed the Life Sciences Library.

On taking up his new appointment, Frank resigned from his various national and international committees associated with medical problems, except those associated with the World Health Organization's campaign for smallpox eradication. However, he managed to spend considerable time working on the second edition of *Medical Virology* (B6).

Once appointed, Frank immediately set about bringing together a team of specialists in economics, systems analysis, hydrology, ecology and human ecology, making CRES a unique academic institution.

At the end of his period as Director of CRES, Frank wrote an account of its activities from 1973 to 1979 (161). Apart from listing members of staff and publications, he expressed three personal views that are worth reporting. First, he commented that he believed CRES was too small with only twelve academic staff. Originally a larger institute had been planned, but curtailment of funds in 1974 made this impossible. Second, he expressed his disappointment that there had not been more interaction between the staff of CRES and other parts of the University. Finally, Frank expressed his disagreement with the Review Committee's recommendation that the staff of CRES should be employed most of the time on a succession of major projects each lasting two or three years (never more than three years). He believed that emphasis should be placed on the development of new ideas and concepts, and he provided examples of how this was happening in CRES.

During this phase of Frank's career he served on many national committees concerned with environmental matters, including the Australian Academy of Science's Flora and Fauna Committee from 1967 to 1974 (Chairman), its Fauna Committee, 1974–81; the Standing Committee on National Parks and Conservation, 1970–81 (Chairman, 1970–2); the National Committee for SCOPE, 1971–8 (Chairman); the Standing Committee on the Environment, 1970–8; and the National Committee for the Environment, 1979–82.

Frank was Editor-in-Chief of SCOPE publications from 1977 to 1980 and an *ex officio* member of its Executive Committee. From 1978 to 1982 he was a member of the Senior Scientific Board of the United Nations Environment Project, 'The State of the Environment Ten Years after Stockholm'.

Mention should be made of the fact that, from the mid-1960s onwards, Frank played a pivotal role in the development of Human Ecology as an academic discipline at ANU. There was considerable opposition to this move from established areas of specialism and Human Ecology would probably not have found a place in teaching and research for another thirty or more years, had it not been for his support. It is now firmly established, appropriately, in the Fenner School for Environment and Society.

Retirement

Frank reached the then mandatory retirement age of 65 in 1979. Having no desire to stop working, he became a University Fellow and the John Curtin School provided him with an office and everything he needed to write. Having chaired the Smallpox Eradication Committee of the WHO, he decided to write a book detailing the eradication so that the lessons learned could be applied to other, similar programmes. What began as a single-author undertaking ultimately blossomed into a book of 1,460 pages with five authors that took eight years to complete (B13). Frank considered it the most important and satisfying of his writing accomplishments. In April 1988 he and his major co-authors, D. A. Henderson and I. Arita, were rewarded with the Japan Prize.

While writing the smallpox eradication history, Fenner also found time to collaborate again with David White, his co-author on *Medical Virology*, plus four veterinary virologists to write *Veterinary Virology* (B11), published in 1987. He also saw that there was scope for a more complete catalogue of information on orthopox viruses

than was present in *Smallpox and Its Eradication* and this led to *The Orthopoxviruses* (B16) with K. R. Dumbell and R. Wittek in 1989 (B16).

Historical perspectives continued to occupy his writing for the remainder of his 'retirement'. Examples include *Portraits of Viruses: A History of Virology* (B14) with Adrian Gibbs in 1988, *History of Microbiology in Australia* in 1990 and *Biological Control of Vertebrate Pests: A History of Myxomatosis, an Experiment in Coevolution* (B19) with B. Fantini in 1999.

By 1998, the John Curtin School of Medical Research had existed for fifty years and Frank Fenner had been Professor of Microbiology for nineteen years, Director for six years and, post-retirement, a University Fellow or a Visiting Fellow for eighteen years. He knew a lot about the School and what had made it world-class, possibly more than anyone else. If he had a competitor in this regard, it was probably David Curtis who began as a PhD scholar in Physiology in 1954 with John Eccles, became a Professor by 1966 and then headed the new Department of Pharmacology in 1973 until he became Director in 1989. After retiring in 1992, he also continued working in the School as a University Fellow or Visiting Fellow. It was fitting then that Fenner and Curtis collaborated to produce *The John Curtin School of Medical Research: The First Fifty Years, 1948–1998* (B20), published in 2001. This volume is one of Fenner's most important historical contributions because it incorporates contributions from many senior staff members of the School, providing insight into factors that resulted in the School's two Nobel prizes in Physiology or Medicine. The first, in 1963, to John Eccles for 'discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membranes', was awarded for discoveries made in the Department of Physiology in the 1950s. The second, in 1996, to Peter Doherty and Rolf Zinkernagel for 'discoveries concerning the specificity of the cell-mediated immune defence' was awarded for discoveries made in the Department of Microbiology in 1973–5.

By any objective analysis, Frank Fenner's legacy must be judged as enormous. He published over 300 scientific papers and authored or co-authored 21 books. Not only was Frank an outstanding author and clinical and laboratory investigator, he also excelled as a facilitator, as was evident from the first-rate scientists whom he hired when he was Head of Microbiology in the John Curtin School so that a wide range of virological experience and expertise was always circulating through the department.

When Director of the School, he had the vision to set up new Departments of Human Biology, Immunology and Pharmacology, a specific pathogen-free animal house to improve immunological research, and a computing centre. His diplomatic qualities were on show in his chairmanship of various international committees, culminating in the Smallpox Eradication Programme. Who else offered experience with diseases caused by poxviruses in the laboratory, the field and the clinic? And who else combined this with leadership of the highest international standard in biomedical research and behaviour worthy of a senior diplomat or statesman?

Frank was one of the first group of Fellows elected to the Australian Academy of Science in 1954 and his service to the Academy over the years was outstanding, including the editing of histories at the 25, 40 and 50 year points (B10, B18, B21). He was elected a Fellow of the Royal Society of London in 1958 and a Foreign Associate of the US National Academy of Sciences in 1977. He was also elected to many other national and international scientific societies (see list below).

Donations

In 1984 Frank and Bobbie Fenner decided to make annual donations to support the two scientific interests that had been central to Frank's life: medical research and concern for the environment. Substantial donations were made to the John Curtin School of Medical Research. Most of this went towards establishing the Frank and Bobbie Fenner Conferences on Medical Research.

The Australian Academy of Science also received many donations. Especially significant was the money that made possible the highly successful Fenner Conferences on the Environment. In addition, he was a strong supporter of the Academy's Basser Library.

Frank also donated substantial sums to the Fenner Hall students' residence. Much of this was used to establish the Bobbie Fenner Scholarships.

Figure 2. Frank and Bobbie Fenner with their daughter Marilyn at the entrance to their house in Red Hill, ACT, December 1956.

From 1998 until his death Frank made annual contributions to the Nature and Society Forum, a community-based organization of which he was Patron. These funds enabled the Forum to employ an office manager during this time.

Frank and Bobbie also made donations to numerous other organizations and causes.

General

From 1956 Frank and Bobbie lived in the Canberra suburb of Red Hill in a house designed by the renowned architect Robin Boyd. They had two daughters, one of whom died when she was fifteen (Fig. 2). Bobbie died of cancer in 1995. Frank would often tell what a wonderful support she had been to him over the years.

Frank was not an ideas man, and he was often heard to say that he was not an original thinker. However, he was very interested in the ideas of others. He was an avid reader of the literature and had an amazing knack of picking out that which was really significant and to synthesize

and communicate it effectively in his extensive writings. He grasped good ideas and made them bear fruit.

Frank's amazing memory was legendary and his ability to notice details remarkable. On one occasion when he was talking to a female scientist about a new labelling method for tissues using a certain blue dye, he was heard to say that the colour was 'rather like the ear-rings you were wearing last Thursday'.

Frank felt very strongly that the public at large, and particularly politicians, are dismally ignorant of the findings of the life sciences. In the mid-1960s a proposal was put to the Menzies Government for the establishment of a new kind of public institution in Canberra—called at that time a Biological Centre and later called a Biocentre—that would bring knowledge gained in the life sciences to the people, especially as this knowledge had bearing on the health and well being of humans and of the natural environment. Frank threw his weight behind this proposal, and we now know that it almost became a reality and would have done had there not been a change of government at a critical moment in the process. Later, in the 1990s, he was Chairman of a group working to revive this idea.

It was Frank's belief in the importance of scientific understanding of the human place in nature that was behind his support of the Nature and Society Forum (NSF) from early in the 1990s until the time of his death. NSF is a community-based organization concerned with the future well being of humankind and the natural environment. Its slogan is 'healthy people on a healthy planet'. It aims to encourage, across the community, understanding of nature and the human place in nature, and to promote the vision of a society that is truly in tune with the processes of life within and around us. It forms a bridge between academia and interested members of the public. Frank joined NSF in 1992 and became an active member. In 1997 he was appointed Patron. Not only was he a generous donor to this organization, he regularly attended NSF's monthly discussion meetings. He missed the meeting immediately before he died, but he went to the one before that.

The following story about Frank nicely brings together two of his endearing characteristics. First, he was a workaholic. He always got to his office in the John Curtin School or CRES around 6 am or earlier and so managed to get two or three hours' work done before most of his colleagues arrived on the scene. Second, whatever the circumstances, he was always very calm. He was never seen to be in the least ruffled or flustered. So, one day in CRES he arrived as usual at around 6 am and got into the lift to take him to the fourth floor. But the lift became stuck between floors, and it was a long time before he was rescued. Later in the day people were commiserating with him about this ordeal, but Frank simply replied that it was no ordeal. On the contrary, he just sat down on the floor, took out the contents of his brief case, and was able to get an hour or so of good work done, completely uninterrupted.

Frank was always pessimistic about the future of humanity. He often said there would be no effective shift towards ecological sustainability until a major ecological catastrophe occurred. He saw the efforts of environmentalists as worthwhile not so much because they might prevent such disaster but because their work could provide a rational basis for rehabilitation of surviving groups after the collapse.

He later became even more pessimistic and a few months before his death publicly stated to the press that he believed humankind would become extinct within a hundred years due to its own activities. However, afterwards he was asked privately if he would rule out the possibility that human society might wake up in time to the ecological realities and take appropriate action to avoid total collapse, and he answered that of course it was not impossible. And he must surely have harboured a glimmer of hope for humankind, otherwise he would not have supported so generously such groups as the Nature and Society Forum and Sustainable Population Australia.

Frank's dedication to his work did not mean he was physically inactive. He enjoyed his game of tennis every Saturday morning with the same group of friends over very many years, until one Saturday when he was in his late eighties when he hurt his arm rather badly. He did not play again. He was also a keen gardener and in his later years regularly provided his friends with a big range of vegetables and fruits. He was out there in his gardening clothes only three weeks before he died.

Frank was very fond of Fellows Garden at University House at ANU. After his official

Figure 3. Frank Fenner at the annual meeting of the Australian Academy of Science, May 2010. Sharing the joke is Professor Jan Anderson, FAA, FRS.

retirement in 1980 he would often have lunch there with friends. These were very relaxed and enjoyable occasions and the conversation ranged over all manner of topics—myxomatosis, university politics, climate change, biocentres, Frank's vegetable garden and so on. But it frequently drifted back to what Frank saw as the biggest problem of all—far too many people alive on planet Earth. He would often argue that medical science (including, for example, the eradication of smallpox) is largely responsible for this situation. This would lead to some lively discussion. He also liked to reminisce, and in recent years he would often talk about his memories of Bobbie, who was his loving and much loved companion for over fifty years. The last of these luncheons at University House took place on 11 November 2010, eleven days before his death.

This unassuming, resolute, courteous, generous and much loved man is sadly missed by very many people (Fig. 3). He is survived by his daughter Marilyn, two grandchildren and one great grandchild.

Honours and Awards

Decorations

Member of the Order of the British Empire (Military) (MBE), for work in malaria control, 1945

Companion of the Order of St Michael and St George (CMG), for medical research, 1976

Companion of the Order of Australia (AC), for service to medical science, to public health and to the environment, 1989

Memberships of Learned Academies and Professional Bodies

Fellow of the Australian Academy of Science (FAA), 1954

Fellow of the Royal Society of London (FRS), 1958

Fellow of the Royal Australasian College of Physicians, (FRACP), 1959

Fellow of the Royal College of Physicians, London (FRCP), 1967

Honorary Life Member, Australian Society for Microbiology, 1975

Foreign Associate, US National Academy of Sciences, 1977

Fellow, World Academy of Art and Science, 1986

Emeritus Member, American Society for Virology, 1991

Honorary Fellow, Indian Virological Society, 1991

Honorary Member, Australian Veterinary Association, 1993

Fellow, American Academy of Microbiology, 1996

Honorary Fellow, Australasian College of Tropical Medicine, 1999

Honorary Fellow, University House, ANU, 2002

Medals and Awards

Syme Prize for Research, University of Melbourne, 1949

Harvey Lecturer, Harvey Society of New York, 1957

Listerian Oration, S.A. Branch of the British Medical Association, 1958

Walter Burfitt Medal, Royal Society of New South Wales, 1959

Leeuwenhoek Lecturer, Royal Society of London, 1961

Mueller Medal, Australia and New Zealand Association for the Advancement of Science, 1964

MD *honoris causa,* Monash University, 1966

Matthew Flinders Lecture, Australian Academy of Science, 1967

Britannica Australia Award for Medicine, 1967
Lilly Lecturer, Royal College of Physicians, London, 1970
Ciba Lecturer in Microbial Biochemistry, Rutgers University, 1970
Victor Coppleson Lecturer, Australian Post-Graduate Medical Foundation, 1971
David Memorial Lecture, Australia and New Zealand Association for the Advancement of Science, 1973
Sydney Rubbo Memorial Oration, University of Melbourne, 1974
Octagon Lecture, University of Western Australia, 1976
ANZAAS Medal, Australian and New Zealand Association for the Advancement of Science, 1980
ANZAC Peace Prize, 1980
Florey Lecture, Royal Society of London, 1983
Fogarty Medal, National Institutes of Health, USA, 1983
Burnet Lecture, Australian Academy of Science, 1985
Mudd Award, International Union of Microbiological Societies, 1986
A.W.T. Edwards Memorial Oration, The Australian Society for Medical Research, 1987
John Murtagh Macrossan Lecture, University of Queensland, 1987
WHO Medal, 1988
Japan Prize (Preventive Medicine), 1988
Advance Australia Award, 1989
Wallace Rowe Lecture, American Committee on Laboratory Animal Diseases, 1989
Gordon Meiklejohn Lecture, USA, 1990
Doctor *honoris causa*, University of Liège, 1992
DSc *honoris causa*, Oxford Brookes University, 1995
Copley Medal, Royal Society of London, 1995
DSc *honoris causa*, Australian National University, 1996
Edwin H. Lennette Lecture, American Society for Virology, 1997
Senior Australian Achiever of the Year, 1999
Derrick-Mackerras Lecture, Queensland Institute of Medical Research, 1999
Albert Einstein World Award of Science, 2000
Clunies Ross Science and Technology Lifetime Award, 2002
Prime Minister's Prize for Science, 2002
ACT Australian of the Year, 2003
Centenary Medal, 2003

Other Marks of Recognition

Frank Fenner Research Award, Australian Society for Microbiology
Fenner Medal, John Curtin School of Medical Research, established 1995
Fenner Hall, residential college of the Australian National University, named 1992
Fenner Fellowship, Australian Animal Health Laboratory
Fenner Medal, Australian Academy of Science, established 1999
Frank Fenner Building, ANU campus, named 2003

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